RUGGEDISED
Designing smart, resilient cities for all

Vol. 2

Implementation report Rotterdam

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1. Progress summary visualisation table

Progress summary visualisation table	R1	R2	R3*	R4	R5*	R6**	R7	R8	R9	R10	R11*	R12	R13
Business model development Business model feasibility proven	Done Go decision	Done Go decision	Done No-go Decision	Done Go decision	Done N/A	Done N/A	Done Go decision	Done Go decision	Done Go decision	Done Pending decision	Done Go decision	Done Go decision	Done Go decision
Financial plan Finances approved by investors	Done Go decision	Done Pending decision	Done No-go Decision	Done Pending decision	Done N/A	Done No-go Decision	Done Go decision	Done Go decision	Done Go decision	Done Go decision	Done No-go Decision	Done Go decision	Done Go decision
Partners' Cooperation agreements cooperation agreements signed	Done Go decision	Done Go decision	N/A No-go Decision	Done Go decision	Done N/A	N/A N/A	Done Go decision	Done Go decision	Done Go decision	Done Pending decision	N/A No-go Decision	Done Go decision	Done Go decision
Project implementation plan development Project plan approved	Done Go decision	Done Go decision	N/A N/A	Done Go decision	N/A N/A	N/A N/A	Done Go decision	Done Go decision	Done Go decision	N/A N/A	N/A N/A	Done Go decision	Done Go decision
Approval/permit procedures All permissions and notifications procured	Done Go decision	Done Go decision	N/A N/A	Done Go decision	N/A N/A	N/A N/A	Done Go decision	In progress Pending decision	Done Go decision	Done Go decision	N/A N/A	Done Go decision	Done Go decision
Procurement process Key components procured	Done Go decision	Done Go decision	N/A N/A	Done Go decision	N/A N/A	N/A N/A	Done Go decision	Done Go decision	Done Go decision	Done Go decision	N/A N/A	Done Go decision	Done Go decision
Project implementation Project commissioned	Done Go decision	In progress Go decision	N/A N/A	In progress Go decision	N/A N/A	N/A N/A	Done Go decision	Done Go decision	Done Go decision	Done Go decision	N/A N/A	Done Go decision	Done Go decision
Monitoring phase Monitoring completed	In progress Pending decision	Delay Pending decision	N/A N/A	Delay Pending decision	N/A N/A	N/A N/A	In progress Pending decision	In progress Pending decision	In progress Pending decision	In progress Pending decision	N/A N/A	In progress Pending decision	In progress Pending decision
Upscaling phase Plans for upscaling	In progress Pending decision	In progress Pending decision	N/A N/A	N/A N/A	N/A N/A	N/A N/A	In progress Pending decision	In progress Pending decision	Done Go decision	N/A N/A	In progress Pending decision	N/A N/A	Done Go decision
Replication phase Replication planned	In progress In progress	In progress In progress	N/A N/A	N/A N/A	N/A N/A	N/A N/A	In progress In progress	In progress In progress	In progress In progress	In progress In progress	In progress In progress	In progress In progress	In progress In progress

In progress | Done | Go decision | Pending decision | N/A Not applicable | No-go Decision

* These solutions are still expected to be executed, but outside the scope and timeframe of the RUGGEDISED project.

** These feasibility studies have been executed and the solutions have feasible business case. The execution of these projects will be done outside the scope of the RUGGEDISED project.


Source: City of Rotterdam / Adrienne Wildeman

2. Executive summary

The Dutch City of Rotterdam has a proud, ongoing history as a global port city, is home to a socio-economically diverse population and aims to become a leading city both in digital development and sustainability. As such, the city's involvement in the EU-funded RUGGEDISED project is a way to combine these ambitions and develop one of the smartest districts in Europe in the neighbourhood of 'Hart van Zuid' or 'Heart of South'.

Even before the City was awarded funding as part of the RUGGEDISED project in 2016 to make its dream of smart sustainability leadership a reality, the City and private partners worked closely together. Since then, RUGGEDISED has helped strengthen this development through the demonstration of a series of sustainable and smart urban solutions in the 'Heart of South'. The district is located in the larger area of Rotterdam South and is home to the large venue Rotterdam Ahoy – a close collaborator of the project – as well as office buildings and cultural institutions, such as a theater, swimming pool and more.

Since 2016, this area has become smarter through work to implement thirteen RUGGEDISED solutions (R1-13). The thirteen smart-city solutions are currently in different phases of implementation, an overview of which is provided in the visualisation table.

The smart solutions specifically look into:

1. **Thermal energy** through the deployment of a Smart Thermal Grid connected to buildings, aquifer wells underground, thermal pumps and a smart management system.
2. **Smart Electricity** in the form of massive solar installations and the deployment of smart solutions – and thinking – to charge e-vehicles and installations in the area.
3. **A 3D Digital twin** allowing the City of Rotterdam to become a leader in sustainable city-planning and management using data.

By early 2020, Rotterdam had achieved many of its original goals: Most importantly, the Smart Thermal Grid (R1) is now deployed and connected to various buildings in the area and to aquifer wells underground. Studies on possible heat exchange have also been completed for both the Thermal Energy from Waste Streams (R2) solution and the pavement heat-cold collector (R4), which are both being installed. A possible method of extracting energy from surface water (R3) has also been studied, but was found to be unfeasible.

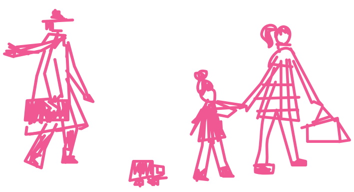
Extensive work, including the development of various business models and scientific studies, has been done on the development of photovoltaic installations and a charging station for e-Buses (R5). Meanwhile, solar panels are being installed on no less than 16,000 square metres of rooftop in the area. A solution for smart charging parking lots (R6) is currently on hold due to a separate procurement process that was run in the city and won by non-RUGGEDISED partners. However, important work has nonetheless been done to optimise e-charging of busses through advanced modelling (R7). In addition, a contract to install Energy Management Software (R8) has been signed with the Rotterdam Ahoy venue.

Rotterdam has also made great leaps forward in the development of a 3D city operations platform (R9) and has made several Proofs of Concept to add different functionalities to the "Digital Twin" of the Heart of South. Fourteen Smart Lighting poles (R11) – feeding data into the 3D city operations model – have also been installed and a successful smart waste solution (R13) is running in the Smart District. Unfortunately, due to public procurement hurdles, none of those run on the LoRa (Long Range) network (R10) as originally foreseen. Finally, a feasibility study has showed that there is a potential for a business case, although (R12), although this will not be completed as part of RUGGEDISED.

There are several upscaling plans for all of the project themes (thermal, electric and digital). Here are the highlights: The 3D digital twin has been extended with several new functions and options. For example, to support a city development plan, the model was used to integrate and overlap several sustainability challenges. Scaling-up electric grids is difficult because of regulations. Most of the upscaling deployment is within the theme of thermal energy. For several large city developments (two old city harbors – Rijnhaven and Merwe-Vierhaven - and Feyenoord City) the possibilities of a smart thermal grid are being explored. The potential of extracting energy from wastewater has been mapped for the whole city and several concrete plans are in preparation to exploit this.

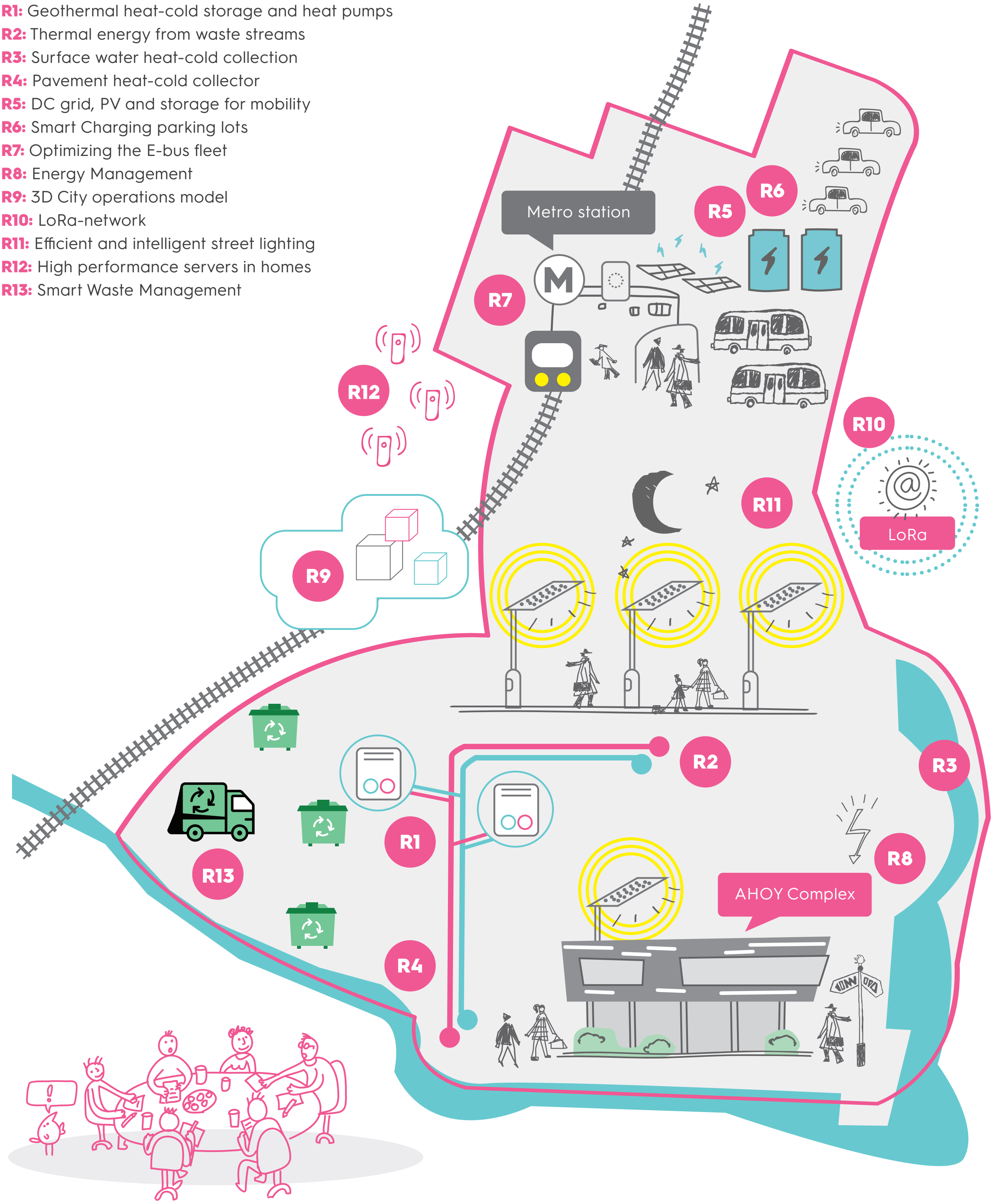
Thermal energy is a hot item in the city and surrounding municipalities. The team that is working on RUGGEDISED has grown and is working fulltime on energy related projects throughout the city. The cooperation with our municipal policymakers and city developers has intensified. Also, the cooperation with our external partners, for example RUGGEDISED partner Eneco, has intensified. We learned about the policies of city heating in relation to thermal grids.

