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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 surface water’ (R3).

In short, the surface water system extracts heat and cold from surface waters 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 seasonal aquifer thermal energy storage (ATES) (R1), to use it in another season. This solution is related 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, the thermal energy that is extracted from surface water could feed into the STG.

The implementation process consisted of several aspects. Preparation studies have taken place to investigate if the type of soil was adequate. Afterwards, the necessary permits were be obtained at the Water Board. The Municipality of Rotterdam had to show that the system would have no negative impact on the water ecosystem. Then calculations on the energy potential of the system were carried out. There resulted to be a large potential. Also, was investigated how the system could be optimally integrated into the surroundings and what party would be responsible for what task. Parallel to other processes, studies are done on financial feasibility. These studies show that when the full potential of the system is used, there is a positive business case.

However, the STG resulted to have a smaller capacity than expected on beforehand. This implied that not all the potential of the Smart Solutions could be used. Other Smart Solutions, like the pavement collector, resulted to be more cost-efficient and therefore had a preference to feed in. In the case that the surface water system was not fully exploited, the business case was negative, and because of that was decided to not implement the surface water installations in Heart of South.

Concluding, although the calculations showed that thermal energy from surface water has a large energy potential and a positive business case when optimally exploited, the system was not implemented due to local circumstances (too little capacity on the STG). Several recommendations to partners can be given. For example, that the characteristics of the area and the spot where the technical installation is placed are very determinative for the return of the investment. Another recommendation is to keep in mind that the profitability is dependent on the requirements of the concerning Water Board (as they might forbid to use the full potential).

# 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 within the area itself. Two grids were designed, one

Smart Thermal Grid (STG) and one Smart Electric Grid (SEG). Only the STG was realized as shown in the drawing below.
Figure 1: An overview of the Heart of South realised implementations.

## 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 bussiest 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 a Smart Thermal Grid (STG), which is based on renewable energy sources and facilitates the exchange of heating and cooling between buildings. The establishment of the STG potentially makes the Ahoy area natural gas free and thus possibly 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 document further elaborates on one of the solutions that could have contributed to feeding energy into the grid, namely extracting thermal energy from surface water (R3), which is displayed in the yellow circle in figure 4 It is a proven technology, but never used as a renewable energy source for – and connected to – a Smart Thermal Grid, ea. 5th generation energy network.

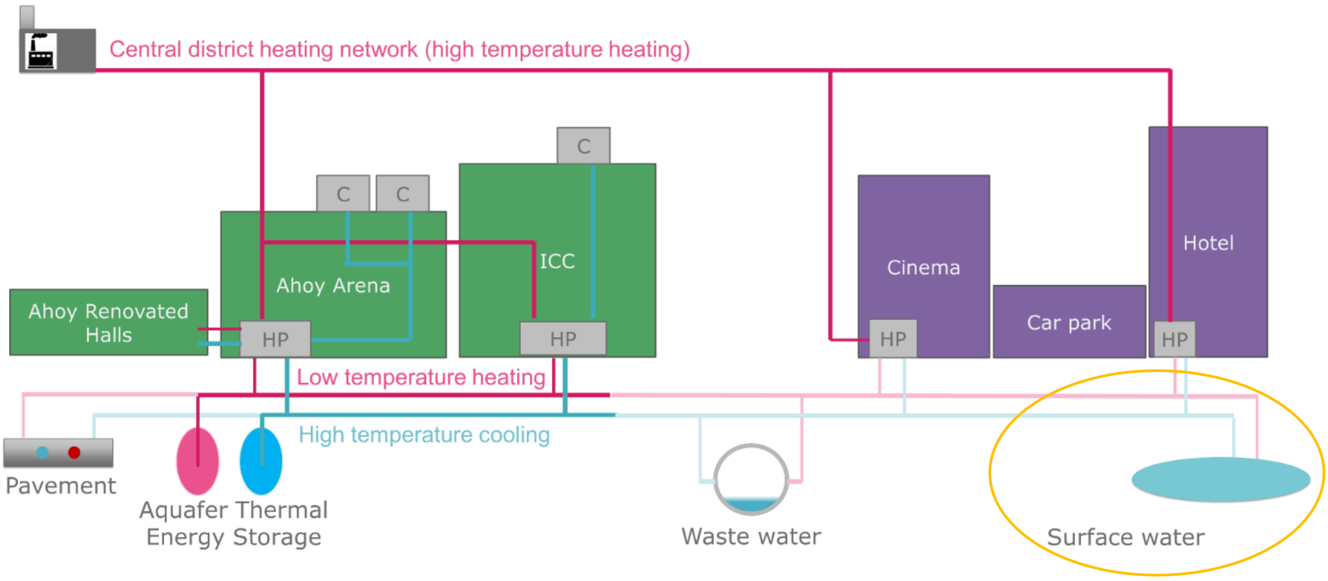


Figure 4: An overview of the buildings that are possibly connected to the STG in Heart of South.

STG is the whole system
C: compression chillers
HP: Heat pumps

Collecting heat or cold from surface water to produce thermal energy, is one of the solutions which is part of the Smart Thermal Grid. The STG is designed to deliver heating or cooling to the different halls of Ahoy, the Rotterdam Ahoy Convention Centre (RACC) and 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 it is not necessary to always heat or cool the whole complex.
Currently, the Ahoy area uses a hybrid heat and cooling system, in which a city district heating and the STG are combined. The STG is fed with four different energy sources, district heating and heat pumps/compression chillers for regenerating the base temperature, a pavement collector, and a wastewater collector to deliver the base load. All excess heating or cooling is stored in the seasonal Aquifer Thermal Energy Storage (ATES). Energy from surface water was supposed to be an additional source to the Smart Thermal Grid.
The idea was to situate this energy source in the surface water on the southern side of Ahoy. This water is the nearest to the installations of the STG in Ahoy. This is also visible is figure 6.

