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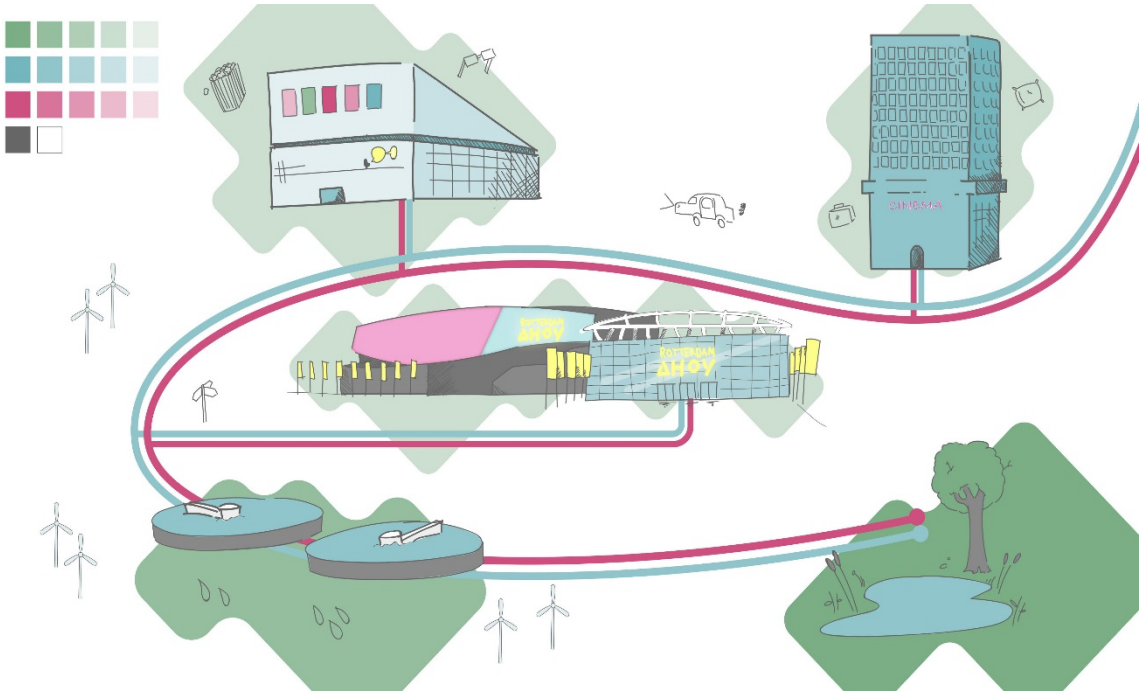


Towards an Energy Transition in the City of Rotterdam:

Smart Thermal Grid initiatives

RSM - a force for positive change

Introduction

At the end of 2016 the Dutch government set a national Energy Agenda[1] with the aim of having a carbon-neutral economy by 2050 to fulfil the the EU's climate and energy goals [2]. As of 2017, 38% of energy consumption in the Netherlands was used for heating. Half of this was used in residential buildings, which contributed approximately 10% of Dutch CO_2 emissions. The government was racing to reduce CO_2 emissions from the built environment by 80% in time to meet the 2050 target date[3].

At the beginning of 2022, Rotterdam, a city of 651,631 inhabitants[4], was home to Europe's largest sea port. As such, it also had relatively high annual carbon emission levels, contributing nearly 20% of the country's total CO_2 emissions[5]. Like the rest of the Netherlands, the city of Rotterdam developd a 'heat transition programme' to become emissions-free by 2050, in the hopes of becoming a more sustainable place to live. As part of the Energy Agenda Rotterdam aimed to make approximately 8,000 homes free of natural gas and have them be supplied with energy generated from waste streams in the period leading up to 2030.

