A search for a central sustainable heating solution for the neighbourhood of Maldenhof

FINAL REPORT

(From: DNArchitecture, 2015)

Carmen van den Berg	3373533	Energy & Materials
Ineke van den Oever	5571219	Energy & Materials
Thanh Hà	4228081	Environmental Governance
Paula Land	5495334	Environmental Governance
Kyra Weerts	5569478	Joint Programme
Martijn van Huizen	5570077	Water Science & Management

November 4th, 2015

Course: Transdisciplinary Case Study
Master Programme: Sustainable Development

Universiteit Utrecht

Executive summary

This study aims at assisting the Maldenhof initiative to identify a more sustainable alternative to fossil gas for home heating, and to determine a pathway for successful transition into this alternative. From the perspective of transition theory, the Maldenhof initiative is one social network within the technological niche of sustainable heating. Broadly speaking, transition into sustainable heating solutions can occur when this niche gains momentum to take over the current socio-technical system of fossil fuels. The social feasibility and characteristics of the technology in question are key to successful transitions. A rather mature, safe and feasible technology makes transitions more likely. Accordingly, a feasible and sustainable heating solution must first be identified. To do so, a multi-criteria assessment framework utilizing PROMETHEE method is designed and applied to evaluate the level of feasibility and sustainability of two potential heating solutions: (i) waste heat from a nearby power plant, and (ii) aquifer thermal energy storage using energy from surface water (ATES+).

The waste heat solution was first proposed by the neighbourhood, and the negotiations with other stakeholders to install the solution have already commenced. ATES+ utilizes the thermal storage capacity of underground aquifer to store water in the summer to be used for heating in the winter and vice versa. There is much potential for implementing ATES+ in Maldenhof due to the presence of lakes and aquifers here. Both technologies have already been implemented in other parts of the Netherlands. They both promise economy of scales and high levels of emission reduction.

The two technologies are assessed based on five criteria: (i) technical feasibility, (ii) social feasibility, (iii) environmental sustainability, (iv) economic sustainability, and (v) social sustainability. All criteria have value scales from 1 (extreme negative) to 5 (extreme positive). The weights of criteria are determined by stakeholders' preferences. Each criterion is a composite of several indicators and sub-indicators.

Data for assessment is obtained through a variety of techniques, including surveys, interviews, desk research and analysis of primary documents provided by stakeholders.

Results of the assessment and PROMETHEE analysis indicate that waste heat is a more feasible and sustainable heating solution for Maldenhof. On average, ATES+ scores better than waste heat on environmental sustainability, but waste heat scores slightly better in terms of technical and social feasibility, and much better in terms of economic sustainability. Both technologies score equally on social sustainability. There are many limitations to the results of this study. Calculations for assessment are based on average estimates, which may result in margins of errors. Results are also averaged which may produce biases. The results of economic assessment especially contain substantial margins of error, due to highly limited cost data on ATES+ systems. However, it is certain that due to low energy efficiency, the houses in Maldenhof must be retrofitted (on varying scales depending on the state of each individual house) in order to be suitable for an ATES+ system. There are possibilities for reducing the costs of the waste heat system in order to improve economic sustainability.

This report recommends the Maldenhof initiative to investigate different venues to reduce the costs for transitioning into waste heat (i.e. applying for subsidies), and at the same time investigate decentralized solutions such as solar panels and hybrid heat pump (which can reduce gas consumption by 70%). Decentralized technology may provide optimal tailor-made solutions for individual households.

Analysis results also show that while the neighbourhood is generally positively minded towards sustainability, individual attitude toward sustainability issues associated with home heating, and toward changes in energy infrastructure could be further improved in order to facilitate more forward thinking and stronger political will for energy transition. Individual attitude could be improved through sharing of sustainability related values. To do so, the Maldenhof initiative must further improve its organization and communication strategies. Analysis shows that 70% of non-initiative neighbours are not even aware that the initiative exists. This implies that communication and knowledge sharing beyond the initiative is suboptimal. Analysis also shows that communication and knowledge sharing among core members of the initiative is still limited. Moreover, the initiative could further strengthened its ties with other actors in the niche, including the municipality of Amsterdam and expert communities in sustainable energy in order to gain more knowledge and leverage on emerging opportunities. Finally, it is important that the initiative maintains unity and makes decisive actions following the result of this study. Transitioning into any form of sustainable heating solution requires effective communication and organization within the initiative, and cooperation with the broader neighbourhood and local authorities.

Dutch version

Dit onderzoek is uitgevoerd om de wijk Maldenhof te ondersteunen in het bereiken van een transitie van een gasgestookt verwarmingssysteem naar een duurzaam verwarmingsalternatief. De Maldenhof projectgroep kan vanuit een transitie theorie gezien worden als een sociaal netwerk binnen de technologische niche voor duurzame verwarming. Een transitie naar een dergelijk alternatief wordt bereikt als de niche in daadkracht toeneemt en vervolgens in staat is het huidige socio-technische systeem met fossiele brandstoffen te vervangen. Voor een succesvolle transitie zijn de sociale haalbaarheid en de kenmerken van de technologie van belang. Hiervoor zijn factoren als een doorontwikkelde, veilige en haalbare technologie noodzakelijk. Of er aan deze factoren voldaan wordt, moet eerst worden onderzocht. Hiervoor is een Multi-criteria analyse ontworpen dat wordt uitgevoerd met de PROMETHEE methode om het haalbaarheidsniveau en de duurzaamheid te analyseren van de volgende twee potentiële opties: (i) restwarmte van een nabij gelegen energiecentrale en (ii) een thermische aquifer voor het opslaan van energie uit oppervlakte water (ATES+).

De optie met restwarmte is al eerder voorgesteld door de buurt. Onderhandelingen hebben hiervoor eerder plaatsgevonden met andere stakeholders. ATES+ is een nieuwe optie waarvoor veel potentie is in Maldenhof. Voor deze optie is een aquifer noodzakelijk om warmte in de zomer op te slaan, wat vervolgens gebruikt kan worden tijdens de winter en vice versa. De nabij gelegen oppervlaktewateren en aquifers zijn hiervoor geschikt. Beide technologieën worden al toegepast in Nederland. Daarnaast zijn deze opties veelbelovend vanwege economische schaalvoordelen en aanzienlijke reductie in broeikasgassen.

De technologieën zijn getoetst op 5 criteria, namelijk (i) technische haalbaarheid, (ii) sociale haalbaarheid, (iii) duurzaamheid voor het milieu, (iv) economische duurzaamheid en (v) sociale duurzaamheid. Vervolgens zijn de criteria gewaardeerd met een schaal van 1 (extreem negatief) tot 5 (extreem positief). De weging van de criteria is bepaald door middel van de voorkeuren van stakeholders en is opgebouwd uit verschillende indicatoren en sub-criteria.

De benodigde gegevens voor de toetsing zijn verkregen via enquêtes, interviews, literatuur onderzoek en analyses van primaire documenten verschillende stakeholders.

Uit de resultaten van de toetsing en de PROMETHEE analyse blijkt dat restwarmte op basis van haalbaarheid en duurzaamheid de meest geschikte oplossing is voor huisverwarming in Maldenhof. Gemiddeld scoort het ATES+ systeem beter op duurzaamheid, daarentegen scoort restwarmte iets beter op technische en sociale haalbaarheid en aanzienlijk beter op economische duurzaamheid. Beide technologieën hebben eenzelfde score voor sociale duurzaamheid. De resultaten voor toetsing in deze studie zijn echter gebaseerd op berekeningen met gemiddelde aannames waardoor afwijkingen kunnen optreden. Vooral de resultaten van de economische evaluatie zijn beperkt vanwege de beperkte beschikbaarheid aan data voor kosten van een ATES+ systeem. Er kan met zekerheid worden vastgesteld dat wanneer een ATES+ systeem wordt aangelegd, de huizen in Maldenhof moeten worden gerenoveerd om de energie-efficiëntie te verhogen en ATES+ toepasbaar te kunnen maken (afhankelijk van huidige staat). Een restwarmte systeem biedt daarentegen wel mogelijkheden om kosten te verlagen en de economische haalbaarheid te vergroten.

Dit rapport geeft de Maldenhof projectgroep het advies om te kijken naar verschillende alternatieven om de kosten voor transitie naar restwarmte (i.e. met gebruik van subsidies) te verlagen. Daarnaast moet ook onderzoek gedaan worden naar decentrale oplossingen, zoals zonnepanelen en hybride warmte-pompen (dit kan de gas consumptie met 70% reduceren). Decentrale opties bieden de mogelijkheid voor een optimale op maat gemaakte oplossingen voor individuele huishoudens.

Analyse van de resultaten laten verder zien dat de buurt over het algemeen positief gestemd is over duurzaamheid. Echter de individuele houding tegenover opties, zoals het verwarmen van huizen en het aanleggen van de benodigde infrastructuur kan worden verbeterd, zodat er een toekomst gerichte visie en politiek klimaat gecreëerd kan worden voor energie transities. De individuele houding kan worden verbeterd door uitwisselen van persoonlijk waarden ten aanzien van duurzaamheid. Voor de Maldenhof projectgroep betekend dit, dat de organisatie en communicatie moet worden verbeterd. De analyse toont aan dat 70% van de niet-betrokken inwoners op de hoogte is van het initiatief. Dit houdt in dat communicatie en kennis uitwisselingen buiten de projectgroep sub-optimaal is. Daarnaast is ook onder de initiatiefnemers sprake van gebrekkige communicatie en kennis. Dit kan worden verbeterd door een beroep te doen op andere actoren binnen de niche, zoals de gemeente Amsterdam en experts op het gebied van duurzame energie. Tot slot is het van belang dat de projectgroep een eenheid blijft vormen en dat er naar aanleiding van dit onderzoek weloverwogen keuzes gemaakt zullen worden. Een transitie naar een duurzaam verwarmingssysteem vraagt om een effectieve communicatie en organisatie binnen de projectgroep en de samenwerking tussen de buurt en lokale autoriteiten.

Table of contents

***** Word counts of disciplinary parts are indicated behind the chapter headers

** Word count of non-disciplinary part: 2497 words

Introduction

Energy consumption by residential buildings accounts for 10% of total greenhouse gas (GHG) emission in Europe (Balarasa et al., 2007). In the Netherlands, residential heat and electricity consumption produces 26% of the country's total GHGs; and space heating together with domestic hot water represent 70% of total energy demand of Dutch households (Klaassen & Patel, 2013). The primary fuel source for heating in the Netherlands is natural gas (*Ibidem*). Although the Netherlands is currently a net producer and exporter of natural gas, it is still importing gas from other countries, and is forecasted to become a net importer in the period of 2020 – 2025 (OECD/IEA, 2014). Thus, implementing sustainable heating solutions with low GHG emission levels for residential buildings can help the Netherlands lower its GHG emission and strengthen its energy security.

In the Maldenhof neighbourhood in the southeast area of Amsterdam, a group of 25 households has formed an initiative to search for a more sustainable alternative to natural gas for space heating and hot water. They have considered several options, including utilization of waste heat from a nearby gas power plant, implementation of aquifer thermal energy storage using energy from surface water (ATES+), and installation of solar roof panels. However, due to the lack of a systematic approach and analytical tools, the stakeholders cannot decide which option is more sustainable and, at the same time more feasible. Moreover, concern for the risk of 'lock-in' and the wish for 'no-regret' solutions have resulted in a standstill, which is a negative outcome for lowering GHG emission in the long run. The initiative is also struggling to gain more support among the neighbours in Maldenhof.

To assist the Maldenhof initiative in overcoming the current standstill and gaining more momentum, transition theory is used as an overarching theoretical framework to establish a successful transition pathway into a sustainable heating system. Accordingly, a sustainable and feasible heating solution must first be identified. To do so, a multi-criteria assessment framework utilizing PROMETHEE method will be designed and applied to evaluate the level of feasibility and sustainability of two potential heating solutions: waste heat, and ATES+. These alternatives are chosen for the analysis for the following reasons. Waste heat is available with close proximity in the neighbourhood. It was first proposed by the neighbourhood, and the negotiations with other stakeholders (i.e. utility companies) have already started. This technology has been well investigated by involved experts so there is much information available on this option. ATES+ only utilizes water from natural sources (i.e. lakes and aquifers) for heating and cooling, and therefore emits virtually no GHG. There is much potential for implementing ATES+ in the neighbourhood due to the presence of many lakes and aquifers in the area. Furthermore, both technologies have already been implemented in other parts of the Netherlands; and as both are centralised solutions, they promise economy of scales and high levels of emission reduction.

This research paper will not only provide information to aid the Maldenhof initiative in achieving successful transition into a sustainable heating system, but will also contribute to scientific literature in the energy field by enriching empirical information on waste heat and ATES+, and by laying out a framework that can be utilized for similar analysis.

To guide the analysis in this paper, the following main research question is posed:

"*Which of the two heating solutions under consideration (waste heat from nearby gas power plant and ATES+) is more sustainable and feasible for residential heating and hot water in Maldenhof? And in which ways can the Maldenhof neighbourhood organize itself to transition into the sustainable heating solution identified in this study?*"

To address this question, review of relevant literature is conducted to define feasibility and sustainability, and to identify criteria for assessing the level of feasibility and sustainability. The assessment is performed utilizing multi-criteria analysis in combination with the PROMETHEE method. The weight of each criterion is determined through a stakeholder survey. Then each solution is given a score for each criterion. The final index for feasibility and sustainability is calculated from these scores to compare the two alternatives on these dimensions. Data for the assessment is obtained through desk research, surveys, interviews and primary document analysis.

To provide a context for this paper, the Maldenhof initiative is described in details in the next section. The subsequent chapter explains the theoretical and methodological frameworks, and how the assessment is conducted. Then each technological scenario is described and analysed following the methodological framework. The paper concludes with a preferred solution and recommendations to further progress the initiative.

Case description

As indicated in figure i, Maldenhof is located between the Gaasperplas lake and the Academic Medical Center (AMC) hospital.

