Potential of Aqua Thermal Energy in the Utrecht Heuvelrug: Working Towards a Climate-Neutral Future

Research Report

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Abbreviations

In this chapter, all the abbreviations used in this paper will be stated and explained. Some abbreviations are from Dutch origin, so therefore it is convenient to explain their meaning in English.

Abbreviation	Meaning	Explanation
ATES	Aquifer thermal energy storage	Storage of water in aquifers, both to store warm water from summer for winter and cold water from winter for summer.
GHG	Greenhouse gas	Gasses like CO_2 that cause a rise in temperature at the Earth.
HDSR	Hoogheemraadschap de Stichtse Rijnlanden	Local water authority within the area of the Utrecht Heuvelrug
LT	Low-temperature	Heat that is of low temperature nature, which is the case with aqua thermal energy.
SDE++	Stimuleringsregeling duurzame energie	Subsidy from the Dutch Government to reduce CO_2 emissions by the use of renewable energy. First subsidy that included aqua thermal energy.
TCO	Total cost of ownership	An estimate to determine the indirect and direct costs of a product or service.
TEA	Thermische energie afvalwater	Aqua thermal energy that is retrieved from wastewater, for example from a WWTP.
TEO	Thermische energie oppervlakte water	Aqua thermal energy that is retrieved from surface water, like lakes, rivers and canals.
WWTP	Wastewater treatment plant	Place where wastewater is being cleaned to be used again. Here, TEA can be used to retrieve heat.

1. Introduction

In 2015 the world agreed that global warming should not exceed 1.5 degrees (UNFCCC, 2015). To reach this goal, the Paris Climate Agreement has been signed by 189 countries to date, including the Netherlands (UN, n.d.). As a follow-up on the goals set by the Paris Agreement, the Netherlands created their own deal in 2019; the National Climate Agreement (Klimaatakkoord). As part of this deal, the Dutch Government stated that by 2030 greenhouse gas emissions should be reduced by 49% compared to 1990 levels, and 90% by 2050. As part of the deal, each municipality is responsible to incorporate these targets into their policies and transition towards sustainable heat and energy (Dutch Government, 2019) with support from the 'regional energy strategy' (RES) (NPRES, n.d.).

To complete these targets, alternatives to fossil fuels must be found; especially in the Netherlands which is one of the most fossil fuel reliant countries in Europe (Verhagen et al., 2020). In the residential housing sector alone, natural gas accounted for 71% of heating in 2018 (IEA, 2020).

Aqua thermal energy (also termed as 'aquathermy') is a possible replacement for natural gas for heating. Aquathermy uses heat and cold from different water sources: surface water, drinking water and wastewater (NetwerkAquathermie, n.d.). It is often coupled with aquifer thermal energy storage (ATES) systems, where the heat extracted from water during the summer is stored in aquifers, and used to heat homes during the winter months, and vice versa . This technology is relatively new, but since the Netherlands is known for its large number of canals and advanced water technology, aquathermy systems are slowly popping up across the Netherlands (STOWA, n.d.). Some examples will be presented in the following section.

As mentioned above, aquathermy is a new technology, and as such, there is a lack of research on it. To our knowledge, there is no report on the possibilities of implementing aquathermy at the Utrecht Heuvelrug or its surroundings, even though some projects are being planned in this region. Therefore, this paper is focusing on this area, with the following question to guide the research:

What are the opportunities, barriers, and policy improvements of aqua thermal energy (aquathermy) at the Utrecht Heuvelrug?

To answer the main research question the following sub-questions will be researched:

1. What criteria does a location have to fulfill for aquathermy to be implemented there?
2. Are there suitable locations around the Utrecht Heuvelrug for implementing aquathermy?
3. Is there an interest for aquathermy in the region among the municipalities, companies and other stakeholders?

4. What barriers exist prior to the implementation of aquathermy?
5. What policies are already in place for aquathermy and based on these findings, what policies are missing?

First, a literature review into the topic and previous case studies will be given. This is followed by the methods that were used during the research, as well as the results and discussion. Finally, the conclusion and the relevance of this research will be presented.

2. Literature review

2.1 Background

Aquathermy – the technology of using surface, waste or drinking water for heating and cooling – is a relatively new technology that has not yet been researched as thoroughly as other renewable energy sources. Nevertheless, aquathermy has a strong potential to contribute to the energy transition in the Netherlands (NetwerkAquathermie, n.d.). It is mentioned in the Klimaatakkoord as a renewable replacement, and several aqua thermal energy systems already operate throughout the Netherlands (Dutch Government, 2019; STOWA, n.d.). Specifically, the Province of Utrecht highlights the strong potential of aqua thermal systems in the area. However, it is not yet integrated in the province's policy plans (Provincie Utrecht, 2020).

One of the advantages of aquathermy is that it is a versatile source, as it can be used for both heating and cooling. However, there are some factors to take into account, such as the proximity of the water source (CE Delft & NP RES, 2020), and how well insulated the buildings are (NetwerkAquathermie, n.d.). Moreover, aquathermy can be combined with other technologies to reduce heat loss, such as ATES (van der Hoek, et al., 2018) or a cluster grid, where different energy providers and consumers exchange heat based on supply and demand (Verhoeven, et al., 2014).

2.2 Case studies

Even though aquathermy is not yet widespread, several projects already exist in the Netherlands. It is important to analyze these examples and incorporate the lessons learned into our research. A few of these studies about aquathermy are discussed next.

The first case study is the Minewater project in Heerlen, where a low-temperature (LT) district heating system was launched in 2008. The former mining fields of Heerlen are filled with warm water, which is the basis of a circular energy system. This LT source supplies both heating and cooling. The mine is also used for the storage of residual heat from the environment and other sources in the heating network. The Minewater project has achieved a reduction of 65% CO_2 emissions (Verhoeven, et al., 2014).

The next example is in Amsterdam, where cold recovery from drinking water was applied at a pharmaceutical company, and it led to a reduction in GHG emissions of 869 tons CO_2 equivalent. However, a possible issue with cold recovery is that it warms the water, which may negatively affect the water quality due to higher microbial activity (Van der Hoek, et al., 2018). Cold recovery reduced not only 90% of the GHG emissions but research has shown that in this case, cold recovery has a 17 times lower total

cost of ownership (TCO) compared to traditional cooling (Van der Hoek, et al., 2018). However, there is a difference between our research and this case study, as the aquathermy from this project focuses only on cooling and not heating.

Lastly, the case study with the most similarities to our research is the Merwedekanaal area in Utrecht. The municipality of Utrecht is planning to implement surface water aquathermy (TEO) here. TEO at the Merwedekanaal, in the form of energy recovery in summer, can be converted into high-quality energy for the heating of buildings or for hot tap water. TEO can be supplemented by a heat and cold storage system in the ground (i.e., ATES). To make this project happen, the municipality works together with HDSR, Rijkswaterstaat, the Province of Utrecht, and IF technology (a research institute focused on the transition from fossil fuels to sustainable energy) (Scholten, 2017). The reason this case study fits our research proposal so well is not only the location, but also the stakeholders who are involved have many similarities with our research.

Table 1. Overview of case studies used in the literature review

Location	Type of Aquathermy	Characteristics	Differences	Reference
Heerlen	Heat / cold recovery and storage in old mines.	- 65% Reduction in CO_2 emissions. - District heating system is used. - The water is also used for heat storage.	The Minewater project is underground (technically it is geothermal energy).	(Verhoeven, et al., 2014)
Amsterdam	Cold recovery from drinking water.	- 90% Reduction in CO_2 emissions. - 17% Lower total cost of ownership. - The increase of water temperature may increase bacterial growth.	Only focuses on drinking water. Uses water for cooling only.	(van der Hoek, et al., 2018)
Utrecht (Merwedekanaal)	Surface water as a renewable energy source.	Aquathermy could be combined with ATES to warm/cool the neighborhoud.	The project fits in our research. However, the case study is still in planning stage.	(Scholten, 2017)

3. Methods

The main goal of this research is to gain more in-depth understanding of aqua thermal energy systems to build towards a well-structured answer to the main research question and its sub-questions. This was done by collecting primary qualitative data from several interviews with important stakeholders, and secondary data through literature research of articles, reports and case studies. How each sub-question was answered is laid out in Figure 1. Once enough data was collected to answer each sub-question, the data was brought together and combined to answer the main research question.