# 2. Thermal energy from surface water

## 2.1 What is thermal energy from surface water?

There are several sources from which aquathermal energy can be extracted, one of them is surface water. In this case, in summer, heat is extracted from surface water. This heat is stored in the ATES and can be used to heat buildings in wintertime. It is possible that the temperature of the heat is not high enough and in such a case a heat pump is used to warm it up to the desired level in the winter. The other way around, it is sometimes also possible to use the cold of the winter to cool buildings in the summer.

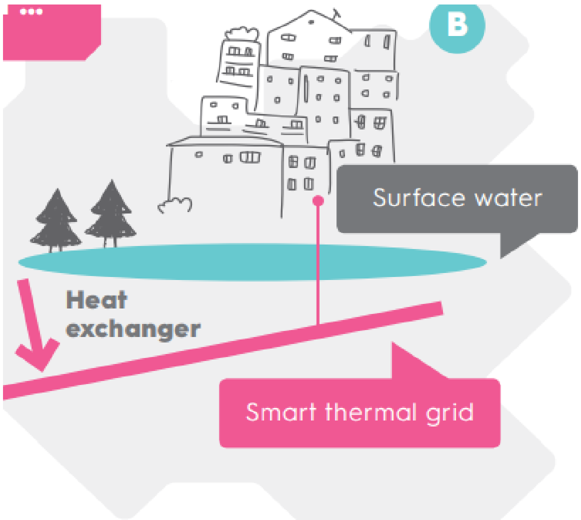



Figure 5: schematic overview of extracting energy from surface water.

## 2.2 The surface energy system  in Rotterdam?

The system consists of four main parts: the maintenance room, the pipelines and the in- and outflow provision. In the maintenance room, among others, the heat exchanger is situated, which enables extracting heat from the water. A schematic overview can be seen in figure 6. The maintenance room is connected to the pipelines. Two types of pipelines can be divided: 1) the pipes that go from the source (surface water in Zuiderpark) to the maintenance room and 2) pipes that go from the maintenance room to the STG. The buildings can use the heat or cold directly or the heat and cold is stored in the Thermal Aquifer Storage (ATES), which is located below the Ahoy complex. The type one pipelines are placed underneath the road surface and are around 50 meters long. More details about the type one pipes are given in Annex I. The inflow provision is placed near the source and pumps the surface water to the technical area. In this process the water is filtered to remove the most substantial pollution. In Annex II is further elaborated on the inflow provision. The outflow provision makes sure that the colder water returns after passing through the heat exchanger. In this way, the temperature of the water in Zuiderpark becomes lower which is advantageous for the ecosystem in the water.

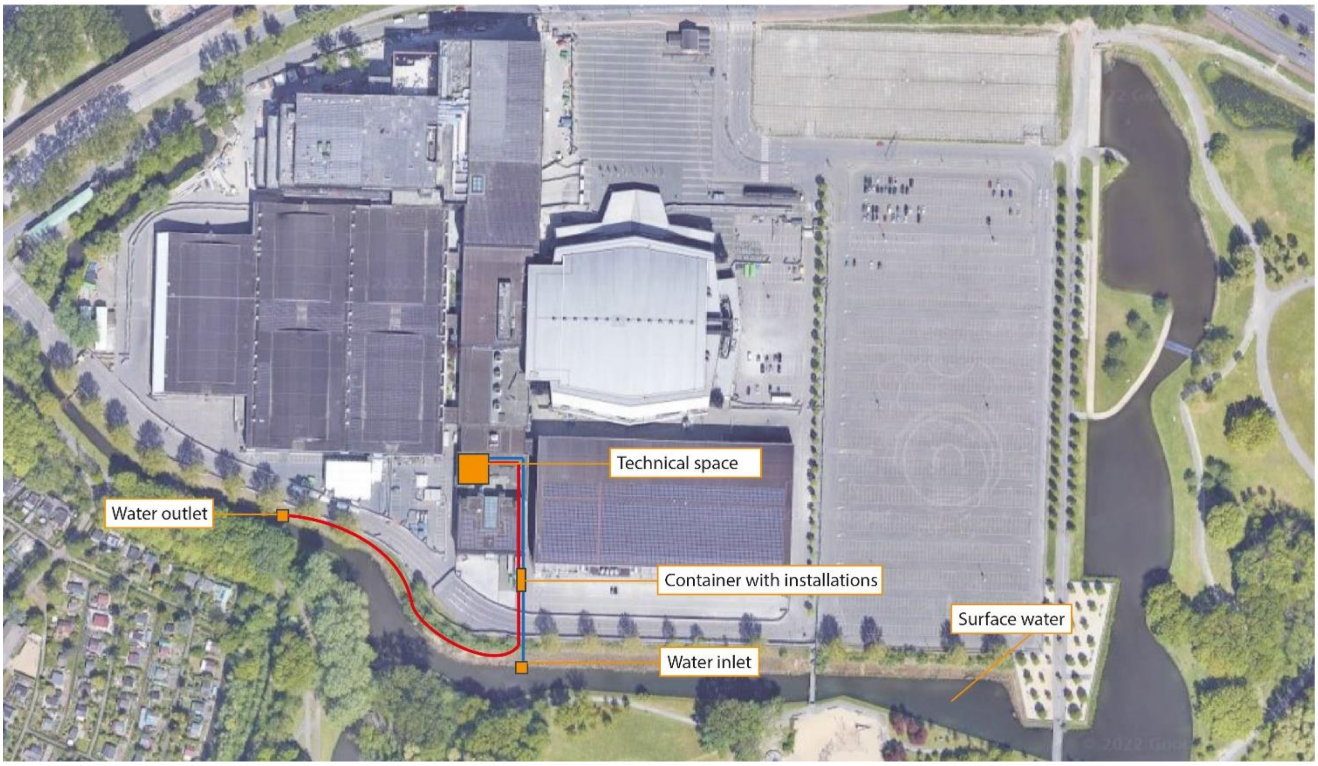



Figure 6: Schematic overview of installations in and around Ahoy

# 3. Implementation

## 3.1 Designing the system

Various studies have been caried out in anticipation of the planned work. For example, there was an environmental soil study to find out the characteristics of the soil, and a flora and fauna study to make sure the intervention would not harm the natural habitat of species in the area.