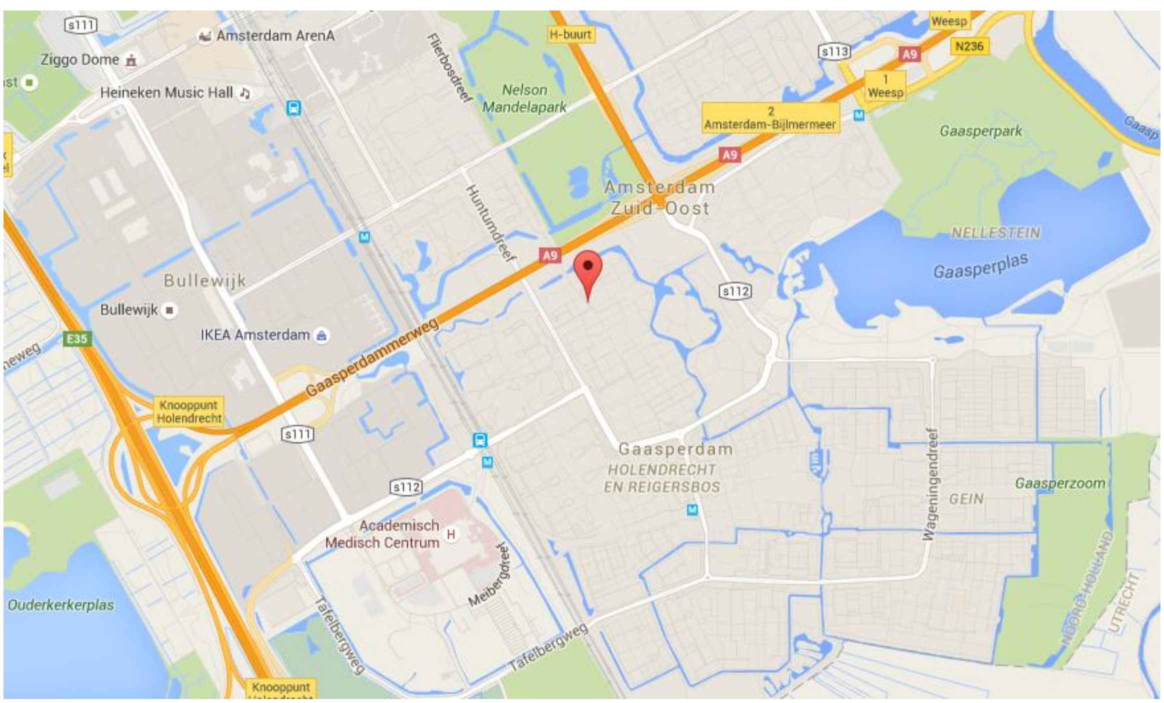

Figure i - The case neighbourhood situated between the hospital and the lake (Google Maps, 2015)

The neighbourhood consists of 300 houses, of which a 100 are owned by the housing corporation 'Stadgenoot', and the remaining 200 are privately owned. Most of the houses were built in the early 1980s, which means that construction wise, only a few have insulation and/or double glass. However, Maldenhof still has a slightly lower average annual gas demand compared to the Netherlands i.e. 1500 m^3 instead of 1600 m^3 per household (Statline, 2015). Approximately 1450 m^3 of this gas demand is used for household heating (Alliander, 2015a).

The real energy demand is calculated based on average gas demand for heat. Because 86% of the residential buildings in the Netherlands is heated with high-efficiency boilers; and the general efficiency of such boilers is at least 100% (ECN, 2012; Sijpheer & Strootman, 2004), it is assumed that high-efficiency boilers with an average conversion efficiency of 100% are applied in Maldenhof. Using the next formula shows that the real energy demand for heating in Maldenhof is (1450 m^3 * 31.65 MJ/m^3* 100%)/1000 MJ/GJ = 45.9 GJ, wherein 31.65 MJ/m^3 is used as the caloric gas value. Correspondingly, current carbon dioxide (CO_2) emissions are calculated with the use of 1.78 kg CO_2/m^3 as emission factor for natural gas (Wicke, 2005). Thus, the amount of emitted CO_2 is 1450 m^3/hh/year * 1.78 CO_2/m^3 = 2581 kg per household per year.

On average, households in Maldenhof pay €0.65/m^3 for gas (Alliander, 2015a). Moreover, they must also pay for gas boilers, which on average costs €1500 per unit. The gas boiler has a lifespan of 10 to 15 years, and it costs approximately €100 per year for boiler maintenance (Stijkel, 2015). Based on these data, the average annual cost of gas consumption per household in Maldenhof is calculated as shown in table 1.

Table 1 - Annual costs for gas heating per average household (1500 m^3, of which 50 m^3 for cooking in gas)

Category	Total costs (€)	Notes
Variable gas cost	975	1500 m^3 x €0.65
Fixed cost for gas supply	443[1]	Consisting of standing charge for gas, gas transport, gas boiler depreciation and maintenance
Total	1418	

[1]Fix cost for gas supply was calculated by one of Maldenhof residents (Alliander, 2015a)

Demographic data of Maldenhof residents is presented in Annex I. Notable features include a high number of inhabitants within the age category of 50-70, and a high percentage of residents with non-Dutch nationalities. A group of residents actively participates in different community projects, including initiatives such as *Slim wonen Gaasperdam* and *Besmettelijke Buurtkracht 2.0.* This indicates an active attitude towards sustainable living, and a certain degree of social cohesion within the neighbourhood. The main aim of these initiatives is to discuss central and decentralised sustainable energy options to become more sustainable as a neighbourhood.

Theoretical framework and methodology

This section will discuss which transitions and pathways are needed to develop alternative heating solutions, followed by an outline of the overarching method employed for analysis.

Transition theory

The possible transition towards more sustainable heating options in the neighbourhood of Maldenhof can be studied from a transition theory perspective. Within transition theory, the multilevel perspective on socio-technical systems developed by Geels (2002) is commonly used to understand energy related sustainability transitions. With regard to the case study at hand, the socio-technical system is the current heating and energy generation system. This framework suggests looking at three levels of actions as analytical categories to assess interaction and transitions within the system: niches, regimes and the landscape.

A niche is a space of experimentation and learning that allows for new technologies to be tested without market pressure. Within a niche, innovative frontrunners, consisting of different stakeholders, form social networks to exchange knowledge and promote sustainable alternatives. In this case, the neighbourhood initiative can be regarded as one social network within the technological niche of sustainable heating (Naess & Vogel, 2012).

Niche actors' actions are nested in a wider field of the dominant socio-technical regimes. The regime determines conventions, norms and rules as well as laws regarding the use of different technologies. At the regime level of heating, technological lock-in situations occur easily, through path dependencies such as the use of gas linked to the establishment of infrastructure and institutions reinforcing the use of gas (Geels, 2011).

The regime is itself located in and influenced by the (exogenous) socio-technical landscape (Geels, 2004). The landscape describes events and trends, which are beyond the regime's influence but constitute a major factor of influence for the regime. In the Dutch case this could for example be the depletion of the gas fields close to Groningen, the depletion of fossil resources more generally and climate change directed laws.

Broadly speaking, transitions are said to occur when a destabilization of the regime occurs and well-formed niches gain momentum, in feedback loops with the regime level and the landscape (Di Lucia & Ericsson, 2014). This assumption assigns a crucial role to niche innovators, such as the Maldenhof neighbourhood initiative. In many ways then, technological niches and their developments through experiments and learning processes are seen as the key to successful broad scale transitions (Shackley & Green, 2007). This perspective on transitions offers an appropriate angle to study the possible heating transition in Maldenhof. The neighbourhood initiative forms part of a broader 'sustainable heating niche', which also includes technology developers, companies, and progressive policy makers.

For transitions to be successful, the social feasibility and characteristics of the technology in question are key. A rather mature, safe and feasible technology makes transitions more likely (Geels, 2004). Therefore, the research will cover both aspects in terms of the feasibility assessment followed by a sustainability assessment in the framework of a multicriteria analysis. This research process allows us to give recommendations to the initiative on a) how to improve their own situation and processes as niche innovators and b) which heating technology would be the most suitable for their demands, given the present situation.

Integration methodology

A multi-criteria analysis using the PROMETHEE method will be applied to assess the feasibility and sustainability of the two heating solutions under study. Multi-criteria analysis is an analytical procedure aiding decision-making that integrates effects of all criteria under evaluation. The result is expressed in the form of a general index calculated using PROMETHEE, allowing for comparison of alternatives (Afgan & Carvalho, 2008).

According to Tsoutsos et al. (2009), the multi-criteria analysis framework is deemed most appropriate to aid decisions pertaining to energy planning because it allows for the integration of different interests of multiple stakeholders while ensuring the highest level of objectivity. Because sustainable energy solutions must take into account possible consequences on current and future generations, assessment of energy technology must be holistic with a long-term perspective. Multi-criteria analysis method is therefore suitable for sustainability and feasibility assessment because it captures the complexity of decision-making under uncertainty with long-term consequences on both socio-economic and biophysical systems (Kolwalski et al., 2009).

The first step in PROMETHEE is to identify relevant criteria for assessment. To select appropriate criteria, the concept of feasibility and sustainability must be clearly defined. In the context of technological transition, feasibility is understood in terms of both technical feasibility – how technically possible to install a given technology – and social feasibility – how socially possible to achieve this installation. Indicators of technical feasibility include *technical maturity/reliability* (Ghafghazi et al., 2010), *energy system flexibility*, *energy potential*, and *security of supply*. The social feasibility is defined in terms of *transitional capacity* and the *institutional framework* (Tsoutsos et al., 2009). Indicators of transitional capacity include: *individual attitude*, *social dynamics* and *organizational structure*. Indicators of institutional framework include: *national energy vision*, *local political developments*, *permits* and *subsidies*.

Many variations of the concept of sustainability exist in the literature, but the presently most popular concept defines sustainability as "a combination of ecological, economic, and social compatibility" (Carrena & Mack, 2010 p.1031). Based on this definition, a heating system is only sustainable if it is environmentally friendly, economically viable, and socially beneficial (*Ibidem*). Indicators of environmental sustainability include *carbon dioxide emissions* (Afgan et al., 2000; Afgan & Carvalho, 2004; Kolwalski et al., 2009; Tsoutsos et al., 2009), *water and soil quality* (Kowalski et al., 2009) and *other harmful ecological impacts* (Dombi et al., 2014). Departing from common literature that uses investment costs and operating expenses as indicators for economic sustainability, this paper uses *the potential for annual cost savings* in heat consumption to evaluate economic sustainability of each alternative. Social sustainability is defined as *contribution to local development and welfare* (Afgan et al., 2000; Ghafghazi et al., 2010; Kolwalski et al., 2009; Tsoutsos et al., 2009).

In sum, five criteria chosen for the assessment are: (i) technical feasibility, (ii) social feasibility, (iii) environmental sustainability, (iv) economic sustainability and (v) social sustainability.

The second step in PROMETHEE is to assign weights on a scale from 0 to 1 to these criteria based on stakeholders' preferences. Data collection method to determine the weights is elaborated in the subsequent section.

Thirdly each scenario is given a score for each criterion on a scale from 1 (negative extreme) to 5 (positive extreme). These scores are translated into standardized values ranging from 0 to 1 using the following formula: (scale-1)/4, so that the final index also has a value between 1 and 5.

The fourth step is to calculate the final index in order to compare the alternatives (Tsoutsos et al., 2009). The final indices of each heating solution are calculated as follows:

Index = (standardized value of criterion *1*) x (weight of criterion *1*) + (standardized score of criterion *2*) x (weight of criterion *2*) + …+ (standardize score of criterion *5*) x (weight of criterion *5*)

Data Collection

To derive criteria weights from the neighbour preferences two surveys were conducted. The target group of the first survey is the 25 members of the initiative. They are the frontrunners of the initiative, therefore their preferences should be considered in the first place. The second survey is targeted at all neighbours living in Maldenhof, preferably not in rental houses. This is due to up-scaling prospects of the project. If an alternative is found, it needs to be adopted by more than the 25 first members. Ensuring that the broader neighbourhood's preferences are also taken into account makes the weighing of the five criteria more realistic and applicable to a project on a larger scale. The survey involves questions on all five criteria, asking the respondents to score them on a scale from 1 (least important) to 5 (most important). All the scores for each question is averaged. If there is more than one question applicable to a criterion, the average value of both questions is taken. The scores for the criteria are then converted into values between 0 and 1 using the (scale-1)/4 formula.

If available, the broader neighbourhood's preferences and those of the initiative are averaged. If there is no data available for the broader neighbourhood, the weight values of the initiative are taken. Additionally, the inclusion of transitional capacity as an aspect of social feasibility is an added value to the multi-criteria analysis. However, this aspect cannot be weighed with regards to the neighbours' own preferences because it is illogical to ask for their preference regarding their own capacities. As the capacity for a transition is crucial, it is assigned a score of 5 and averaged with the weight value of the institutional framework to make up the weight for social feasibility.

The questionnaires for each survey can be found in Annex IIa and IIb. Table 2 clarifies how each question relates to each indicator.

The data to assess each criterion is collected through a variety of additional techniques. Details on data collection for each criterion will be discussed in corresponding disciplinary part of the paper.

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Table 2 - Criteria and their corresponding weighing questions in the two surveys

Criterion	Question in survey 1	Question in survey 2
Technical feasibility	#6, #7	n.a.
Social feasibility	#24	n.a.
Environmental sustainability	#3, #4	#7
Economic sustainability	#1, #2	#5, #6
Social sustainability	#5, #16	#8

Two Technological Scenarios for Assessment

This section will describe in detail two different scenarios of sustainable heating for Maldenhof: waste heat and aquifer thermal energy storage using energy from surface water (ATES+).

Scenario 1: Waste heat

The use of waste heat that is generated at a power plant is actually a proven technology called combined generation of heat and power (CHP). There are different types of CHP, but in general the plants have gas turbines. When heat is not put into use at a plant it is defined as waste heat, and is usually disposed through cooling water. This cooling water is gradually heated by heat exchange with the combustion gasses. At a CHP plant, the heated cooling water is used for heat supply or reused in a waste heat boiler. Combining the generation of electricity and heat provides a couple of advantages: it generally requires less primary energy, lowers carbon emission and is often less costly (Blok, 2007). A schematic illustration of CHP technology is shown in figure ii.

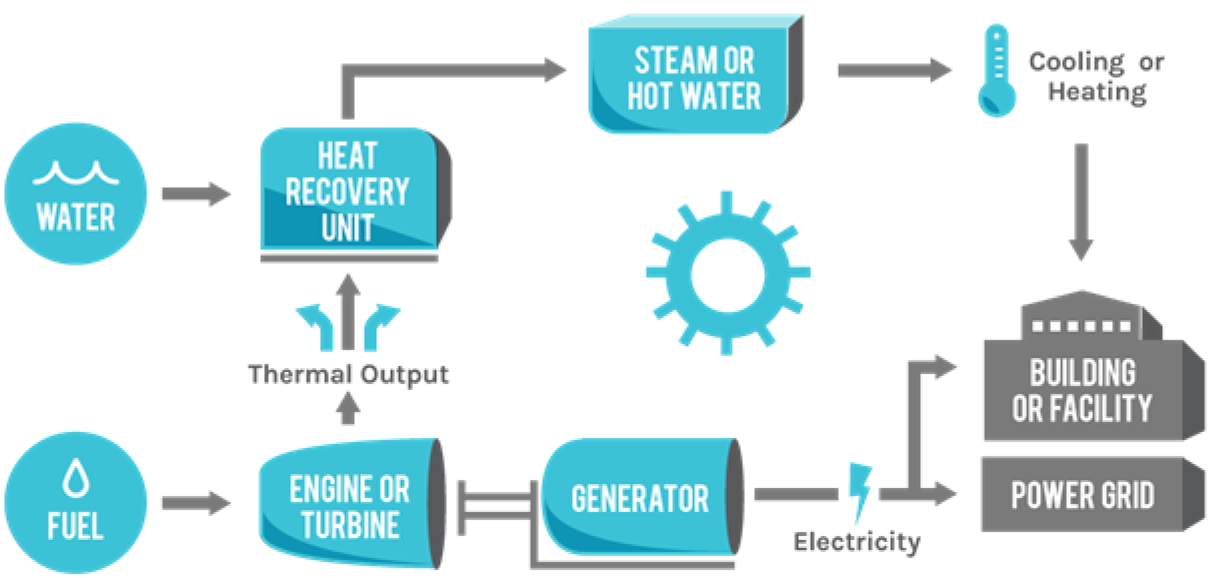


Figure ii – Schematic illustration of cogeneration of heat and power (Dynamic Energy, 2015)

The Academic Medical Center (AMC) already uses CHP to meet its electricity and heat demand, which is beneficial because it ensures energy supply during power failures. The energy plant of the hospital was renewed between 2010 and 2013. The current electricity plant has three CHP engines and additionally six gas boilers which produce warm water and steam. However, a substantial share of the produced heat is still not put into use by the hospital: 20% of the input fuels in the CHP and 20% of the heat from the gas boilers is vented from the plant as waste heat (130,609 GJ) (AMC, 2012).