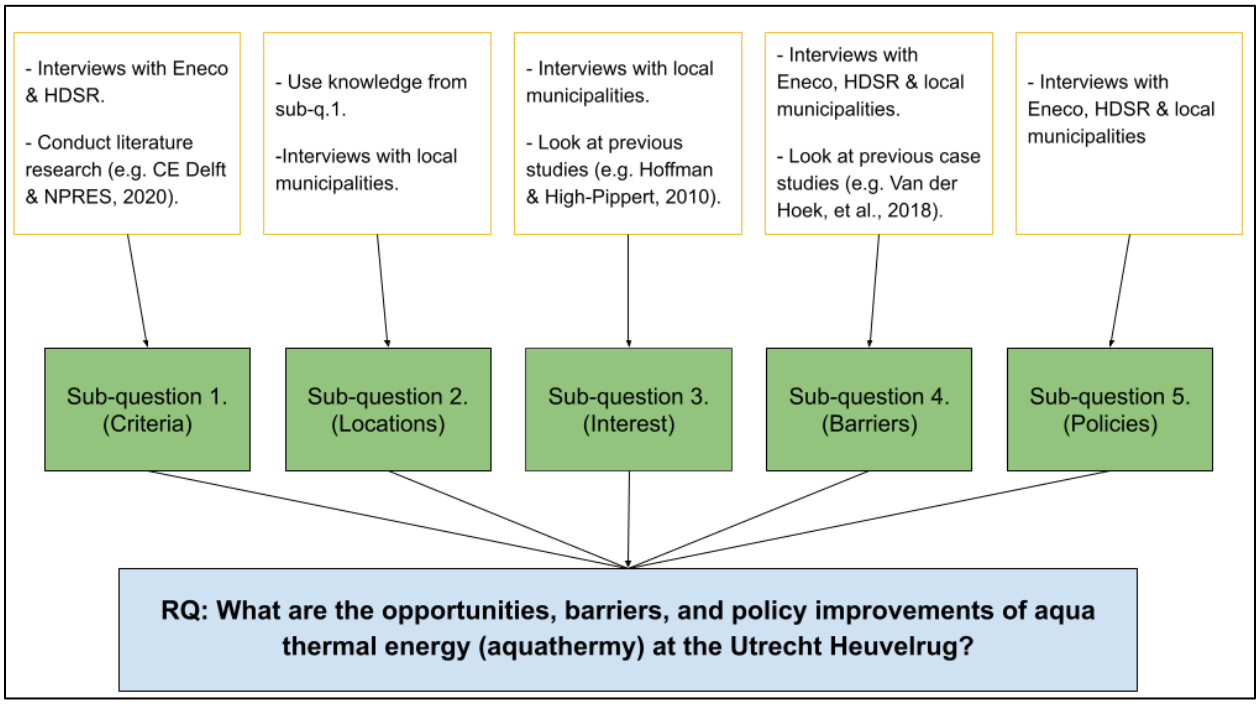

Figure 1: Block-diagram Showing the Methodological Steps to Answer the Research Questions.

First existing literature was researched; this was done by reading relevant articles, reports and case studies. The literature research granted general, as well as specific knowledge, about aqua thermal energy which was important to get a thorough understanding of the topic, but also helped to answer several of the sub-questions. Three of the five sub-questions were partially answered by this literature review: “What criteria does a location have to fulfill for aquathermy to be implemented there?”, “What possible barriers exist prior to the implementation of aquathermy?” and “What policies are already in place for aquathermy and based on these findings, what policies are missing?”. These sub-questions were looked at during both the literature research, as well as the interviews. By combining these two methods it was possible to gather enough data to form a clear answer.

Besides looking at existing literature, conducting interviews was the main method of collecting primary qualitative data and essential for connecting our knowledge to the Utrecht Heuvelrug. These interviews with various individuals helped answer all five sub-questions, including the questions mentioned earlier which were also answered by literature research, as well as the other two: “Are there suitable locations around the Utrecht Heuvelrug for implementing aquathermy?” and “Is there an interest for aquathermy in the region among the municipalities, companies and other stakeholders?”.

For the interviews several stakeholders were considered relevant and important; an energy supplier (Eneco), the local water authority board (HDSR), and several municipalities; including the Utrecht Heuvelrug. The interviews were conducted in the form of semi-structured interviews which was appropriate for this research. Prior to the interviews appropriate questions had already been prepared and placed in a logical order. By using semi-structured interviews most of the questions had already been formulated but it gave the freedom to ask follow-up questions and clarifying questions. The interviews provided a lot of useful information helping us work towards an answer of the research question.

For the interview with Eneco, a large energy supplier in the Netherlands, the ‘manager project development heat’ agreed to an interview. He is the project manager mainly for sustainable heat projects including aqua thermal energy. Since he has experience working with aquathermy he provided a lot of useful information regarding project criteria and barriers. Second, the interview with HDSR was with their ‘senior policy advisor’ who focuses on water and energy. He also had valuable information, especially regarding policies. Finally, for the interviews with the municipalities, contact was made with several municipalities, but only three responded and were eager to talk with us: Utrecht, Utrecht Heuvelrug, and Zeist. In the interview with Utrecht we had contact with the ‘senior advisor of water and energy’, in the interview with Utrecht Heuvelrug with the ‘policy advisor of sustainability and energy transition’, and in the interview with Zeist with the ‘project manager heat’. The interviews with the municipalities gave insight to the interest and pre-existing knowledge of the municipalities in aquathermy. In Table 2., all the information regarding the interviews is summarized.

Table 2: Summary Table of the Conducted Interviews

Name	**Function and Organization**	**Main Topic of Interview**	**Data of Interview**
Boudewijn Jans de Jong	Manager project developer heat at Eneco	Criteria and barriers of aquathermy	26th of May
Marco van Schaik	Senior policy advisor at HDSR	Criteria and barriers of aquathermy	28th of May
Mila Verdonk	Project manager heat at municipality of Zeist	Opportunities of aquathermy within the municipality of Zeist	1st of June
-	Senior advisor of water and energy at municipality of Utrecht	Opportunities of aquathermy within the municipality of Utrecht	1st of June
Femke Batterink	Policy advisor of sustainability and energy transition at municipality of the Utrecht Heuvelrug	Opportunities of aquathermy within the municipality of the Utrecht Heuvelrug	3rd of June

In total five interviews were conducted, and all took place online; all interviewees signed a consent form or gave verbal consent prior to beginning. Each interview took approximately 30 minutes to an hour. Since all interviewees consented to recording the interview, it was possible to transcribe all the interviews afterwards. These transcriptions can be found in the appendices. Once the transcriptions were complete, we manually categorized our findings per sub-question using different codes per interviewee; in this case each interviewee was assigned a different highlight color. This way it was possible to keep track of who said what, or where the information came from. After grouping by topic and analyzing what each stakeholder said, as well the findings from the literature research the results could be organized into several categories relating to each sub-question. Then from the results it was possible to answer the sub-question. With each separate sub-question answered, the answers were combined to answer the overarching research question.

4. Results

4.1 Criteria for Implementing Aqua Thermal Energy

Before looking at the potential of aqua thermal energy at the Utrecht Heuvelrug, it is important to come up with criteria that a location must fulfill. Especially in the interviews with the project developer at Eneco and the policy advisor at HDSR several technical criteria were mentioned. First, the distance from the water source (either a wastewater treatment plant (WWTP) or surface water) to the infrastructure is important. As heat retrieved with aquathermy is often of LT the risk of losing heat along the way is high. A distance of maximum 1 kilometer is feasible, both regarding costs and loss of heat (de Jong, 2021). Secondly, houses need to be well insulated in order to properly make use of the already LT heat. This makes new building projects more suitable for aquathermy (Advisor Water and Energy, 2021). Lastly, to be able to get the heat from source to houses, district heating systems are needed. These either need to be constructed, or the aqua thermal energy project needs to be close to an already existing system. Eneco owns almost half of the district heating systems in the Netherlands (de Jong, 2021).

Besides the technical criteria, economic and policy related criteria also have to be met for implementation of aquathermy. First, government subsidies are essential (de Jong, 2021; van Schaik, 2021). Further, the importance of collaboration between all stakeholders involved was mentioned by several interviewees. Aqua thermal energy projects have many different aspects and therefore involve a number of different stakeholders: the local water authority (e.g., HDSR), energy companies (e.g., Eneco), municipalities, and residents represented by energy cooperatives. Therefore, collaboration is necessary to let these projects succeed. In Figure 2. below, all the criteria based on the conducted interviews are presented.

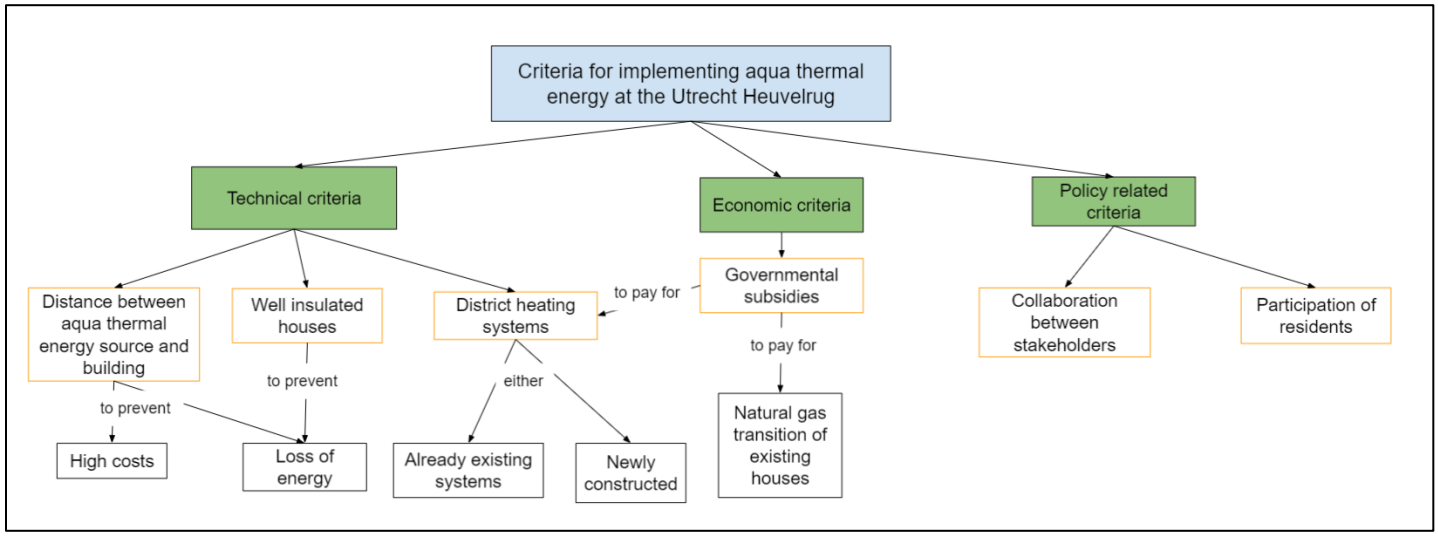

Figure 2: Block-diagram of Criteria for Aqua Thermal Energy; Own Elaboration Based on the Conducted Interviews

4.2 Barriers for Implementing Aqua Thermal Energy

In order to formulate policy improvement to encourage the implementation of aqua thermal energy, barriers need to be identified.