Furthermore, the necessary permits had to be obtained. For instance, permission was asked to the Water Board to extract and discharge water. The Water Board established several preconditions related to thermal effects, management and maintenance, and physico-chemical and biological effects. The Municipality of Rotterdam and the Water Board came to the agreement that a limited amount of water can be used and that the system must be monitored. The parties agreed that the Municipality is responsible for monitoring the operational data, like temperature near the in- and outlet, operating hours and flow rates. The Water Board monitors parameters like physics and nutrients of the water. The preconditions of the Water Board are further described in Annex III.

Also, several calculations were made. The potential of the thermal surface water installation for example had to be estimated. The potential of the system depends on the difference in temperature of the supply and retour flow. This means that 117 kW of power is generated at a ∆T of 1 °C. With a ∆T of 4 °C, this increases to 467 kW, while with a ∆T of 6 °C it is 700 kW. More explanation can be found inin Annex IV. From these calculations became clear that there is a limit on the amount of energy that can be supplied, due to the STG temperatures. Furthermore, calculations are done related to the energy yield of the installation. These calculations are explained in more detail in chapter 4.

Another aspect was the designing phase, which included finding an adequate location, spatial integration and finding the right materials for the technical system. Figure 7 below shows the final spot that resulted most fit. An important advantage of this location was, that it is close to the building. Figure 7 shows also how the system is integrated in the surrounding. Figure 8 shows the section of the container with all equipment such as pumps and a heat exchanger in the container.