This is the second of three implementation reports from Rotterdam and covers the implementation of solutions until early 2022.



Map of RUGGEDISED Solutions in the Heart of South district

R1: Geothermal heat-cold storage and heat pumps
R2: Thermal energy from waste streams
R3: Surface water heat-cold collection
R4: Pavement heat-cold collector
R5: DC grid, PV and storage for mobility
R6: Smart Charging parking lots
R7: Optimizing the E-bus fleet
R8: Energy Management
R9: 3D City operations model
R10: LoRa-network
R11: Efficient and intelligent street lighting
R12: High performance servers in homes
R13: Smart Waste Management



Source: City of Rotterdam / Claire Droppert

3. Rotterdam and RUGGEDISED

The current period in which we live is characterised by rapid technological development, the continuing globalisation of (social and economic) activities and a need to protect our living environment and to ensure social stability. As part of 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 smart solutions that are able to exploit and explore sustainable urban development opportunities.

The three overall aims of RUGGEDISED are:

1. Improving citizens' quality of life by offering a clean, safe, attractive, inclusive and affordable living environment.
2. Reducing the environmental impacts of activities, amongst others, by achieving a significant reduction of CO_2 emissions, a major increase in the investment and usage of renewable energy sources and an increase in the deployment of electric vehicles.
3. 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 boosting start-up and existing companies' ability to exploit the opportunities of the green digital economy and Internet of Things.

Rotterdam chose to focus its RUGGEDISED Smart City work on an area known as the "Heart of South." This district is part of the larger area of Rotterdam South and has 200,000 inhabitants who have diverse backgrounds spanning 169 different nationalities.

Rotterdam South faces relatively severe socio-economic challenges, such as low education levels, below-average incomes, higher unemployment levels, poor quality of housing, and an unattractive business climate. The area has been dominated by an infrastructure that mainly focuses on cars.

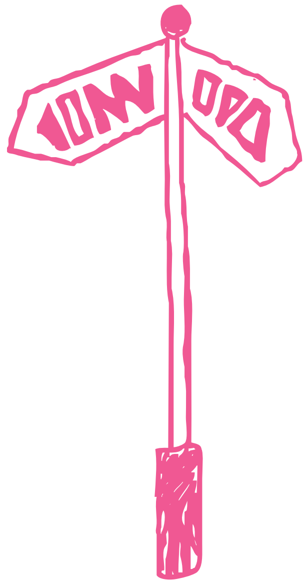
Prior to RUGGEDISED, the Heart of South district had already been chosen to undergo a serious transition in the upcoming years, consisting of the renovation of an outdated shopping centre, public transport hub, as well as various large-scale multifunctional buildings (e.g. a swimming pool, arts building, exhibition halls, congress centre).

Furthermore, the public space in the area is being drastically redeveloped. The City of Rotterdam is preparing Rotterdam South for the future, with a focus on the Heart of South. The redevelopment aims to achieve maximum energy efficiency and CO_2 reductions, as well as to have a major socio-economic impact (e.g. creating jobs, increasing levels of participation among citizens, increasing quality of life, etc.). The renovation of the area began in 2016 and is planned to continue until 2023.

Rotterdam's main objective within the RUGGEDISED project is to plan, implement and monitor thirteen RUGGEDISED Smart City demonstration solutions in the Heart of South area, to prove the feasibility of smart solutions for further implementation in Rotterdam and beyond.

The specific objectives for RUGGEDISED in Rotterdam are:

- To produce a majority of consumed-energy locally, by using and testing a variety of solutions.
- To increase the share of Renewable Energy Sources (RES) substantially and to optimise the use of RES for heating and cooling in the Heart of South.



- To expand the use of thermal waste streams.

- To reduce CO_2 emissions and air pollution, and improve local air quality by securing the roll out of electric vehicles (e-buses).

- To enable more efficient planning to optimise the e-bus fleet.

- To create business models that enable the local generation and selling of electricity and/or heating and cooling energy.

The redevelopment of the Heart of South used an innovative tendering process, combined with a twenty-year agreement on maintaining of the area. A coalition led by the developer Ballast Nedam/Heijmans won the tender in 2013, and the actual renovation and construction of new buildings is set to end in 2023. With the Heart of South project, the Municipality of Rotterdam and Ballast Nedam/Heijmans underlined their enormous ambitions for the area.

These large-scale ambitions would be substantially supported by connecting buildings and mobility and energy sources through the use of information and communications technology (ICT). **Hence, the RUGGEDISED Smart City idea was born in Rotterdam**.

Drivers that led Rotterdam to join RUGGEDISED

Partners in Rotterdam had multiple reasons to join forces and become a team in the RUGGEDISED consortium.

- Rotterdam's Smart City policy was adopted following periods of research, conclusion and next step planning, executed by the strategic global consultant Jeremy Rifkin and his TIR Consulting Group LCC. In this context, the time was right to start the RUGGEDISED project, which suits the current policy and political climate.

- RUGGEDISED is part of the second European Commission Horizon 2020 programme call on Smart Cities and Communities Lighthouse Projects.

- High ambitions among lighthouse cities were thus a necessity and provided Rotterdam a chance to stand out.

- Since the sustainability aspects of the original Heart of South development project had to be omitted during the years of global financial crisis, the RUGGEDISED project was a welcome incentive for the municipality and Ballast Nedam/Heijmans to work together to achieve the ambitious sustainability goals for the area, while progressing work on a smart thermal grid.

- Joining the RUGGEDISED project opened doors to build a more citizen-friendly environment and has allowed Rotterdam to experiment with the local production of energy.

The process of prioritising smart solutions

For Ballast Nedam/Heijmans, there was a strong desire, almost a requirement, to bring sustainability goals back within the project's scope. The company wanted to experiment with smart thermal and electrical grids, and the Heart of South was the perfect place to do so. The area contains a large public transport hub, the Rotterdam Ahoy Arena, several public buildings (swimming pool, arts building/library) and some new commercial buildings (convention centre, cinema and hotel), which were the big drivers behind this project.

A change of ownership meant the priorities of Ballast Nedam/Heijmans ultimately shifted away from such experimental projects. The energy company Eneco took its place as the leading private company in the RUGGEDISED project in Rotterdam. As an energy company and not a building contractor, Eneco has a different approach to sustainable energy sources and energy policies overall.

To prioritise which smart solutions to work with, two creative sessions were arranged for all parties to share and discuss ideas. These ideas were divided into three sub-groups:

1. Thermal energy
2. Electricity
3. 3D Digital twin

For work related to the Thermal Grid and the Electrical Grid (STG & SEG), it was necessary to plan the different steps in phases. First: the thermal storage, aquifer, and heat exchangers had to be in place. These were owned by Ahoy, but were not being used to their full capacities. Eneco has taken over ownership from Ahoy and has redesigned the thermal grid to make the best use of the thermal storage and aquifer. A backbone also had to connect the different buildings to the aquifer, allowing it to be enriched with other sources, like sewage, asphalt and surface water, and to balance the grid.

Unfortunately, the project area did not receive the necessary "experimental status" designation from the government that would have been necessary to pursue electrical grid optimisation. Furthermore, renewable energy sources are not part of the European grant, and concessions for placing smart charging poles in the public area was not granted to RUGGEDISED partners. These factors made it impossible for Eneco to deploy these smart poles.

To exploit the data in the smartest way possible, Rotterdam uses a "3D Digital Twin," designed to integrate all solutions within the RUGGEDSIED project, to visualise the impact of the smart solutions and to allow stakeholders to react based on the information provided in a unifying platform. The development of such a digital platform for the city is a learning process in itself. Both platform development and the process of feeding data (energy or public transport) into the system are continuously being optimised.

COVID-19 Impact

During the first 'wave' of COVID-19, the Ahoy centre was designated an emergency hospital. Therefore, for a couple of months, no one from the project was able to enter the Ahoy perimeter. This especially affected the progress of smart solution R4: the pavement collector. Because the road in which the collector will be placed is part of the Ahoy perimeter, and the technical room is inside the building, we were not able to explore some details in the design.

The pumping station from smart solution R2: 'thermal energy from waste streams' is also located on Ahoy's property. Small parts of the COVID virus were found in the sewage system, therefore nobody was allowed to enter the pumping building. Not even colleagues from the maintenance department or the contractor who cleans the building were able to enter for a couple of months. This affected the progress of this project.

There were also some positive effects for this project that were experienced during the COVID-period. In this time, when most people were working from home, the (underground) waste bins were filled much more quickly compared to 'normal' times. As a result, the advantages of the smart waste sensors were proven. It is now possible to empty the waste bins on demand, so that no waste is misplaced next to the bins. Because of the success of this solution, and a busy schedule for the drivers, an extra waste truck was ordered.

The delays, caused by COVID, also affected the project material-wise. There are now longer delivery times and the costs of products and materials have increased.