First, a couple of technical issues exist. In the first place, a lot of differences in height occur at the Utrecht Heuvelrug. This makes, for example, the potential of the Lek river for aquathermy smaller (van Schaik, 2021). The Lek river is situated at the bottom of the Heuvelrug and pumping water all the way up to the top is both too expensive and too far regarding distance between the source and the buildings. To elaborate on the distance; a lot of potential sources for aqua thermal energy lay at the edges of the national park; this often makes the distance too large. The use of a heat pump also creates excessive costs. Additionally, a titanium heat exchanger is very costly but necessary to prevent deterioration due to micro bacteria (de Jong, 2021) .

Costa are not the only problem with the heat pump, but sound as well. The device is very loud and therefore needs to be further away of houses and well-insulated (de Jong, 2021). Another problem within several municipalities is the lack of surface water (Verdonk, 2021). This makes the potential of aqua thermal energy retrieved from surface water at some places almost zero, which results in municipalities looking for other options. The feasibility of aquathermy therefore decreases due to expensiveness, loss of heat, absence of surface water, and due to the degree of insulation of houses. Additionally, existing houses are often not well insulated to make the LT heat useful (Batterink, 2021). Therefore, most municipalities are looking at using TEO or TEA within new building projects.

Regarding TEA, there is a difference in the use of aquathermy between influent (untreated) and effluent (treated) wastewater (van Schaik, 2021). Untreated wastewater cannot be cooled down as much, as removing certain chemicals is more difficult with lower temperature water. This must be considered when using TEA. Lastly, one of the most important barriers is the lack of knowledge on the ecological effects of TEO specifically. Other research, like the one on aqua thermal energy from drinking water, present that temperature changes do affect the water quality (van der Hoek, et al., 2018). However, we cannot be sure that this also applies to aqua thermal energy in this area. This makes implementing on a large scale still unlikely (van Schaik, 2021).

Beside technical barriers, both social and policy barriers were mentioned. First, the government stated in the National Climate Agreement that by 2030, 1.5 million houses should be cut of natural gas (Dutch Government, 2019) and to reach this goal, technologies such as aquathermy need to be implemented. However, the government currently does not provide infrastructures such as district heating systems.

Municipalities are afraid to make such an investment when they are not sure of the potential it will have (van Schaik, 2021). Secondly, as previously mentioned, residents are an important stakeholder within aquathermy projects. Currently, residents are not well enough represented. Although energy cooperatives exist, these mostly consists of residents that are keen to change the energy use within their neighborhood. The lack of knowledge among residents results in them having less confidence in the technology since it is not widely implemented yet. This was mentioned by most of the interviewees and therefore, this barrier can be seen as an important one. An overview of the mentioned barriers is shown in Figure 3.

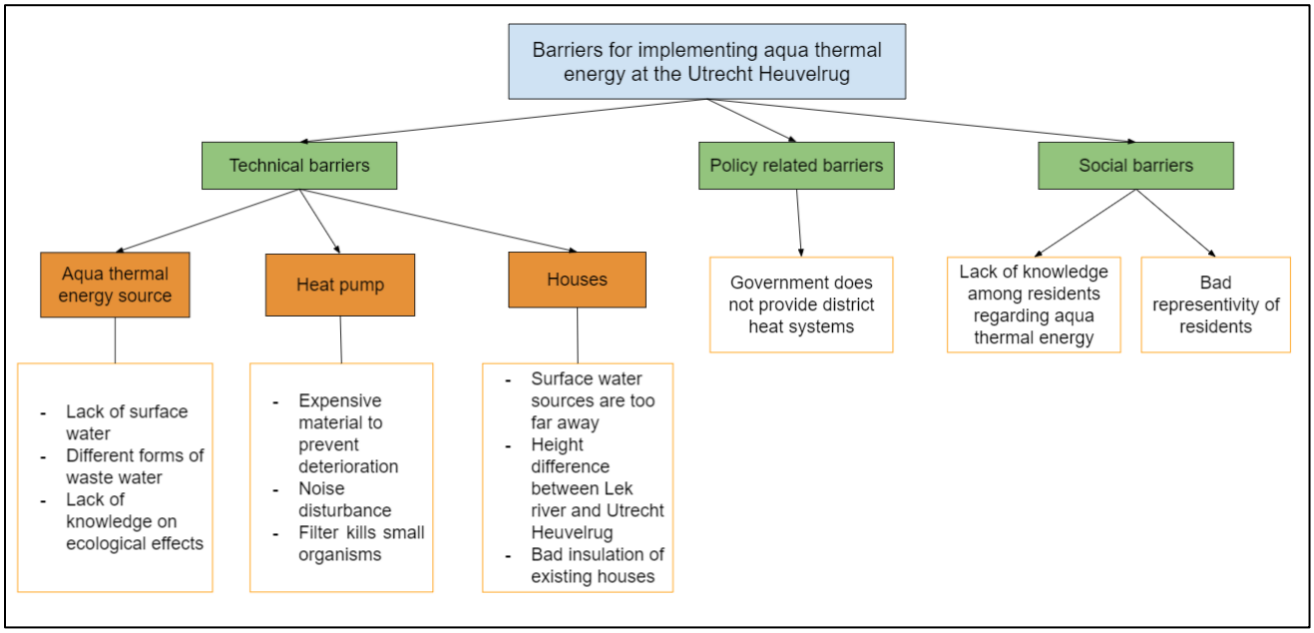

Figure 3: Block-diagram of Barriers of Aqua Thermal Energy; Own Elaboration Based on Conducted Interviews.

4.3 Suitable Locations in and around the Utrecht Heuvelrug

Our study focuses on a specific area: the Utrecht Heuvelrug. Therefore, it is important to know if there are possible location for that area regarding the implementation of aqua thermal energy.

Aqua thermal energy can be implemented via TEO and TEA. Both options have a good potential according to the municipality of Utrecht and Zeist, as well as Eneco and HDSR. However, the potential for TEA is much bigger in the Utrecht Heuvelrug. Due to the lack of surface water (because of the difference in height), TEO is less likely to be feasible.

A few possible locations for TEO are the cities around the river the Lek (Figure 4.), like Amerongen, Rhenen and Wijk Bij Duurstede (van Schaik, 2021). Also, the areas that are close to the Merwedekanaal or the Amsterdam-Rijnkanaal have a potential for TEO (Advisor Water and Energy, 2021). In Houten there is

already a project being developed for TEO where a district heating system is already available (de Jong, 2021).

However, in the Utrecht Heuvelrug TEA is likely to be more achievable. For example, in Den Dolder there is a Remia factory which is a source of warm residual water. This water could be used to warm an entire neighborhood in Zeist (Verdonk, 2021). There are also WWTPs in Utrecht, Driebergen, Zeist, de Bilt, and Rhenen, which have a potential for TEA (van Schaik, 2021). There is already a project in Overvecht (Utrecht) being built by Eneco regarding a heat pump project in the WWTP (de Jong, 2021). Based on the information retrieved from the interviews, TEA has a higher potential at the Utrecht Heuvelrug.