The waste heat water leaves the AMC with a temperature of 70°C. This could be redirected to the Maldenhof area through an underground pipe system in order to heat water for the heating system or tap water with heat exchangers. The specifics of this pipe network depend on a variety of aspects, among which the diameter of the pipes, the depth in the ground, the type and thickness of isolation material, the temperature of the water, soil properties and of course the length of the pipes (Rosa & Svendsen, 2011). The latter depends on the distance from the production site to the user site (2.0 kilometers) and the number of users. According to Bakema (2015) the required length of the pipes for 425 households is 3.2 kilometers. According to Çomakli, Yücksel & Çomakli (2003) an average heat loss of 10% during transport may be presumed for a certain underground network.

Scenario 2: Aquifer thermal energy storage +

ATES is denoted as aquifer thermal energy storage whereby energy in terms of 'heat' and 'cold is stored in groundwater aquifers; this source of energy then used to heat and cool buildings. Below a depth of 20 meters, groundwater temperatures gradually increase following a geothermal gradient, and facilitate a reliable source of low temperature geothermal energy (Lee, 2013). As a result of groundwater flow, thermal energy is transferred into and out of an aquifer in ATES systems. By means of an open-loop geothermal system groundwater is extracted with a water well, passed through a heat exchanger at surface level and transported to individual heat pumps in the residential space to upgrade low water temperature (±20°) to standards for showering and heating (Lee et al., 2013) (figure iii).

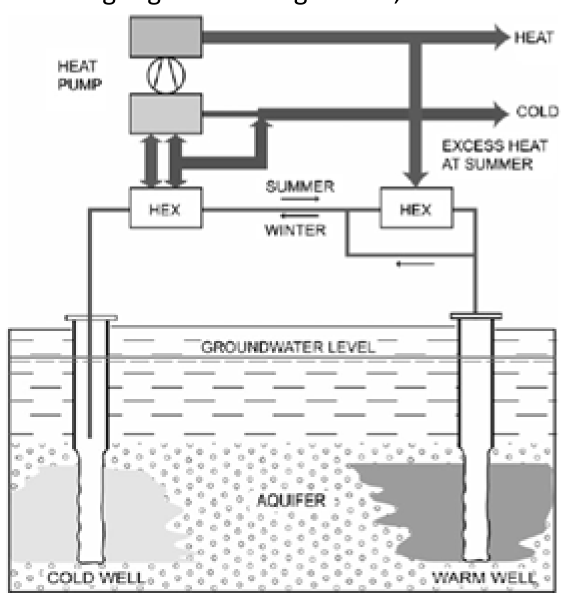


Figure iii - Principal ATES configuration (HEX = heat exchanger) (Lee et al., 2013)

Water wells function as both production and infiltration wells to maintain groundwater balance and restore thermal balance between warm and cold wells (Lee, 2013). By charging the well with a heat or a cold mass, a thermal front moves in a radial direction from the well whereby energy from the flowing groundwater is stored in grains of the aquifer (Lee, 2013). Depending on thermal properties and flowing circumstances in the aquifer, reinjected groundwater may hold a higher or lower temperature that deviates from the natural groundwater temperature. ATES is praised for the ability to use pumped water from the aquifer as energy source or sink to meet high demands for heating and cooling during short periods. Long-lasting differences in heat and cold demand, such as that for residential buildings, lead to thermal imbalances and reduce efficiency (Graaf et al., 2008).

ATES systems could be expanded by means of a connection with surface water whereby water with natural stored energy in the top layer will be extracted, passed through a heat exchanger and distributed to the individual household heat pumps (IF Technology, 2015) (figure iv). This system is denoted as ATES+. ATES+ uses a concept based upon the four seasons, whereby groundwater wells and surface water will be utilized in different configurations to operate as efficiently as possible and to enlarge durability (Scholten, 2012). This means that during the winter time, only heat from the groundwater well (±20°C) will be used if surface water temperature drops below 12°C. However, during early spring, surface water above 12°C could already be utilized to provide heat (if necessary) and minimize (heat) extraction from the groundwater source. The same configuration holds during the fall. The summer configuration is used to reload the warm well with the highest possible temperatures facilitated by surface water energy, and to supply both cold mass to the surface water and residential spaces.

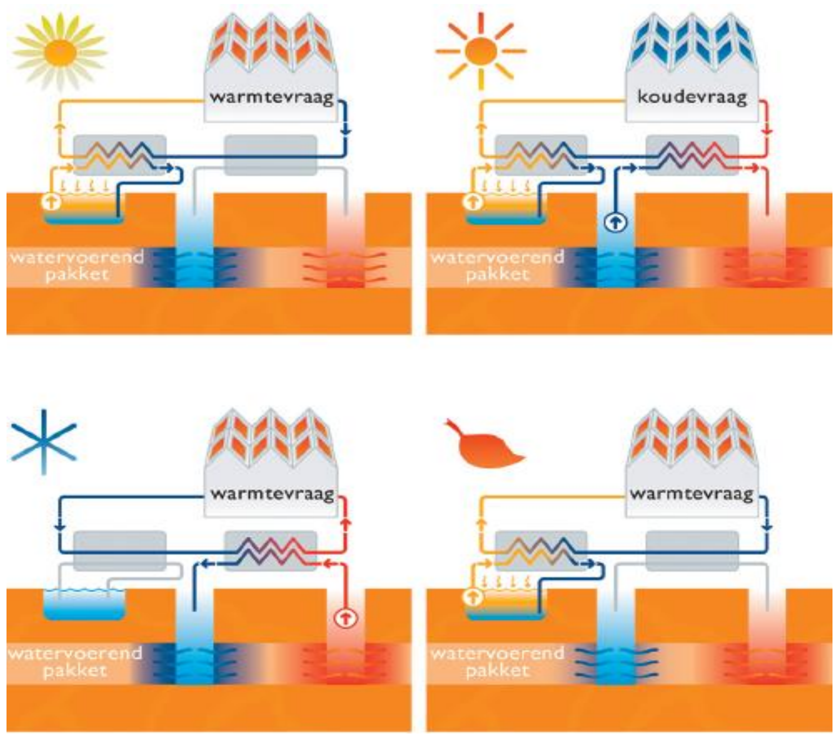


Figure iv – Schematic designs of ATES+ in four seasons, in clockwise direction: spring, summer, autumn and winter (Scholten, 2012 p.2)

The presence of a broad aquifer system and a large surface water system around Maldenhof emphasizes the potential for ATES+ application (Rijksoverheid, 2015). Lake 'Gaasperplas' is situated close to Maldenhof and could be utilized as an energy source for residential heating in Maldenhof.

Assessment

I) Technical feasibility

The first aspect of technical feasibility is the *energy potential (i)*: how much energy will be available, and whether it meets the energy demand of the neighbourhood (Tsoutsos et al., 2009). The second aspect is the *system flexibility (ii)*: the level of complications in opting in and out of the system. The third aspect is the *technical maturity (iii)* or reliability, i.e. its spread at national and European level (Tsoutsos et al., 2009). The last aspect is the *security of supply (iv)*, with regard to possible interruptions in the supply of heat to the neighbourhood. This results in the degree of stability of the system (Tsoutsos et al., 2008).

RQ: What is the technical feasibility of waste heat and ATES+ in terms of energy potential, system flexibility, technical maturity and security of supply?

For both technologies, case studies were consulted to determine the *system flexibility*, *technological maturity* and *security of supply*. Additionally, experts in the field were interviewed about their practical experiences on these aspects. More knowledge about ATES+ was provided through an interview with IF-Technology (Biemond, 2015a, annex IIIa), Waternet (Mol, Reinstra & Ouboter, 2015, annex IIIb) and Techneco (Van Alphen, 2015, annex IIIc). More information about waste heat was provided by interviews with Alliander (Bakema, 2015, annex IIId) and the municipality (Koelemeij, 2015, annex IIIf). Inputs from experts in the field are used to construct a value scale in table 3 for the indicators. The indicator *energy potential* does not have values for the complete scale, simply because the answer to the question is only a no (1) or yes (5). This chapter concludes with an overview table of these scores and the average score for technical feasibility for each scenario (table 4).

Table 3 – Value scale of indicators for technical feasibility

i) Energy Potential	ii) System Flexibility	iii) Technical Maturity	iv) Security of Supply	Score
The system does not meet the demand of the neighbourhood	System is not flexible: opting in and out of the system is not possible	The system does not exist	The system does not provide a steady and reliable energy supply	**1**
-	System is barely flexible: opting out of the system is extremely difficult	The system is in a niche phase: it is under development	The system is not reliable: it has longer periods of energy supply interruptions	**2**
-	The system is partly flexible: in theory it is possible to opt out of a system but it is difficult because of strict requirements	The system is in a transitional phase: it is technically feasible, but there are implications for implementation	The system provides a reliable energy supply, but is still sensitive to energy failures	**3**
-	The system is quite flexible: opting in and out of a system is a little complicated, but definitely possible	The system is developed and implemented, but not yet widely applied in the country	The system has a reliable security: it is able to provide a reliable energy without significant supply failures	**4**
The system completely meets the demand of the neighbourhood	The system is totally flexible: opting in and out a system is easily achieved	The system is mature: a developed and proven technology in the country	The system is highly reliable: it provides a steady and reliable energy supply all year round	**5**

Waste heat

i) *Energy potential*

To calculate the energy potential of waste heat, it is important to distinguish the energy input and output flows at the AMC. Figure 5 presents the energy flows of the hospital, showing that that the AMC purchases different energy carriers to produce heat, electricity and cooling. The heat is provided by the boiler and the CHP (AMC, 2012).

The total annual input of natural gas is equivalent to 653,043 GJ of energy. This input fuel will be divided between both heat producers, approximately 83% is used in the CHP, and 17% in the boiler. Using these numbers, the energy input is calculated as follows. Figure v also shows the energy in terms of m^3 of natural gas. Therefore, the amount of GJ is converted with the standard caloric value of 31.65 MJ/m^3, according to the international organization for standardization (ECN, 2012).

- Input Boiler = 653,043 GJ * 17% = 113,043 GJ / year
- Input CHP = 653,043 GJ * 83% = 540,000 GJ / year

20% of this input energy is not used by the hospital and leaves the plant as waste heat by chimney losses (AMC, 2012). The amount of waste heat is calculated as follows:

- Boiler waste heat output = 113,043 GJ * 20% = 22,609 GJ / year
- CHP waste heat output = 540,000 GJ * 20% = 108,000 GJ / year

The sum of above figures represents the total potential waste heat output of the AMC power plant, assuming that all CHP plants and boilers are in use.

- Total potential waste heat output = 22,609 GJ + 108,000 GJ = 130,609 GJ / year

Next, the heat potential for Maldenhof is calculated. As it is not certain that the heat that left the plant could directly be recovered for transport to the neighbourhood, a conservative calculation is assumed. This takes into account the energy loss during the production of warm water from waste heat, and the heat loss during transport. According to McKenna & Norman (2010), 50% of the heat in an exhaust stream might be recovered as useful heat. In the case of the AMC, 20% of the total heat input is known as waste heat, thus 10% of the flow could technically be recovered. The amount of heat loss during transport is dependent on the temperature of the water, the distance of the network, the thermal resistance of the insulation material and the thermal resistance of the soil. The convective resistance of the surface water pipe and the thermal resistance of the pipe wall are negligible (Dalla Rosa et al., 2011). A case study from Germany showed that the heat loss during transport is approximately 8-10% (Çomakli et al., 2003). As there are currently no accurate estimates on the heat loss in Maldenhof, the upper limit will be assumed in the next calculations. Thus, 100% -10% = 90% of the heat remains.

- Potential heat Maldenhof = 130,609 GJ * 50% * 90% = 58,774 GJ / year

A final calculation is on the number of houses that could be heated with this potential amount of heat production. In order to calculate this, the total useful heat production for Maldenhof is divided by the already calculated average heat demand per household per year (i.e. 45.9 GJ).

- Number of houses that could potentially be heated per year = $= \frac{58{,}774\ GJ}{45.9\ GJ}$ = 1280 houses
- 58,774 GJ / 45.9 GJ = 1280 houses

Because the system completely meets the heat demand of the neighbourhood (300 households), the waste heat scenario is given a score of 5 for energy potential.

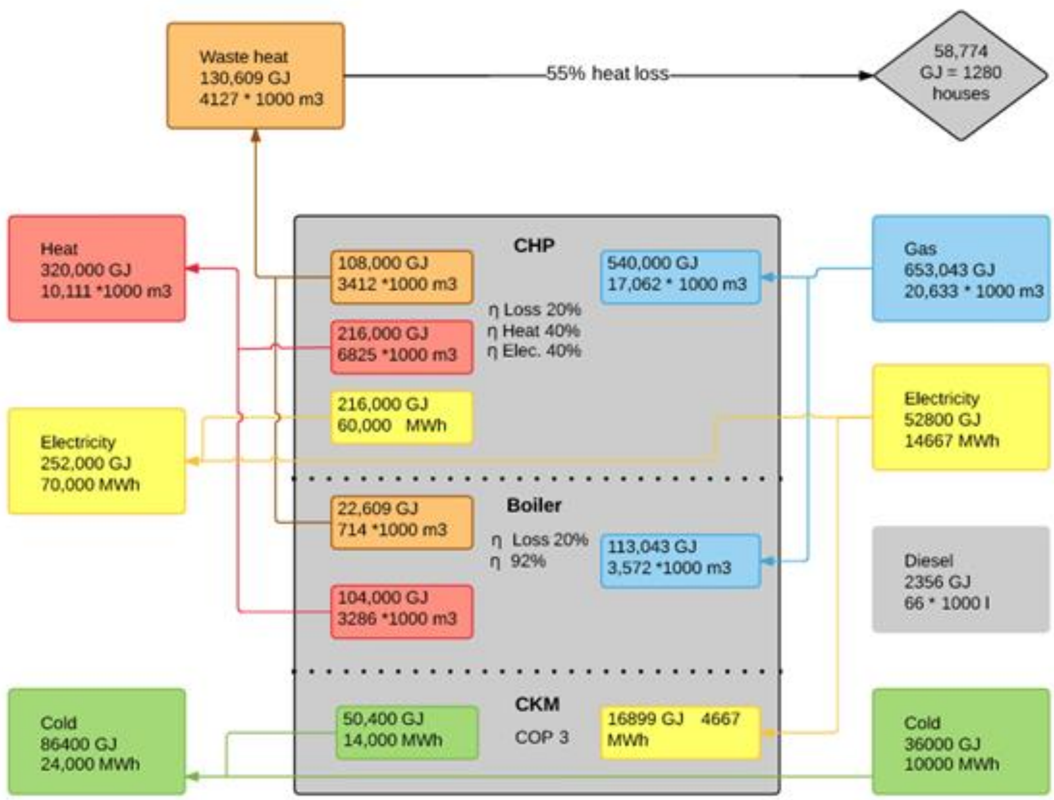


Figure v: Energy flowchart of the AMC (partly from AMC, 2012)

ii) System flexibility

An advantage of switching to central heating provided by a heat network is that it can be controlled in a similar way as with individual gas boilers (which need to be deinstalled), with meters and radiator valves (Bakema, 2015). Moreover, the heat network typically has lifetime of 40 years (Lund et al., 2010). This makes the network less flexible. However, there is already another heat network in place, which could partially be used for this new waste heat network. The total implementation phase takes about 26 weeks (Bakema, 2015).