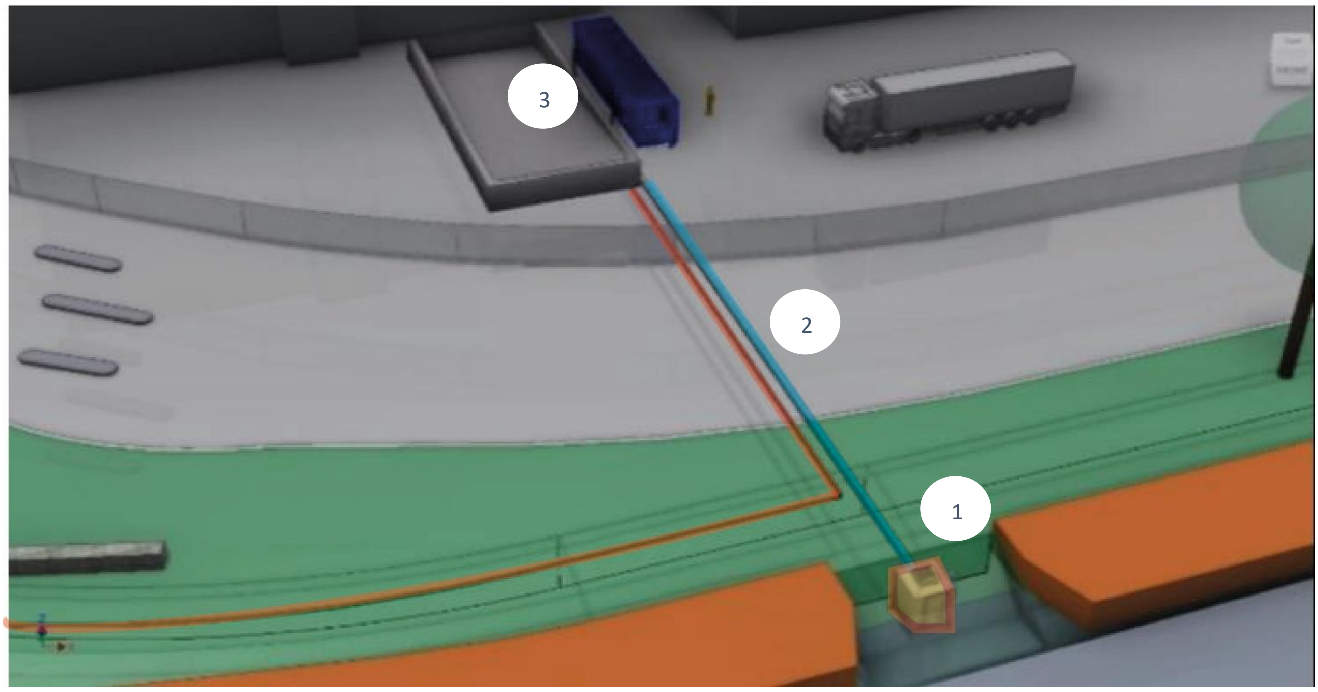



Figure 7: Overview of 1. inlet, 2. piping and 3. container

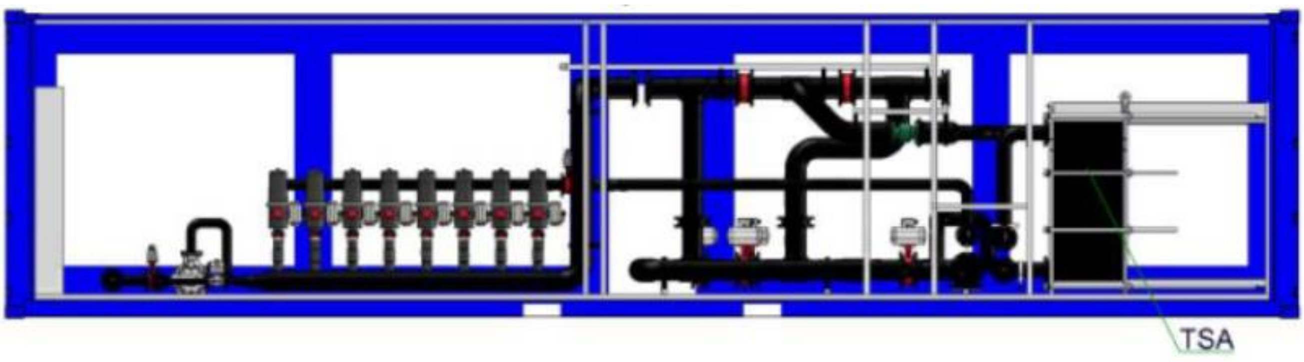



Figure 8: Sideview of the inside of the container. Technical installation with pumps and heat exchanger (TSA).

Moreover, asset management must be considered, which includes dividing management, maintenance and ownership of technology among various organizations and stakeholders. Decided is that the Property Department of City Development is the owner of the installation and that the management and maintenance is in hands of Xylem, a company that is specialized in innovative technical solutions related to water. Furthermore, Eneco is an important party as the organization is the owner of the ATES and also offtaker of heat extracted from the surface water installation.

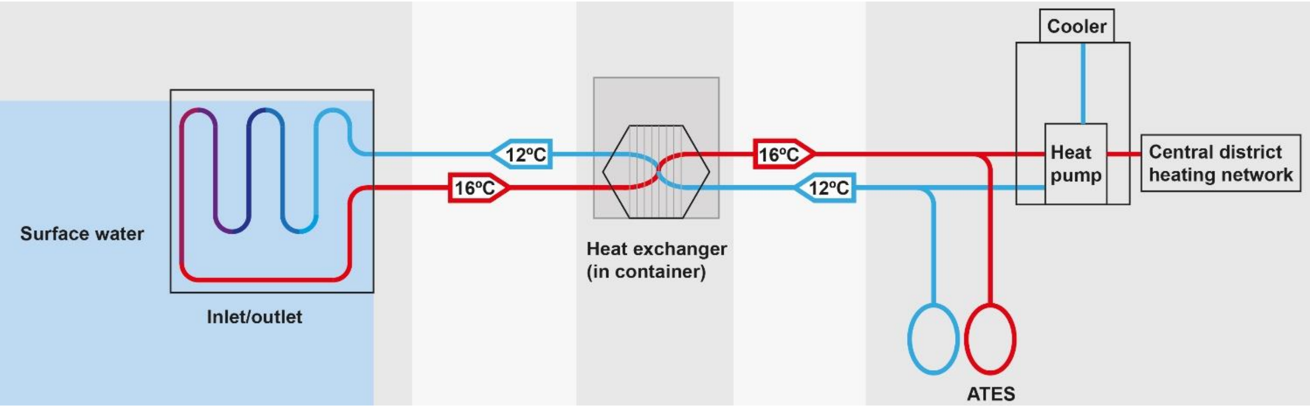



*Figure 9: schematic overview of the system*

The extracted surface water is part of the STG as the extracted heat and cold feeds into the grid. Depending on the demand, the heat and cold can be used directly or stored in ATES. The established heat-cold storage is referred to as solution R1. Besides this solution that focusses on surface water, there is another solution that focusses on sewage water, which is referred to as solution R2. These different water streams flow seperately into the STG.

## 3.2 Final decision

The maximum amount of usable energy yielded (1,223 GJ/year) is relatively low compared to the theoretical maximum available (approx. 7,000 - 23,000 GJ/year). The disadvantage of this lower usable energy yield is that less thermal energy can be generated with what is largely the same technical installation and the same associated investment costs. This has a negative impact on the financial return of the installation. The risk here is that other sustainable heat sources, such as aquathermal energy from wastewater or asphalt collectors, may be cheaper in relation to the relative yield. However, the advantage of the lower usable yield is that no problems due to intense cooling of the water system used are expected. It is also expected that enough heat will be utilised, so the thermal and other effects on the water system will remain visible and measurable. This means it will still be relevant and useful to monitor the effects on the water system.

After all, the final decision is that the negative business case outweighs the other aspects, such as research and monitoring of the water conditions. The yearly maintenance costs and investment costs do not outweigh the calculated yields of this smart solution.

# 4. Business plan

## 4.1 Expected impact

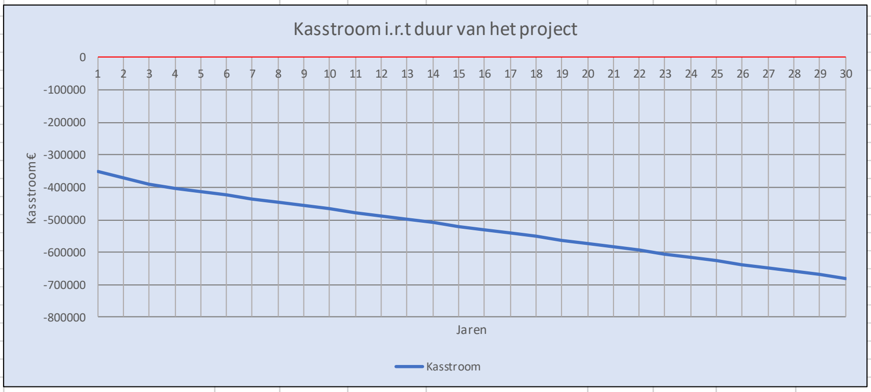
In the initiation phase there were large expectations of the STG and the Smart Solutions contributing to it. In reality, some developments took place which resulted in not all ambitions being fulfilled.