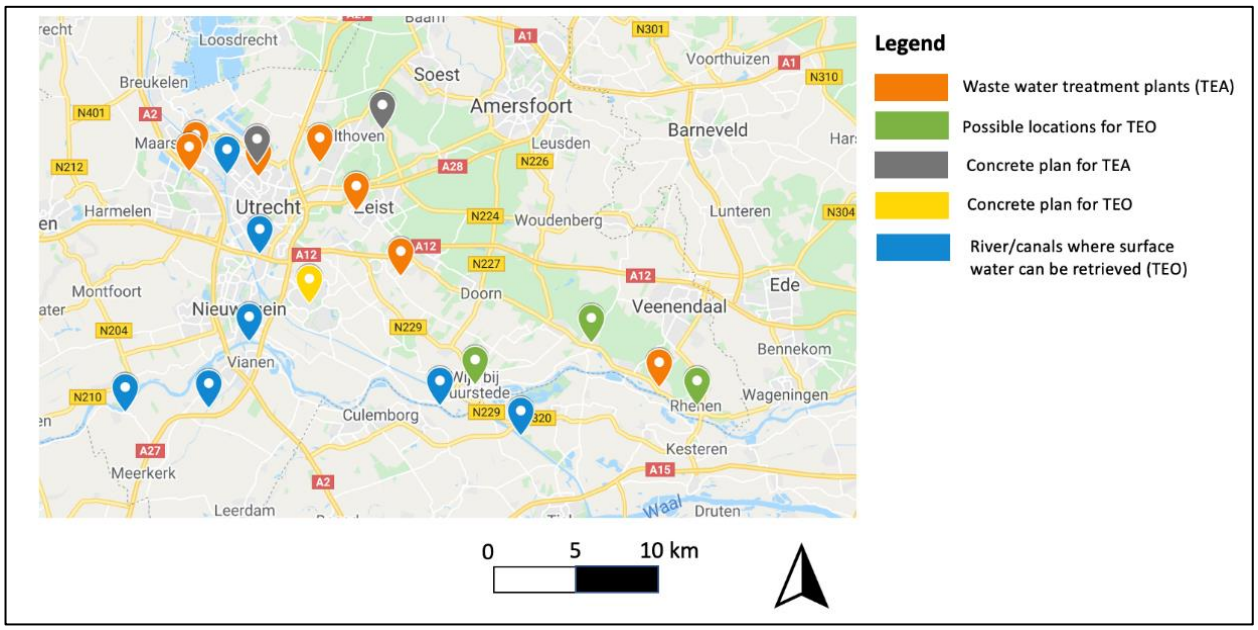

Figure 4: Possible Locations for Implementing Aqua Thermal Energy; Own Elaboration Based on Conducted Interviews (made with Google Maps).

5. Discussion

5.1 Is There a Potential for Aqua Thermal Energy in the Heuvelrug?

In order to answer the main research question, this section will briefly answer the sub-questions based on the collected information.

For the first sub-question, six criteria were found (Figure 2.). Regarding the technical criteria, successful implementation of aquathermy depends on distance from the source to houses, insulation, and presence of a district heating system. According to the interview conducted with Eneco and the National Program of Energy Transition, the distance from source to house is maximum 1 kilometer (CE Delft & NP RES, 2020; de Jong, 2021). Looking at social and policy related criteria, subsidies, collaboration between stakeholders, and participation of residents is important.

Regarding sub-question 2, suitable locations in and around the Utrecht Heuvelrug were found, including the Lek river, WWTPs, a factory with residual heat, and canals like the Merwedekanaal (Scholten, 2017). Generally, TEO has a lower potential than TEA because of the lack of surface water in the area. Figure 4. presents the suitable locations.

Sub-question 3 aimed to look at the interest regarding aqua thermal energy. All the municipalities have a document called Transvisie Warmte. This document, e.g., the one from Zeist, states the steps the municipalities plan to take to reach sustainability in terms of heating (DeWarmteTransitieMakers & Gemeente Zeist, 2021). The interviewed municipalities all had aquathermy incorporated into their future plans or were already working on aquathermy projects. Therefore, the interests of aquathermy are high within the interviewed municipalities.

The fourth sub-question focuses on the barriers. As shown in Figure 3., there are three categories of barriers: technical, policy related and social. Most barriers fall into the technical category: for example, differences in height and distance, bad insulation, and lack of surfaced water can render aquathermy impossible to implement. Regarding policy related barriers, the government currently does not provide the expensive district heating systems. Social barriers include lack of knowledge and representativity among citizens. So, in order to successfully implement aquathermy, these barriers need to be overcome.

Sub-question 5 is concerned with the policies around aquathermy. From the interviews, it appears that there are no specific policies on aquathermy, only subsidies to fund projects. However, these can be inadequate; for example, Eneco experienced problems with getting a subsidy for their aquathermy project (de Jong, 2021). Another difficulty is that the cooperation between stakeholders is often difficult to

arrange. One example is the Remia factory, which produces residual heat, but lacks awareness on the advantages of aquathermy. Thus, setting up a project is difficult, despite the available potential (Verdonk, 2021).

Using the information provided above, the main research question can be answered. First, there are opportunities for aquathermy within the area of the Utrecht Heuvelrug. However, TEA has a higher potential than TEO due to lack of surface water within some municipalities. Before aqua thermal energy can be implemented, some barriers need to be resolved to make future projects a success. An important barrier is the lack of research on ecological consequences of aquathermy. Specifically for the area of the Utrecht Heuvelrug, the lack of surface water, as well as the large height difference and distances, ask for more insights in other options. This can mean implementing TEA, but also combining aqua thermal energy with other technologies can be an option. The last part of the research question regards policy improvements. To fund future aquathermy projects, subsidies need to be available and be more specific. This is a particularly crucial point, as subsidies are key in performing future projects. Also, policies need to allow more collaboration between all the different stakeholders. As aqua thermal energy projects involve a lot of stakeholders, it is important that they align.

To conclude, a lot of interest already exists within the municipalities in and around the Utrecht Heuvelrug. Depending on the presence of surface water, aqua thermal energy can have a high potential. However, policy improvements are needed to successfully implement new projects.

5.2 Recommendations for Future Projects

As has been mentioned before, there is interest in aquathermy among the municipalities, but other than Eneco's project in Overvecht there are no current ongoing aquathermy projects within the municipalities. From the results on sub-question 5 regarding existing policies, we also found it important to suggest future policy recommendations. This is especially important since (1) there is an interest in aquathermy and (2) from the data that has been gathered, existing policies are lacking. For example, one TEO project in Houten has been put on hold due to permitting issues and lack of guidelines from Rijkswaterstaat (de Jong, 2021).

Our first recommendation is to have more collaboration and communication between stakeholders. The most relevant stakeholders that have been identified are municipalities, energy suppliers (e.g., Eneco), the (local) water authority, as well as residents. If these stakeholders worked together, solutions could be arrived at sooner. Involving residents in the planning "is also very important, because in this way you can also tackle social problems in combination with aqua thermal energy" (van Schaik, 2021). That is why we

recommend using a bottom-up approach and communal-energy corporations as is researched and recommended by Hoffman & High-Pippert and Klein & Coffey (2010; 2016). They both concluded that gaining community participation is just as important as maintaining the participation. By involving all stakeholders, it promotes communication and reduces the possibilities of conflict between different parties.

Further, more collaboration between municipalities and energy suppliers would be beneficial to reach the targets stated in the Kilmaatakkoord. For example, Eneco is only building aqua thermal energy plants that contribute to their own district heating network, and for municipalities it is expensive to invest in an aquathermy projects since they do not have their own district heating networks. If municipalities, Eneco, and other energy suppliers could work together on projects it might be possible to speed up the timeline of many plans or projects. Thus, sharing resources, knowledge and district heating networks could be extremely helpful. After all, everyone is working towards the same goal to move away from natural gas heating.

Another important recommendation is regarding subsidies. Subsidies play a key role in kick-starting aquathermy projects because “with a subsidy, you have a project, and without, you do not” (de Jong, 2021). In September 2020, the Ministry of Economic Affairs announced a budget of 5 billion euros for SDE++. This was the first government subsidy made available for aquathermy (Dutch Government , 2020). In a letter from the House of Representatives there were 4 applications for subsidies for aqua thermal energy projects. These four applications were in the timespan of three weeks (Ministry of Economic Affairs and Climate, 2021). Given the substantial number of applications in such a brief time period shows further interest in the technology. It also shows the need for these subsidies and that many projects will not succeed without them. In contrast, HDSR mentions that the government is not making enough money available, especially when having such an ambitious goal: to remove 1.5 million houses from natural gas heating (van Schaik, 2021).

There are a few suggestions to implement these recommendations. First, as mentioned earlier, it is important to have more support from the government regarding subsidies and infrastructure such as district heating networks. Secondly, we suggest that the municipalities work together with energy suppliers to host information sessions to get citizens involved in the process, as well as factories such as Remia, who have potential for aquathermy. Further, we recommend a pilot project to initiate this collaboration between stakeholders. A pilot project will come with its challenges but will be very useful in building a foundation and policies for future projects.

5.3 Limitations of the Research

Multiple limitations appeared during the research process. The main data collection method used was conducting interviews. This method allows to gain a lot of information but comes with limitations.

First, interviews are subjective. Therefore, one interview will not represent the opinion and view of the organization as a whole. So, the information obtained can to some extent contain bias. Also, the content of the interviews is interpreted, so this may not be entirely objective. Furthermore, follow-up questions, as part of semi-structured interviews, were used to gain more information. However, there is a chance the guidelines of an objective interview were not abided by when asking those follow-up questions.

Moreover, we conducted only five interviews: with three municipalities, Eneco, and HDSR. If more interviews had been conducted, our research would have been more valid. Also, not all relevant stakeholders were interviewed. For example, the local residents or the Ministry of Economic Affairs and Climate Policy were not included in this research.

Also, the interviews were conducted at a specific moment in time. It could happen that the opinion of the interviewee changes over time. Lastly, our research applies to a specific region which leads to low external validity. This means that our research might not be applicable in other areas inside or outside of the Netherlands.