Considering it takes 26 weeks to construct the network and the possibility to opt out in 1 day, the flexibility is valued with a 4; it is a little complicated but definitely possible.

iii) Technical maturity
Application of technologies that utilize waste heat has increased over the past decades. The first heat networks were developed in a technological niche during the 1960s and 1970s, predominantly in blocks of flats. During the 1980s and 1990s, heat networks lost interest as a result of the waning popularity of high-rise housing, and the poor design, construction and economic performance of early heat networks. However, heat networks regained interest in the last decade due to higher gas prices and restrictions on carbon emissions (GOV.UK, 2013).

Subsequent research has contributed to improve solutions for heat distribution to buildings via heat networks. This created a regime, which resulted in a more common use of heat networks in Scandinavia, Eastern Europe, Germany, South Korea and major cities in the USA and Canada (GOV.UK, 2013). On-going research shows that heat networks can be further improved. In the Netherlands, waste heat was started as a niche in 1983 for greenhouse cultivation; and is used in more recent projects for residential household heating (Van der Velden & Smit, 2007; Warmtenetwerk, 2013). However, waste heat is still not yet widely applied in the Netherlands (ECN, 2012)

Above analysis shows that the technology is quite mature and still improving. As this technology is not yet widely applied in the Netherlands this indicator has score of 4.

iv) Security of supply
When utilizing waste heat from the AMC power plant to heat houses in Maldenhof, the level of security of energy supply is high. Energy supply is vital for hospitals; therefore the AMC produces its own electricity and heat in order not to be dependent on external energy suppliers. In the case of failing gas pressure, the hospital is able to switch from energy production with gas to gasoline, in the case of emergency situations (AMC, 2012). Moreover, according to Bakema (2015) a backup system (gas boilers) for the waste heat network will be installed to guarantee the delivery of heat.

In conclusion, a steady and highly reliable heat flow to Maldenhof can be guaranteed. This results in a score of 5 for security of supply.

ATES+

i) Energy potential

For ATES+, surface water is used to keep the balance between extraction and infiltration from warm and cold wells, since the heat demand for residential buildings is higher than the demand for cold. This means that more groundwater is required from the warm well than from the cold well, which can lead to efficiency losses after a few years if this imbalance is not restored in time. By using surface water as a heat source, extra heat can be added to the warm groundwater to increase the lifetime of the ATES+ system.

To calculate the energy potential of the ATES+ system, two potential sources of heat were considered, namely heat available from the natural groundwater flow and heat from surface water that can theoretically be added to the groundwater system. The theoretical gross heat availability of both sources is not available in practice, since infiltration and extraction speed of both groundwater and surface water is regulated by law to minimize disturbances to the natural environment. Moreover, exchanging heat from surface water to groundwater and eventually to the houses will result in heat losses that need to be taken into account.

Gross heat potential of the groundwater system depends on different characteristics of the aquifer system. These parameters influence temperature distribution in groundwater and soil and therefore the operation of the ATES+ system. They are included in the heat transport equation expressed by MMB (2012 p.81) as:

$$\left(1+\frac{1-\theta}{\theta}\frac{\rho_s}{\rho}\frac{c_{Psolid}}{c_{Pfluid}}\right)\frac{\partial(\theta T)}{\partial t}=\nabla\cdot\left[\theta\left(\frac{k_{Tbulk}}{\theta\rho c_{Pfluid}}+\alpha\frac{q}{\theta}\right)\cdot\nabla T\right]-\nabla\cdot(qT)-q'_s T_s$$

Besides the complexity of this calculation, possible inhomogeneities in the aquifer - which are not yet determined - can influence the outcome of variables that are used as inputs in the heat transport equation (MMB, 2012). More detailed information from the groundwater system around Maldenhof must be collected before the gross energy potential of the groundwater system can be calculated.

To calculate gross energy potential of Gaasperplas, a simplified heat balance equation is used (Graaf et al., 2008):

Htot = Hsl + Ha + Hl + He + Hc + Hf (Annex VIa)

Total heat balance of surface water is determined by solar radiation to, and from the lake. Solar radiation is constantly heating the earth and water surfaces via shortwave radiation (Graaf et al., 2008). Atmospheric radiation comes from atmospheric elements emitting (longwave) radiation to the lake; the lake returns radiation in the form of heat emitted from its water surface. Evaporation heat is the heat extracted from surface water by evaporation processes; and conduction heat flux, or sensible heat flux, is the flux that is driven by temperature differences between water temperature and air temperature (Graaf et al., 2008). Meteorological data from the weather station Schiphol (closest to Maldenhof) and water temperature data from the nearest water body (i.e Amsterdam IJkanaal) are used as input to calculate the gross energy potential of the year 2014 for the Gaasperplas (KNMI, 2015; Rijkswaterstaat, 2015). Excluded from this heat balance method are other heat contributors such as turbulence, transport by precipitation, heat conduction to and from the bed sediments, and biological and chemical degradation processes, since their influence is limited to equilibrium temperature (Graaf et al., 2008). Furthermore, it is assumed that the water system of the Gaasperplas operates as a fully mixed system, because of the size of the lake allows generation of currents.

Based on these assumptions and input of meteorological and water data, gross energy potential for the Gaasperplas was calculated for 2014 (figure vi). Gross potential energy from the Gaasperplas is available from February till September, with highest levels during the summer period. High solar radiation in combination with evaporation results in high water temperatures. Extraction rate determines eventually how much water (and heat) from the Gaasperplas can be extracted and stored in the groundwater system. This rate depends on how much the water temperature is allowed to deviate from the natural equilibrium temperature (Lieten et al., 2012). Figure vii shows the maximum number of houses that can be heated with this available gross energy potential based on the earlier mentioned assumption that an average household in Maldenhof consumes around 3.8 GJ per month. To note here again, these results only present the gross heat potential of the surface water, not gross energy potential of the groundwater.

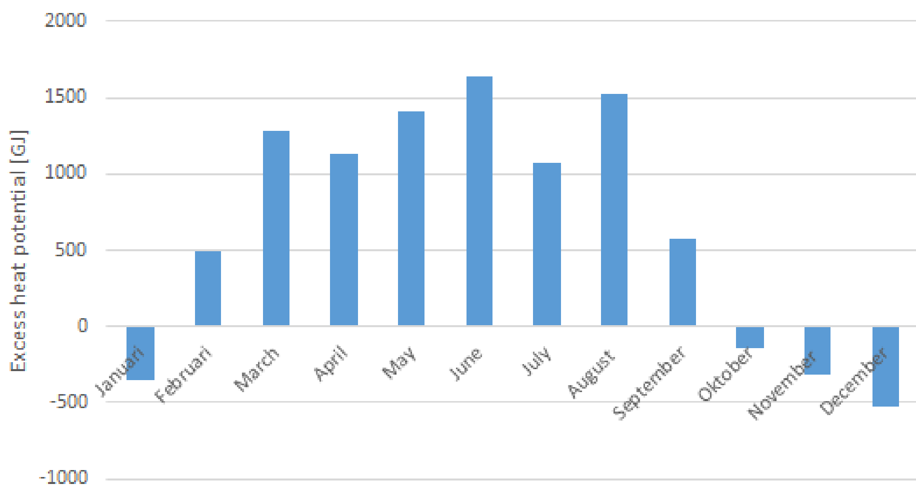


Figure vi - Gross nergy potential Gaasperplas

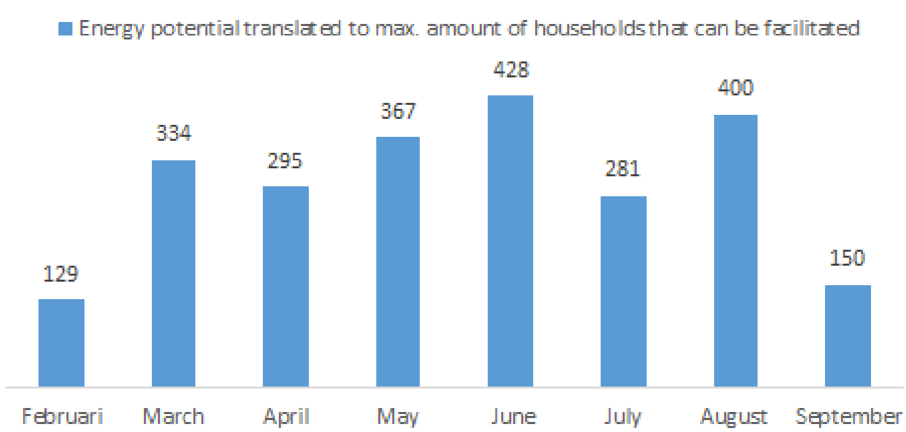


Figure vii - Gross energy potential Gaasperplas expressed in max. houses per month

Based on this first energy potential analysis it can be concluded that the ATES+ is able to provide the heat demand of the Maldenhof neighbourhood. This result can be improved by including calculation of gross energy potential for the groundwater of Maldenhof. Therefore it translates into a score of 5 for energy potential.

ii) Flexibility

In general, ATES+ technology can be designed according to three different modes of heating: low temperature heating (8-15°C), medium-high temperature heating (30-60°C) and high temperature heating (60-90°C) (IF Technology, 2014). Since high temperature heating solutions require a heat source with high temperatures, ATES+ is mainly suitable for low temperature heating. This is because groundwater and surface water are not able to reach temperatures above 30°C. Low temperature operates more efficiently in combination with a floor or wall heating system; regular heating panels require much higher incoming temperatures (i.e. ± 60°C) (Drijver, 2012). Residential buildings in Maldenhof were built in the 1980s with low insulation levels, and high temperature heating panels.

To operate the ATES+ system, replacement of heating panels for floor- or wall heating in these houses is essential. According to Biemond (2015), insulation of walls, windows and roofs is not a necessity. This is based on the fact that in existing residential houses, demand for heating is higher than for showering, and the individual heat pump per house can be designed mainly for heating instead of for showering to compensate for weak insolation. Alphen (2015) confirmed this possibility in theory, but in practice it is not feasible since this type of operation shortens the lifetime of the heat pump. According to Alphen (2015) insulation in combination with floor- or wall heating in existing residential houses are essential for effective operation of the heat pump. These strict requirements for buildings reduce the flexibility of ATES+ in Maldenhof.

Based on the flexibility analysis it can be concluded that ATES+ is partly flexible, since it is possible to opt in or out of the system, but it might be difficult because of the strict entry requirements. This translates into a score of 3.

iii) Technological maturity

First experience with ATES technology on a small scale is dated back to the first half of the 20th century. The first project in Zürich with ATES+ was completed in 1938, and currently is still functioning. One of the first large projects was realized in 1982 in Switzerland, and after that more pilots were started in Denmark and the USA (Graaf et al., 2008). The number of ATES systems in the Netherlands has also grown rapidly over the last decades (figure viii). There is a broad aquifer system in the country, and in almost every major city a number of projects are currently in operation (IFTech, nd). Until 2000, ATES technology was mostly applied to individual buildings like offices and hospitals. Since 2000, ATES was introduced as a central (collective) solution for a number of buildings, mixed developments, and housing projects (Graaf et al., 2008).

Specific components of the ATES system, such as the piping system, pumping station, heat exchangers and heat pumps are highly reliable and well developed. Developments of heat exchangers and heat pump are taking place rapidly in the market, especially in order to increase the efficiency of heat exchange or production (Hepbasli & Kalinci, 2009). Failing ATES projects in the past showed that there are still some knowledge gaps for invisible components in the aquifer system. Research about hydrological effects (such as changes in water tables, groundwater currents, water quality) or thermal effects (such as temperature changes, chemical and microbiological composition of the groundwater) is still ongoing (MMB, 2012). These research projects improve understanding of the groundwater system and how to optimize ATES technology in a natural environment.

It can be concluded that ATES is a mature technology with a lot of developments and proven projects. ATES+ however is relatively new and not widely applied in the Netherlands. Therefore it gets a score of 4 for this indicator.

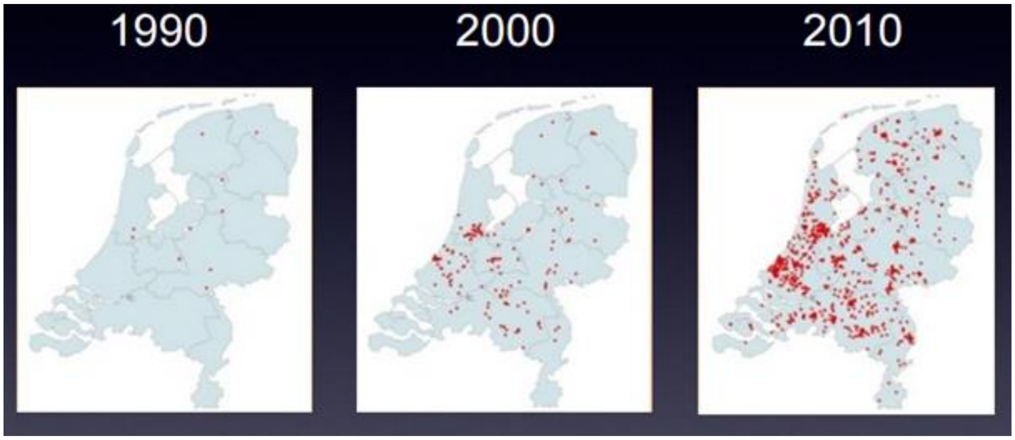


Figure viii – development of ATES projects between 1990-2010 (DistrictEnergy, 2012)

iv) Security of supply

New knowledge and developments in the ATES market have contributed significantly to improving the security of supply for this technology. Problems with reduced energy yield as a consequence of thermal imbalance are now solved by using additional heat from surface waters. Other issues, such as cold winters with higher heat demand and lower surface water temperatures can be compensated by the use of heat pumps. Different flows and components in the systems are monitored by flow- and temperature meters (i.e. pressures meters and water level meters) (Agentschap NL, 2012). These meters measure the amount of pumped groundwater, extraction and infiltration, temperatures, energy amounts, pressure in the system, water level in the wells, etcetera. Interruptions in electricity supply can result in a complete shut down, but this can be solved by running the system on solar panels. For example, a heat pump requires six solar panels per household to operate (Alphen, 2015).

Based on this analysis, it can be concluded that ATES+ has a reliable security of supply and is able to facilitate energy without significant supply failures. This translates into a score of 4 for security of supply.

