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Executive summary

This report provides insight in one of the thirteen Smart Solutions that are implemented in the Heart of South area in the City of Rotterdam. These innovative solutions are part of the RUGGEDISED program, which is subsidised by the European Union, and aims to test, implement and accelerate the Smart City model across Europe. Smart Cities include places were traditional networks and services are made more efficient with the use of digital technologies, for the benefit of its people. The smart solution this document further elaborates on is ‘extraction of thermal energy from sewage water’, also known as ‘riothermia’.

First is explained what the solution includes. In short, the system extracts heat and cold from sewage water near Heart of South and heats or cools down buildings in the area with it. The heat or cold can be used directly or stored in the ground, in the geothermal heat and cold storage (R1) to use it in another season.

Then is elaborated on several aspects of the implementation process. The most time-consuming task in the process was to fit in the elements of the riothermia system, like the heat collector and heat exchanger, in the local context. Normally these parts are placed in sewage pipes but none of the sewage pipes in this area resulted suitable. Therefore, it is chosen to establish the parts in the pumping station of the sewage system.

Furthermore, it is explained how this solution contributes to the Smart Thermal Grid (STG) in Heart of South. A STG enables heat and cold exchange between buildings and relies on renewable energy sources. Together with other solutions, like Pavement collectors (R4), the thermal energy that is extracted from sewage water feeds into the STG.

Thereafter, insight is given into the business case: the financial concept and the expected impact and costs. In this particular location it was quite hard to realise this solution with a feasible business case, let alone a profitable one. The energy sources connected to STG are competing with District Heating and compression chillers on the roof of Ahoy (already present) which convert the outside air into cold air to cool the buildings. Therefor the riothermal energy is competing to the energy produced to the energy of the Distrit heating and these chillers

In the last chapter it is concluded that riothermia is commercially and technically viable in Heart of South. Also, several recommendations to partners are given, like giving importance to finding an adequate location for the system, as this impacts the economic yield.

Contents

1. Introduction

RUGGEDISED is a Smart City project funded under the European Union's Horizon 2020 research and innovation program. The European Commission defines a smart city as: "A place where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefit of its inhabitants and businesses". The goal of the project is to test, implement and accelerate the Smart City model across Europe.

1.1 Lighthouse cities

The current period in which we live, is characterised by rapid technological development, strong globalisation of (social and economic) activities, a need to protect our living environment and to ensure social stability. In the European-funded Smart City project RUGGEDISED, the three lighthouse cities of Rotterdam, Umea, and Glasgow work together with a number of partners from academic, business and consultancy backgrounds to develop and test solutions to exploit and explore sustainable urban development opportunities offered by smart solutions.

The three overall aims of RUGGEDISED are:

- Improving citizens' quality of life by offering a clean, safe, attractive, inclusive and affordable living environment.
- Reducing the environmental impacts of activities, amongst others by achieving a significant reduction of CO2 emissions, a major increase in the investment and usage of renewable energy sources and an increase in the deployment of electric vehicles.
- Creating a stimulating environment for sustainable economic development, by generating more sustainable jobs, stimulating community involvement in smart solutions (as consumers and as producers) and to boost start-up and existing companies to exploit the opportunities of the green digital economy and Internet of Things.

Within Rotterdam the main focus is on Smart Energy systems, with the goal to reduce import of energy from outside the area and produce as much as possible energy within the area itself.
Two grids are designed, one Smart Thermal Grid (STG) and one Smart Electric Grid (SEG) as shown in the drawing below.

Figure 1: An overview of the Heart of South implementations

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1.2 Smart thermal grid in Rotterdam

The City of Rotterdam played an important role in the RUGGEDISED project. Rotterdam is the Netherlands second-largest metropolis and is characterised by its diverse, multi-ethnic community and Europe's busiest port. The City of Rotterdam introduced the Heart of South, the city centre of the South side of Rotterdam, as their lighthouse district. Through RUGGEDISED the area is undergoing a transition, consisting of renovating event centre Ahoy and building new facilities like a shopping mall and a cinema.

Figure 2: Map of the city of Rotterdam

Figure 3: An overview of the Heart of South area and the Ahoy complex.

One of the main goals of the project in Heart of South is to connect several buildings in the area to the STG, which is based on renewable energy sources and facilitates the exchange of heating and cooling between buildings. The establishment of the STG – in combination with city heating - made the Ahoy area natural gas free in 2019, which leads to CO2 reduction.