Rotterdam smart city vision

"Sustainability and energy savings for all buildings in the Heart of South are of the utmost importance."

Rotterdam's Smart City measures - that address energy and integrated infrastructures - apply the 'Rotterdam Energy Approach Planning' (REAP) methodology, which serves as the City's main strategy on realising maximum energy efficiency in buildings and public spaces in individual districts and across the city.

The REAP has three pillars: The first focuses on reducing energy demand as much as possible (based on the high Return on Investment (ROI) associated with these measures). The second pillar aims to reuse waste energy as much as possible, while the third looks at remaining energy demand. This residual energy demand must be supplied by renewable energy sources where possible in order to facilitate the desired energy transition.

To support the development of the ICT aspects of being a Smart City, Rotterdam has established 'Sensible Smart Rotterdam' (CODE 010). This platform places the City of Rotterdam in a position to embrace the digital economy by offering a suite of (public and private) ICT systems that support initiatives for the common good of residents.

Today, digital connections are a basic necessity. All citizens, companies and institutions in Rotterdam should have access to open digital infrastructure, both physically and wirelessly (e.g. 5G). This is not only a precondition for establishing and maintaining an innovative, attractive and future-proof business climate, but also a requirement for digital services, such as healthcare applications, online banking, shopping, news services, social media and much more.

The City of Rotterdam provides digital 'hubs' on almost every street corner through smart lighting posts. Using this

The three pillars of REAP (Rotterdam Energy Approach Planning')

1: Reduce energy demand
2: Reuse waste energy
3: Use renewable energy

"Sustainability and energy savings in all buildings in the Heart of South are of utmost importance."

Rotterdam smart city vision

Source: City of Rotterdam / Iris van den Broek

infrastructure, digital applications are available to the city and municipal services, as well as to residents and visitors.

Rotterdam is a “thick market” (i.e. high density, with a lot of interaction and therefore a lot of data) for profit-driven platforms. The local government therefore has good reason to set requirements for digital companies to follow, in order to ensure fairness. However, the municipality’s role as a ‘market master’ will only be accepted if administrative leadership is demonstrated. There also needs to be sufficient operational expertise and a clear mandate in order to make binding agreements with market parties and social organisations about the use of digital data, and regarding the preconditions (rules) required for platforms to be admitted into Rotterdam’s digital public space.

Relationship between the city’s vision and the RUGGEDISED “Implementation and Innovation Framework"

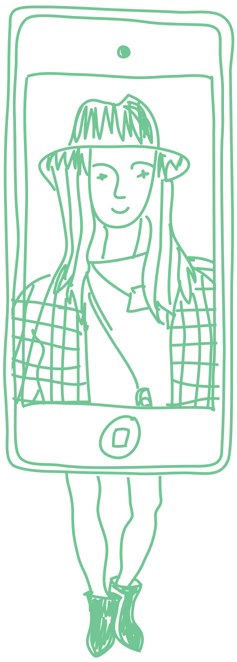
The renovation of the Heart of South district is taking place in phases between 2016 and 2023. Major components include:

- The sustainable integration of a 50-metre swimming pool in a former office block (2016-2018);
- The integration of a cultural centre and an arts building (2018-2020);
- The renovation of the existing Ahoy exhibition halls (2017-2019);
- The construction of a new convention centre (2018-2020);
- The renovation of the bus and metro station (2020-2022);
- The construction of a cinema and hotel (2020-2023);
- And the modernisation and expansion of the shopping centre (2021-2023).

Achieving sustainability and energy savings in all buildings in the Heart of South is of the utmost importance. Almost all structures are expected to receive a ‘very good’ label as defined by “BREEAM” (Building Research Establishment Environmental Assessment Method). Energy demand will decrease by 50% thanks to sustainability measures, and the demand for heating and cooling in new buildings will be minimised through effective thermal shelling. Heat recovery from ventilation systems, toilet flushing, and shower water will be utilised. Other measures include the use of LED lighting, floor and roof insulation, light-coloured roofs and high performance (HR++) glass. Special attention is being given to the air-tightness of all buildings. These traditional measures are all part of the first pillar of REAP, which focuses on reducing energy demand.

In addition to these measures, RUGGEDISED has introduced several innovative integrated energy infrastructure elements to make sure that the goals of the second and third REAP pillars will also be pursued to the fullest degree.

A variety of buildings will be connected to this innovative energy infrastructure over time. As buildings have different functions and energy consumption profiles throughout the week, these connections will open the possibility for local energy exchange. With the solutions laid out above, total energy demand will decrease and smaller-scale infrastructure will also be possible.



4: Description of Smart Solutions

SOLUTION R1: Geothermal heat-cold storage and heat pumps

General description: A central goal of this solution was to connect the large buildings in the area to a single thermal grid. This means enabling local heat and cold exchange to lower the use of energy and the cost of ownership. To maximise the use of waste derived from heating and cooling the various buildings, seasonal storage in a geothermal layer was planned for implementation (heat-cold storage). Over time, each building will be connected to a low temperature grid and provided with a heat pump to meet heat requirements. The heat generated waste will be fed back into the heat-cold storage. Cooling for the warmest days will be provided directly from the Smart Thermal Grid.

Expected Impact: When connected to the Smart Thermal Grid – in combination with connection to city heating – the entire Ahoy complex can be disconnected from natural gas. Because of the diversity of functions of the connected buildings and the energy sources, peak demands will, at different times, need a lower total base load. This will save costs on installations due to the decreasing total energy demand. The expected decrease in energy consumption is 924.000 kWh per year; this will lead to an annual CO_2 reduction of 70 tons.

Current implementation stage: Pipes used to transport heat and cold from the Aquifer Thermal Energy Storage (heat-cold storage located deep underground) have now been connected to the storage system of two Ahoy buildings in the Heart of South. Furthermore, the existing aquifers have been tested -including activities such as camera inspections and testing of the electrical pumps in the well. Based on these tests, various improvements have been made to bring the storage up to the standards required for this smart solution to work, including a higher quality pumping system.

Innovation: Innovation includes combining the Smart Thermal Grid with the aquifer, and combining heat pumps with various features such as waste-water heating/cooling and asphalt recovery. Due to the diversity of functions of the connected buildings and connected energy sources, peak demand occurs at different times and therefore the system as a whole now requires a lower total base load of energy.

Connection to other smart solutions: This solution links to the thermal energy from waste streams solution (R2) and pavement heat/cold collector (R4). All of these smart solutions will be connected to the Smart Thermal Grid.

Results: Because of the Smart Thermal Grid, the entire Ahoy complex is now independent from fossil fuel energy sources. Most of the heat, cold and electricity is produced locally, on-site or extracted from underground.

Upscaling plans: Other buildings in the area can be connected to the grid and other energy sources can be added. The most concrete plan for upscaling is the intention to connect a cinema, which is set to begin construction, to the existing Smart Thermal Grid.

In general, the idea of 4th and 5th generation thermal grids is becoming more common. Research from other areas in the city exploring local grids is becoming 'mainstream'. In this research we take all lessons learnt from RUGGEDISED and the situation in and around the Ahoy complex into account. Through this research, Eneco and the municipality learned about vital business cases, the potential difficulties faced when working with (local) energy sources, and further details about the combination of the smart grid and city heating.

Replication Assessment: The situation in Rotterdam is quite unique, also in the Netherlands, mostly because of the existing city heating network. The combination of the Smart Thermal Grid and the city heating – a hybrid solution – works very well for this location. It may be difficult to replicate this kind of heating (and cooling) system, although it is generally agreed that a thermal grid with local sources is the most sustainable choice.

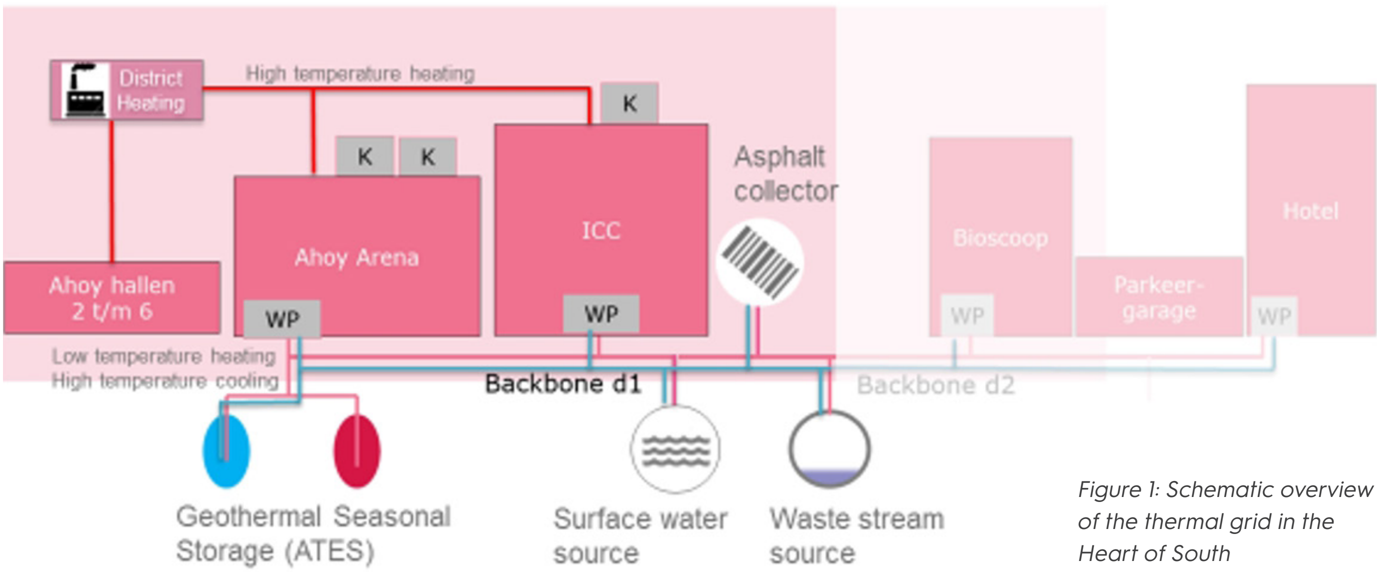


Figure 1: Schematic overview of the thermal grid in the Heart of South

SOLUTION R2: Thermal energy from waste streams

General description: In addition to thermal storage and heat pumps in solution R1, the use of other thermal waste streams will be stimulated as much as possible by making further connections to the Smart Thermal Grid. On the district scale, the district sewage water from nearby households can be used to extract heat or cold for use by the grid. Depending on the need, it can be used directly or stored to refill storage and create a thermal balance.