Table 4 - The average scores for technical feasibility

	Waste heat	ATES+
i) **Energy potential**	5	5
ii) Flexibility	4	3
iii) Maturity of the technology	4	4
iv) Security of supply	5	4
AVERAGE SCORE	**4.5**	**4**
STANDARDIZED SCORE	**0.88**	**0.75**

II) Social feasibility

This section analyses the social feasibility of the neighbourhood initiative, with regards to their characteristics as niche innovators (transitional capacity) as well as the socio-technical regime they are located in (institutional framework). Based on the multilevel perspective on socio-technical transitions the following research question is posed:

RQ: How well is the transitional capacity of the neighbourhood Maldenhof and how does the legal framework impede or support the transition towards more sustainable energy solutions?

To answer this question the analysis proceeds in two sections: one directed at the social and individual level, the other directed at the regime level, thus the institutional structure.

Transitional capacity

The neighbourhood initiative's major struggle is that for any kind of heating installation to be affordable, as many inhabitants as possible need to be convinced to join (Oijenvaar & Boon 2015, Koelemij 2015). As previously discussed, a group of 25 neighbours is technically willing to implement a heating transition; however, disagreement over ways to move forward is slowing down the process (Buurtzoektwarmte 2015). This section will assess the neighbourhood's transitional capacity. This term refers to the neighbourhood's given social capacity to implement a new heating system. Assuming that one preferable technical solution is found, it is crucial to assess how the capacity for an actual transition can be created and improved within the neighbourhood.

Methods

For the niche innovators in Maldenhof to act as successful drivers of a transition, they themselves need to possess of a forward thinking mind-set, be willing to take on risks and to experiment (Geels, 2004). It is assumed that a positive attitude towards sustainability in general and new technologies such as solar panels in particular (including potential changes in infrastructure), is supportive of the transitional capacity. Furthermore, dynamics such as social ties within the initiative are assumed to increase cohesion, information exchange and therefore the potential for learning, knowledge gain and collective action. Social ties within the neighbourhood, beyond the 25 frontrunners, are equally believed to improve those factors. The organisational structure, defined as ways of communication and knowledge spread as well as links established with other stakeholders, is an equally important factor to build a successful niche.

Therefore transitional capacity is operationalized as *individual attitudes* (sub-indicators: *attitude toward sustainable energy (i)*, *awareness of sustainability issues in heating sector (ii)*, and *attitude towards change in the energy infrastructure (iii)*), *social dynamics* (sub-indicators: *social ties within the initiative (iv)*, and *social ties beyond the initiative and within neighbourhood (v)* and *organisational structure* (sub-indicator: *spreading of knowledge within the initiative (vi)*, *spreading of knowledge beyond the initiative(vii)*, and *niche network characteristics(viii)*). Each of these sub-indicators (i-viii) will be assessed on a value scale from 1 to 5, as indicated in table 5. Results of sub-indicators will be averaged for their respective indicators; results of indicators will then be averaged for a score on transitional capacity. After the assessment, a possible comparison between ATES+ and Waste Heat will be discussed shortly.

Table 5 - Description valuation method per sub-criteria (i-viii)

i	ii	iii	iv	v	vi	vii	viii	Value
Rejecting sustainable energy	No awareness of general sustainability issues or local sustainability issues	Rejecting any kind of change of status quo	No close or loose social ties within initiative	No close or loose social ties within neighbourhood	No shared level of knowledge, no attempts to reach out, knowledge inaccessible	No shared level of knowledge, no attempts to reach out, knowledge inaccessible	No reach-out to other stakeholders	1
Sceptical towards sustainable energy	General awareness of sustainability issues without link to heating and local issues	Sceptical towards large scale changes	Some loose ties within the initiative	Some loose ties within the neighbourhood	Some knowledge is spread, but with frequent misunderstanding, difficult to access	Some knowledge is spread, but with frequent misunderstanding, difficult to access	Unstructured, limited reach-out to other stakeholders	2
Indifferent towards sustainable energy	General awareness of sustainability issues, some degree of awareness of local issues such as heating	Indifferent towards minor changes	Loose ties and some close ties within the initiative	Loose ties and some close ties within the neighbourhood	Information spread via limited channels, not everyone is reached, knowledge is accessible	Information spread via limited channels, not everyone is reached, knowledge is accessible	Reach-out to other stakeholder, but no established broad network	3
Positive attitude towards sustainable energy, own investments planned (solar panels, insulation, etc)	Awareness of general sustainability issues as well as local issues, especially heating	Acceptance of potential minor changes and some major changes	Loose and close ties within the initiative	Loose and close ties within the neighbourhood	Regular spread and exchange of information, almost everyone reached, knowledge is very accessible	Regular spread and exchange of information, almost everyone reached, knowledge is very accessible	Established network, with most key stakeholders	4
Fully supportive of sustainable energy, own investments already undertaken (solar panels, insulation, etc.)	Great deal of awareness and concern regarding all kinds of sustainability issues, especially local issues like heating but also others	Fully supportive of minor or major, long-term changes	Many close ties and many loose ties within the neighbourhood	Many close ties and many loose ties within the neighbourhood	Regular spread and exchange of information, everyone reached and at same level of information, knowledge is actively made very accessible	Regular spread and exchange of information, everyone reached and at same level of information, knowledge is actively made very accessible	Well established network including all key stakeholders	5

Data collection

Three research methods are employed to obtain knowledge on individual attitudes and social dynamics: a guided group discussion with members of the initiative, a questionnaire for all members of the initiative, and a survey for a random set of Maldenhof's inhabitants. Both of these surveys were conducted in connection with the surveys to get data on the priorities described in the general data collection.

The group discussion was conducted to gain in-depth knowledge about processes and dynamics within the initiative, and to learn more about personal attitudes and priorities within the project. The guideline to the group discussion and a summary can be found in Annex IVa. All members of the initiative were invited to join the discussion via e-mail, but only three people were willing to participate. As a follow-up of the group discussion, an e-mail questionnaire was sent to the participants to gain more in-depth knowledge especially regarding the spreading of information and knowledge as well as the communication within and beyond the initiative.

Regarding the surveys, the items on the questionnaire directed at the members of the initiative involve beliefs regarding sustainability in general, social contacts within the neighbourhood, and the motives to support sustainable heating transitions. The questionnaire and a summary of the answers can be found in Annex IVb.

The survey targeting randomly selected inhabitants in Maldenhof was conducted to obtain information about the residents' level of knowledge regarding the neighbourhood initiative, the ways in which they received this knowledge, aspects of personal beliefs regarding sustainable heat generation and openness for infrastructure change. It did not cover questions about social ties within the neighbourhood (in the way that is covered in the questionnaire directed at initiative members), as these questions were deemed too personal for an anonymous survey. During the survey, conversations with the respondents gave some further insights into their personal situation or the general situation in Maldenhof. These anecdotes are documented in Annex IVc and will be taken into account in the assessment. Some factors limit the significance of the available data: more invested neighbours were also more likely to participate in the research.

Information regarding the organisational structure and procedures was derived from documents provided by the client, the surveys, the group discussion and meetings with the client. The documents provided by the client include protocols from group discussion sessions of the initiative (Annex IVd).

Table 6 indicates which items on both questionnaires (survey 1: within initiative, survey 2: in the neighbourhood of Maldenhof) cover which aspect of the indicators.

Table 6 – Indicators of transitional capacity and their corresponding survey questions

Indicator	Corresponding Questions
Individual Attitudes	
Attitude towards sustainable energy	3, 4, 8, 10, 23 (survey 1), 3 (survey 2)
Awareness of sustainability issues in the heating sector	9, 15 (survey 1), 2, 4 (survey 2)
Attitude towards change in energy infrastructure	7, 9, 11 (survey 1), 5 (survey 2)
Social Dynamics	
Social ties within the initiative	13, 16, 20 (survey 1)
Social ties beyond the initiative, in the neighbourhood	14, 17, 18, 25 (survey 1)
Organisational Structure	
Spreading of knowledge within the initiative	12, 13
Spreading of knowledge beyond the initiative	17, 18, 19, 22 (survey 1); 1 (survey 2)
Niche network characteristics	Group discussion, e-mail interviews, material provided by client

i) *Attitude towards sustainable energy*

Among the initiative members, a slight majority is oriented towards sustainable products in general (figure ix). Most of them are also satisfied with their investments in sustainable energy. This is supported by findings in the group discussion. All participants were very keen on getting information regarding sustainable energy and making their own energy consumption more sustainable. In the broader neighbourhood however, only 50% of the respondents were interested in getting more information over possibilities to generate energy more sustainably. However, 22% have already invested in solar panels, and two respondents indicated that they already have a green electricity supplier. Therefore, a value of 4 is assigned, factoring in those who are very enthusiastic and have invested in sustainable energy, as well as those who are more sceptical.

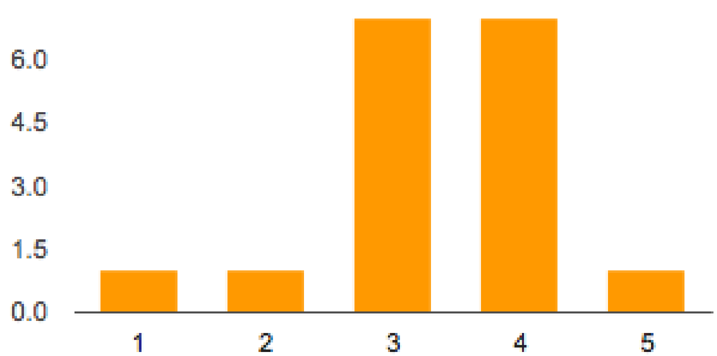


Figure ix - Question item "in the store I buy mostly sustainable products" (x axis 1: completely disagree, 5: fully agree; y axis: number of respondents)

ii) Awareness of sustainability issues in the heating sector

The majority of the initiative members thinks of sustainability as an important factor, with 75% indicating that CO2 emissions is an important factor in heating systems and more than 75% indicating that the impact of heating on the local environment is important to very important. In the group discussion scepticism towards energy supply companies was mentioned which indicates a higher level of awareness. A slight majority of initiative members prefers independent heating solutions (figure x):

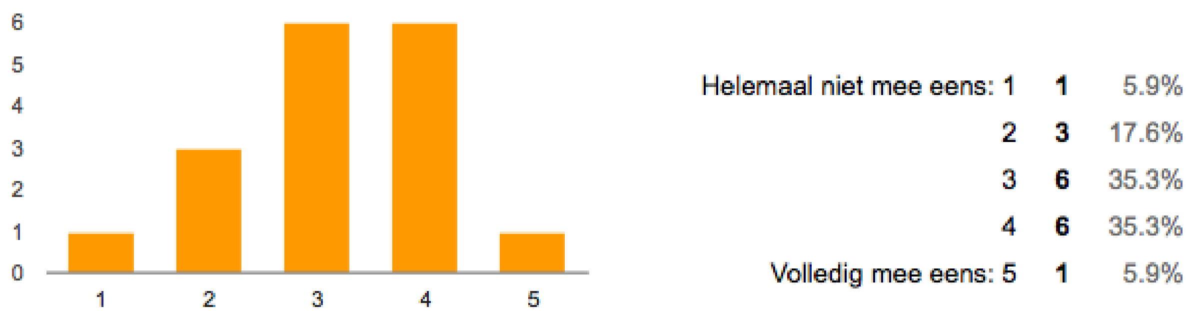


Figure x - "I prefer independent heating solutions" (x axis: degree of agreement, y axis: number of respondents)

Within the neighbourhood, 50% of the respondents have looked for information about sustainable heating, which indicates a mediocre level of awareness; and 50% are aware of political action in regards to sustainable heating. Clearly awareness within the initiative is higher, but considering the entire neighbourhood, this factor scores a 3, with general awareness of sustainability issues, and some degree of awareness of local issues such as heating being present.

iii) Attitudes towards change in the energy infrastructure

Many people within the neighbourhood and also in the initiative have recently changed to a new gas boiler, meaning they are less willing to invest again in a new heating infrastructure (group discussion, survey 2). Furthermore, initiative members are rather reluctant to agree to long-term changes and like to stay flexible (See Figure xi).

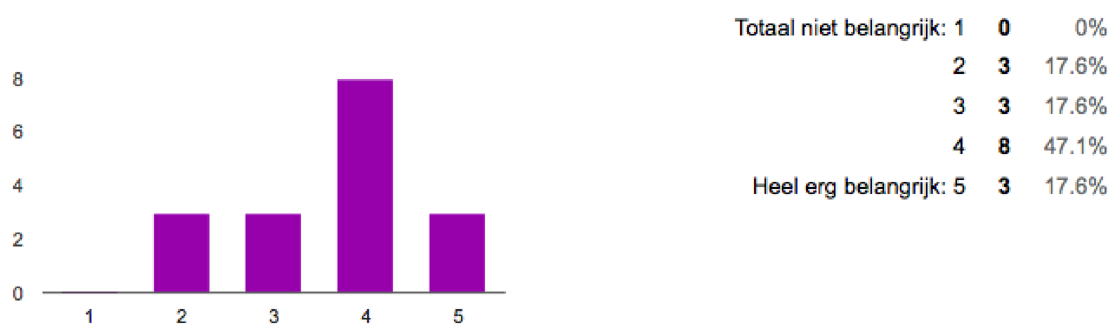


Figure xi - "How important is it to for you to stay flexible in your energy supply?" (x axis: degree of agreement, y axis: number of respondents)

However, most neighbours indicated that major infrastructural changes outside their houses would not affect them negatively (survey 1: 54%, survey 2: 47%). Therefore the **score is a 3**, based on all available data, and assuming that the majority of inhabitants would accept minor changes.

iv) Social ties within the initiative

The vast majority likes organising their heating endeavours in a group (70.5%). When analysing the social connections within the initiative, figure xii shows that the picture is diverse, with a slight majority of people having most ties in the initiative, and also a significant amount (23.5%) beyond the initiative. This indicator therefore scores a 4, with close and loose social ties within the initiative.

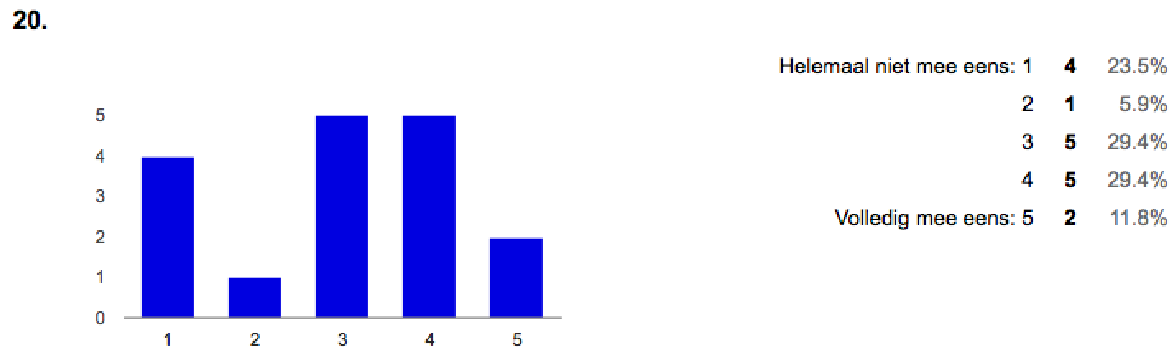


Figure xii - "Most people I am in close contact with are also part of the initiative" (x axis: degree of agreement, y axis: number of respondents)

v) Social ties beyond the initiative within the neighbourhood

Figure xiii shows that most members know other people in Maldenhof, and 18.8% of the members have been approached by other inhabitants regarding their initiative or other sustainable energy devices around their houses. This indicates rather strong social ties within the neighbourhood which leads to a score of 4.