In total thirteen innovative solutions are implemented in the area, from which several solutions contribute to the establishment of the STG. The solutions are highly related; for example, some solutions focus on extracting energy, while other solutions focus on the storage of that energy.

This deliverable elaborates on one of the solutions that contributes to feeding energy into the grid, the extraction of heat and cold from sewage water, also known as “riothermia” (R2), is displayed in the yellow circle in figure. It is a proven technology, but never before used as a renewable energy source for, and connected to, a STG, ea. 5th generation network.

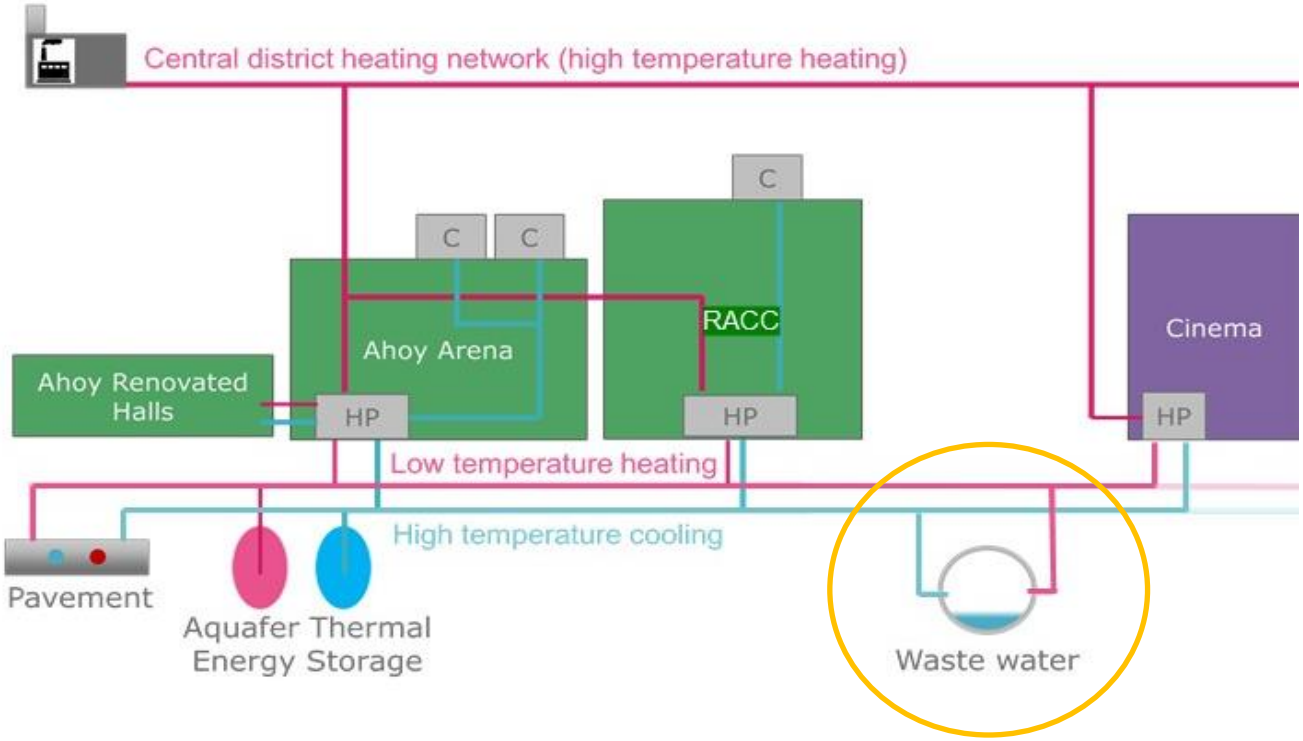

Figure 4: A schematic overview of the buildings that are connected to the STG in Heart of South.
STG is the whole system
C: compression chillers
HP: Heat pumps