Part of this energy transition was taking place in Rotterdam's *Hart van Zuid* district (Heart of the South Side)[5]. Towards this end, several Smart Thermal Grid (STG) initiatives in Hart van Zuid had been started in 2017 as a part of the RUGGEDISED project[6], in which Rotterdam was one of the lighthouse cities. These STG initiatives primarily targeted sustainability and energy savings, with the aim of establishing an integrated energy solution for the area. The STGs were built to connect the large buildings in the area with pipes that facilitated low-temperature heating (using hot water that did not exceed 35°C or 45°C when it left the heat generator) and high-temperature cooling (using higher-temperature chilled water at approximately 16 °C as compared to the conventional 6 °C).

Before the RUGGEDISED project, Hart van Zuid had already been selected as a pilot area to undergo a serious transition. This district was to be thoroughly renovated in the period 2016-2023 through a separate project called the 'Hart van Zuid' project. The confluence of these two projects brought challenges and complexities for the Municipality of Rotterdam (one of the stakeholders in both projects), because it needed to collaborate with many different parties – from housing associations to energy providers – with different goals and priorities.

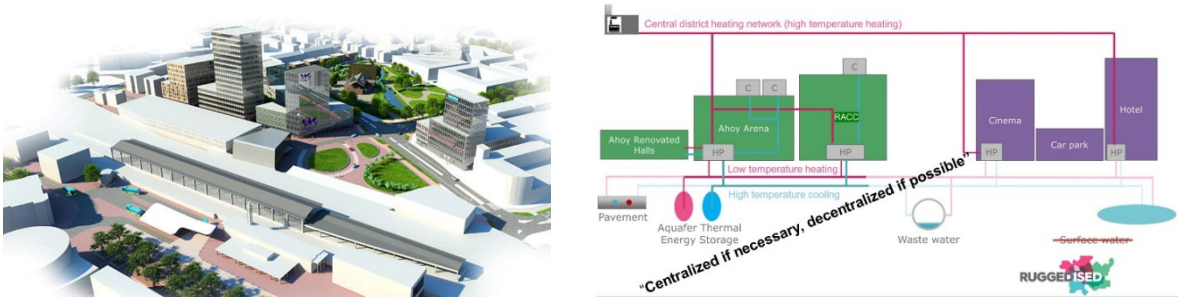
This teaching case was written by Dr. Samaneh Bagheri under the supervision of Dr. Marcel van Oosterhout at the Rotterdam School of Management (RSM), Erasmus University. We would like to thank Tao Yue at the RSM Case Development Centre for her time and input. We would also like to thank Katelien van den Berge and Roland van Rooyen from the Municipality of Rotterdam. The case is part of the RUGGEDISED project.

This case is based on field research. It is written to provide material for class discussion rather than to illustrate either effective or ineffective handling of a management situation. The authors have anonymised some data to protect confidentiality.

The challenge lay not only in the technical aspects of STG solutions but also in organising the collaboration in such a way that all stakeholders were able to contribute to the realisation of the energy-neutral area. In September 2021, Katelien van den Berge, RUGGEDISED City Coordinator Rotterdam, was reviewing the challenges. She wanted to fully understand exactly what they were, how complex they were, and what she could do to overcome them in order to realise the benefits of STG initiatives in Hart van Zuid.

Hart van Zuid District of Rotterdam

Rotterdam's Hart van Zuid district had 200,000 inhabitants and faced relatively severe social-economic challenges accompanied by a young and multi-cultural population[7]. Two projects were being undertaken in this area (**Exhibit 1**). Each project is described in the following sections.



Renovation- Hart van Zuid project

STG initiatives- RUGGEDISED project

Exhibit 1. Two projects in Rotterdam's Hart van Zuid district

Hart van Zuid Project

The Hart van Zuid project was a large-scale renovation and (re)development project in the Hart van Zuid district, in which approximately €330 million was being invested[8]. The area consisted of four clusters (**Exhibit 2**) and had been undergoing a serious transition since 2016, including the sustainable renovation of an outdated shopping centre, the integration of the neighbourhood's cultural arts building, and the renovation of the existing Ahoy exhibition halls, which were to be integrated with the construction of the new convention centre, the renovation of the bus and metro stations, and the modernisation and expansion of the shopping centre on Ahoy's first floor.