Expected Impact: The thermal energy from waste streams will be used to balance the ATES and is therefore a (potential) profitable part of the grid. The expected decrease in energy consumption is 261.000 kWh per year, this will lead to an annual CO_2 reduction of 36 tons.

Current implementation stage: Implementation of this solution requires close cooperation between the Municipality of Rotterdam (owner of the sewer) and Eneco (operator of the Smart Thermal Grid).

The activities carried out during the first period of RUGGEDISED involved the development of a plan to reuse the heat from waste streams in the Heart of South district. The sewage water from the surrounding district can be used to extract heat and to balance the Smart Thermal Grid. Depending on the need, it can be used directly or stored for several months in the Aquifer Thermal Energy Storage (ATES) deep underground. The heat waste can help regenerate the storage and create a thermal balance. The heat waste produced by cooling systems in buildings will be reused immediately by other buildings in the area, or stored in the ATES.

After careful consideration of the different sewage streams available in the system and the possible energy extraction techniques, it has been decided that the preferred technology is a heat exchanger, which will be fitted into the existing pumping station of the sewage system. This will maximise possible heat exchange.

The design of the heat-exchanger plates in the basin of the pumping station has been finalised. The design was done by German contractor Uhrig Bau, one of Europe's leading companies in extracting thermal energy from wastewater (also known as riothermia). The design of the connection between the heat exchanger and the Smart Thermal Grid is nearly complete. The final steps of the design, including adaptations inside the pumping station, have been completed by the RUGGEDISED team, maintenance department, Eneco and the contractors.

Innovation: A thermal heat recovery system in the sewage system, in combination with a Smart Thermal Grid, has the potential to increase the impact of both solutions.

Table 1: Impact of different variations of Solutions R2-R4

SS	Design	Investment	Efficiency	Impact	Maintenance*	Incorporation
R2	Outside piping	Average	Low	Average	Low	Average
R2	Inside piping	Average	Average	Low	Low	Good
R2	Surge tank	High	High	High	High	Hard
R3	Surface water direct	Average	Low	Average	High	Hard
R3	Surface water piping	High	Average	Average	High	Average
R4	Bricks collector	Average	Low	Low	Low	Easy
R4	Asphalt collector**	Average	Average	Low	Low	Easy

* Maintenance includes energy costs.
** Insights gained through the study also led to new insights on the solutions on surface water (R3) and the 'asphalt collector' R4.

Connection to other smart solutions: The recovery of heat and cold from waste streams is connected to the other thermal grid solutions in Rotterdam (R1 and R4).

Results: No monitoring data yet.

Upscaling plans: Smart thermal grid solutions are being integrated into the development of other areas in Rotterdam to use (smart) thermal waste as part of the local heating and cooling systems. Lessons learned from this smart solution process, and implementation, are helpful in the design phase of other projects.

The potential use of thermal waste streams is being mapped for the whole city. The possibilities include pumping stations, like the RUGGEDISED smart solution, for larger sewage piping where there is a heavy water flow. The maintenance department, responsible for the maintenance of the sewage system in the city, is also interested in the solution's potential. There is cooperation for several projects; for example, one opportunity that has emerged is to apply the process of riothermia to the waste streams of one of the largest museums in the city.

Replication Assessment: As an energy source for the thermal grid or a nearby building, thermal energy from wastewater has great potential. Every street in Europe – with exceptions – has a sewage system. This makes this smart solution very replicable. The contractor for the heat exchanger in Rotterdam is one of Europe's leading companies on this subject, with work undertaken in several countries.

Another example of thermal energy as a source comes from another Horizon 2020 city: Stavanger, Norway. Here, the heat exchangers are successfully installed in the sewer tunnels of the city.

SOLUTION R3: Surface water heat-cold collection

General description: Surface water heat is another source of thermal energy that can be used directly or stored in the Aquifer Thermal Energy Storage (ATES) to help regenerate the storage and create a thermal balance. A pond in the Heart of South was considered for this solution.

Expected Impact: The thermal energy from the surface water could be used to balance the ATES and was therefore a (potential) profitable part of the grid. The expected decrease in energy consumption was 39.000 kWh per year, which would lead to an annual CO_2 reduction of 19 tons.

Current implementation stage: Unexpectedly, the analysis showed that the solution is not economically feasible. The situation on the ground, combined with experience from projects elsewhere in the Netherlands, showed that installing a surface water system in a pond with little water flow leads to exorbitant maintenance costs caused by a layer of "biofilm" (a sheet of organic material including bacteria and algae). Together with the Dutch Water Board, in charge of the maintenance of ponds, investigations were undertaken as to whether or not the local drainage system (designed to manage water levels during heavy rainfall) could be used to create the necessary flow in the water system. However, calculations showed the additional energy required for pumps to create a flow would amount to more than the heat collected from the system.

As this would run contrary to the expected CO_2 reduction goals, other ways to implement this solution are being investigated.

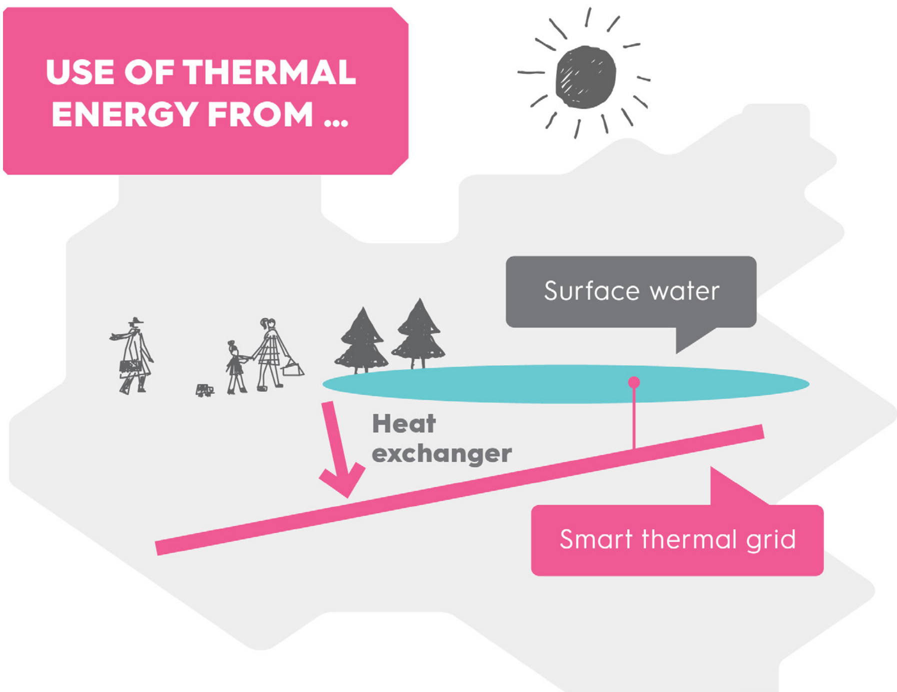
Last year, the feasibility study of thermal energy recovered from surface water was re-started. A new location, at the back of Ahoy and close to the pavement collector smart solution, was analysed. The advantage of this location was that it was closer to the technical room in Ahoy and piping could potentially be shared with the pavement collector. Unfortunately, this study also showed that the costs were higher than the yields. Therefore, this smart solution turned out to be unprofitable.

Connection to other smart solutions: This smart solution is connected to the other smart thermal grid solutions (R1, R2 and R4).

Results: No results available, smart solution will not be executed.

Upscaling plans: In theory, thermal energy from surface water has potential for the city of Rotterdam. There is a lot of surface water, especially in the river Meuse. The potential of thermal energy from surface water is limited by infrastructure costs. For developments further away from the river or other waters, the investments in infrastructure are too high. Financing the project is not profitable, therefore there are no upscaling plans at the moment.

Replication Assessment: For towns and cities with (larger) flowing open waters or rivers, this might be a nice solution to replicate. To avoid exorbitant costs, it is important that the source of water is not too far from the installations. The location and temperature of the water, in winter as well as in summer, has a lot of influence. It is important to keep the effect of this system on water quality in mind.



SOLUTION R4: Pavement heat-cold collector

General description: Testing of sewage heat extraction included a pavement heating system, which was used to keep a stretch of 400m² pavement frost-free in winter times. Several possible locations have been considered for scaling-up the pavement heat collector in the Heart of South.

This smart solution involves balancing the Aquifer Thermal Energy Storage (ATES) by using pavement as a heat-cold collector. Heat and cold are extracted from the heat exchanger under the surface of the pavement. The pavement heat-cold collector can keep the pavement frost-free during the winter. During summer, the pavement is cooled, increasing its lifetime and decreasing the urban heat island effect.

Expected Impact: The thermal energy extracted from the pavement collector will be used to balance the ATES and is therefore a useful part of the grid. The expected decrease in energy consumption is 108.000 kWh per year, this will lead to an annual CO_2 reduction of 52 tons. In winter the road will be slightly heated so the pavement will not freeze.

Current implementation stage: After considering several locations for the pavement heat-cold collector, a location behind the Ahoy Exhibition Complex was selected. The location was chosen due to its proximity to the heat pumps of the Smart Thermal Grid and due to the re-paving of an existing asphalt road. The location is also suitable for a heat exchanger, allowing the heat and cold to be fed back into the Smart Thermal Grid.

Installation of the pavement collector is planned.

Innovation: A pavement heat collecting system in combination with the Smart Thermal Grid in the Heart of South area.

Connection to other smart solutions: The solution is connected to the other smart thermal grid solutions (R1 and R2).

Results: Monitoring in progress.