One development is related to the capacity of the STG. Relatively late in the process became clear that the capacity of the STG was not large enough to incorporate the full potential of all Smart Solutions that would feed into the grid. The asphalt collector mainly supplies heat during the day, so the surface water installation would have been able to supply in the evening. This implies however that the calculations showed that energy from surface water potentially has a large potential, this potential could not optimally be exploited. Therefore is chosen to not implement the energy extraction from surface water system.

## 4.2 Expected costs

Managing and maintaining a surface water installation (100 to 200 m3/h) is expensive. Approx. 13,100 euros per year. This TEO installation contains a wide variety of different parts. The installation, in particular the rotating parts (pumps of the thermal heat exchange installation (TSA)), require maintenance on a daily basis. The future supplier of the skid (Xylem) has indicated the daily maintenance costs of the installation on the basis of unit prices. The total costs over the service life of 10 years would approximately be 131,000 euros. The annual management and maintenance costs would approximately be 13,100 euros. The owner of the system would be the one to bear these costs.

| | TEO-installatie | | Operationele kosten | | Inkomsten | |
|---|---|---|---|---|---|---|
| | Technische ruimte | 85.000 € | O&M Warmtewisselaars | 1550 €/jaar | Variabele warmteprijs (2€/GJ) | 2.446 €/jaar |
| | Circulatiepomp | 25.000 € | O&M pompen | 1550 €/jaar | Variabele koudeprijs NTB | 0 €/jaar |
| | Filtersysteem | 65.000 € | O&M leidingen | 3000 €/jaar | Totaal per jaar | 2.446 €/jaar |
| | Leidingen | 30.000 € | O&M filters | 5.000 €/jaar | | |
| | Adviesuren (500 uur á 100€) | 50.000 € | Elektriciteit installatie | 2.000 €/jaar | NB: eventueel te vervangen door PV-panelen met meerinvestering | |
| | Onvoorzien | 10.000 € | Totaal per jaar | 13100 €/jaar | | |
| | Warmtewisselaars | 75.000 € | | | | |
| | 2 jr begeleiding monitoringskosten | 20.000 € | | | | |
| | Totaal investering | 360.000 € | | | | |
| Totalen (levensduur 30 jaar) | | 360.000 € | | 393.000 €/30jaar | | 73.380 €/30jaar |




| jaar | (her)Investering | operationele kosten | Inkomsten | verschil | cumm. |
|---|---|---|---|---|---|
| 1 | 340.000 | 13100 | 2446 | -350.654 | -350654 € |
| 2 | 10000 | 13100 | 2446 | -20654 | -371308 € |
| 3 | 10000 | 13100 | 2446 | -20654 | -391962 € |
| 4 | 0 | 13100 | 2446 | -10654 | -402616 € |
| 5 | 0 | 13100 | 2446 | -10654 | -413270 € |
| 6 | 0 | 13100 | 2446 | -10654 | -423924 € |
| 7 | 0 | 13100 | 2446 | -10654 | -434578 € |
| 8 | 0 | 13100 | 2446 | -10654 | -445232 € |
| 9 | 0 | 13100 | 2446 | -10654 | -455886 € |
| 10 | 0 | 13100 | 2446 | -10.654 | -466540 € |
| 11 | 0 | 13100 | 2446 | -10654 | -477194 € |
| 12 | 0 | 13100 | 2446 | -10654 | -487848 € |
| 13 | 0 | 13100 | 2446 | -10654 | -498502 € |
| 14 | 0 | 13100 | 2446 | -10654 | -509156 € |
| 15 | 0 | 13100 | 2446 | -10654 | -519810 € |
| 16 | 0 | 13100 | 2446 | -10654 | -530464 € |
| 17 | 0 | 13100 | 2446 | -10654 | -541118 € |
| 18 | 0 | 13100 | 2446 | -10654 | -551772 € |
| 19 | 0 | 13100 | 2446 | -10654 | -562426 € |
| 20 | 0 | 13100 | 2446 | -10654 | -573080 € |
| 21 | 0 | 13100 | 2446 | -10654 | -583734 € |
| 22 | 0 | 13100 | 2446 | -10654 | -594388 € |
| 23 | 0 | 13100 | 2446 | -10654 | -605042 € |
| 24 | 0 | 13100 | 2446 | -10654 | -615696 € |
| 25 | 0 | 13100 | 2446 | -10654 | -626350 € |
| 26 | 0 | 13100 | 2446 | -10654 | -637004 € |
| 27 | 0 | 13100 | 2446 | -10654 | -647658 € |
| 28 | 0 | 13100 | 2446 | -10654 | -658312 € |
| 29 | 0 | 13100 | 2446 | -10654 | -668966 € |
| 30 | 0 | 13100 | 2446 | -10654 | -679620 € |

*table 1 & 2:Business case estimation*

Given the fact that the sales price of the produced energy competes with the price of district heating, we estimated that this installation is not generating profits. 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.

As explained before, there is decided to not implement the surface water installation, as the lower usable energy yield of the surface water installation had a negative impact on the financial returns of the installation, as the technical installation and thus the investment costs stay the same. This implies that other sustainable heat sources, such as thermal energy from pavement collectors, were cheaper and thus preferable.

# 5. Conclusions and recommendations

These are the overall conclusions from research to energy from surface water. The research is done by a team from the Engineering Office of the Rotterdam Municipality.

The conclusions are:

- The water surface has a considerable energy potential (7,000-23,000 GJ/year), but the actual energy that can be added to Eneco's Smart Thermal Grid (STG) is very limited (1,223 GJ/year).
- The 'current' capacity of the STG is not sufficient for all Smart Solutions.