Reuse of wastewater streams to produce thermal energy, is one of the solutions which is part of the STG. The STG is designed to deliver heating or cooling to the different halls of Ahoy, Rotterdam Ahoy Convention Centre (RACC) and the newly to be build Cinema, according to specific demand needed. The whole complex is equipped with sensors, which are operated from a central portal to heat or cool a certain hall. This means that not the whole complex needs to be heated or cooled.
Currently, the Ahoy area uses a hybrid heat and cooling system, in which a district heating system and the STG are combined. The STG is fed with 4 different energy sources, district heating and heat pumps/compression chillers for regenerating the base temperature, an asphalt collector and the wastewater collector to deliver the base load. All excess heating or cooling is stored in the seasonal Aquifer Thermal Energy Storages (ATES).
The energy source is situated in a main pumping station from the sewage system on the south bank of Rotterdam, quite a complex location to use as testcase. The installation in the pumping station is connected to the backbone of Ahoy and the RACC (R1) by a 2nd backbone. The 2nd backbone is connected to the pumping station and the newly to be build cinema which will be added next to the pumping station (not within the project scope).

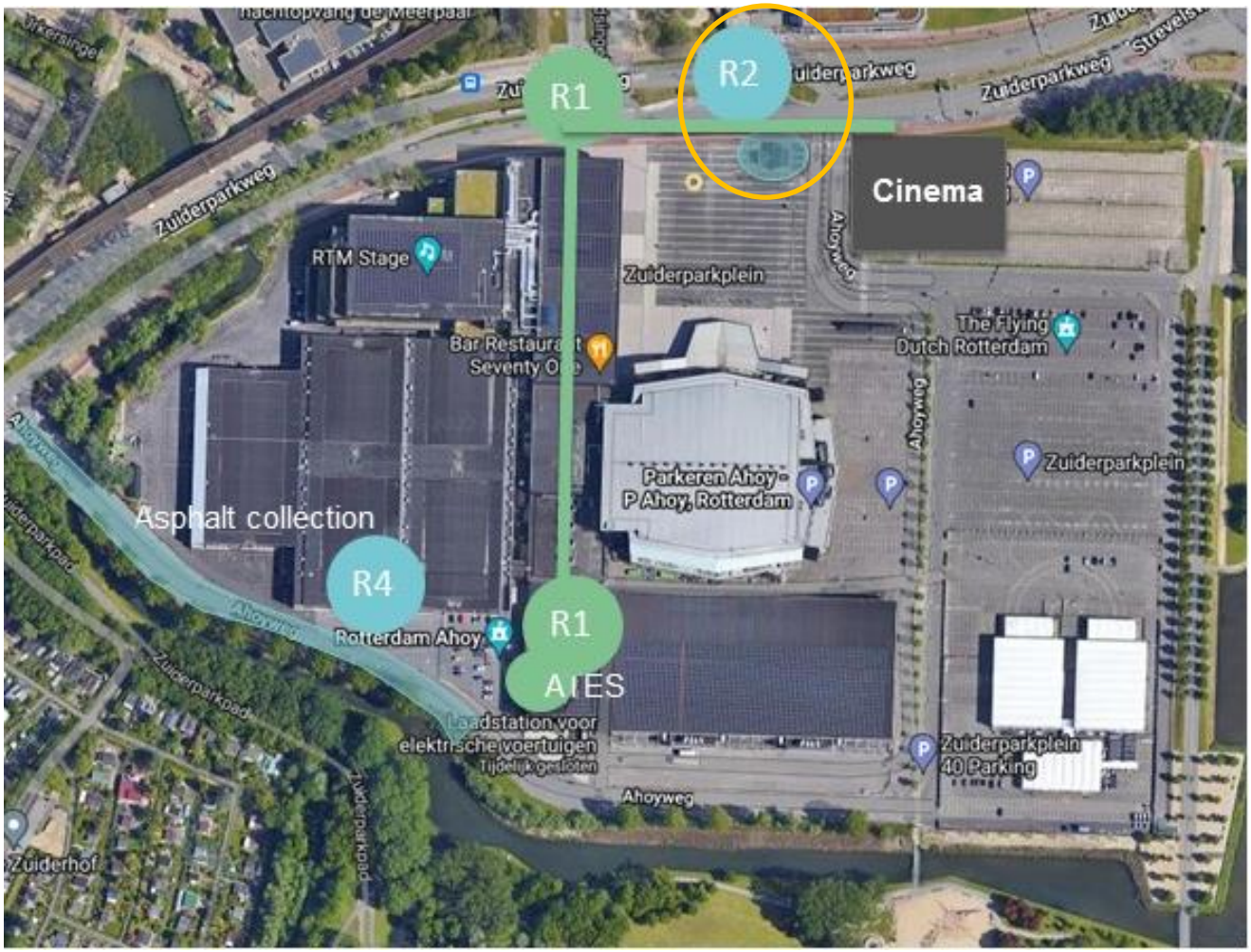

Figure 5: An overview of the Ahoy complex, RACC and cinema. All buildings connected by the main backbone (R1) and 2nd backbone to the cinema