Upscaling plans: If this solution proves to be effective in dealing with heat stress during summer time, it has huge upscaling potential in other areas of Rotterdam. Within the city centre there are quite a lot of squares that cause intense heat stress during summer. At the moment there are no upscaling plans; results from RUGGEDISED may help to explore potential areas for implementation.

Replication Assessment: Since every town or city has paved streets, this solution has a lot of potential. An important element is that there is space for storage of both heat and cold. The solution is useful for southern European countries, since it can extract a lot of heat, but also potentially cool the surface of pavements. Northern European countries could benefit from non-frozen roads in winter time.

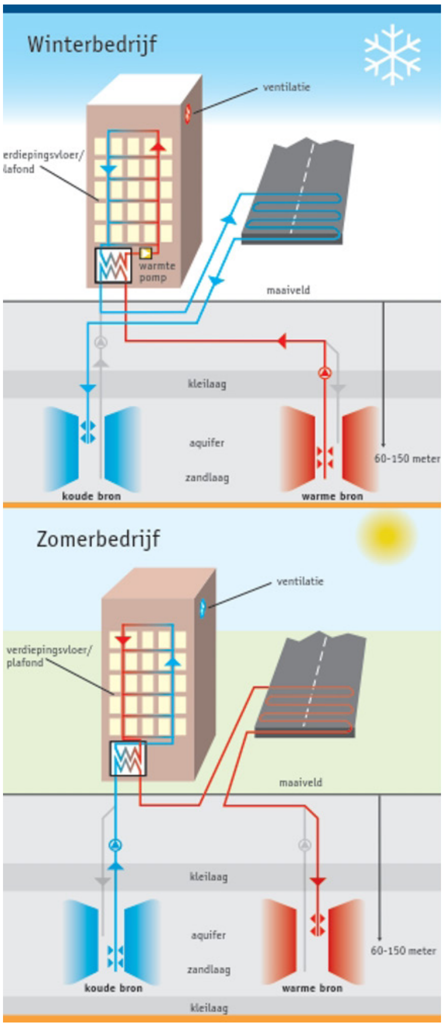


Figure 3:
Schematic winter/summer overview

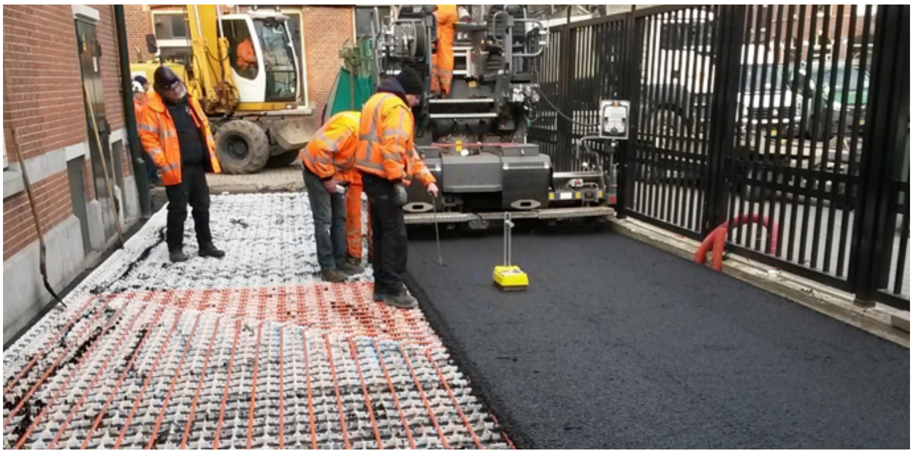


Figure 4:
An example of the kind of pavement heat/collection system being installed

SOLUTION R5: DC grid, PV and storage for mobility

General description: The existing grid at the bus station cannot provide enough power for the fast charging of electric buses in Rotterdam. The public transport operator and RUGGEDISED partner RET, will place photovoltaic (PV) panels on the roof of the bus and metro station in order to deliver sustainable energy directly from the grid into the charging points of the buses.

Electric smart grid business model development

Throughout 2018 and 2019, RUGGEDISED conducted a feasibility study for the Smart Electric Grid (SED). The conclusion was that the installation of 12,000m² of solar panels on roofs in the Heart of South seems possible. In this period, Eneco, Ballast Nedam/Heijmans, AHOY, and the Municipality of Rotterdam negotiated who will construct, finance and/ or reap the benefits of the solar panels. Two options were considered:

1. Construction would be organised by the owner of the building (Rotterdam Municipality) or the local developer (Ballast Nedam/ Heijmans) or
2. An operational lease construction, in which Eneco finances and handles the solar panels for the next 20 years, would be organised

The production and storage of solar energy has an impact on the capacity of the regular electrical network. The operator of the electrical grid had reservations on how solar energy would influence the overall use of the grid and therefore its revenue and ability to maintain the network.

The installation of solar panels was included in the design of the Ahoy Convention Centre, another hall of Ahoy, the bus station, the metro station and the cultural centre.

Another study was conducted to investigate how the proposed solar panels might influence volume from concerts and other programming at Ahoy. It is clear that the solar panels increase the noise resonation somewhat and, therefore, the investigation is now focusing on how these solar panels can be placed at a different angle to lessen the effect. Since Ahoy is next to a residential area, the regulations on noise are very strict.

The feasibility study revealed that there is no potential for peak energy shaving if a local battery, in combination with a small, new net connection, were to be installed. However, a follow-up study showed that connecting solar panels directly to the fast charging system of the new E-buses (in combination with a small new net connection) provided the best business case. Because of this, installing a new, big connection to the main network could be avoided. This means increased electricity demand for the main power station will be avoided.

Expected Impact: The expected decrease in energy consumption is 1.800 kWh per year, this will lead to an annual CO_2 reduction of one ton.

Current implementation stage: In the initial period, the team worked on the design and calculations for the electrical grid. Technical solutions were discussed to further specify the design of the grid's elements (e.g. PV panels, small wind turbines). Possible integration of the electrical grids with the data hub, which links energy management (R8) and the 3-D City Model (R9), was also discussed.

After looking into the weight of the PV-panels and the capacity of buildings in the area, the contract for adding PV panels on the roof of the existing Ahoy building and the new Convention Centre was signed.

Approximately 12.000 square meters of photovoltaic panels are installed on the roofs of the Ahoy centre. Both on already existing buildings as well as the newly built RACC (Rotterdam Ahoy Convention Centre). About a quarter of all electric energy used in Ahoy is now produced by the PV-panels.

Connection to other smart solutions: The smart solution 'DC grid, PV and storage for mobility' is connected to the other smart grid solutions (R6, R8 and R9.)

Results: Monitoring in progress. Using the Simaxx software (solution R8), the energy consumption of every Ahoy hall can be monitored.

Lessons learned:

- Research shows a direct connection can provide a more lucrative case for business than the installation of batteries.
- To fulfil CO_2 emission targets, more PV panels are needed. Instead of 12,000 square meters of PV, 16,000 square meters are to be installed.

Upscaling plans: In another part of the city, RET plans to build another parking and electric charging station for its buses. A canopy full of solar panels will also be created.

Replication Assessment: PV panels are a common feature when looking to harness sustainable energy. The possibilities for exchanging electricity between buildings or users may differ from country to country. It is also possible to 'give energy back' to the electricity network, but regulations on this might be different in each country.

SOLUTION R6: Smart charging parking lots

General description: The goal of this smart solution is to reduce peak loads by introducing smart charging at parking lots. This smart system is based on the idea of charging when the demand is low. The cars will be charged when there is extra capacity available from the network. During the early months of the project, the surfaces where solar PV panels were to be installed, including on Ahoy's rooftops, on the new convention centre, swimming pool and arts building, were further investigated based on the assumptions of the original project application.

In January 2019, Eneco looked at the possibility of installing 25 charging stations at the Ahoy premises. It was not possible to place the charging stations in the parking area because Ahoy is using this area as a festival space and, therefore, it must be free of obstacles at times.

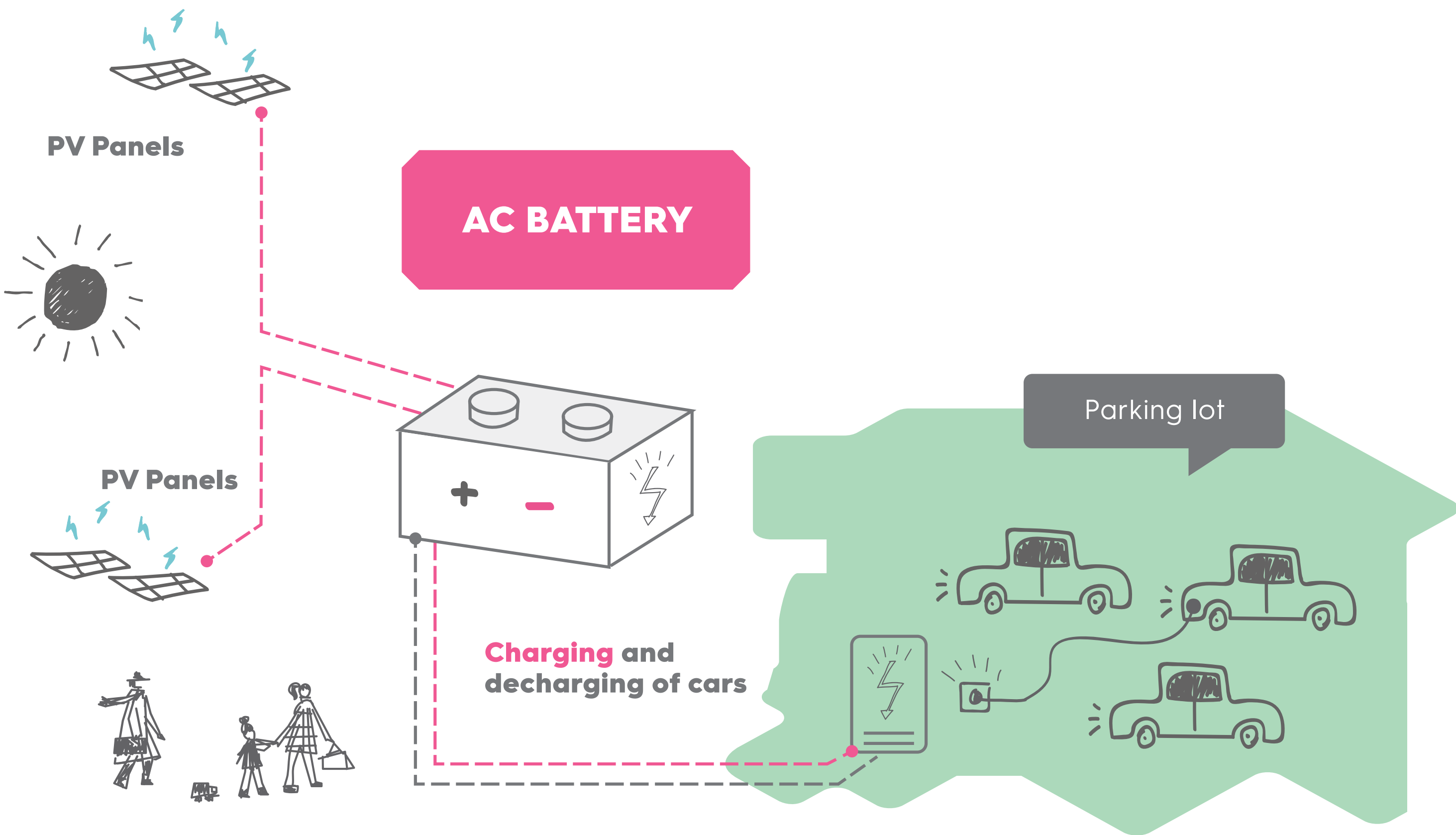
Expected impact: The expected decrease in energy consumption is 5.750 kWh per year; this will lead to an annual CO_2 reduction of 3 tons.