6. Conclusion

This paper has analyzed the opportunities and barriers of aquathermy at the Utrecht Heuvelrug. As a result, possible policy improvements were also found. It has been established that for the implementation of aqua thermal energy, certain criteria must be met. For the technical side, the distance between the water source and the houses must be below one kilometer, houses must be well insulated, and they need to be part of a district heating network. For the social and policy side, collaboration is needed between relevant stakeholders, with particular attention to citizen's involvement, and necessary government subsidies to make aquathermy possible.

There are several barriers that limit the number of places in the Utrecht Heuvelrug. Most importantly, there is little available surface water in the region. This surface water cannot be fully exploited because the houses in the region are dispersed, often at a higher elevation than the water source, and often not sufficiently insulated. There are social, economic and policy related obstacles as well, such as the lack of knowledge on aquathermy (both among residents, and in the scientific community on the possible effects on water quality), high investment costs, and insufficient subsidies. Despite these barriers, there are possible locations, especially on the edges of the Utrecht Heuvelrug and the surrounding areas. For example, the Lek river has potential for towns as Wijk bij Duurstede and Rhenen. WWTPs are present in Zeist, Driebergen and de Bilt and can be used for TEA.

The stakeholders interviewed during the research showed interest in pursuing these opportunities. However, to overcome the barriers that hinder the implementation of aquathermy in the Utrecht Heuvelrug, more cooperation is needed between participants. Aqua thermal projects involve multiple stakeholders and require large investments. Thus, a stronger subsidy support is also necessary to reach the full potential of aqua thermal energy.

Despite its potential, the literature on aqua thermal energy is scarce compared to other renewable energy sources. This report hopes to contribute to this field but has a limited scope. To expand on our findings, it would be beneficial to conduct further research in areas that were beyond the capacity of this report. Finding out more about the ecological effects of aquathermy on different water sources and about the opinions of residents on this technology would give further insight into the barriers of aquathermy in the region. Moreover, similar research projects could be conducted in other regions too.

Further research could help inform policymakers and stakeholders, encouraging the implementation of aqua thermal energy. This could help the wider employment of this technology, reducing the reliance of

the Netherlands on fossil fuels in the heating sector, and thus contributing to reaching the climate goals set in the Klimaatakkoord and the Paris Agreement.

7. Relevance and Integration Possibilities

Nowadays, natural gas is mainly used to heat buildings. In the Netherlands, the CO_2 emissions caused by the urban heating with natural gas account for almost 36% of the total emissions (Verhagen, van der Voet, & Sprecher, 2020). Because of the unsustainable nature of natural gas, the Dutch government has decided to completely cut this fuel use by 2050 (Dutch Government, 2019). This is a step in the direction of becoming climate neutral by 2050. To reach this target, both in the Netherlands and the municipality of the Utrecht Heuvelrug, technologies such as aqua thermal energy need to be better developed to contribute to the natural gas transition. As mentioned above, aqua thermal energy is either heat or cold retrieved from surface water, wastewater or drinking water, which can be used to heat buildings (CE Delft & NP RES, 2020). It is a desirable alternative for natural gas, as it has a high potential to heat buildings in a sustainable way, especially in the Netherlands where water is plentiful. This emphasizes the importance of the research on the potential of aqua thermal energy as a renewable heating technology.

With this research, more insights are provided in the barriers, potential solutions and opportunities of aqua thermal energy in the Netherlands, and specifically in the Utrecht Heuvelrug. Using these insights, we want to come up with policy recommendations. This is useful information to contribute to the overarching research question of topic 5: “Can the Utrecht Heuvelrug become climate neutral by 2035, and what barriers currently stand in the way of this goal?”. Aqua thermal energy can play a significant role in contributing to the energy transition of the Utrecht Heuvelrug and this emphasizes the importance of our research. In order to formulate a good answer to the overarching research question, the outcomes of the other groups’ research are also needed. Group 5A performs an analysis of the energy road map of the Utrecht Heuvelrug. Their outcomes can be combined with ours, by trying to fill up the gaps in the energy map with implementing aqua thermal energy. This can create a more complete view on how the municipality of the Utrecht Heuvelrug is doing in becoming climate neutral by 2035. Furthermore, group 5B and 5D will take a closer look in the position of residents towards renewable energy and sustainable mobility. This can give us a good insight in the potential social barriers regarding the energy transition. So, to be able to look at the complete picture regarding climate neutrality, integration of the different groups within topic 5 will be needed.

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Appendix 1: Transcript interview Marco van Schaik (HDSR)

Question 1: Can you shortly introduce yourself and your role within your organization?

I have been employed by HDSR since 2000, but I haven't really done much for that in the last 5 years. In the time of the Paris accords, I actually discovered aqua thermal energy because I read something about a project of a care home heated with water from the city canal. I also worked on climate adaptation in collaboration with quite a few municipalities in the Utrecht region. Aqua thermal energy can not only help to get rid of gas, but at the same time it also cools the water (climate adaptation). Then we had an opportunity card made and it showed that the potential is very high. At some point I joined the union of water boards in combination with STOWA. They were interested in aqua thermal energy as a new technology. At the moment I work partly at HDSR; I contribute to the regional structure heat. This is part of the regional energy strategy that all 30 regions should make.

Question 2: Taking into account what you said about aqua thermal energy having positive effects in terms of climate adaptation; are there also negative ecological effects associated with aqua thermal energy? (Water quality, organisms in the water)

When it comes to aqua thermal energy, you have three variants: TEA (wastewater), TEO (surface water) and TED (drinking water). The possible ecological consequences of TEO are currently being investigated. As for the cooling of the water, you can look at it from two sides. The positive effect of cooling is that the water can contain more oxygen, resulting in less blue-green algae and botulism (disease caused by dead fish) in the summer. Possible negative consequences of the local discharge of cold water can be that it can cause a shock effect for fish, for example. It can also hinder the growth of fish in the spring. There is also a problem in the fact that the water is filtered before it enters the heat exchanger. This filter allows zooplankton and fish larvae to pass through, which of course do not survive the heat pump. So, we actually know very little about it and that is why STOWA, together with other institutions, is working on a national monitoring program to be able to investigate these effects. There are also plans to conduct a literature study on existing cooling installations, because these effects are very similar to the potential effects of aqua thermal heating.

Question 3: During our literature review we also read things about distance from source to target, for example. Do you think there are more important barriers and criteria to consider if aqua thermal technology is applied on a large scale in the future?

When we talk about the Utrecht Heuvelrug, the river Lek is actually the most important source for TEO. You could certainly apply this in, for example, Amerongen and Rhenen, but this becomes more difficult further up the Heuvelrug. This is mainly due to the great distance, but of course also the height that you have to bridge. Aqua thermal energy from surface water is therefore not really an option there. There are two sewage treatment plants on the edge of the Utrecht Heuvelrug, so you could do something with TEA there.

Question 4 (follow-up): So, you say that surface water does not really stand a chance on the Utrecht Heuvelrug, but wastewater does. To what extent do you think that wastewater has potential in this environment, compared to surface water?

TEA would then mainly have a chance in Driebergen, Zeist and De Bilt. There is also a sewage treatment plant in Rhenen, so that might also be of interest. What you should pay attention to is the difference in

influent (untreated) and effluent (treated) sewage. With influent you have to make sure that it does not cool down too much, because then the nitrogen removal during purification will no longer work. This is therefore a fairly small source that you could mainly apply to, for example, an apartment complex. A sewage treatment plant could be used on a large scale; that is what they are also looking at in Driebergen and De Bilt. This concerns neighborhoods with around 1,000 homes.

Question 5: The projects you mention are quite regional. Which stakeholders then play a role in this; does the government or the province also have something to say about this?

The municipality is actually the leader in the energy transition; they look at which sustainable solution is suitable for each district. The residents are of course also very important, because they are ultimately the consumers of the heat. At the same time, that is also difficult, because how do you reach the residents? In Driebergen in de Bilt, for example, you have energy cooperatives for that. They are formed by people from the neighborhood itself and therefore represent the neighborhood. The question is, of course, whether this is representative, since only the motivated residents are probably part of the cooperative.

Question 6 (follow-up): If we understand correctly, does the problem lie more in getting residents enthusiastic than in actually realizing aqua thermal energy?

That is actually interrelated. Suppose you come up with a plan that ensures that residents will pay less for heat in the future, then that already has a positive effect. What is also important is that people gain confidence in the technology. That is why it is all the more important that more projects involving aqua thermal energy are realized. This way you can show people that it also works in other places, in order to instill confidence. Another problem is the low price of natural gas; at the moment almost, all sustainable alternatives are more expensive than natural gas. The government is now making very little money available, while they do set the goal of removing 1.5 million homes from gas by 2030. To get a home off the gas or often between € 5000 and € 10,000 is required and this is also an investment that is not recouped. So, the government really needs to come up with more money to really realize their goal. This could be solved in two ways: either natural gas should become more expensive, or more money should be made available for neighborhoods that rely on gas. An important point is therefore money from the government, and that does not only apply to projects involving aqua thermal energy. You could possibly heat 10% of the homes on the Heuvelrug with this, so you also have to rely on solar thermal, for example. Because you get most of the heat from the sun in the summer, you need a lot of space for storage. Because the Heuvelrug is very high with a low groundwater level, this is a perfect place to store this heat.

Question 7: At the moment, money is the main problem. Do you think that the current policy in the provinces and municipalities is suitable for being able to apply techniques such as aqua thermal energy? Or do you think things still need to change?