2. Riothermia

Riothermia includes extracting warmth and cold from sewage water to deliver the base load for heating or cooling buildings. In summertime, this technique can use the coolness in the sewage system for passive or active cooling of buildings, as the temperature of sewage water is often lower and more constant than the outside temperature.
A riothermia system consists of a technical space, pipes and a delivery system in the building. The main components of a riothermia system are usually a heat collector (extracts heat from waste water), heat exchanger (brings heat from the sewage pipe to the building) and a heat pump (to boost the heat to an adequate building temperature). However, in the case of Rotterdam it is chosen to not use a heat pump because this was too costly (chapter 4 further elaborates on this). This implies that Ahoy needs additional heating systems (in their case district heating) to come to the desired temperature in the building. The heat from sewage water forms thus part of a larger heating system. The heat exchanger and heat collector are usually placed in the sewage pipes, but this is done differently in Heart of South (chapter 3 explains why). Furthermore, the riothermia system consist of two circulation pumps that pump the water around in the system.

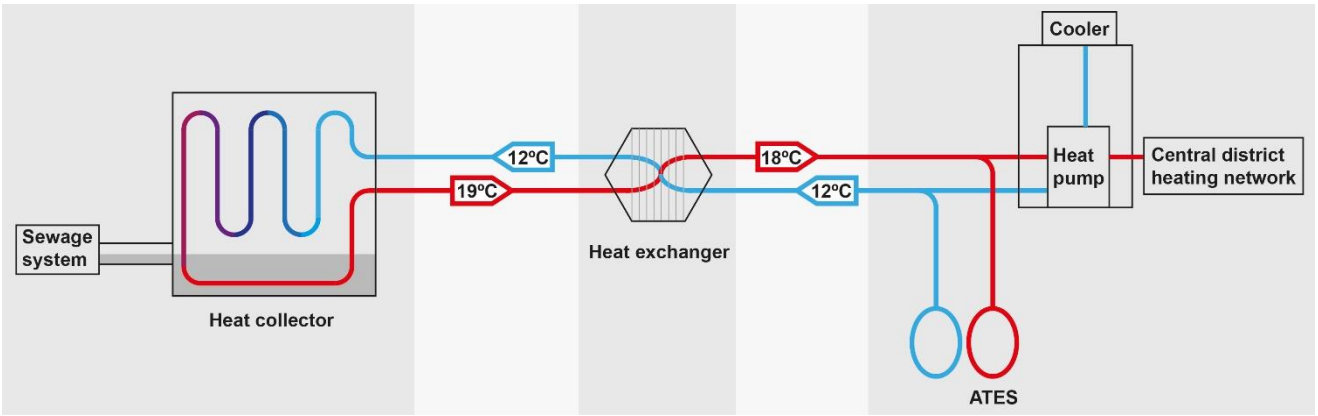

Figure 6: schematic overview of the functioning of riothermia

3. Implementation

3.1 Designing the system

Every sewage water extraction system has to be adapted to local circumstances. The first part of the implementation process thus started by investigating specifics on the available waste streams in the district.

The first step in the implementation process of riothermia in Heart of South was finding an adequate location of the heat exchanger and heat collector. The heat exchanger is usually placed close to the building, because heat is preferably transported over a short distance so relatively little heat losses take place. The pumping station of the already existing sewage system is located close to the Ahoy building, this seemed the best place to install the heat exchanger. Finding an adequate location for the heat collector was more complicated. Normally, the heat exchanger is placed within a sewage pipe and therefore the following options were explored: the inside of a gravity sewer pipe, in the incoming pressure sewage pipe or in the outgoing pressure sewage pipe. However, these pipes were not suitable for this system. The existing sewage pipes were due to be replaced, planned a few years after the RUGGEDISED project. It was decided that it would be a waste to implement the system for just a few years whilewhile the riothermia system lasts at least 20 years. Within the other sewage system near the complex there were a lot of, non-return valves in the pipes. These obstacles made it impossible to implement a certain length of contiguous plates within the sewage pipes The third sewage piping system was impossible to use due to a complicated angle of the sewage pipe. After the exploration of these options, the pumping station was explored. This resulted to be an adequate solution because, in contrast to the other options, there was enough space to place the heat exchanger.