Current implementation: In early 2017, the contract to place electric charging stations throughout the entire city of Rotterdam was won by the energy company Engie, meaning Eneco would be unable to place two-way charging stations anywhere on public City property and thus also in the Heart of South area. While the original plans are on hold, negotiations with Ballast Nedam/Heijmans to install several charging stations in the planned parking garage are ongoing.

Results: Smart solution not executed, therefore no results available.

Upscaling plans: In the coming years, around ten thousand (normal) electric charging poles will be installed in the city of Rotterdam.

Replication Assessment: This is a good example of a realistic solution for replication. PV panels are becoming a standard for new buildings and electrical cars are also replacing fossil fueled vehicles. Cities are in transition, buildings and cars both need power. This solution tries to find balance and is therefore very replicable for other cities embarking on an energy transition.



SOLUTION R7: Optimising the E-bus fleet

General description: The bus station in the Heart of South is part of a dense public transport network in which a consistent number of buses needs recharging. Therefore, the energy produced by the solar panels can be stored or used by the electric buses immediately. This solution aims to support the transition from conventional diesel buses toward battery powered electric buses.

The first step toward achieving this goal was to develop an evaluation tool to quantify any potential impacts of the transition on current RET bus schedules. By running the tool for different parameter values concerning energy consumption, number of buses, and charging infrastructure, it was possible to evaluate the impact of transitioning to an electric bus network under varying circumstances and to identify the most important factors for related costs.

After this initial investigation, focus was placed on how to develop tailored schedules for an electric bus network. This process consisted of two main decisions: 1) assignment of trips to buses and 2) scheduling of charging activities. For the first decision, RET purchased planning software that is able to optimise bus schedules for electric buses.

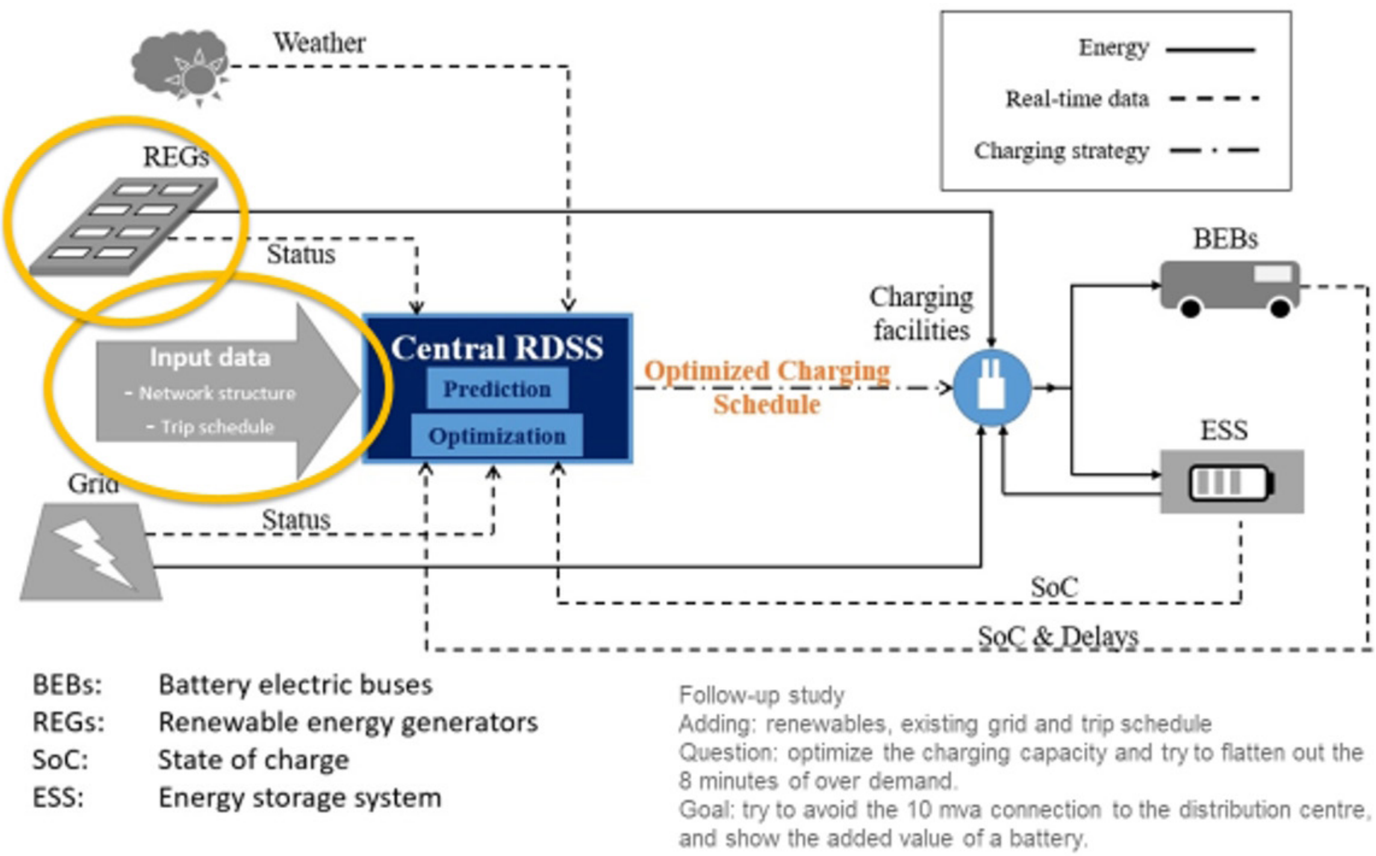
However, this planning software is not able to schedule charging activities. Erasmus University has studied this challenge in close collaboration with RET.

This process has resulted in two types of models. First, a simulation model that evaluates different charging strategies was developed. A charging strategy specifies where, when, and for how long each bus should charge. Common sense strategies include a first-come, first-serve rule (where a bus charges whenever it has time to use an available charger) and a lowest State of Charge highest priority strategy. According to the latter strategy, a bus with a lower State of Charge (SOC) can take the charger from a bus with a higher SOC. By adding data accounting for delays to the simulation, it became possible to evaluate the impact of delays on the feasibility of the schedules.

Secondly, Erasmus University developed an optimisation model that could find an optimal charging schedule with respect to two objectives: 1) minimise the number of charging activities and 2) minimise the charging cost. The first part of the model aims to minimise the number of charging activities by defining a strategic schedule. The second objective is to ensure charging occurs at cheaper, off-peak hours.

Expected impact: The introduction of electric buses and the charging infrastructure is not just a matter of implementing new technology; it is a matter of introducing a completely new transport system that is more similar to a tramway than to bus deployment. The expected decrease in energy consumption is 1.900.000 kWh per year, this will lead to an annual CO_2 reduction of 780 tons.

Figure 5: Schematic overview of the studies being done to optimise the battery buses charging scheme



Current implementation stage: In close collaboration with RET, both the simulation model and the optimisation model have been tested on a fleet of 50 electric buses, charged at the Heart of South bus terminal. The first results show that, under planned conditions, the schedules are feasible, but the schedules are not adequate when experiencing delays. Re-optimisation during the day will be necessary to achieve a feasible schedule. Currently, the models are being adapted to allow re-optimisation, based on real-time data.

Originally, RET was planning to start with six e-buses, but the transition to electric buses will be implemented at a faster pace than foreseen.

This transition requires a significant shift in the deployment of the bus fleet. One challenge revolves around the reliability of public timetables on a large scale. Thus, RET tested the reliability of the ICT software in real-time to see the effects on the complex logistic operations. In addition, to obtain optimal results, simulation models from the Erasmus University of Rotterdam, in collaboration with RUGGEDISED, were also used.

Connection to other smart solutions: This simulation model proves that most of the generated renewable energy can be used directly to charge the buses. As a result, the added value of installing a battery (R5) is limited. The solution also feeds into the energy management of the Heart of South (R8) and the 3D City-Model (R9).

Results: Monitoring is still in progress, but several lessons can be drawn:

- The introduction of chargers into a city environment is a complex, time consuming challenge for the municipality, the grid provider and the transport company.
- Calculations (about range, energy consumption, state of charge and so on) are theoretical and need to be proven in practice. Because many issues influence the calculations, the practical outcome can be significantly different from the theoretical assumption.
- Careful planning of charging moments can reduce the impact on the grid in terms of maximum available capacity.