The maximum amount of energy that can be used (1,223 GJ/year) is relatively low compared to the theoretical maximum available (approx. 7,000 - 23,000 GJ/year). As mentioned, the information from Eneco, which made it clear that the power to be injected into the Smart Thermal Grid is limited by and dependent on the real-time cooling demand on the grid, has meant that the maximum usable amount of usable energy has decreased by about 61%. Whereas previous calculations could assume that the maximum amount of usable energy was about 7,715 GJ/year (BC project plan 2020), only 1,223 GJ/year can now be assumed following this information.

The disadvantage of this lower amount of usable energy is that less thermal energy can be generated with what is largely the same technical installation and the same associated investment costs. This has a negative impact on the financial return of the installation.

- The location is very determinative for the investment. Advice for the future is to realise a water inlet and outlet point at the shortest possible distance (max 100 m), and the emission of heat close to the end user (max 100 m).

The design and engineering phase have looked at the whole range of different locations for the TEO installation. After conducting the necessary consultations and site visits, this ultimately resulted in a definitive location for the technical area. In this design process, one starting point was of great importance; the technical area had to be as close as possible to the watercourse and the Smart Thermal Grid.

- Managing and maintaining a TEO installation (100 to 200 m3/h) is expensive. Approx. 11,500 euros per year.

This TEO installation contains a wide variety of different parts. The installation, in particular the rotating parts, will require maintenance on a daily basis. The future supplier of the skid (Xylem) has indicated the daily maintenance costs of the installation on the basis of unit prices. The total costs over the service life of 10 years are approximately 115,000 euros. The annual management and maintenance costs are approximately 11,500 euros. The future owner of the system will have to bear these costs.

- Generating energy from surface water is profitable if you can meet the requirements of the water boards, and where utilisation of the remaining energy potential is maximised. An installation with industrial filters (> 200 m3/h) is recommended.
- The requirements of the water boards mean that the generation season is limited, which reduces the energy potential of the TEO.

The surface water is cleaned by the filters before it enters the heat exchanger. The filter system uses the surface water to flush the filters clean with a backloop. This water enters the return pipe, where it is transported to an outlet in the canal next to Ahoy.

Water Board conditions
The temperature of the discharge water is leading for the ecological effects. The purpose of these criteria is to prevent cold discharges having an adverse impact on the development of macrofauna and fish.

The discharge water must be free of additives and contain at least as much oxygen as the inlet water and chemical cleaning is not permitted (mechanical cleaning of the technical installation is necessary for this).

The extraction of the surface water may not lead to large-scale suction of organisms such as fish and fish larvae. This requires measures at the inlet point. The CIW assessment system for heat discharges provides tools for this. Depending on the situation in the water system, it must be examined whether the current that arises has a positive or negative effect on water quality. In urban areas, for example, it is desirable to stimulate flow to maintain oxygen levels, and fight botulism and duckweed growth. The same principle applies in the summer with low, warm water. However, it is possible that during dry periods, withdrawing water is not allowed to protect the water system.

From the implementation of the surface water system in the RUGGEDISED project several technical, organisational and financial conclusions can be drawn. The studies on spatial integration showed that the system could have been integrated in the Ahoy area and the calculations showed that the system could have a large energy potential. Furthermore, there were organisations willing and able to implement the system. Financial studies showed that if the system is fully exploited, there would be a positive business case. However, in the case of Heart of South, the surface water system can not fully be exploited due to the limited capacity of the STG. Practice showed that other energy solutions, like pavement collectors, have lower operating costs and are thus preferable.

There are several recommendations for partners. One is that the location is very determinative for the investment. For the location it is advisable to realise the water in- and outlet point at the shortest possible distance and the emission of heat close to the end user, both with a maximum of 100 m. Furthermore, it is very important that the technical area of the installation is as close as possible to the watercourse and the Smart Thermal Grid.The placing of three different pipelines – inlet to TSA, TSA to technical space and TSA to outlet – need to be well thought out. Inlet and oulet not to close to each other, to avoid influence of the outlet water to the inlet water and a short pipeline in general to avoid heat losses in the pipeline. Also, the infrastructure will be more expensive when the piping is longer. More costs and less energy with longer piping might cause a negative business case. Also, it is important to realise that the profitability of the solution depends on the requirements of the Water Boards, if existing in the country you're working in. If the Water Board forbids to use the full potential of the system because of ecological reasons, this could mean that the system becomes financially unfeasible. Within this solution you need to strive for positive effects for the local biodiversity. The surface water could benefit from cooler water when it's hot and hotter water when it's cool. This might lead to less growth of algae, which is positive for the status of the surface water.

# 6. Appendix List

## 6.1 Annex I: details on pipelines

Below is described what pipes are used to transport water from the source to the technical installation. The pipes from the technical area to the STG are thus not included.

The pipework can be divided into the following pipes:

- Ø 200 mm HDPE SDR17, length approx. 45 m, from inflow provision to skid, concerns suction pipe for surface water.
- Ø 63 mm HDPE SDR17, length approx. 45 m, from skid to inflow provision, concerns flushing pipe for cleaning the intake filter.
- Ø 200 mm HDPE SDR17, length approx. 305 m, from skid to outflow provision, concerns return flow to surface water. This pipe section is also provided with six plastic inspection wells.

The pipework for laying the required monitoring/measuring equipment can be divided into the following pipes:

- Ø 40 mm HDPE, length approx. 45 m, from skid to inflow provision.
- Ø 40 mm HDPE, length approx. 305 m, from skid to outflow provision.

## 6.2. Annex II: inflow provision

In this Annex more information is given on the inflow provision.

In order to arrange the inflow of surface water, a well must be built. The well structure is made of concrete (1,500 x 1,500 mm internal size) and built around 45-meter south of the technical area in the waterline.

The inflow provision is provided with a coarse-waste grate, partition beam grooves (in connection with drying out the pit for maintenance), a 700x700 millimetre opening (for inserting and removing the filter), and a handrail. All these provisions are for preventive cleaning and easier maintenance of the intake filter. Figures 6 gives an impression of the inlet concerned.