I think the cooperation is already very good at the moment; within the municipality, for example, the heat department already works together with the department that deals with the design of public space. If the street is already open for aqua thermal heating, then you can also start designing districts climate-proof in this way. Collaboration with residents is also very important, because in this way you can also tackle social problems in combination with aqua thermal energy. In Gelderland, for example, you have the so-called "Districts of the future" where such an integrated approach is already being applied. They want to tackle everything in it, so no natural gas, but also climate adaptation. In this case, collaboration is very important to make this kind of project a success.

Question 8: You are very interested in aqua thermal energy, but what about the HDSR as an organization?

The board is certainly interested, but the organization must of course follow. The point is, of course, that HDSR is only a small part of the entire chain that aqua thermal energy involves. The water board is the manager of the water; a producer takes care of the heat pump and the ATES; and finally, a party that takes care of the heat system and the supply to residents. The water board therefore only plays a role at the beginning of the process. Furthermore, the municipality is of course also crucial. The problem now is that the heat system, the largest investment in an aqua thermal project, is not yet supplied by the government. I think it would help the heat transition a lot if this were to happen in the future, given that a heat system has a payback period of up to 50 years. This is not really attractive for companies. The government is still very much focused on privatization, but to make the heat transition a success, it is essential to finance a heat system from the government.

Question 9 (follow-up): You say that the construction of heat systems is not yet regulated by the government. Is this because they are not yet widely used, which is the case with, for example, electricity cables or water pipes?

No, not that, because it is already used everywhere in the Netherlands. The point is that the systems that are now in place are owned by companies such as Eneco. A heat system is attractive for such companies, because they have a lot of heat left over and can make this useful with a heat system. However, the heat systems that we will need in the future for aqua thermal heating and geothermal energy are different, and the government could play a greater role in this. In my opinion this could also be arranged very well at the provincial level.

Appendix 2: Transcript interview Boudewijn Janse de Jong (Eneco)

Question 1: Could you introduce yourself and your role within Eneco?

First of all, I'm working for the department within Eneco that develops off-shore wind and on-land solar, hydrogen and also making industry more sustainable with e-boilers and hydrogen and heat. And heat is district heating. In the Netherlands have district heating systems, in The Hague, Rotterdam, Amsterdam, Utrecht… there are about four hundred thousand clients connected to the district heating systems in the Netherlands (not sure if that is the exact number), and Eneco has about half of it, so 200 000 connections, households let's say. These district heating systems are not fired by gas, like electricity plants. In Utrecht we have got two plants of about 2x 200,000 MW, (180,000 to be precise), that make electricity, and their residual heat is pretty sustainable (if you make electricity anyway) to fill up the gap of solar and wind. So, then it is interesting to have cheap, pretty sustainable residual heat. But then, we have the shift from gas to more renewable sources in the near future.

I am responsible for the development department of Eneco's heat projects, and focusing on residual heat from industry, but also on geothermal projects, aqua thermal projects, and of course as your baseload, you also need some projects for when there is a peak, then we look at gas, e-boilers, etc. to fill in your demand curve. And also, day-night storage and seasonal storage. So, all kinds of new energy technologies; I'm working for new energy development, to be precise, located in Rotterdam, but now I am in Utrecht. Also, working on these kinds of projects and zooming in on aqua thermal heat pumps to be precise, that is quite a potential technology. So, we think this is more interesting than for example geothermal projects.

We run into subsidies, so these projects' success factor, these projects are based on do we have subsidy or not, and as you may know the Economic Department and RVO Netherlands has created a category for aqua thermal heat pumps, which can be quite interesting, because with a subsidy, you have a project, and without, you do not. And of course, you have to arrange things like permitting, ground position, you need to have the technology right. So, I am developing right now the biggest heat pump in the Netherlands. We have the 40 megawatts one in Malmö (?), you got 10 megawatts in Calemburg (?), Stockholm, so all in Scandinavia, we have a lot of projects, but in the Netherlands, we do not, because we are from origin some kind of rich gas-fired nation, and not really into sustainable technologies yet, so there is a lot that needs to happen. But we are looking forward to, and we are in the contracting phase right now. We have been in the developing phase for three years, and we need another half a year to finalize the contracting phase; then we will have construction phase of one and a half – two years, and then this 25-megawatt heat pump project in the sewage installation in Overvecht, Utrecht, should be operational at the end of 2023. With a COP of around – I do not know how technical you guys are – but that is what we are doing there. In partnership with the sewage company in Utrecht and HDSR. The Netherlands is the only country in the world where we have *waterschappen*, like the water companies. So, we have a partnership with them. The other thing, it is a 100% Eneco development, so we invest ourselves, it is a 30 million project, plus around project, and the role that the sewage company has is the ground position – you need some football fields for it, like a building with thick walls, because the heat pump makes a lot of noise. And they kind of deliver or provide clean water, so we do not get the dirty water, we get the clean water at the end of the water line. So, before they dump it to the Vecht (he said a Dutch word, not sure if it is this), we can use it to use the temperature. In the winter it is 12, in the summer, it is 24, and we abstract around 7 degrees of it. So, we do not make ice cubes, but we do use

the heat, put a big heat pump on it to bring it to the temperature that our clients need. So that is what we call the heating line (stooklijn), it is different each season. But the maximum outward temperature, so we lift the return temperature to a maximum 85 degrees, because these heat pumps have ammonia as a refrigerant. So, no HFOs; Vattenfall has a project in Berlin, they use HFOs, but we do not use these kinds of refrigerants. We use ammonia because it is better. We are also investigating HFOs, but not for this project.

Question 2: We were wondering about what are the criteria that you use to determine whether a certain water source would be suitable to start a project there. Like for example the proximity to the houses, or the temperature, or anything?

So, success criteria, right? So first of all, you need is district heating system close to a sewage, and space for the project itself. Then what you also need is a district heating system that does not have temperatures higher than the supply temperature of 85 degrees. So, you need a temperature match, you need a ground position match, you need a match of the existing district heating clients. All the system close to the sewage, because if you go more than 1 km, it is quite expensive, you may not have a business case anymore to transport this kind of heat, it is not very interesting.

And then of course the temperature it is I think the same over the Netherlands, like 12-24 so that is not really a criterion, that's a given. It comes like it is provided and it is created by dishwashers and of course when we use the toilet, etc. That is where the heat comes from, and we use it. But that gives an idea of the success factors I think so close to a sewage company, and close to a district heating system, and the temperature match.

Question 3 (follow-up): This is only for sewage water, or do you also know criteria for surface water aqua thermal or is that different?

A: Of course, we use TEA and TEO in Dutch. For TEO, we are also developing a project in, where we also have a district heating system and there is like 5 to 10 megawatts I think, but someone else in my team is developing this project. And it is a little bit on hold because of permitting issues and there of course the surface water is a little bit colder, and the Rijskwaterstaat does not really know yet what their guidelines are; how cold the water can be before we throw it in this case in the Amsterdam-Rijnkanaal. So, there is some uncertainty on that point.

And then you also need storage like the WKO (warmte-koude opslag), because in the winter the surface water is too cold to use directly in your heat pumps, and then it is not so clean like you need the heat exchangers (warmtewisselaars in dutch). So, it should be fine, but yeah, it is a little bit more difficult so if you have a sewage company with ground position close by, you prefer that over surface water.

Question 4 (follow-up): You also mentioned filling out the curve of demand and we were wondering about the spring and autumn or fall. Of course, in summer, the water can be used for cooling and in winter it can be used for heating, but is there a gap in the spring and the fall?

Yes, but that is where the subsidy floating hours are based on. So, we produce around 6000 floating hours with these kind of heat pumps. Of course, the year is a little bit longer than 6000 hours, so in the other seasons you use the peak sources to fill in your heat demand.

Question 5 (follow-up): So, if I understand correctly, you store the surplus heat or cold during the year?

No, you do not store it, you use it directly in your district heating system, where you use other sources a little bit less. So, there is a system of a lot of sources, so if you do not have the clients yet then you have to make it a little bit of engineering choices: for how many clients do you develop this source? But it is very relaxing if you already have the clients, and just replace the sourcing for it. So, what we do here is that it will reduce our gas fired assets; they will produce less heat and this project will produce more. And then we also have biomass, and a lot of sources in Utrecht actually. But this is it, you just add it to the system.

Question 6: You already told us quite a lot about this project and all that, but we were wondering if there were some experiences with the implementation of aqua thermal energy in general that you feel like you would need to keep in mind, maybe for future projects, or some lessons that you've learned from projects already in implementation?

We actually love it for this SDE category, so we love the subsidy which succeeded. That is a great milestone. There were some technical [issues]. We have a smaller project in The Hague and there we learned a lot on for example fouling. The issue was fouling on the heat exchanger, so there were some kind of micro bacteria in the water that was damaging the heat exchanger. So, some kind of micro bacteria were damaging our heat exchanger, and then you need a heat exchanger which is built of not gold, but titanium. Indeed, titanium heat exchangers, which are very expensive, to prevent this issue. So, this is the technical department.

Also, there were issues of vibrations. These machines make a lot of noise like 110, 120 decibels close to the machine roots, so you have to isolate this sound in your building. This also impacts contracting, so the one that delivers the heat pumps does not also build the building around it, so what do you do with this risk of sound within your permitting space? Et cetera, and vibrations as well. So sound, vibrations and fouling are some technical issues there that we faced. And there are of course solutions for it.