The entire renovation and new building construction had been tendered together with the district's twenty-year maintenance contract by the Municipality of Rotterdam. A coalition led by two companies, Heijmans and Ballast Nedam, won the tender in 2013. The actual renovation and construction of new buildings began in 2016 and was expected to be finished in 2023[8]. After completion of the Hart van Zuid project, Ballast

Nedam and Heijmans would remain involved in the management and maintenance of the various public buildings and the public space for twenty years.

However, from a sustainability perspective, this project was not a truly future-proof area development contract, as the project's sustainability goals were already outdated. The RUGGEDISED project was thus an opportunity for the Hart van Zuid project to devote more attention to sustainability.

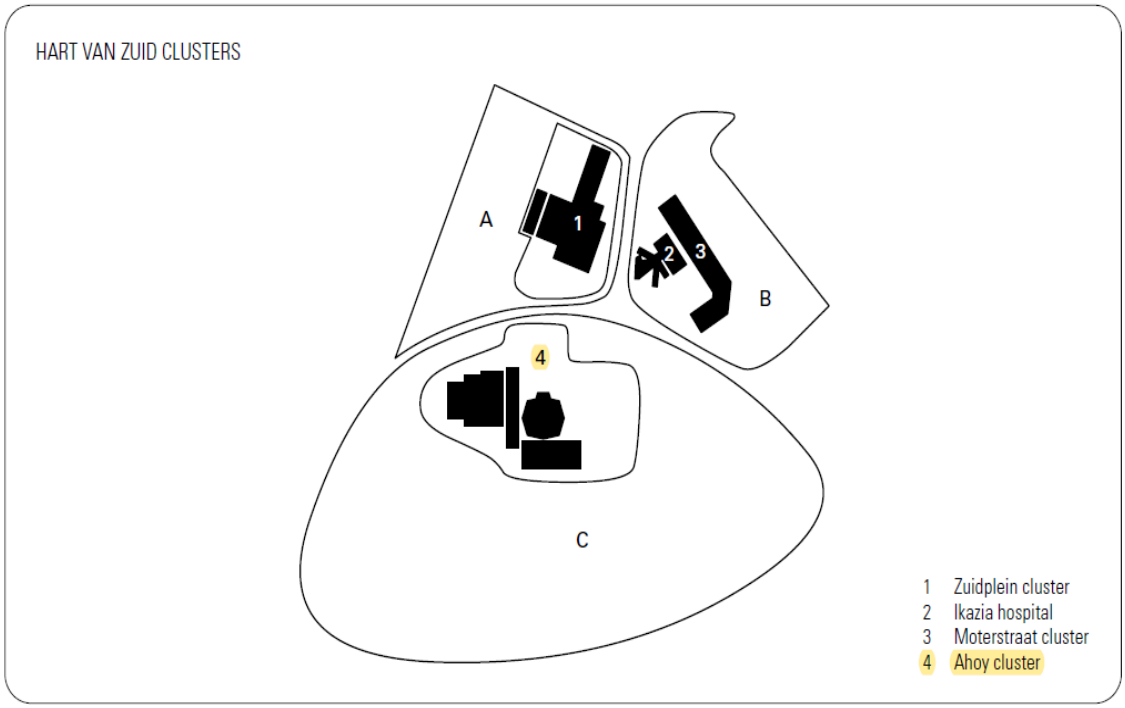


Exhibit 2. Hart van Zuid clusters (Rotterdam Energy Approach & Planning, 2009)

The RUGGEDISED Project

With a focus on the Ahoy cluster (**Exhibit 3**), the city of Rotterdam was preparing the Hart van Zuid area for the future, intending to achieve maximum energy efficiency and CO_2 reduction, in which the needed thermal energy would be produced, shared and used locally through a smart grid. The goal was to develop a sustainable and reliable heating and cooling network with the use of renewable energy sources.