Upscaling plans:

- The start of the electric bus fleet contract (55 buses) in December 2019 also marked the transition towards zero emission bus transport. This contract will not expire before December 2034. After two years, the introduction of another 50 buses is expected. Between 2025 and 2030 two batches of 150 buses in total are foreseen and will replace all buses equipped with combustion engines for zero emission vehicles.
- Transition towards zero emission buses, i.e. transition to electric transport is faster than originally expected.

Replication Assessment: The most logical next step is to change all fossil fuel buses to zero emission buses. Rotterdam chose electric vehicles, but hydrogen is of course also a possibility. The infrastructure of the bus company also needs to change, for example, by building loading stations for the bus batteries or fuel points for hydrogen. The second step is to optimise the schedule; this is more data driven. It is possible to combine this with a digital twin.

SOLUTION R8: Energy Management

General description: The energy and building software Simaxx will be implemented at the Ahoy Convention Centre as part of RUGGEDISED. Eventually, the ambition is to have Simaxx software implemented in all buildings in the Heart of South, which will allow for the visualisation and optimisation of energy consumption, production, etc., of the buildings. The Simaxx software at building level can visualise and optimise energy usage, comfort level and heating, ventilation and air conditioning (HVAC) operations.

Expected Impact: The expected decrease in energy consumption is 383.000 kWh per year, this will lead to an annual CO_2 reduction of 155 tons.

Current implementation stage: The contract between Simaxx and Ahoy is signed; implementation finished and monitoring is ongoing. A contract has also been signed with a swimming pool in the Heart of South, and discussions are happening with more building owners.

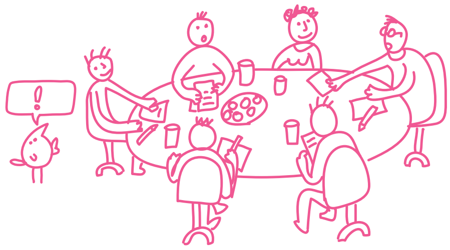
Innovation: Making the energy usage of the buildings in Heart of South, which are connected to the Smart Thermal Grid, visible and optimal.

Connection to other smart solutions: The Energy Management solution is connected to the smart solutions of the Smart Thermal Grid (R1-R4).

Results: Monitoring in progress.

Upscaling plans: No upscaling plans are known at the moment.

Replication assessment: A smart solution like this one has the potential to be replicated throughout all of Europe. The possible impact elsewhere depends on the number of data points and whether it is possible to connect to smart grids – like in Rotterdam.



SOLUTION R9: 3-D City operations model

General description: The development of the 3D city operations platform is an iterative process of learning. Learning by understanding happens through studies and engaging with peers. The main research question is how to organise the governance of the platform and which role the municipality of Rotterdam plays in this.

The development of the platform took place through the execution of three proofs of concept, of which two are already finished as part of RUGGEDISED.

Figure 6: State of thinking 2016 on open urban platforms

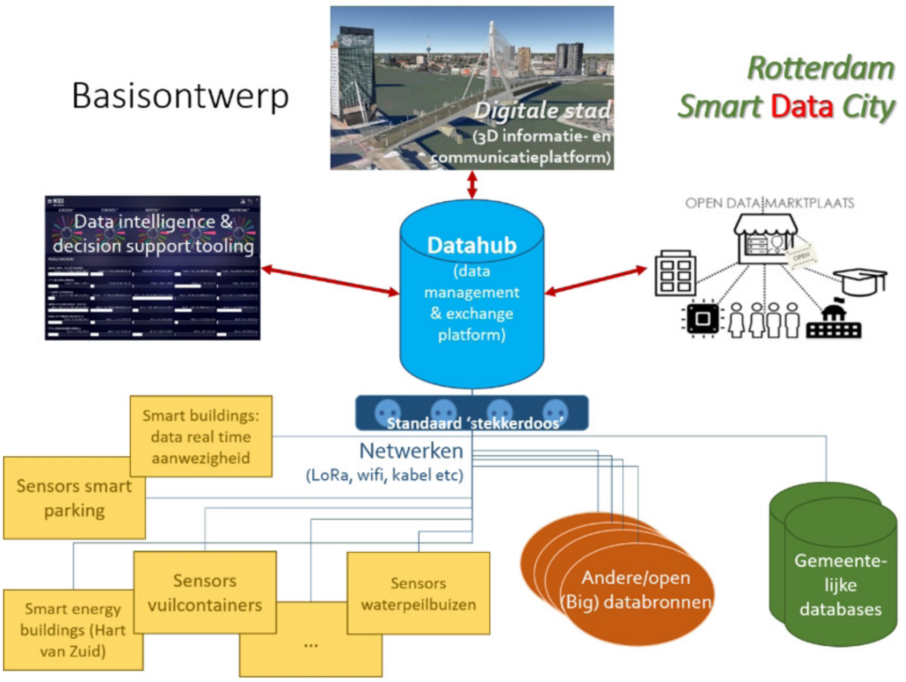
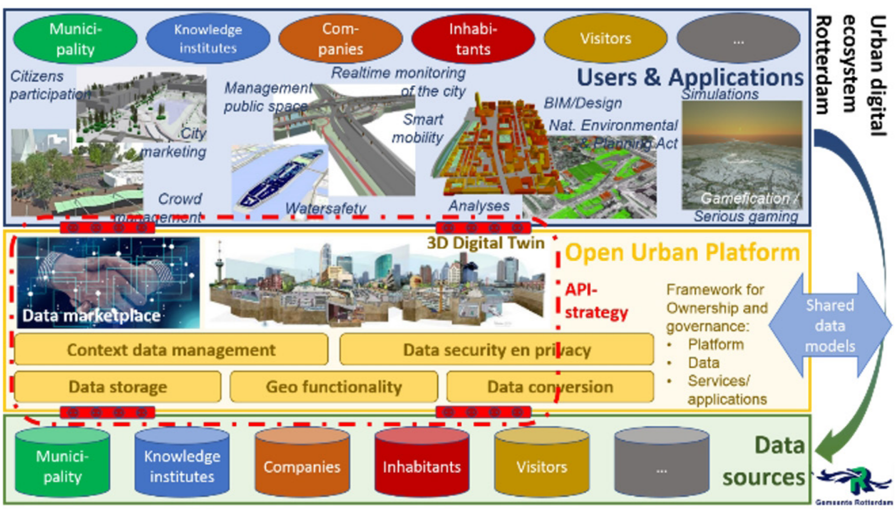


Figure 7: State of thinking on open urban platforms (and ecosystem), summer 2019



The 3-D City operations model will become a digital twin of the Heart of South.

Expected Impact: The expected decrease in energy consumption is 82.000 kWh per year, this will lead to an annual CO_2 reduction of 41 tons. Furthermore, this solution is expected to open up space for other innovations and increase the overall impact of other smart solutions.

Current implementation stage: A proof of concept (PoC) has been done at different times throughout the project and the platform now successfully includes a number of features.

In the first proof of concept, the goal was to prove that the municipal vision of the platform was technically possible. To do this, real parking lot data was successfully integrated in the 3D City Model.

Information was the central aspect of the second proof of concept. The platform is technically possible, but is it still flexible enough to give answers to real questions? And which functional components are needed on the platform? In this second PoC, real-time data concerning traffic mobility, public transport and open bridges was shared in the 3D City Model. Several open data standards were also tested. This PoC offered a lot of information about open data standards and about the process of disclosing real-time data that is owned by the municipality, but comes from (private) data sources. In the meantime, different scientific studies led to a much better understanding of the functionalities needed for the platform.

The support of RUGGEDISED was very useful for the first implementation phase of the digital twin in Rotterdam. In the current phase, the development continues. Most of the new possibilities and features of the model will extend beyond the scope of RUGGEDISED.

Results: Monitoring in progress.

Lessons learned:

- The municipality does not want to be the owner of data that is employed by a solution that the municipality itself has developed and paid for. The municipality usually played the role of end user.
- The municipality has not made any agreements on how data should be 'transported.'. No agreements have been made as to the format of the data.
- The use of open data is more complicated than it seems, but should be seen as a worthwhile investment in the long run.
- Not all open data standards are accessible and easy to use. The municipality has to test these itself or use the experiences of other municipalities.
- Experience developing the basic functionalities for an urban platform (storage, conversion, geo-functionality, context management, security and privacy, market place, 3D digital twin) has been gained.

Upscaling plans: The City of Rotterdam will continue to build on the city's 3D model. The municipality will also add new features and possibilities. For example, the idea of using the digital twin to visualise new building plans through augmented reality is being explored. Also, the possibility of energy savings calculations and PV panel potential is being assessed. Lessons learnt from the RUGGEDISED project will be implemented in future models and versions.

Replication Assessment: The concept of a digital twin is most likely replicable. The content is of course developed specifically for the city of Rotterdam, but every city can develop the content itself, with topics related to the local situation.

SOLUTION R10: LoRa-network

General description: One part of the RUGGEDISED project includes the introduction and rollout of the LoRa (Long Range) network by partner KPN. The LoRa network ensures that WiFi and/or 4G is not required. The LoRa-network will make dozens of applications possible. The network is meant for equipment that does not constantly need its own internet connection.

Expected Impact: The expected decrease in energy consumption is 339.000 kWh per year, this would lead to an annual CO_2 reduction of 104 tons.

Current implementation stage: The LoRa network has not been implemented in the Heart of South area. The two test cases that were supposed to use LoRa were not able to continue using the LoRa network. The implementation of LoRa began early in the RUGGEDISED project with the smart waste solution, but stopped due to the "law of the inhibiting lead".

Two other RUGGEDISED solutions, 'efficient and intelligent street lighting' (R11) and 'Smart Waste Management' (R12) did not in the end make use of the existing LoRa network.

For the intelligent street lighting, the LoRa network is not required as there is a dedicated power line available, which makes the low power aspect of LoRa redundant. Regarding the smart waste management, during the procurement process a different sensor system was selected for use.