And then also contracting, it is a small market for the heat pumps, like the bigger heat pumps. We are now in the contracting phase, and there are some parties let us say, a few that that can offer these machines. It is not a market like with wind on land, that you have 10 or 20 suppliers of the turbines. So that is something to be aware of. For HFOs, of course Eneco is part of the Mitsubishi corporation, so for HFOs we have lot of parties that can deliver this kind of a technology, also Mitsubishi itself so another part of the company in Japan. And commercial, you can never pay something for the effluent. You do not pay euros for the sewage company to have availability to the effluent. You just do not. And that has been a long discussion for one or two years with the sewage company on why that is not the case. Because if you do, you do not have a project anymore. So, if the sewage company gets dollars in their eyes, end of project; that is good to know. Of course, we pay for the ground position, but they are, of course, a government company, so what you say it is a social contribution, they just add to the common goods, that is what they do. If they have a ground position, we pay for it. But we also attribute to their sustainability score, so that is what is in it for them as well. So that's more commercial point of view.

Also, COP (coefficient of performance) is important, should be around 3 or more, so the efficiency of the machine, you need one third electricity, and the other two come from effluent heat. It is how you can divide this pie. Or an efficiency of 300% if you compare it to your gas boiler at home. So that is

important. CapEx [capital expenditure], OpEx [operational expenditure], of course development expenses can be high. There is a team of around 20-25 people working on it right now (not full time, of course), some people in Denmark as well supported us from an engineering company there, so we got all the Scandic lessons learned in house, that is quite important. Yeah, I think it is quite a lot already.

Question 7: Do you feel that in general policies enable you to implement this technology, or would they be more of a restriction, could it be better?

It could be better. Well, the subsidy, it is great that we have a category for aqua thermal projects, but it does not score really well in the merit order. So, you compete on CO_2 levels, in the SDE++ [Sustainable energy transition subsidy scheme]. So, the ones that need the least subsidy to abate their CO_2 will get the subsidy, and if it gets too costly you will not get it. And then wind offshore (well, wind offshore does not have a subsidy anymore), but wind on land and solar compete with the relatively expensive heat categories. And that is not really fair, like carbon capture storage is quite cheap to do it, but do you really believe in it? And of the 5 billion rounds of last year's round, they will use half of it almost, and then you have to see if there is still something left for the technologies that we also need, but that are more expensive in the CO_2 abatement costs. So yeah, that is quite interesting.

And also – how do I explain this – the COP is 3, so the 2/3 of the heat in the effluent does count as renewable heat, but the other third, even if we source allocate a wind project for this electricity, that still does not count in the building regulations as renewable heat. So, the 1/3 does not count, and the 2/3 of heat (renewable heat) in the effluent does. So, we would like to have that the complete 100% thermal output of this project counts as renewable heat, in order to do so. And it is also logical, because we really use, we allocate wind park Houten for example for this project. So, the off take, you can explain why this should be 100% renewable, and it is not. So that is something we lobby for. I think that is it. It is not from the regulatory… Of course, there are some fiscal… but that is far too complex, that there are some aspects that you have to arrange. But these really dig a little bit deeper into the fiscal part of the business case, and I think for you guys that is not… yeah. But everyone loves it; you cannot see it, there is no wind turbine 120 metre metres high, there are no emissions, there is just a big pluck and a building and that is it. So, it is not so bad.

Question 8: You mentioned in the criteria, that you need a certain area of space. How big would that need to be for the heat pump to sit there?

I could show you guys a little bit, this is the building that we use, see the sewage company here, and there we have the two buffers (by the way, a buffer can also buffer the heat, it is day-night storage we use there), and this building is around 50 by 40, so 2000m^2. I think the plot needed in Overvecht here. That is for 25-megawatt project, that is fine. It is also on the project website, the overview of what is needed, some update or level planning, et cetera. So, we are looking forward to doing some more projects like this in other parts of the Netherlands.

Question 9: If you were to start a new aqua thermal project in the future, or now, what would you maybe do differently, or what are things that you would keep in mind?

Well, it is always when you do the things for the first time, you get a lot of lessons, firsts, and a lot of signposts, you know. And one of the success factors is if you have subsidy, and on the right level. So, I would have a bit for the subsidy, you need permitting right and a ground position. So do things in the

right order. But when we started, we did not have the subsidy yet, and so we started with feasibility, technology, business case, commercial agreements with the partnerships. So always start with the partnership, have what we call the connection. You need to understand each other, like Eneco as a commercial company, which while it is – well, in some ways it is not. And then the sewage company. So, you need to have that connexion in order, in place, and subsidy. So, if you arrange these things fast, you can have successful a project, and otherwise it will never be any good.

Appendix 3: Transcript interview Mila Verdonk (Municipality Zeist)

Question 1: Can you describe your role within the municipality?

Mila Verdonk is a project manager regarding heat in Zeist. She is involved in a lot of projects, but for the last couple of years the is mainly focused on heat.

Question 2: What priority does the municipality give to the energy transition that is needed to reach the goals as stated in the Climate Agreement?

Within the municipality, the priority for the energy transition is very high. The municipality is looking already at a couple of sources, not only aqua thermal energy but also geothermal energy. However, the municipality is not the only party that has a say in this case. If we want to implement technologies as aqua thermal energy, we also need help of residents, energy companies and the water authority of the region.

Question 3: Is the municipality interested in aqua thermal energy? If yes, did you already look at potential sources within the municipality?

Zeist doesn't have useful amounts of surface water: only small ponds and the canals around the castle. Therefore, TEO is not feasible within the municipality. It is rather looking at TEA and also residual heat from the Remia factory nearby. However, the sewage water cleaning installation that is located in Zeist is probably not going to be there for long. This is because the ones in both Driebergen and Zeist are quite small, so the plan is to kind of combine them. Therefore, the municipality is afraid to invest in aqua thermal energy of wastewater at that site, because the probability is high that is will not stay there for long. Also, some pilots ran in de Bilt and Driebergen on aqua thermal energy from the sewage water cleaning installations and these came back negative. Secondly, the Remia factory is a huge source of residual warm water. Right now, this water is cooled at a cooling installation, but if this could be shut off, the heat can actually be used to heat neighborhoods. However, Remia is no energy company, so they are not very active in starting this project. The municipality is in charge but due to covid, the project has laid still for almost a year. There is still research going on how to use the residual heat for heating homes, so the municipality is working on this project.

Question 4 (follow-up question): So, the main problem is the collaboration that is needed to successfully implement technologies as aqua thermal energy. Do you think that the presence of energy corporations can help to familiarize people with new technologies, and thereby contribute to the collaboration with residents?

The main problem now is the collaboration that is needed between the municipality, the energy company and the residents. The municipality is the moderator in this process; they come up with the plan, and the other stakeholders can help them with implementing it. The residents need to become familiar with the technology, as both aqua thermal and geothermal energy are not very common yet. Aqua thermal energy is known between the residents, but it also really depends on the region within the Netherlands whether or not is it going to be accepted. Energy cooperation's can help with this: in Zeist, you have the Energy Loket that gives advice about how people can change their individual behavior regarding energy consumption, and also an energy cooperation. This is meant to make residents share their energy. For example, if you have a lot of houses with shade at places where you are not allowed to

cut trees, you could put solar panels at the roof of a school. Other residents can then invest in these panels and indirectly use the sustainable energy.

Question 5 (follow-up question): Do you think that combining the construction of a heat system with for example climate adaptation of a neighborhood can help with this? Like making residents more enthusiastic as well as the municipality to invest in the heat system.

It really depends. Like I said before, the municipality is often not the stakeholder that provides the heat system. That is the role of the energy company. They are often more willing to build this construction, whether or not it is going to be useful in the nearby future. Also, with the example of making a neighborhood more climate adaptive; this is often also a very new thing for residents. Combining new things is not going to make things easier, I think. However, these kind of 'koepelcases' are indeed very useful, but maybe in other way than you proposed.

Question 6: Are you using other renewable energy technologies and what are the advantages of these technologies above aqua thermal energy?

Like I already said, TEO is not really an option in Zeist. TEA can be an option, but due to the closing of the sewage water cleaning installation this is a very uncertain option. Therefore, we are also looking deeper into geothermal energy. This is a very useful source of water with a temperature up to 70 degrees. However, in order to use this source, we need to drill up to three kilometers deep and this is a bit tricky regarding residents. As drilling is very controversial, think about what has happened in Groningen, residents are afraid of the consequences this drilling might have. However, the risks of drilling for drinking water quality and earthquakes for example are very low. Also, drilling to access the geothermal energy costs millions of euros, so it is a huge investment. However, if it works, then approximately 100.000 houses can be provided with sustainable heat. Right now, it seems very futuristic and not feasible, but I think it can be very useful in the future. We managed to put whole cities of gas all in once, so why wouldn't this work?

Appendix 4: Transcript interview Femke Batterink (Municipality Utrecht Heuvelrug)

Question 1: Could you shortly explain your role within the municipality?
I'm a policy advisor for the municipality, so I work in a team. We are all working on sustainability, and I merely work on projects such as windmills and solar panels, most on roofs and ground and also for sustainable entrepreneurship. So, I work in a team, and I advise also the board of the municipality (wethouder).