The second phase of the implementation process included aligning requirements of the municipal maintenance department, who are the asset owners and therefor responsible for the safety of the sewage system. The maintenance department's main objective is to secure the operational reliability. This pumping station is one of the largest in the city and therefore of vital importance for the sewage system of the southern part of the city. The department checks the capacity of the basin, the possibility of obstruction by piping in the basin and the effects of the heat exchanger to turbulences in the basin and the system.

The layout of the system is as follows: the heat exchanger and the heat collector are placed in the basin of the pumping station, below ground level. The heat exchanger can be seen on the left side in figure 7. The circulation pumps are placed on the other side of the pumping station, a room previously in use as shower and changing room. The pumps for the internal circuit in the pumping station and the external circuit to Ahoy are together known as 'skid'. The skid is shown on the right side of figure 7. Those installations, heat exchanger and skid, are connected by piping which crosses the pumping station.

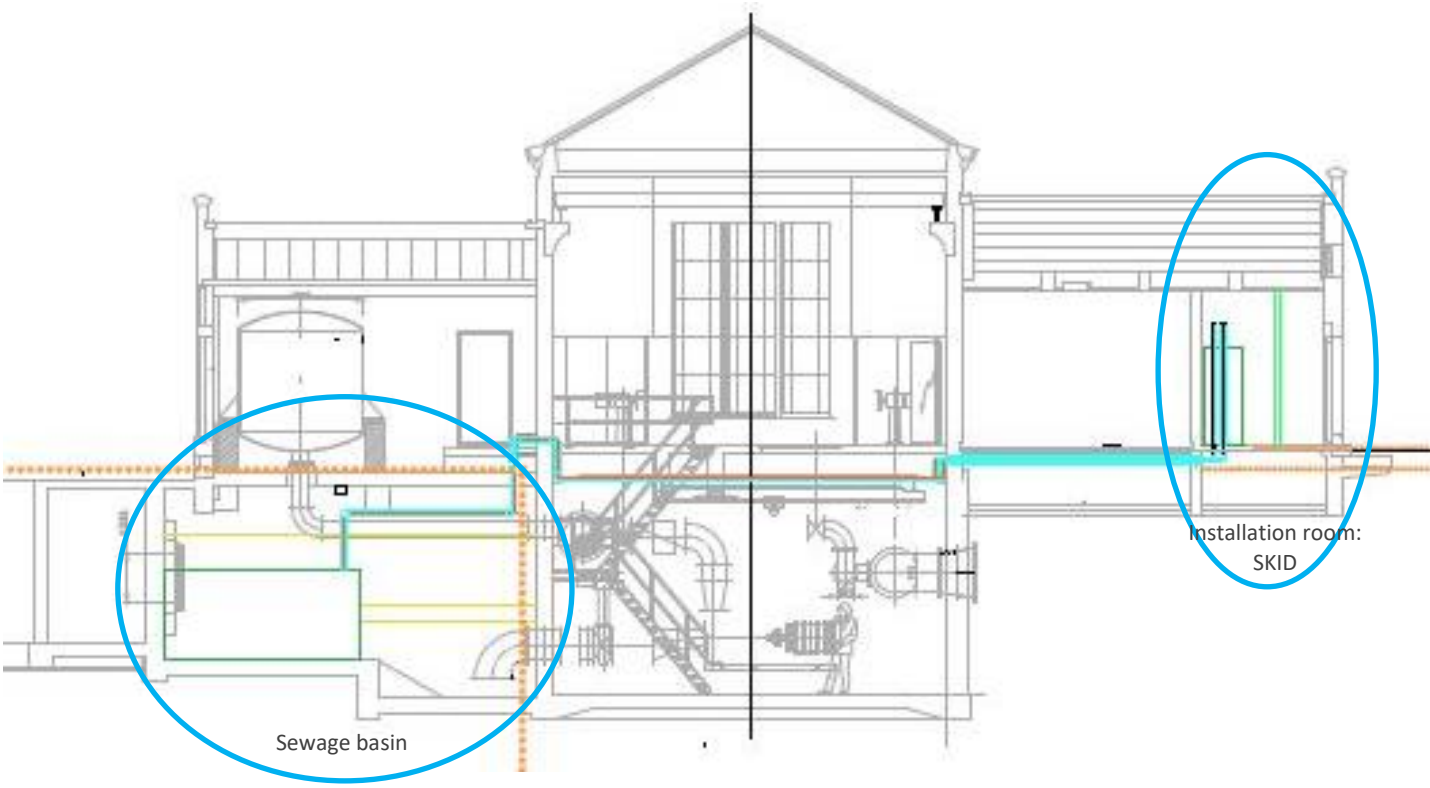

Figure 7: Schematic overview of the riothermia system within the pumping station