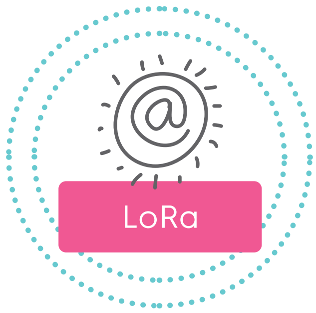
KPN and Rotterdam are still in the process of finding other opportunities to use LoRa outside of the scope of RUGGEDISED.

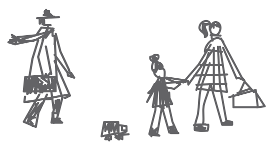
Connection to other smart solutions: The network is ready to receive the input of sensors and diverse data from other smart solutions. There are no use cases or solutions using LoRa for connectivity thus far. The smart waste and smart street lighting solutions were originally meant to be equipped with LoRa. This will not happen due to the final terms of these solutions' public tenders.

Results: Smart solution not implemented.

Upscaling plans: There are no plans for upscaling in Rotterdam at this point.

Replication Assessment: Although not installed in the Heart of South, there is possibility for replication. It might be a solution for smart connectivity. The LoRa system is patented. There are over 500 members of the LoRa association.





SOLUTION R11: Efficient and intelligent street lighting

General description: The lamp posts being used within the Heart of South retain, serve and enhance the principal obligations of street lighting (navigation, public safety). By using LED lighting, the lamp posts have lower emissions. They are connected as a network, enabling system wide control (i.e. a central management system) and the integration of sensors that have power 24/7 to enable continuous smart services.

Expected Impact: The expected decrease in energy consumption is 29.000 kWh per year, this will lead to an annual CO_2 reduction of 14 tons.

Current implementation stage: The smart street lighting poles were installed in October 2019. Six poles were used as a test case, located between the swimming pool and the bus station. The rest of the poles can only be placed when the public area design is executed.

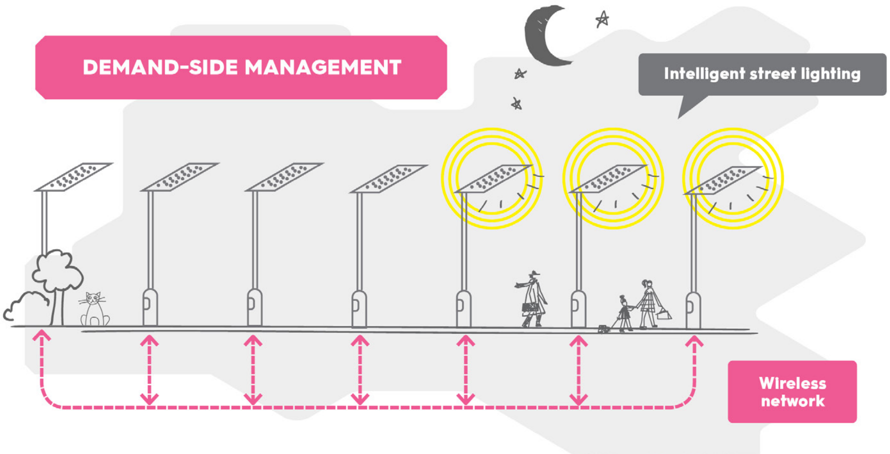
The six test poles are equipped with a tele-management system and LED lights. From a distance, they can be controlled, monitored and can provide insight on their energy use. The energy use data can be fed into the 3D model of the digital twin to provide insight on their performance.

Connection to other smart solutions: The smart lighting feeds data into the digital twin (Solution R9).

Results: Monitoring in progress.

Upscaling plans: In the coming years, a large share of all light poles in the city of Rotterdam will be replaced. Lessons from RUGGEDISED and insight from the applied technologies will be included in the plans.

Replication Assessment: Just like sewage systems and road surfaces, street lighting is common in most streets. Therefore, this solution has potential for replication. One of the requirements is a tele-management system connected to, for example, WiFi or LoRa.



SOLUTION 12: High performance servers in homes

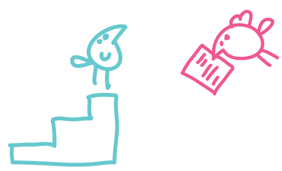
General description: A feasibility study was conducted by Eneco and the start-up Nerdalize (partially owned by Eneco) to explore whether high performance servers in residential buildings (built by Ballast Nedam) could provide highly distributed computing power (computing facilities, data centres) while, at the same time, heating homes for free to drastically reduce overall CO_2 emissions. The results of this innovative proposition were promising and Ballast Nedam and the municipality were enthusiastic. Unfortunately, Nerdalize declared bankruptcy in late 2018.

Innovation: Reducing CO_2 emissions by recovering heat from computing power facilities and data centres.

Results: The results in terms of reducing CO_2 emissions were promising before Nerdalize declared bankruptcy. Although Nerdalize was declared bankrupt, the development of the building continued. All buildings are zero-energy houses.

Upscaling plans: No upscaling plans are known at the moment.

Replication Assessment: Replication of this solution is possible, although there is a prerequisite for a nearby power facility or local data centre. Recovering heat from (bigger) data centres might have more potential.



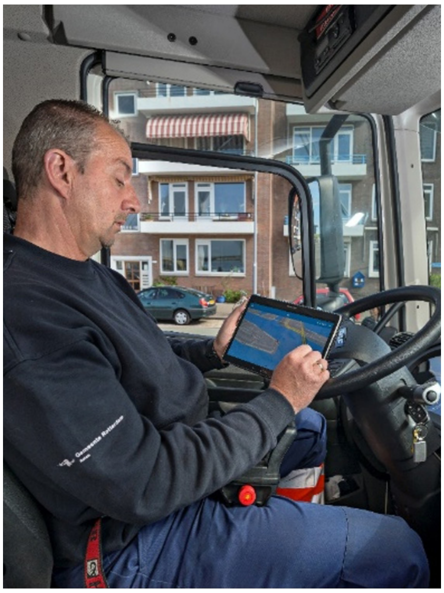
SOLUTION R13: Smart Waste Management

General description: In Rotterdam, there are approximately 6,500 underground waste containers. RUGGEDISED partners equipped all the textile, paper and glass waste containers in the Heart of South with a smart sensor. The so-called 'filling degree metre' in the waste container measures how full the container is every hour. Based on this information, the system determines when the container can best be emptied. The routes for the drivers are automatically generated, based on the collected data to allow for 'dynamic route planning'. All drivers are equipped with a tablet/ navigation system, which shows them the ideal route to collect the waste. The moment the waste is collected, the containers are approximately 75 percent filled.

Expected impact: The expected decrease in energy consumption is 315.000 kWh per year, this will lead to an annual CO_2 reduction of 72 tons.

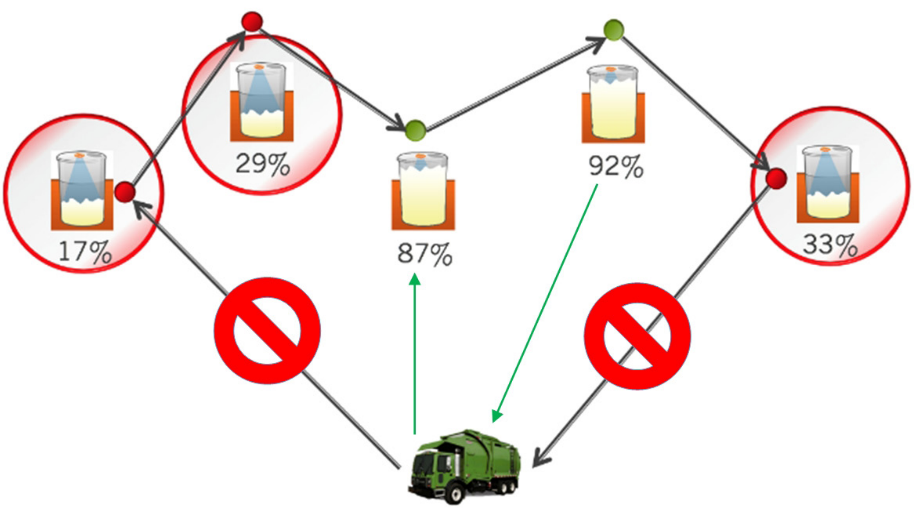
Current implementation stage: The smart solution is successfully implemented in the Heart of South district (and the rest of the city).

Innovation: A static waste collection turned into a smart dynamic waste collection, with efficient use of people and equipment.



Figures 8 and 9:
Driver checking his route for the day and collecting the designated bins

Figure 10: Schematic overview of the optimised garbage collection



Results: With the sensors in the waste containers, the City of Rotterdam contributes to a more efficient management of the waste containers and better service for the people of Rotterdam. Data is collected to better understand the savings in driven kilometres and thus CO_2 savings. It seems that the goals set out as part of RUGGEDISED (25% savings in kilometres and 20% in CO_2) will be met. The first results were very positive: the number of days necessary for waste collection was reduced.

Upscaling plans: After a successful two-year test in the Heart of South area, the smart waste collection system was implemented in all other parts of the city of Rotterdam. By the end of 2018, all waste containers in the city of Rotterdam were equipped with a smart sensor.

Lessons learnt: During the procurement process of smart waste systems, the City did not state that the use of the LoRa network was mandatory for the smart waste system. The chosen software provider uses 4G instead of LoRa, which was not foreseen by the department responsible for the smart waste containers. The desired network should be specified in the procurement phase.

Replication Assessment: This smart solution does have replication possibilities for cities with underground waste bins or other types of waste collection where smart sensor installation is possible. For optimal use of this system, it is necessary to monitor the amount of waste in a container or bin.

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About the project
RUGGEDISED is a smart city project funded under the European Union's Horizon 2020 research and innovation programme. It brings together three lighthouse cities: Rotterdam, Glasgow and Umeå and three follower cities: Brno, Gdansk and Parma to test, implement and accelerate the smart city model across Europe. Working in partnership with businesses and research centres these six cities will demonstrate how to combine ICT, e-mobility and energy solutions to design smart, resilient cities for all.

About the publication
This is the second in a series of three implementation reports from the European Smart Cities and Communities Lighthouse City of Rotterdam. It details the work Rotterdam has done through RUGGEDISED to become an even smarter and more sustainable city.

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Partners

Designing smart, resilient cities for all

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