Question 2: What is the position of your municipality towards the energy transition as stated in the Climate Agreement? So, does the energy transition have a high priority?
Yes, it has a high priority, and it is also politically now one of the issues that gains a lot of attention. So, there is a lot written about in the newspapers and there is a lot of debate in the local council (gemeenteraad).

Question 3: How much does your municipality know about the technology of aqua thermal energy?
Well, that is one of the issues that we are looking into and mainly for the issue of how to heat our houses in the future. So, every municipality needs to look at how to heat the houses in the future, because in 2050 we want to be free of fossil gas and that is a big challenge. And aqua thermal energy is one of the technics that could help in this.

Question 4: Did you already consider implementing aqua thermal energy or is there a big interest in it in the municipality?
There is interest in it but there is also a lot of technical issues, one of the problems is that the heat from aqua thermal energy is not very high so it is a low temperature. You can only heat houses with low temperature if they are well insulated and most of our houses are not well insulated enough. The other problem is that the distance between the water and the houses, because of the low temperature you do not want the pipeline to be too long, you want them to be close to each other: your source of energy and the use of energy. And it does not really look like we have a lot of potential where the distance is short enough. But we still hope it can be part of the mix of our energy sources.

Question 5: What are suitable locations in your municipality that you are aware of?
Well, there is one we have a sewage treatment plant in Driebergen, and it looks like this could be a source of hot water for heating the houses that are nearby this plant. And this is a project that we are seriously looking into.

Question 6: Are you also looking at other renewable sources of heating?
Yes, that would mainly be electrical probably, so heat pumps can be a solution and maybe biogas but there is probably not going to be enough biogas for all of us. So, we are really looking into this mix but in our municipality where the houses are far from each other it looks like that a lot of the houses will be heated electrically.

Question 7 (bonus question): What are the policies, are you deciding on them on the municipality level or more on regional or national level? Are there policies that help the use of renewable energies or are they more restrictive and make it difficult?
We have got the national agreement, the Climate Agreement, in which the municipalities have agreed to make these kinds of policies. And we also do it in regional scale, but with most of the policies the more concrete it gets it is on the municipal level.

Appendix 5: Transcript interview Advisor Water and Energy (Municipality Utrecht)

Question 1: Can you briefly describe your role within the municipality?

We are working on the use of water as a heat source, aquathermy, and on the one hand I am concerned with what sources are available to Utrecht and how can we distribute them? That, in turn, is related to what other sources we have, and at the moment all the municipalities are working on drawing up a transition vision for heat. We in Utrecht are also very busy with this and it will state what type of solution you would like to realize at the lowest cost and where. This will also give us an insight into how aquathermy can be used. And on the other hand, we have individual projects. So far, these are mainly new construction projects. In these projects people are already seriously considering the use of aqua thermal energy as part of a collective low-temperature heat network, i.e., TEO, often in combination with heat and cold storage in the ground.

Question 2: What is the municipality's attitude towards energy transition as described in the Climate Agreement; is this a priority for the municipality?

Energy transition is one of the challenges the municipality of Utrecht is working on. Sometimes we have to make urban living possible for all Utrecht citizens. It is very important, we are paying a lot of attention to it, and it is also true that the national government has decided that all buildings must be made independent of natural gas and that agreement, the climate agreement, has been concluded nationally. But the municipality actually has a directing role in continuing that transition. So, the municipality is very busy with that.

Question 3: What kind of knowledge does the municipality have about aquathermy?

We have so far, if we look at aquathermy, we have last year a consultancy firm Greenpeace did a study, potential study we call it. Then they actually looked at how much potential we have available from all the different sources, including therefore also there actually the aqua thermal sources. So, in that respect we know approximately how much heat is available in relation to what the ultimate demand is from the municipality, so we have insight into that. At the moment we are busy looking at how you can match supply and demand. In theory, you can have that demand available, but is it also possible in practice to get that heat from the source to the customers, to the buildings? And what kind of infrastructure do you need for that? And in addition, at the moment we do not yet have a working TEO installation, for example, so that we really win heat and cold. We are looking at new developments, so we are investigating whether that could be a possible heat solution.

Question 4: We also had an interview with Eneco, and they were talking about the wastewater system they are building, so that's also part of it?

That is another very good one, that is indeed from Eneco together with HDSR, so we as a municipality know about that but that project is for Eneco's own heat network. So, it is for the buildings that are already connected to a heat network. But most of the heat network is still fueled by natural gas and Eneco has the task of making this network more sustainable. So, in Utrecht you actually have the existing city heat network and that supplies high temperature heat. That is owned by Eneco and indeed they are going to extract that heat from the RWZSI to supply heat to that and that is to be used as a sustainable source. And

in addition to that, in Utrecht, as a municipality, we have the existing buildings and the new buildings, which of course we are also busy with.

Question 5: Returning to what you said earlier that there must be a demand for this energy transition to aquathermy, has this been looked at in terms of the people who live there in the district where it will be installed, is there much demand for it or what do those people think about it?

Well, what we have looked at so far and that is actually based on public or available data, so a neighborhood level estimate. So, have we looked at how old are the buildings and related to that, so what is the heat temperature? So, the heat demand temperature? Because a very old building that is poorly insulated, that is not comfortable to heat with underfloor heating. So, then you still need radiators and thus high temperature heat. And for new buildings you can use low temperature heat, for example floor or bandage heating to provide cold heat and also sometimes cold. So, in Utrecht we actually looked at neighborhood level to see what we expected the required supply temperature of heat would be and what sources we had for that. And in this way, you can see that the old center is generally a high-temperature area, except perhaps for a new-build project. And then actually the neighborhoods around that you see a little bit of that middle temperature, but for example Leidsche Rijn, which is much newer, which was built after 2000, and the new construction that we have now, which is then also, would also be suitable for low temperature. So that is how we distribute that. And in addition, we have also recently, for example with an expedition heat, we have actually looked into whether there are neighborhood initiatives that want to get existing buildings off the earth gas using a low temperature source to learn together whether it is possible, what is needed, and can you make a business case feasible. So is it also affordable, an interesting to invest in. So, it is not like we are thinking of asking every resident: what temperature do you want, or do you want to use this source? But we do try of course to do that in collaboration with residents.

Question 6: So, there is certainly interest from the municipality in aquathermy?

Yes, there is definitely from the municipality interest in aquathermy, and it is actually so that we say it is a very important source for us. Because it is a pretty big source, it has a lot of potential, but it is also pretty certain that it can become available, because that surface is already there. So, we know the resource is there and we'd like to use it, but we're still looking for ways to make it affordable. But yes, we certainly have interest in it.

Question 7: But there are no plans yet to build something or is that more looking?

So, for the new building, there are plans being worked out. We are looking at that and for the existing construction we are not that far along yet. What we're actually doing there is that we're going to work on each neighborhood and there currently Overvecht-Noord is being made natural gas free. Or at least a neighborhood implementation plan is being made. And then we look at what sources you have in the neighborhood and what they are a good strategy here. And I think: if in the future in a certain neighborhood there is an aqua thermal source in the neighborhood, then it will definitely be taken into consideration.

Question 8: Do you already have a few locations in mind for aquathermy, or that you already know where it would be good?

Well, of course you already have the WWTP that Eneco wants to use. I think in addition to that, we expect, and also hope, that the other wastewater treatment plants can also be used in the same way. They are

not as big. But it is still a heat source. And then if we look at surface water, there's a chance that we would want to use the Merwedekanaall at least. And well, the biggest source we have of course is the Amsterdam Rhine Canal so we're certainly looking at that as well.

Question 9: Another question about those projects, because we had heard in previous interviews that mainly a big problem is, as you had mentioned earlier, the affordability and subsidies of those. Do you guys experience that as well, or do you have other aspects that end up thwarting the project?

Well, I think it varies from project to project. So, just on with the limited experience that I have with it, let me add that, and the projects that I've experienced then you see that at least in new construction the affordability is better than in the case of existing construction. So that that helps a lot. And we do have in our transition vision heat, which is therefore policy actually what we want to establish. In it we do have a number of criteria, what we call public value, in addition to affordability which we say there is very important consider. There I think you can, if you go to Utrecht.nl/transitievisiewarmte, you can possibly find some of it.

Question 10: Do you use or plan to use other sustainable heat sources? If so, what techniques and what are the advantages of this over aquathermy?

Well, there are several sources there, after which we look. So, you have a number of renewable sources, including for example geothermal or solar thermal and different sources have different advantages. So, for example, geothermal has a higher temperature. Which can be more beneficial, for example, for the old city center and has the advantage that so quite a lot, probably at lower cost can be supplied. The disadvantage is whether it will actually be possible later is still uncertain. So, we do not know yet, while aquathermy is, so far often more expensive. But the source is very certain, and the water is already there, even at such a wastewater treatment plant, that sewage always arrives, then always think a certain temperature. So, in that respect aquathermy has many advantages and that's why you notice that it is getting a lot of attention in Utrecht, but also throughout the Netherlands at the moment. Also, because people think that it might even have a positive effect on surface water if you can cool it down a bit. So, what the effects are ecologically and perhaps also the heat radiation of the city, there is still a lot unknown about that. But it could well be that in addition to possible negative effects, there are also positive effects.