Prior to commissioning, the watercourse is dredged (in consultation with the Water Board) to the regular draft, so that the surface water is sucked up as efficiently as possible.

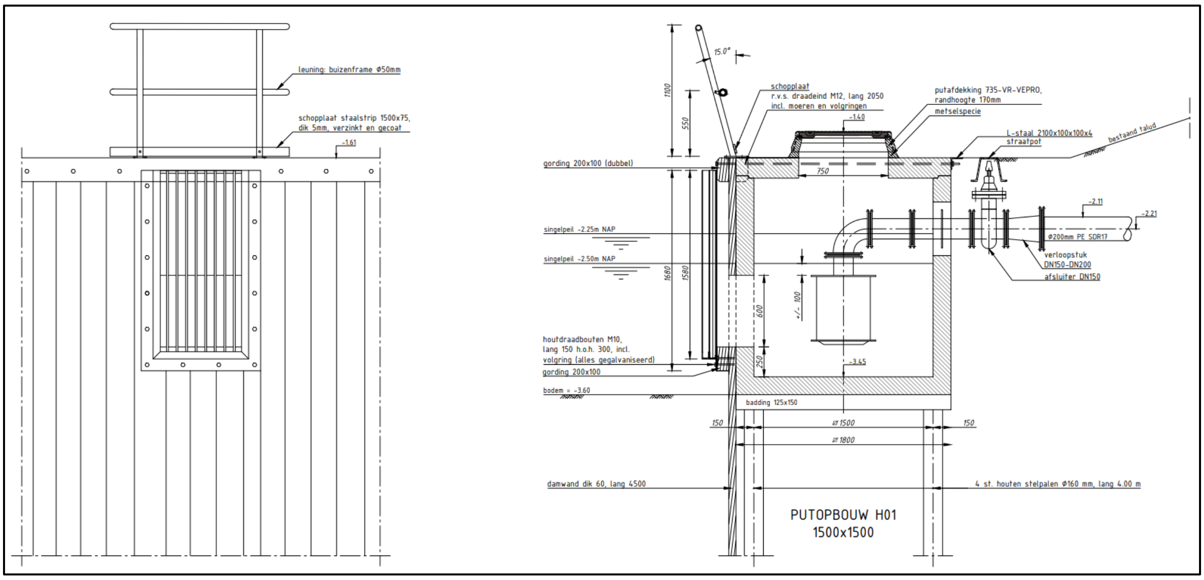


Figure 6: Inflow provision for the suction of surface water.

## 6.3 Annex III: preconditions of Water Board

The Water Board set various preconditions that must be met when extracting and discharging water. The organization established conditions related to thermal effects, management and maintenance, and physico-chemistry and biology.

### 6.3.1 Thermal effects

The temperature of the discharge water is a leading criterion for ecological effects. The purpose of these criteria is to prevent cold discharges having an adverse impact on the development of macrofauna and fish. The conditions for example must prevent a biological extension of the winter season in the spring.

1. In the spring, water may be extracted at a temperature of 16 °C and higher.
2. The temperature of the receiving water must not fall below 15 °C.
3. The discharge water must not be colder than 10 °C.

### 6.3.2 Management and maintenance

1. The discharge water must be free of additives and contain at least as much oxygen as the inlet water.
2. Chemical cleaning is not permitted (this implies that mechanical cleaning of the technical installation is necessary).

### 6.3.3 Physico-chemistry and biological preconditions

1. The extraction of the surface water may not lead to large-scale suction of organisms such as fish and fish larvae. This requires measures at the inlet point. The CIW assessment system for heat discharges provides tools for this.
2. Depending on the situation in the water system, it must be examined whether the current that arises has a positive or negative effect on water quality. In urban areas, for example, it is desirable to stimulate flow to maintain oxygen levels, and fight botulism and duckweed growth. The same principle applies in the summer with low, warm water. However, it is possible that during dry periods, withdrawing water is not allowed to protect the water system.

## 6.4 Annex IV: calculations energy potential

Below is explained how the energy potential of the surface water is calculated. Certain starting points and progressive insights are used for theoretical potential calculations. The document 'water system_potential_randvoorwaarden' describes the theory behind the calculations in further depth.

The theoretical energy potential of the TEO system is determined by the equation Q=m*c*ΔT.

Q = energy supplied [kW]
m = mass flow [kg/s]
c = specific heat of water [4.2 kJ/(kg.ºC]
ΔT = temperature difference [ºC]

In this calculation the difference achieved with the heat exchanger in the surface water installation is used. This ΔT will vary between 1 and 6 °C, depending on the season and the water temperature.

A surface water installation with a flow rate of 100 m3/hour is chosen. This means that 117 kW of power is generated at a ΔT of 1 °C. With a ΔT of 4 °C, this increases to 467 kW, while with a ΔT of 6 °C it is 700 kW. This shows that the amount of power generated is very sensitive to the ΔT across the heat exchanger, which is why it took a lot of effort to examine what values could be achieved in each season. In addition, the STG requires that the supplied energy is of a certain temperature, and the values of the supplied energy on their turn depend on the outdoor temperature. The relation between the water and outside air temperature is shown in figure 7.