To this end, several Smart Thermal Grid solutions (such as heat pumps and aquifer heat-cold storage) were tested in the Ahoy area in the period 2017-2022 within the scope of the EU-funded project RUGGEDISED[6]. One of the main objectives of RUGGEDISED was to connect several buildings to an STG, to facilitate the exchange of heating and cooling between buildings, and to make better use of the existing Aquifer Thermal Energy Storage at the Ahoy exhibition centre. Heat-cold exchanges within one building were already commonly used, but the RUGGEDISED grid connected all buildings in the area and optimised the distribution of heat and cold

among buildings. The Smart Thermal Grid supplied the existing Ahoy exhibition halls, the new international convention centre and the cinema.

These STG initiatives aimed to demonstrate that energy from different renewable sources could be shared between a range of buildings in the Hart van Zuid district. Because improving sustainability and energy savings in all buildings (such as the Rotterdam Ahoy convention centre and hotels) was greatly important, RUGGEDISED planned and implemented several STG initiatives. Two examples of these initiatives are explained below.

Exhibit 3. Ahoy cluster in Hart van Zuid (Rotterdam Energy Approach & Planning, 2009)

STG Example 1: Geothermal heat-cold storage and heat pumps[7]

The main goal of this solution was to connect the large buildings in the area to a single thermal grid. This meant enabling local heat and cold exchange to lower the use of energy and thus the cost of ownership. To maximise the use of waste heat and cold, seasonal storage was created in a geothermal layer (heat-cold storage). Over time, each building was connected by a low-temperature grid and had a heat pump to meet heat requirements. The waste heat of the condenser was fed back into the heat-cold storage. Cooling for the warmest days was provided directly from the smart geothermal grid. This solution linked to the thermal energy from waste streams (**Exhibit 4**).

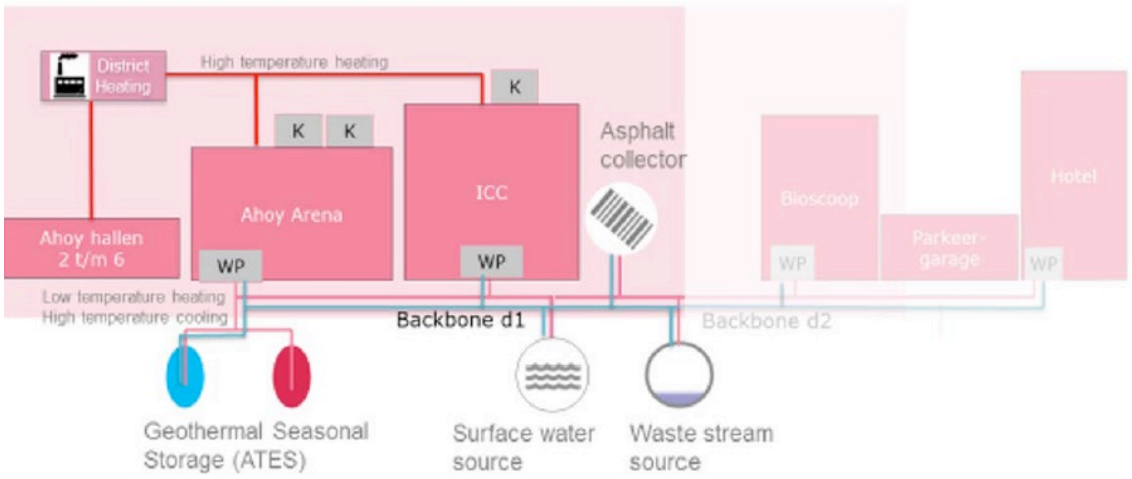


Exhibit 4. Geothermal heat-cold storage and heat pumps

STG Example 2: Thermal energy from waste streams[7]

In addition to the thermal storage and heat pumps in Example 1, the use of other thermal waste streams was stimulated as much as possible by making further connections to the Smart Thermal Grid. On a district-wide scale, sewage water from nearby households was used to extract heat or cold for use in the grid (**Exhibit 5**). This required close cooperation between the Municipality of Rotterdam (the owner of the sewer) and Eneco (the operator of the Smart Thermal Grid).