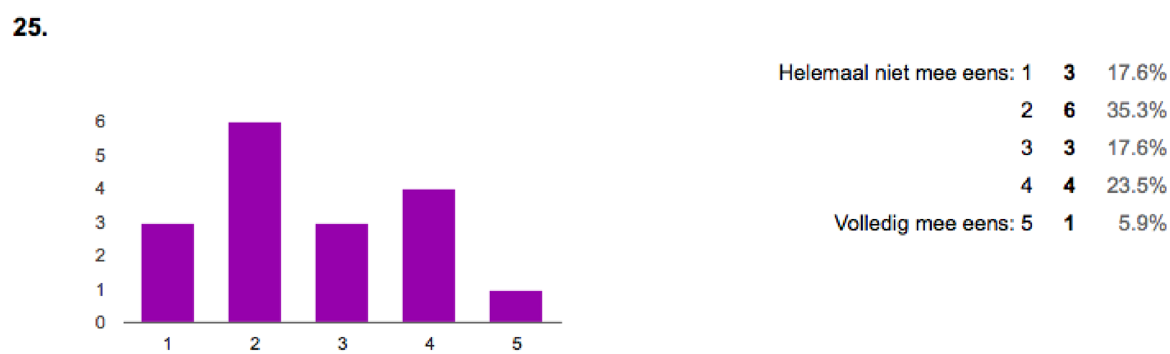
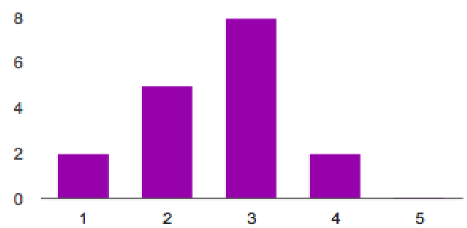


Figure xii - "I don't know many people in this neighbourhood, other than the members of the initiative" (x axis: degree of agreement, y axis: number of respondents)

vi) Spreading of knowledge within the initiative

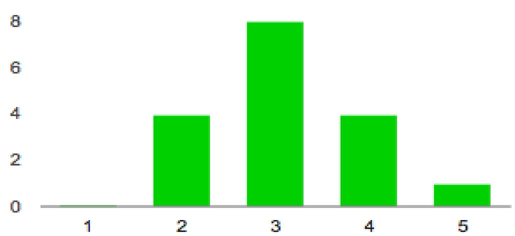
As shown in figure xiv and xv, members are not completely satisfied with decision-making processes, and neither does a majority feel well informed about current sustainable heating options that are under consideration. The group-discussion and follow-up emails showed that communication channels were via e-mail and meetings; of members absented from meetings were informed afterwards. It was not always deemed easily accessible. This hints at communication and spreading of knowledge among core members, but limited or misleading communication with other members, thus a score of 3 is assigned.

13.



Helemaal niet mee eens: 1	**2**	11.8%
2	**5**	29.4%
3	**8**	47.1%
4	**2**	11.8%
Volledig mee eens: 5	**0**	0%

Figure xiv - "I am happy with the current decision making processes" (x axis: degree of agreement, y axis: number of respondents)



Helemaal niet mee eens: 1	**0**	0%
2	**4**	23.5%
3	**8**	47.1%
4	**4**	23.5%
Volledig mee eens: 5	**1**	5.9%

Figure xv - "I am well informed about a potential neighbourhood based heating system" (x axis: degree of agreement, y axis: number of respondents)

vii) Spreading of knowledge beyond the initiative

In preparation for the heating project, flyers were distributed and an information fair was organised by the initiative. This was deemed a success as many people were reached. But the majority of members have not been approached by other neighbours regarding sustainable energy devices such as solar panels or the neighbourhood initiative, however 47% have in some ways spoken about the initiative with other neighbours. A big majority indicates willingness to find new supporters once a good heating system is found. There is also a website and a Facebook page, (Slimwonengaasperdam, 2015) but these are not frequently updated anymore. In survey 2 it was found that 78% of the broader neighbourhood was not aware that the initiative existed. For these reasons a score of 3 is assigned.

viii) Niche network characteristics

The group discussion and follow-up emails as well as contact with the client and attendance of networking meetings made it clear to us that the initiative's core members have close ties to other organisations such as research institutes, the district government and other neighbourhood initiatives. Concerning their own organisation, members excluded the possibility to set up an actual energy cooperative. Since the initiative itself is relatively new, it is not yet possible to speak of a well-established network, therefore a score of 4 is assigned.

Table 7 – Concluding table scores of transitional capacity

Indicator	Score	Average
Individual attitudes		
Attitude towards sustainable energy	*4*	*3.3*
Awareness of sustainability issues in the heating sector	*3*	
Attitude towards change in energy infrastructure	*3*	
Social dynamics		
Social ties within the initiative	*4*	*4*
Social ties beyond the initiative, in the neighbourhood	*4*	
Organisational structure		
Spreading of knowledge within the initiative	*3*	*3.3*
Spreading of knowledge beyond the initiative	*3*	
Niche network characteristics	*4*	
	Total Average	***3.5***

Comparing the two technologies on which one would increase transitional capacity is ambiguous, because on the one hand, most respondents when asked about the political situation and their awareness referred to the "warmtenet", which is based on waste heat. This means that the level of knowledge regarding this technology is relatively higher than for ATES+, and it would therefore score higher on an individual attitude scale. On the other hand, group discussion participants were also excited to hear about a new technology that could suit their needs better as they had heard about problems with waste heat. However, knowledge about ATES+ within the initiative is very limited. The considerations show that a definite higher score for one or the other with regards to the social and individual level of transitional capacity would be misleading. Therefore both technologies are assigned the same score in the individual and social aspects of transitional capacity (3.5).

Institutional Framework

The legal and institutional framework set for the Maldenhof initiative describes the current political climate, and possible future developments. Local authorities have been found to play a crucial role in supporting new heating installations (GOV.UK, 2013). Research has shown that a supportive relation between heating projects and the local authorities is key for success (Bolton & Foxon 2015). Subsequently, (perceived) uncertainty of the legal situation regarding deployment of a new technology might inhibit innovators to implement new heating solutions (Meijer et. al. 2007). Furthermore, the initiative members have indicated in survey 1 that they prefer more political support for these central heating alternatives.

To assess the institutional framework, four indicators are identified. A brief description of these indicators can be found in table 8. Each indicator has a scale from 1 to 5; details of the scale are listed in table 9. The rating is derived from the client's indications of what would be helpful politically to support their endeavours. A concluding table will average the scores of these indicators. The data to conduct this assessment was obtained via the surveys outlined in the integrated methodology chapter, and the group discussion outlined in the chapter on transitional capacity. In addition interviews with the municipality of Amsterdam (Koelemij, Annex IIIf) and Waternet (Mol et. al., Annex IIIb) were conducted. Further data was obtained via policy paper analysis and desk research.

Table 8 - Description of political developments

(i) National Energy Vision: The Dutch Energy Agreement (Warmtevisie)	National vision for a policy framework for the implementation of more sustainable heat networks in the Netherlands
(ii) Local Political Developments	The developments and practicalities for this neighbourhood
(iii) Necessary Permits	Which permits are needed and the level of difficulty to obtain these
(iv) Possible Subsidies	Which subsidies could be applied for and the level of difficulty to obtain these

Table 9 - Description valuation method per sub-criteria

i) National Energy Vision: The Dutch Energy Agreement	**ii) Local Political Developments**	**iii) Necessary Permits**	**iv) Possible Subsidies**	**Value**
The local political developments are unfavourable and hinder the implementation of the alternatives	The local political developments are unfavourable and do not support the implementation of the alternatives	Obtaining permits is very difficult and time consuming	There are almost no subsidies that can be applied for and if so, the likelihood of receiving any is zero	**1**
Favourable policies are still being developed and therefore hinder the implementation of the alternatives	Favourable policies are still being developed at the very beginning of the development phase and therefore do not support the implementation of the alternatives	Obtaining permits is less time consuming due to a better overview of what needs to be applied for; permits still need to be applied for at different government levels and institutions; the likelihood of receiving all permits is more certain.	There are some subsidies that can be applied for but the likelihood of receiving any is very uncertain	**2**
Favourable policies are established but has yet to be implemented	Favourable policy framework are is established but has yet to be implemented	The level of difficulty of obtaining permits is medium; there is a clear overview of which permits are necessary; permits still need to be applied for at different government levels and institutions, however there are plans to make this process more efficient; the likelihood of receiving all permits is 50:50	There are some subsidies that can be applied for and the likelihood of receiving any is medium	**3**
Favourable policies are developed and implemented, but do not yet work optimally	Favourable policies are developed and implemented, but do not yet work optimally yet	Obtaining permits is less time consuming as they can be applied for at one government agency / institution; however, this concept is still quite new and therefore not yet flawless; the likelihood of receiving all permits is high	There are quite a lot of subsidies that can be applied for and it is quite likely that most will be allocated	**4**
The local political developments are in favour of the implementation of the alternatives and favourable policies are well-established policy and working well		Obtaining permits is an easy, not time consuming process and can be done at one government agency / institution that is well established; the likelihood of receiving all permits is certain	There is plenty of subsidies that can be applied for and the likelihood of receiving them it is very high.	**5**

i) *National Energy Vision: The Dutch Energy Agreement*

In April 2015, Minister Kamp of economic affairs wrote a letter describing a new 'heat vision' (Warmtevisie) in which he pleads for a faster transition towards a more sustainable heating. Until recently, it was obligatory to connect to the gas grid for Dutch citizens. However, the Dutch government acknowledges that with new technological developments, gas networks will become redundant in some areas, and therefore decided to loosen the law on the obligation to connect to a gas grid. The ACM (Autoriteit, Consument en Markt) can exempt operators of gas networks from their task in areas where a heat network already exists or plans are made to create one (EZ, 2015). Both alternatives are seen as equally good options for a more sustainable heat supply and are therefore supported by the Dutch government. Considering the above and the rating scale in table 9, the Dutch Energy Agreement is rated 3 for both the alternatives.

ii) Local Political Developments

Waste Heat

The Maldenhof initiative commenced long before Minister Kamp's 'heat vision' and was awarded the P-NUTS award by the municipality of Amsterdam in April 2015. The essential difference between the neighbourhood and Kamp's vision on waste heat is that Kamp also considers the use of heat from the burning of waste (EZ, 2015). The initiative members completely disagree with this as they consider the burning of unsustainable (Annex IVc).

The municipality of Amsterdam announced an investment of 35 million to connect at least 20,000 households to a newly established district-heating network by 2030, using waste heat released by the burning of waste. Their ambition is that by 2040, 230,000 households will be heated by using heat released by burning of waste (Gemeente Amsterdam, 2015a). Whereas the initiative was started as a search for a cheap and more sustainable solution to heat their houses, the prospect of commercialized and taxed waste heat is not in line with initiative's goals. Moreover, there is mistrust in the government to actually comply with possible long-term agreements.

The general conclusion identified by the initiative members was that the local political developments did not meet the initial initiative's expectations (Annex 4b). Considering the above and the value scale in table 9, this indicator is given a score of 4.

ATES+

The legislation to implement ATES is in the development phase. The Dutch government is planning on introducing an Environmental-code (Omgevingswet) that will simplify license application for ATES initiatives by creating one permitting authority that decides whether an initiative will receive a permit (SER, 2013). With an increased implementation of soil energy systems, the necessity to govern below surface areas also increases. The implementation of a 'master plan' for interference areas forms the legal basis for considering the dispensing of licenses in an interference area (Gemeente Amsterdam, 2015b). Provinces are currently responsible for the licensing of ATES applications, but are troubled by an insufficient capacity to carry out the enforcement of the regulations (Provincie NH, 2014). This is temporarily solved by hiring private parties, which often causes delays by the project initiators.

The municipality of Amsterdam has set a goal to increase the sustainable energy generation within Amsterdam by 20% by 2020. As ATES systems generate energy in a sustainable way, their implementation is generally supported (Gemeente Amsterdam, 2015c). The municipality has appointed seven interference areas, for which different master plans have been prepared (Gemeente Amsterdam, 2015b). Maldenhof and the Gaasperplas are not located in an interference area, which increases the chance for their application to be approved. Still, the policy framework for soil energy systems is fragile. The ideas of introducing an Environmental-code to ease the license application sounds very promising, the establishment of such a body will however take time. Therefore, it can be concluded that the licensing application is likely to encounter political difficulties due to the immaturity of the policy framework and insufficient capacity of government parties.

Considering the above and the value scale in table 9, the local political developments for the implementation of an ATES+ system is rated with 2.

iii) Necessary Permits

Waste Heat

For the implementation of a waste heat system the construction of the pipeline system requires a permit called 'Werken in openbare ruimte' (WIOR). This permit is relatively easy to obtain in places where a heat network does not exist yet. A pipeline system close by the neighbourhood already exists and could be used for transporting the heat. This pipeline system is owned by the energy producer NUON, who is eager to supply the neighbourhood. Different meetings between the initiative members and NUON led to a standstill of the initiative because negotiations about the rules as well as prices could not be agreed upon. According to the municipality of Amsterdam it is unlikely that a grant for an independent pipeline system will be permitted. Therefore, implementation of this alternative depends on the agreement. There is some perspective for the enlargement of the power position of the neighbours within these negotiations. On a national level the government considers the privatization of existing heat networks and is developing proposals to make heat networks publicly available. The official legislation will not be in place before 2017 but it is possible that by the beginning of next year, the government will publish a list containing advice and guidelines that favour these developments (Koelemij, 2015).

Considering the above and the value scale in table 9, necessary permits for the implementation of a waste heat system is given a score of 3.

ATES+

Implementing an ATES+ system requires permits from different institutions. First, the investor needs a WIOR permit that allows for construction works in public space (Koelemij, 2015). The construction of the system involves drilling of boreholes, and installation of pumps. Therefore the application for a WIOR permit might be more insecure for the ATES+ compared with waste heat.

Secondly, a permit is necessary from Waternet that allows the use of surface water from the Gaasperplas to run the system. A comparable initiative at the Ouderkerkerplas gives a good indication of the procedure. Waternet has indicated that a comparable procedure would be necessary to assess whether the Gaasperplas is suitable for an ATES+ system. Waternet only grantz the permit if the lake and the neighborhood both benefit from the ATES+ system. The water quality in the Gaasperplas is already high, which means that the Gaasperplas cannot gain much more benefit. Therefore Waternet suggested focusing on surface water from side canals of the Gaasperplas. Using water from the canals increases the chances of getting a permit for surface water (Mol et. al., 2015).

Lastly a permit for groundwater use is required at provincial level. The province of Noord-Holland developed a WKO-tool to stimulate the implementation; this tool assess whether an ATES system is possible in an area concerning the impacts on local soil and environmental (Rijksoverheid, 2015). For Maldenhof these specific criteria are very favourable, which increases the likelihood of obtaining a permit (Annex V).