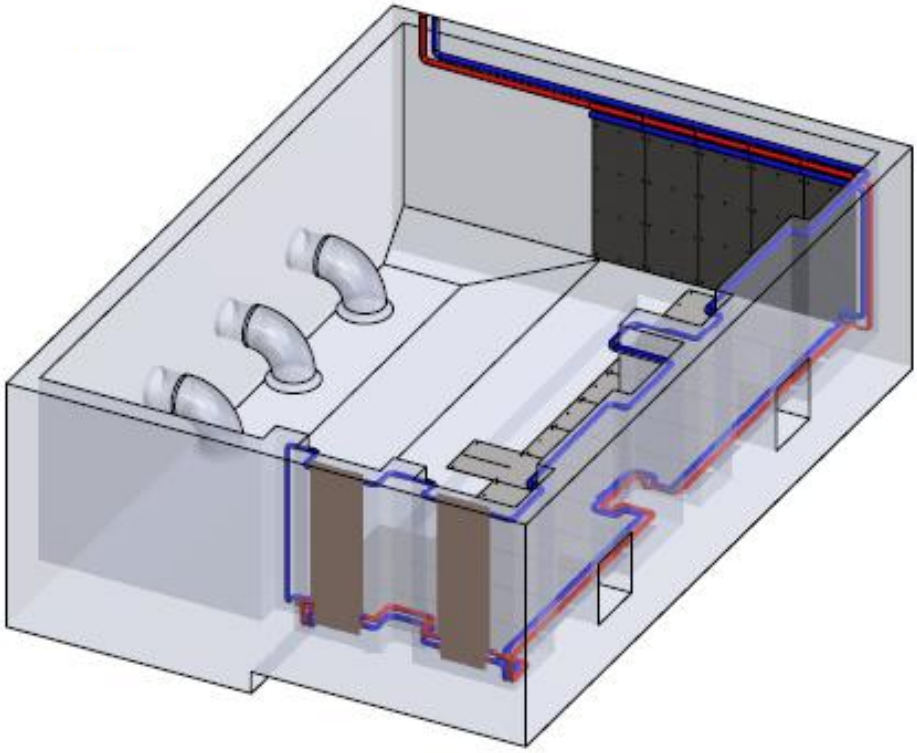

Figure 8:Configuration of the heat collector panels in the basin of the pumping station

Figure 9: Starting of the construction works on the backbone from Ahoy to pumping station

Figure 10: Starting of the construction works on the backbone from Ahoy to pumping station

Figure 11: SKID inside the technical room

Figure 12: Piping inside the pumping station

>> Figure 13: Heat collecting panels inside the basin

Figure 14: Heat collecting panels inside the pumping station on the floor and the wall of the basin

4. Business plan

4.1 Financial concept

Financially, the business case of the waste streams is structured as follows.

The Municipality of Rotterdam is investing in the construction and connection of the equipment of the waste stream grid. The heat collector in the basin and the piping to connect it to the technical room is funded by the RUGGEDISED project. The daily cleaning, inspection of the basin and general maintenance costs were covered by the asset owner of the City Maintenance Department.
Eneco invests in the equipment of the technical room (SKID) and carries out the necessary maintenance.

The investments for the connection of the technical room to the STG (piping to Ahoy) is done by the municipality, funded by the RUGGEDISED project.