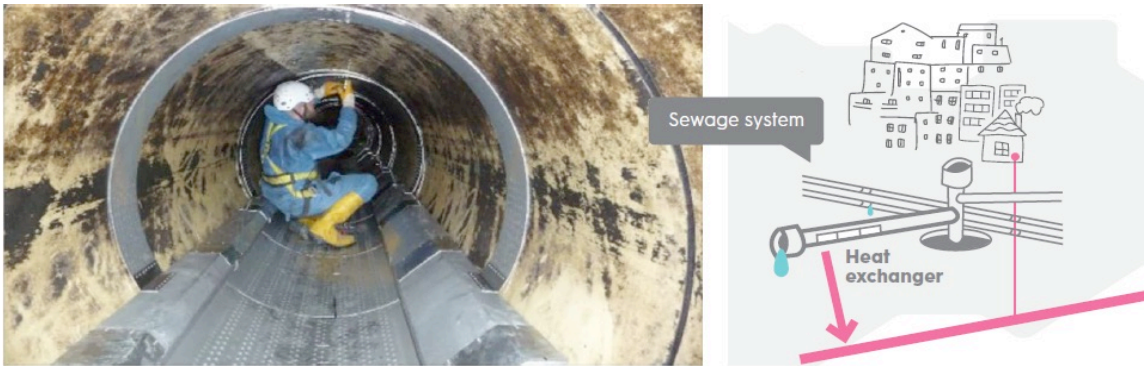


Exhibit 5. Heat exchangers within a sewer

Given that the buildings connected to the smart geothermal grid used more heat than cold, a balance needed to be created by adding cold to the storage system. Surface water nearby the Ahoy exhibition halls was used to provide this. Although the total energy demand in the area dropped, at certain times there was large peak demand. For this remaining demand, a connection with the city heating network was made into the low-temperature water storage to raise the energy efficiency of the total system. The connection to the city district heating system supplied the energy demand when alternative heat sources were insufficient in providing foreseen peak loads.

Benefits of the Smart Thermal Grid in Hart van Zuid

The development and implementation of the STG initiatives in Hart van Zuid, as planned in RUGGEDISED, brought several benefits, summarised in **Table 1**.

Benefit	STG initiatives: RUGGEDISED
Residual heat	Residual heat is valuably reused instead of 'blown off'
Assets	Can supply 20% more buildings with sustainable heat and cold using 20% less power
Flexibility	User flexibility through smart switching between buildings
Lifespan	5-10 year longer lifespan
Energy savings	Estimated at > 50%
CO_2 reduction	> 50 tons per year

Table 1. Benefits of the STG in Hart van Zuid

Stakeholders in the STG initiatives in Hart van Zuid

The development and implementation of the STG took place in a network setting. The RUGGEDISED STG initiatives were based on a consortium between three official partners: the Municipality of Rotterdam, Ballast Nedam/Heijmans and Eneco.

In the context of climate change and energy transition, the **Municipality of Rotterdam** had decided to commit to some goals. Thus, the Municipality was one of the initiators of the climate program 'Rotterdam Climate Initiative'. It was not only a partner in the STG initiatives but also a stakeholder in the Hart van Zuid project. The Municipality was also a real estate developer and was therefore the building owner of many buildings.

Ballast Nedam/Heijmans is a construction company and was one of the developers of the Zuidplein and Ahoy areas in the Hart van Zuid project. It was also a partner in the STG initiatives, as well as a contracting party in the Hart van Zuid project.