Considering the above and the value scale (table 9), the obtainment of necessary permits for an ATES+ system is rated 3.

iv) Possible Subsidies

Waste heat

The municipality of Amsterdam is currently supporting the application procedure of a comparable project at the Jaap Edenbaan ice rinks to gain subsidies from EFRO. EFRO finances projects that stimulate structural changes for low carbon economies. The application entails an extensive and detailed description of the participants and their activities to justify the amount of subsidy. The municipality identified the strengths of the Jaap Edenbaan project in order to support the allocation of subsidies. In the scenario of using waste heat from the AMC, these strengths are also present, which would make it worthwhile to consider starting the application procedure. As the project at the Jaap Edenbaan just started it does not guarantee that it will actually receive the subsidy.

Considering the above and the value scale in table 9, the possibility of receiving subsidies for the implementation of a waste heat system is rated 3.

ATES+

The EFRO subsidy could also be applied for in the scenario of implementing an ATES+ system, because EFRO also stimulates innovation and research, which increases ATES+'s chances of receiving the subsidy as it (Koelemij, 2015).

The ATES+ system requires houses to be well insulated, which raises the question whether there are possibilities to receive subsidies to decrease the insulation costs. Subsidies for the insulation of houses have been changed into a loan system, to enables house owners to borrow money at a low rate. To stimulate a more sustainable energy provision, discussions have started again to shift back to partly subsidize the insulation of houses. A decision on this issue is not to be expected soon. Currently, the only possibility is to get a relatively cheap loan to pay for insulation (Koelemij, 2015).

Considering the above and the value scale in table 9, the possibility to receive subsidy for the implementation of an ATES+ system is given a score of 3.

Table 10 - Summary of scores of indicators

Criterion	***Values Waste Heat***	***Values ATES+***
i) National Energy Vision: The Dutch Energy Agreement (Warmtevisie)	*3*	*3*
ii) Local Political Developments	*4*	*2*
iii) Necessary Permits	*3*	*3*
iv) Possible Subsidies	*3*	*3*
Average	***3.25***	***2.75***

Combining the values assigned to the two aspects to an average, a final value of 3.38 for waste heat and 3.13 for ATES+ is assigned, standardized these become a 0.60 and a 0.53 respectively.

III) Environmental sustainability

To become 'more sustainable', in terms of the environmental impact of a certain technology, is claimed to be an important criterion by the residents. The first part of this criterion is about reducing carbon dioxide emissions. Carbon dioxide is a greenhouse gas that contributes to global climate change and should therefore be reduced by means of reducing the fossil gas use in the neighbourhood. The second type of impacts on the environment that will be discussed is the impact on the water and soil quality in the neighbourhood. The third type of environmental impacts is 'other harmful ecological impacts', comprising such as biodiversity loss (Dombi et al., 2014).

RQ: What is the environmental impact of waste heat and ATES+ in terms of carbon dioxide emissions, water and soil quality and other harmful ecological impacts?

The value for *carbon dioxide emissions (i)* will be determined in relation to the current situation with only gas for heating. It will show how many kilogrammes of CO_2 will be avoided in the new scenario per household. Calculations will therefore require data on current heat demand and associated CO_2 emissions. Considering *water and soil quality* (ii) the impacts of the technologies on the water and soil quality will be examined. Especially in the case of ATES+ where surface water will be used, the question remains what kind of impact this will have on the water quality. *Other harmful ecological impacts (iii)* could for example arise due to the use of an extensive pipe system to distribute the heat to the houses. All impacts on the environment can mostly be found in academic literature about waste heat and ATES+. Furthermore, specific information of the neighbourhood and the technologies will be derived from experts like Alliander (Bakema, Annex IIId), the municipality (Koelemeij, Annex IIIf) or IF technology (Biemond, Annex IIIa), through interviews. The value scale of the indicators is given in table 11. These values present the influence of a system compared to the current situation. The final results of environmental sustainability is presented in table 13.

Table 11 - Value scale of indicators for environmental sustainability

CO_2 Emissions (i)	**Water and Soil Quality (ii)**	**Other harmful Ecological Impacts (iii)**	**Score**
The system emits (more than) twice as much CO_2	The system has major negative impacts on water and soil quality	The system has major deteriorating effects	1
The system emits more CO_2, but not twice as much	The system has minor negative impacts on water and soil quality	The system has minor deteriorating effects	2
There is no net difference in CO_2 emissions	The system does not change water and soil quality	The system does not change	3
The system partially abates CO_2 emissions	The system has minor improvements on water and soil quality	The system has minor improvements	4
The system has no (or negative) CO_2 emissions	The system has major improvements of the water quality	The system has major improvements	5

Waste heat

i) Carbon dioxide

The amount of carbon dioxide that will be abated by using waste heat technology instead of the conventional boiler technology will be equal to all CO_2 emissions that are currently emitted by the boiler, since the new scenario will emit no CO_2. This amount was already calculated in the background section as kg 2581 CO_2 per household per year (Wicke, 2005).

Even though there is no net difference of gas use at the AMC if the plants run at the same load, some might argue that the use of waste heat still contributes to global warming, because it still facilitates the use of fossil fuels. Therefore it is argued that there should not be any incentive for the waste heat provider- in this case the hospital - to produce waste heat. If the provider would receive money for the tapping off of waste heat they might not invest in efficiency measures or sustainable energy sources. When the CO_2 emissions at the hospital associated with 45.9 GJ of heat demand per household are taken into account, a lower amount of abated CO_2 will be the result. The calculation starts with calculating the gas input at the AMC plant associated with 1 GJ heat demand in the neighbourhood. The assumptions are similar as those for energy potential calculation (pp. 8):

- Total natural gas input AMC plant = $\frac{1GJ\ natural\ gas\ input}{90\ \%\ transport\ loss * 50\%\ usefull\ heat * 20\%\ share\ waste\ heat}$

To convert the primary gas input to CO_2 emissions at the plant, the input first converted to cubic meters of gas input (assuming 31.65 MJ/m^3) and then multiplied by the CO_2 emission factor of 1.78 kg CO_2/m^3 natural gas:

- Carbon dioxide emissions at AMC plant = $\frac{11.11\ GJ\ natural\ gas\ input * 1000 MJ/GJ}{31.65\ MJ/m3}$* 1.78 kg CO_2/m^3 = 624.89 kg CO_2 for 1 GJ gas demand in the neighbourhood

Per household with an annual demand of 45.9 GJ:

- Carbon dioxide emissions at AMC plant = 624.89 kg CO_2/GJ * 45.9 GJ/year = 28,682 kg CO_2/hh/year
- Net effect of carbon dioxide emissions = -2581 kg CO_2 + 28,682 kg CO_2 per = 19,242 kg CO_2 /year

This amount is clearly very high and cannot be charged to the households, because the AMC also generates heat and electricity for the hospital itself with this input of natural gas. However, if the plant needs to produce more energy than in the current situation in order to meet the heat demand at Maldenhof, the calculation gets more complex. This would lead to a higher generation of heat and electricity at the hospital, which was otherwise imported. If this is the case, then the amount of associated CO_2 emissions from importing electricity can be extracted from the above-calculated emissions. This calculation starts with determining how much extra electricity is produced at the CHP for every extra gigajoule of heat demand at the Maldenhof. Once again these calculations use the same assumptions as with the potential calculations on pp. 8:

- Extra electricity production at the CHP = $\frac{11.11 GJ * 83\%\ to\ CHP * 40\%\ electric\ efficiency}{3.6\ GJ/MWh}$= 1.02 MWh for 1 GJ gas demand in the neighbourhood

Per household with an annual demand of 45.9 GJ:

- Extra electricity production at the CHP = 1.02 MWh/GJ * 45.9 GJ = 47.03 MWh/hh/year

For the CO_2 intensity of the Dutch electricity production a value of 0.464 kg CO_2/kWh is assumed (CE Delft, 2015) to obtain the CO_2 emissions that can be extracted from the former amount because these are now avoided due to a lower amount of electricity import that is required:

- Actual carbon dioxide emissions at the AMC = 624.89 kg CO_2 - 1.02MWh * 1000 kWh/MWh * 0.464 kg CO_2/kWh = 149.43 kg CO_2 per GJ gas demand in the neighbourhood

Per household with an annual demand of 45.9 GJ:

- Actual carbon dioxide emissions = 149.43 kg CO_2/GJ*45.9 GJ = 6859 kg CO_2/hh
- Net effect of carbon dioxide emissions = -2581 kg CO_2 + 6859 kg CO_2 = 4279 kg CO_2/hh/year

There are future plans of the AMC to let the CHP run on biogas. In that case the amount of CO_2 emissions at the CHP will be zero (because biogas do not cause a net CO_2 effect like fossil fuels), but there will be an effect from the avoided CO_2 amounts from electricity import:

- Avoided CO_2 at the AMC from less electricity import = 1.02MWh * 1000 kWh/MWh * 0.464 kg CO_2/kWh = 475.46 kg CO_2 per GJ gas demand in the neighbourhood

However, the gas input at the boiler (17% of total input) at the AMC cannot be replaced by biogas, so it still emits CO_2:

- Carbon dioxide emissions from gas input at the AMC boilers = $\frac{11.11\ total\ gas\ input * 17\%\ share\ to\ boiler}{31{,}65 MJ/m3 * 1000 MJ/GJ}$ *1.78 kg CO_2/m^3 = 106.23 kg CO_2 per GJ gas demand in the neighbourhood

Per household with an annual demand of 45.9 GJ:

- Avoided CO_2 emissions at the plant = (475.46 kg CO_2/GJ - 106.23 kg CO_2/GJ) * 45.9 GJ = 16,947 kg CO_2/hh
- Net effect of carbon dioxide emissions = -2581 kg CO_2 - 16,947 kg CO_2 = -19,528 kg CO_2/hh/year

However, it seems that the the future plan to use biogas is still uncertain, because the security of energy supply (and the maturity of the technology) is still insufficient (IEE, 2015), and will therefore not be taken into account as a plausible future scenario in this multi-criteria analysis.

Greenhouse gas emissions are not just emitted during the production of heat, but also during other phases of the life cycle. Other emissions occur as a result of producing the pipes and constructing, using and post-use handling of the network. It appears that producing the pipes contributes to more than 90% of the environmental impacts i.e. global warming potential, acidification potential and resource depletion. The materials for the pipes are mainly steel, polyethylene (PE), polyurethane and copper. The actual emissions depend on the specific characteristics of the heat network and can currently not be determined due to the lack of data. However, according to Bakema (2015) the gains during the profit phase outweigh the emissions during the pro-use phase.

Considering that there are still many associated emissions (even though the households cannot actually be charged for them), especially in the case when the AMC plant has to produce more waste heat, the score of waste heat for this indicator is a 2. The total CO_2 emissions are higher, but not more than twice as high compared to the current situation (4279 versus 2581 kg CO_2/hh/year).

ii) Water and soil quality

The construction of a new heat system could cause some soil disturbances during implementation. However, constructing the heat network will not take place at great depths: maximum 100 centimeters according to Bakema (2015). Therefore only shallow disturbances can be expected. As pointed in the institutional framework, a new waste heat system in Maldenhof has to be connected to the existing network. This results in less disturbances of the soil. Considering the effects on water quality no differences are expected compared to the current situation, because water is used in a similar way. These outcomes are supported by Bakema (2015) and Koelemeij (2015). Additionally, literature does not report significant impacts on water and soil quality after implementing a waste heat network in urban areas.

As there are no significant changes with regard to water and soil quality, waste heat is valued with a 3 for this indicator.

iii) Other harmful ecological impacts

Similar to the water and soil quality, it can be expected that there will be no additional harmful impacts on the biodiversity in Maldenhof (Bakema, 2015; Koelemeij, 2015). On the other hand, it is possible that the neighbourhood will experience some nuisance during the implementation phase of the network. Again, literature provides no additional data on this type of ecological impact caused by waste heat networks.

Concluding, no significant different harmful ecological impacts are expected and therefore a score of 3 is given for this indicator.

ATES+

i) Carbon Dioxide

The amount of carbon dioxide that will be abated by using ATES+ instead of using conventional boilers will be equal to all CO_2 emissions that are currently emitted by the gas boiler i.e. 2581 kg CO_2 per household per year.

However, application of ATES+ in Maldenhof requires an individual heat pump that consumes electricity and therefore indirectly emits CO_2. This needs to be included in the calculations to obtain veracious estimates about energy savings and CO_2 reduction by ATES+. Energy consumption and CO_2 emission by a heat pump are expressed respectively in avoided primary energy consumption and CO_2 emission for space heating with a boiler. Renewable energy production with ATES+ for residential buildings is obtained by only calculating heat pump savings for heat production (Agentschap NL, 2010). Cooling is not standard for residential buildings and therefore it is not included in the primary energy consumption.

Table 12 presents the abated CO_2. Starting with the abated CO2 for the heat production with the heat pump. A first step is to calculate the total capacity (1) of the heat pump, the full load hours (2), necessary heat production (3) and the required electric power (4). With these numbers the avoided primary energy for space heating can be determined (5). Subsequently, the CO_2 emissions for space heating are calculated (6). Afterwards the percentage of the total avoided primary energy consumption (7) and the total avoided CO_2 emission per household are given. Implementing ATES+ will result in 50% reduction of primary energy consumption and 38% abated in CO_2 emission per household per year compared with the current situation.

Based on this analysis it can be concluded that ATES+ reduces CO_2 emissions partially if there is a connection with the electricity grid. With solar panel connections it could be free of CO_2 emission, for now it is given a score of 4.

Table 12: Calculation steps for CO_2 emission reduction

Open ATES system with heat pump	Abbreviation	Units and formulas
Total capacity of heat pumps	P in kW ≤ 12 kW heat pump	(12 [kW]*300 households) = **3600 kW_{th}** (outgoing thermal power)
(2) Full load hours space heating and SPF_s	**V_s** = full load hours space heating **SPF_s** = seasonal performance factor for space heating	V_s = **1100 h/yr** (Annex VId) SPF_s = **4.3** [2]
(3) Heat production space heating	**$Q_{hp,s}$ = p* V_s * 3.6** **p**= Outgoing thermal power (kW) **V_s** = full load hours space heating (h/yr) **3.6** = conversionfactor (MJ/kWh)	3600 [kW]* 1100 [h/yr] * 3.6 = **14256 GJ**
(4) Electric power required for heat pump	**$Q_{in,s}$ = $Q_{hp,s}$ /SPF_s** **$Q_{hp,s}$** = heat production space heating [GJ] **SPF_s** = seasonal performance factor for space heating	14,256 GJ4.3 = **3315 GJ per year**
(5) Contribution renewable energy expressed in avoided primary energy for space heating	**$E_{prim,s}$ = $Q_{hp,s}$ /η_{ref} – $Q_{in,s}$ / $\eta_{e,B}$** **$Q_{hp,s}$** = heat production space heating [MJ_{prim}/yr] **η_{ref}** = efficiency reference system **$Q_{in,s}$** = electrical power required for heat pump [MJ/jr] **$\eta_{e,B}$** = electrical conversion efficiency delivered to user	14,256 GJ0.95- 3315 GJ0.408 = **6881 GJ per year**
(6) Avoided CO_2 emission for space heating	$\varepsilon_{net,heat}$ = [$e_{naturalgasCO2}$ * $Q_{hp,s}$ / η_{ref}] – [$e_{elekCO2}$ * $Q_{in,s}$ / $\eta_{e,B}$] **$e_{naturalgasCO2}$** = emission factor gas [kg/GJ]* **$Q_{hp,s}$** = heat production space heating [MJ_{prim}/yr] **η_{ref}** = efficiency reference system* **$e_{elekCO2}$** = emission factor elektricity [kg/GJ]* **$Q_{in,s}$** = electrical power required for heat pump [MJ/jr] **$\eta_{e,B}$** = electrical conversion efficiency delivered to user * *Numbers derived from Agentschap NL (2010)	56.7 kg CO2/GJ * 14,256 GJ0.95- 68.9 kg CO2/GJ *3315 GJGJ0.408 ≈ **291 ton CO_2**
(7) Total avoided primary energy consumption	$E_{prim,cold}$ + $E_{prim,s}$ **$E_{prim,cold}$** = cold production **$E_{prim,s}$** = contribution renewable energy expressed in avoided primary energy for space heating	0 [GJ] + 6881 [GJ] = 6881 GJ 6881 GJ0.408 ≈ 22,9 GJ / hh/ year 22.9 GJ/yr45.9 GJ/yr * 100% ≈ **50% primary energy reduction per household per year**
(8) Total avoided primary CO_2 emission	**$\varepsilon_{net, cold}$ + $\varepsilon_{net, heat}$** **$\varepsilon_{net, cold}$** = avoided CO_2-emission for cold production **$\varepsilon_{net, heat}$** = avoided CO_2 emission for space heating	0 + 291 ton = 291 ton CO_2 291 kg CO2/300 hh ≈ 970 kg/ household/ year 970 kg/yr2581 kg/yr [kg/y] * 100% ≈ **38% primary CO_2 reduction per household per year**

ii) Water and soil quality

Quantifying the effects of ATES+ upon water and soil quality is a study in itself and therefore only the main findings will be presented here.