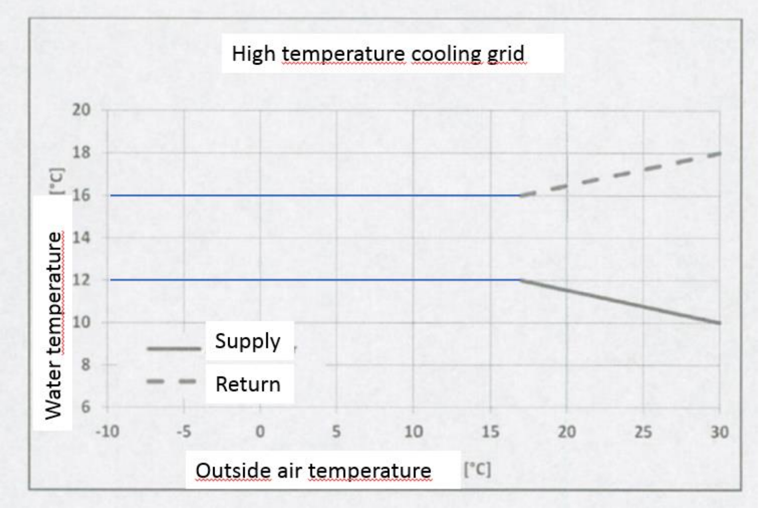



Figure 7: Smart Thermal Grid supply and return temperatures against outdoor temperature.

The figure shows that the STG has a constant value of 16 °C, at outdoor temperatures up to around 17 °C. If the outdoor temperature is higher, the STG temperature rises linearly to a maximum of 18 °C, at an outside temperature of 30 °C.

The average temperature of the surface water from 2016 to 2019 was determined on the basis of Figure 8.

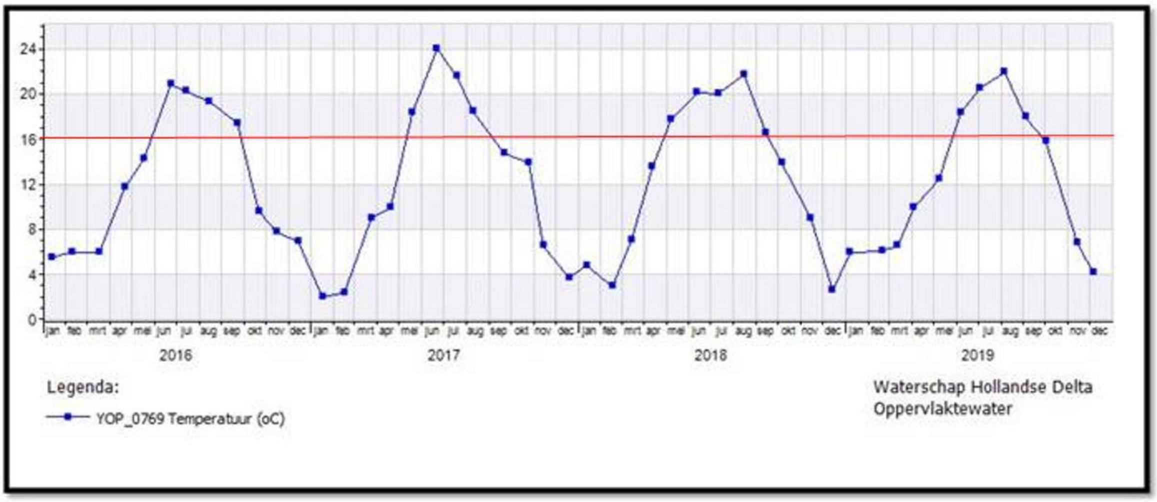



Figure 8: Temperature trend of the water system around Ahoy (Zuiderpark).

Then the long-term average temperatures, according to the Royal Netherlands Meteorological Institute (KNMI), were used to determine what ΔT is possible. The calculations here were conservative: average ΔT of 1 °C (average power 117 kW) in spring and autumn, and ΔT of 4 °C (average power 467 kW) in summer. In winter there is no energy supplied. This limitation in terms of STG temperatures, implies that water has to be withdrawn from the Ahoy water system at a temperature of at least 16 °C and returned at a minimum of 11 °C, in order to be sure that is complied with the discharge requirements of the Water Board. See Figure 9 for more detailed information per season. A total of 872.3 MWh gross of heat can be extracted. After deduction of the pump energy (36.6 MWh), a net amount of 835.7 MWh can be generated. This takes into account Eneco's requirement that energy is supplied on the basis of STG temperatures from 17 °C on.

| | | **TEO - 100 m3/h** | | | |
|---|---|---|---|---|---|
| Seizoen | Tijdsblok | Gem vermogen [kW] | Uren geleverd [uur] | E opbrengst theoret [MWh] | |
| Winter (dec-feb) | 22-6 uur | 0,00 | 0,00 | 0,00 | |
| | 6-17 uur | 0,00 | 0,00 | 0,00 | |
| | 17-22 uur | 0,00 | 0,00 | 0,00 | |
| Voorjaar (mar-may) | 22-6 uur | 117,00 | 96,32 | 9,02 | |
| | 6-17 uur | 117,00 | 132,44 | 12,40 | |
| | 17-22 uur | 117,00 | 60,20 | 5,63 | |
| Zomer (jun-aug) | 22-6 uur | 467,00 | 730,00 | 272,73 | |
| | 6-17 uur | 467,00 | 1.003,75 | 375,00 | |
| | 17-22 uur | 467,00 | 456,25 | 170,46 | |
| Herfst (sep-nov) | 22-6 uur | 117,00 | 96,32 | 9,02 | |
| | 6-17 uur | 117,00 | 132,44 | 12,40 | |
| | 17-22 uur | 117,00 | 60,20 | 5,63 | |
| | | | **Totalen opwek bruto** | **872,28** | MWh |
| | | | | 3.140,20 | GJ |
| | | 0,04 | Inschatting pompenergie | 36,55 | MWh |
| | | | **Totalen opwek netto** | **835,72** | MWh |

Figure 9: Gross and net theoretical energy yield (based on 100 m3/hour).

The RUGGEDISED project proposal contains the commitment that thermical energy from surface water should supply 39.7 MWh of heat. It is positive to note that this requirement is more than met with the estimated generation of 835.7 MWh. Another location, closer to Ahoy, had influence on this.

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