Eneco is a large energy company, a producer and supplier of natural gas, electricity and heat in the Netherlands, serving more than 2 million business and residential customers. In the Hart van Zuid district, Eneco's focus was on reducing the energy consumption of buildings and increasing the comfort level within buildings. Eneco also operated the heat-cold storage system. In addition to these core parties that formed the partnership for the STG initiatives, there were some other stakeholders: Ahoy, Vattenfall (formerly Nuon) and The Netherlands Organisation for applied scientific research (TNO). All stakeholders are illustrated in **Exhibit 6**.

In this project, **Ahoy** is the most important customer of the STG. **Vattenfall** is an important party because it had the exclusive right to connect all new buildings to the power station heat network in Hart van Zuid. As a knowledge partner, **TNO** offered an 'outsider perspective' on the STG projects.

Exhibit 6. Stakeholders of the STG initiatives in Hart van Zuid

Challenges and Complexities of the STG Initiatives in Hart van Zuid

The STG initiatives in Hart van Zuid had encountered several challenges.

First, contractual collaborations and responsibilities were too complex and very difficult to arrange. At the beginning of RUGGEDIESD, the realisation of the STG was defined as being the responsibility of Ballast Nedam, because in this concession area they were an asset owner of the buildings for 20 years, not including the Ahoy complex, and had the mandate to change designs and existing features in the buildings. Early in the project (at the end of 2016), Ballast Nedam carried out investigations regarding the ownership structure for the cold-heat storage (geothermal heating and cooling) in Ahoy. During that period (November 2016 - April 2017) there were still too many uncertainties regarding the STG. The major uncertainty at the time was the proposed length of the grid, which was much longer than the initial estimation.

Moreover, in that period, Ballast Nedam was taken over by an another, larger firm. Because the representative person of that contracting party changed, that party's mandate within RUGGEDISED also changed. Not surprisingly, the new representative had different business objectives than his predecessor and was not motivated to collaborate, as the return-on-investment period was too long and he saw it as not beneficial for his company. So, after the preliminary analysis (January 2017) the RUGEDISED stakeholders found that the Rotterdam business case was under pressure. This was because it was uncertain whether the future dwellings, swimming pool, theatre, shopping center, hotel and cinema would be connected to the grid, and this had been the heart of the business case.

Simultaneously, Vattenfall, which had been awarded the monopoly for delivering high-temperature district heating to new buildings in the South of Rotterdam (including Hart van Zuid), carried out an impact analysis of the consequences of this change for the business case of the district heating supply. With the business case under pressure and a possible clash with Vattenfall, there were no grounds for taking an investment decision. In addition, by the summer of 2017, the construction of the swimming pool had started. This meant that the RUGEDISED partners were no longer able to integrate the STG into the building design. Instead, the swimming pool would be connected to the central district heating system, run by Vattenfall.

After the failure to keep the new swimming pool as a customer for the STG, the partners started the negotiations to determine, moving forward, which partners would be responsible for which parts of the the implementation of the smart solutions. In order to speed up the development of the STG, the partners agreed to transfer the development tasks from Ballast Nedam to the energy company partner Eneco. This

change of responsibilities also allowed the development of the STG to begin, based on an alternative layout – without a swimming pool and theatre, but still including the Ahoy entertainment complex, the new conference centre, and possibly a hotel and a cinema. Moreover, the thermal storage, aquifer and heat exchangers had to first be in place. These were owned by Ahoy but were not being used to their full capacities. Therefore, Eneco took over ownership from Ahoy and redesigned the thermal grid to make the best use of the Thermal Storage and Aquifer[9]. As a result of these shifts in ownership and responsibilities, Eneco took control of the business case and, together with its subcontractor Energie Totaal Projecten (ETP), designed a system for the Ahoy entertainment complex and the new conference centre with a business case that was attractive enough for the Municipality of Rotterdam and Ballast Nedam to participate in. This change of responsibility was issued in May 2019 as the second amendment to RUGGEDISED.