The high up-front investments for the total STG, on top of the RUGGEDISED funding, are equally paid by the consortium partners, Eneco, Ballast Nedam and the Municipality. These costs are paid back, yearly by Eneco, by generated energy from this smart solution (regulated energy prices). When these costs are paid back, the profit is divided by the 3 partners as well. Given the fact that the sales price of the produced energy competes with the buying price of district heating, we estimate that this installation is not going to be very profitable. For cooling, the compression chillers on the roof of Ahoy are used. They were already in use before the RUGGEDISED project started. For cooling, the wastewater is competing with these compression machines. Therefore, this is a true test case to see if riothermie can compete with compression chillers. The investment, however, can be recovered and therefor is expected to be cost neutral.
For this reason, it is not recommended to build these kinds of installations within an area where district heating is the competitor and is offered by the same energy provider. While in any other region / cases, this source can be highly profitable, and it has a more sustainable impact. For the cinema there is an advantage to connect to the STG for cooling, since their demand for cooling is more than the demand for heating. By connecting to the STG, they spare on installing the compression chillers on the roof and they can use the roof for a terraced bar and events.

Expected costs

The costs for this smart solution can mainly be divided in two parts. There is the waste stream equipment itself and the connection to the existing backbone of the STG at the Ahoy complex

The costs including the design and engineering, materials (piping,) and installation will be approximately € 150.000,-

The connection to the backbone of the smart thermal grid costs around € 100.000 as well.

The structural maintenance costs per year are estimated at € 6.500 per year. The reduced costs as a result of the avoided purchasing of district heating plus the extra electricity costs lead to a net cost-neutral business case after a runtime of 20 years. The installations have a lifespan of over 30 years.
The business case was calculated before energy crisis. It would change dramatically with current energy crisis. District heating prices are coupled to gas prices, at the moment, but electricity prices have gone up as well. But the installation uses less electricity, then equally would be needed from District Heating. Monitoring has to give more insight.

4.2 Expected impact

The expected yield is 261 MWh, low temperature (± 18°C) energy per year.
The temperatures throughout the year in the sewage system is within the range of 11°C -22°C. There are some minor differences. During summertime the sewage water temperature is higher than in wintertime, there for the yields in summer are higher than in winter. Rainwater is cooler than sewage water coming from households, this means that during (longer periods) of rainfall the expected yields are lower than in dry periods.

Before implementation, in RUGGEDISED's work plan, it was expected that 30 kW of power could be achieved. While the implemented system is expected to deliver a maximum of 45 kW. Further monitoring will show the actual results. The maximum of 45 kW is an estimated average for the best conditions (summertime, July & August). The increase of impact is due to an increase of square meters of sewage heat exchangers within the basin of the pumping station instead of the sewage pipes.

When connected to the Smart Thermal Grid, and thus part of the energy system of the Ahoy centre, this leads to an annual expected decrease in energy consumption of 261 MWh district heating.

We expect a CO2-reduction impact of 36 ton/year, by adding this energy source to the Smart Thermal Grid, in comparison to the original Ahoy energy consumption before the RUGGEDISED solution were implemented, when Ahoy was still connected to natural gas.

Conclusions and recommendations

The conclusion of the research and the designing process is that the extraction of heat from wastewater is commercially and technically viable in the Heart of South area. There is a constant flow of heat from the wastewater, there is little to no maintenance necessary for the heat exchanger and heat collector in the basin; and just regular maintenance for the heat transfer system, which made this solution viable.

An important recommendation to partners is to carefully choose the basin of the final pumping station, as the functioning and continuity of the station must be secured at all times. If the riothermia system malfunctions this might affect the functioning of the sewage system. In this case, the pumping station is connected to the sewage system of a large area. If something stops functioning in the riothermia system, a large area might experience negative consequences. It is therefore recommended to choose smaller and 'less important' pumping stations in other projects.

Another recommendation related to the functioning of the pumping station is to make clear arrangements on:

- Maintenance and ownership. The demarcation of the different part of the installation should be clear.
- Governance of the installation process.
- Which stakeholder is responsible for the generation of energy? Can it be the asset owner (ea municipality), should it be the energy provider, or can it be a third private partner?
- Which stakeholder is allowed to sell energy to which parties? Is it an energy source feeding into an open network, or is it an asset belonging to the same asset owner (like an air-conditioning belonging to the building its cooling)?
- Which pricing is used to make the business case? Make clear arrangements at the start of the process and do not be too rigid with the daily price, keep a clear margin.

Appendix List

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