Second, as stated before, the design for the development of the Hart van Zuid area had begun before the RUGGEDISED project. The Hart van Zuid contract was signed in 2013, resulting in a public-private partnership contract for a long period of 20 years. A consequence of this long design and the contract period was that several sustainability measures and goals were outdated by the time Hart van Zuid joined RUGGEDISED. Nevertheless, the contract for Hart van Zuid was set in stone. This made it very difficult to introduce additions or adjustments that would make It possible to implement RUGEDISED measures in time of constrcution.

The third challenge was related to insufficient coordination. With RUGGEDISED the challenge was to update the area development plan and align it with the high standards of a smart city. The main issue lay in the planning and timing of the various activities. For some buildings, the development phase had already started, so the smart solutions of RUGGEDISED had to be worked into the existing Hart van Zuid development plans. This required the development teams of both projects to be flexible. Sometimes only minor changes were needed to the original design to be able to implement RUGGEDISED measures. Coordination between the teams was crucial[8]. However, no director had yet been appointed as a point of contact for making the Hart van Zuid development project more sustainable and facilitating collaboration with RUGGEDISED.

The fourth issue was that this STG would compete with the existing central district heating, which made it impossible to optimise the STG from a financial, sustainable or innovative perspective. Eneco was responsible for building and running the STG and for connecting the large buildings in Hart van Zuid to the single Smart Thermal Grid. However, Eneco had to adapt to the complex situation of this region. One of the issues was that a great deal of Hart van Zuid was connected to the central district heating, fed in from a waste incineration plant in the Port of Rotterdam. Consequently, both financially and in terms of energy demand this STG competed with the existing district heating system. For example, buildings in this area were mandatorily connected to central district heating. This made the operation of the STG complex and less effective in terms of CO_2 impact. Therefore, it was important to demonstrate that the business case of this STG would be beneficial to Eneco in the long run. It was suggested that the STG would only be useful if its sustainability performance and cost were minimally competitive with district heating.

Fifth, the simultaneous involvement of several energy providers added to the complexity of the previous issue. Eneco, for example, supplied district heating for the existing buildings in Hart van Zuid, while new buildings in this area were contracted to be supplied by Vattenfall. In other words, the STG solutions developed in the RUGGEDISED plan were not compatible with the district heating that was already in place.

Sixth, the success of any sustainable energy project, such as this STG project, depends on the support of the stakeholders involved. However, due to the multi-actor collaboration involved in this project, identifying the right form of management and cooperation turned out to be one of its major challenges. For instance, the STG project would have had different resources divided over different stakeholders which create mutual dependency among them.

Conclusion

The transition to gas-free heating is far from simple, and any such project requires a tailor-made solution based on local conditions. The RUGGEDISED project aimed to connect all buildings in the Hart van Zuid area via an Smart Thermal Grid to optimise the distribution of heat and cold among buildings. By using a hybrid system, with centralised high-temperature district heating and decentralised low-temperature heating via the STG, the Hart van Zuid area hoped to move towards an optimal energy system that would prevent situations of insufficient supply during high peak demands. However, in the early, uncertain phase of the energy transition, there were many practical questions about organisational forms, financing, ownership, management and transparency. Therefore, the local government and other involved stakeholders needed to learn, exchange knowledge and experiment together.

Several lessons can be learned from the implementation of the RUGGEDISED project in Hart van Zuid. First, the importance of having the right players at the table at the right time is key to determining where to invest, what solutions to implement and how. Second, realising an energy transition by means of an STG requires innovation, a thorough reassessment of roles and responsibilities, and appropriate collaboration among the involved stakeholders. However, the fact that this kind of project is based on innovation necessarily implies that little practical information is available in advance, nor experience with practical consequences. Third, as mentioned in the case, no director had been appointed as a point of contact for facilitating collaboration. This means that everyone involved was thinking from their own vantage point, and there was no overview of the greater whole. A director would have made these projects much smoother, as someone who could bring together the interests of the various parties and pursue the bigger picture. A director would also have been able to promote cross-project collaboration to jointly discuss solutions and approaches to potential issues. This type of discussion should be open and transparent, with an emphasis on how to implement the projects in a balanced manner.

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