First, ATES+ is capable to improve the water quality by preventing botulism. Botulism appears if the oxygen concentrations in the lake drop due to high temperatures which stimulates bacterial growth (Mol et al., 2015; Biemond, 2015a). This has some effects on organisms like fish and birds as well for human health. By extracting warm surface from the top layer, equilibrium of the water column will be disturbed and mixed, this contributes to the water quality. In the neighbourhood only substantial water quality improvements can be accomplished for the local water canals (Mol et al., 2015). The Gaasperplas already has a high water quality. Thereby, the stable environment might be disturbed by extracting water from the Gaasperplas (Mol et al., 2015).

Direct influence of ATES+ upon the soil comprises hydrologic- and thermal effects. Hydrological effects are the consequence of extraction and infiltration of groundwater (Oostrom et al., 2010). Since no other ATES systems have yet been implemented nearby Maldenhof the possibility of interference is excluded, and monitoring is clear from disturbance by other systems. Major disturbances in hydraulic head and groundwater levels are not expected since this location has excellent aquifer properties (i.e sandy soil with relative low conductivity) for application of ATES+ (Biemond, 2015a). Thermal effects could occur as a consequence of storing heat and cold. This can disturb the local temperature balance and might influence chemical and microbiological contents of groundwater. However, large temperature fluctuations can be excluded by ATES+ since the system designed for Maldenhof will focus on a low temperature grid (<25°) with small temperatures difference.

Based on this it can be concluded that ATES+ does not improve the Gaasperplas and soil quality. This translates into a score of 3 for this indicator.

iii) Other harmful ecological impacts

Other possible harmful ecological impacts can be subdivided in flora and fauna during construction phase and operation phase. Construction of ATES+ mainly concerns placement of an inlet system in Gaasperplas, construction of a distribution network from and to the Gaasperplas, building a pumping unit close to the Gaasperplas and a central distribution unit in Maldenhof.

The inlet system will be constructed at surface level in the lake and therefore will have some effects on local fauna. Minimum effects are expected because the Gaasperplas contains a low fish concentration. It can be expected that the construction of a distribution network increase noise pollution in the neighbourhood due to drilling activities. These construction activities can possibly lead to local disturbance of fauna and destruction of habitat of flora and fauna (Arcadis, 2007). It is likely that these effects will be minimal since the distribution network will be designed mainly according to existing street grid to prevent new disturbances. Building of the pumping unit close to Gaasperplas can lead to disturbance of fauna and flora, but this effect is expected to be less significant because it only covers a small area. Similar effects will be expected for the construction of the central distribution unit in Maldenhof.

During operation phase ATES+ will mostly affect fauna in the Gaasperplas by pumping water from the upper layer. This will specifically be in habitats for some protected fish species. Filter mesh sizes for the pumping system will be designed to minimize the effects on the fishes (Arcadis, 2007).

Based on this it can be concluded that ATES+ has a minor negative impact on other harmful ecological impacts. This translates into a score of 2.

Table 13 - Summary of given values

	Waste heat	ATES+
CO2 (kg avoided per household)	2	4
Water and soil quality	3	3
Other harmful ecological impacts	3	2
AVERAGE SCORE	**2.67**	**3**
STANDARDIZED SCORE	**0.42**	**0.50**

IV) Economic sustainability

The economic indicators commonly employed in energy planning literature include investment costs and operating expenses (Afgan et al., 2000; Afgan & Carvalho 2004; Dombi et al., 2014; Ghafghazi et al., 2010; Kolwalski et al., 2009; Tsoutsos et al., 2009). Investment costs include the initial costs of constructing and installing the energy system (Tsoutsos et al., 2009). Operating expenses cover repair, periodical maintenance, materials/fuels, manpower, and other administrative costs (*Ibidem*). However, using these indicators to evaluate economic sustainability of each technological scenario would be misleading, because they only reflect the total costs of producing energy from the perspective of energy producers, not the total costs for consuming energy from the perspective of consumers. Therefore, this section will investigate the total costs of transitioning into a new energy system from the consumers' perspective. However, due to limited data availability, each scenario can only be evaluated in terms of its *potential for annual cost savings* in relations to the annual costs of gas consumption in the base scenario. According to Hollanders (2015), Heat Product Developer of Alliander (the energy grid network company that is currently interested in investing in a grid network to supply heat to Maldenhof), residents in the neighbourhood demand at least 10% savings in annual heat consumption cost from the new energy system. Based on this preference, a value scale from 1 to 5, with 1 equivalent to negative 20% savings and 5 equivalent to positive 20% savings, is constructed to evaluate each energy scenario.

Table 14 - Description valuation method sub-criteria

Level of annual cost savings	***Value***
Potential for negative 20% annual cost savings (annual cost of heat consumption is 20% more than that in the base case)	**1**
Potential for negative 10% annual cost savings (annual cost of heat consumption is 10% more than that in the base case)	**2**
Potential for zero annual cost savings (annual cost of heat consumption is equivalent to that in the base case)	**3**
Potential for positive 10% annual cost savings (annual cost of heat consumption is 10% less than that in the base case)	**4**
Potential for positive 20% annual cost savings (annual cost of heat consumption is 20% less than that in the base case)	**5**

Data for assessment is obtained from various sources, including: internet sources, business documents by Alliander, and interviews with Hollanders, Product Developer of Alliander, Biemond, Energy Specialist of IF Technology (a consulting company with technical, financial and legal expertise in seasonal thermal energy storage), Alphen, Account Manager of Techneco Energiesystemen, and Stijkel, resident of Maldenhof.

As calculated under the case description, annual gas consumption of an average household in Maldenhof is estimated at €1418.

RQ: What is the level of economic sustainability of waste heat, and of ATES+, in terms of potential for annual cost savings in heat consumption?

Waste heat

When switching from gas to waste heat, households should also switch to electric cooking because it is expensive to maintain the gas system just for cooking purposes. Costs of electric stoves listed on Kieskeurig.nl ranges from €249 to €5295, but this paper assumes that each household will purchase a mid-range stove that costs approximately €600. This stove will have an average lifespan of 15 years as commonly estimated for electric stoves (Mr. Appliance, 2015). Electricity consumption for the stove is estimated at 400 kWh per year with unit price of €0.15/kWh (Alliander, 2015a). Moreover, households that have already invested in a gas boiler will still have to bear the cost for the gas boiler over the years using waste heat. Assuming that the lifespan of the waste heat system is 30 years, as such lifespan is typical for this type of infrastructure (Hollanders, 2015), and the lifespan of a gas boiler is 15 years, the annual transitional costs an average household will bear when switching from gas to waste heat is calculated in table 16.

Table 16 – Annual transitional costs for an average household from switching from gas to waste heat

Category	Total costs (€)	Notes
Variable gas cost	975	1500m^3 x €0.65
Fixed cost for gas supply	443[1]	Consisting of standing charge for gas, gas transport, gas boiler depreciation and maintenance
Total	**1418**	

[1] Fix cost for gas supply was calculated by one of Maldenhof residents (Alliander, 2015a)

The total investment costs for a waste heat system for 300 households is estimated at €1,818,000 (Alliander, 2015c), which will include capital costs for the heat exchanger and ancillary equipment installed at the source (within the gas power plant of AMC), capital costs for constructing and installing the grid network infrastructure within Maldenhof, and for connecting individual properties to the grid, and cost for a water pump (Hollanders, 2015). Annual operating costs are estimated at €78,207 (Alliander, 2015c) as detailed in table 17.

Table 17 – Annual operating costs

Category	*Amount (€)*	*Note*
Annual maintenance costs (2% of total investment)	36,360	€1,818,000 x 0.02
Administrative per year (€50 per property)	15,000	€50 x 300
Metering service per year (€25 per property)	7,500	€25 x 300
Electricity consumption for operating water pump at the source (28,980kW, €0,15/kWh)	4,347	28,980kW x 0.15/kWh[1]
Earning risks for Alliander per year (€50 per property)	15,000	€50 x 300
Total	**78,207**	

[1] Average unit price of electricity was obtained from Maldenhof residents by Alliander (Alliander, 2015b)

According to Hollanders (2015), Alliander will only invest in, and operate the heat grid network; an energy corporation (not yet identified) must be engaged to directly supply waste heat to Maldenhof residents. A schematic representation of the parties and contractual agreements involved in order to build and operate a waste heat system and supply heat to the residents of Maldenhof is illustrated in figure xvi.

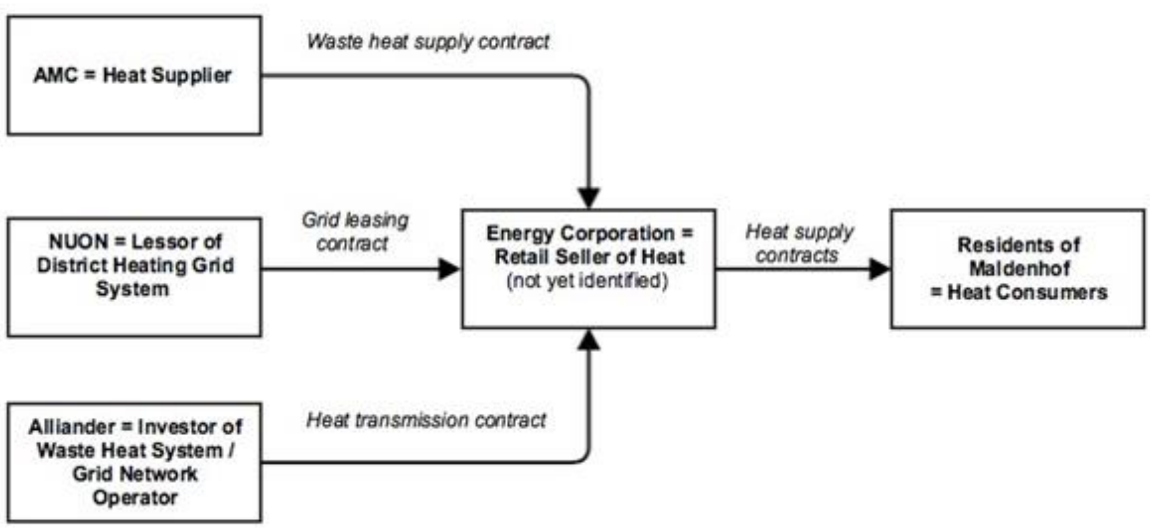


Figure xvi - Schematic representation of the parties and contractual agreements

Typically in this type of project, 15 to 10% of the revenue after tax (tax is 21%) would go to NUON as lessor of the district heating grid system. NUON is an energy supplier that owns a district-heating grid near Maldenhof (highlighted in red in figure X1) that can be rented to bring heat from AMC to the neighbourhood (Hollanders, 2015). The energy corporation would retain 25 to 35% of its revenue and Alliander would earn 50 to 55% from this revenue stream (*Ibidem*). Assuming that Alliander will earn 55%, Alliander's estimated annual revenue is calculated for five different saving potentials in table 18. If the annual cost of consuming heat from the waste heat system is to be equal to that in the base case, fixed and variable costs that an average household pays per year must be equal to that of the base case (€1418) deducted by transitional cost that the household pays per year (€150).

Figure xvii - NUON owns a district-heating grid near Maldenhof (Hollanders, 2015)

Table 18 - Alliander's estimated annual revenue for five different saving potentials

Annual saving potential	***Annual heat consumption cost per household (€) (1)***	***Annual transitional cost per household (€) (2)***	***Annual revenue after tax for energy corporation per household (€) (3) = [(1) - (2)] x 0.79***	***Annual revenue after tax for energy corporation from 300 households (€) (4) = (3) x 300***	***Annual revenue for Alliander from 300 households (€) (5) = (4) x 0.55***
Additional 20%	1,701.60	150	1,225.764	367,729.20	202,251.06
Additional 10%	1,559.80	150	1,113.742	334,122.60	183,767.43
Base case	1,418	150	1,001.72	300,516.00	165,283.8
Savings of 10%	1,276.20	150	889.698	266,909.40	146,800.17
Saving of 20%	1,134.40	150	777.676	233,302.80	128,316.54

Depreciating Alliander's initial investment of €1,818,000 over 30 years and factoring in annual operating costs, Alliander's annual earnings before tax from the investment in different saving potential is calculated in table 19.

Table 19 - Alliander's annual earnings before tax from the investment for different saving potentials

Annual saving potential	**Annual revenue for Alliander from 300 households (€) (5) = (4) x 0.55**	**Alliander's annual operating costs (6)**	**Alliander's fix cost depreciation over 30 years (excluding interest and tax) (7)**	**Alliander's annual earnings before tax (8) = (5) - (6) - (7)**
Additional 20%	202251.06	78207	60,600	63444.06
Additional 10%	183767.43	78207	60,600	44960.43
Base case	165283.80	78207	60,600	26476.80
Savings of 10%	146800.17	78207	60,600	7993.17
Saving of 20%	128316.54	78207	60,600	-10490.46

The results show that in order for the investment to make sense, the energy corporation must at least charge €1268 per household (with a heat consumption of 45.9GJ/year) per year for both standing charge and variable heat cost. The waste heat scenario therefore only has the potential for zero annual cost savings and is given a score of 3.

It is, however, important to note that for the purpose of simplicity, interest rate and inflation rate have not been factored into above calculations. The estimated investment cost for a 300-household network by Alliander is still preliminary, so the margin of error in above calculations is rather large. Furthermore, there are factors that could possibly affect the cost factor such as subsidies from the EFRO program, in terms of lower interest, or investment grant, or government guarantee for project failure (Hollanders, 2015).

ATES+

Similar assumptions are used to assess annual saving potential of the ATES+ system. In addition to the costs for gas boiler, electric stove and electricity for cooking, transitional costs for an average household to switch from gas heating to ATES+ heating also include cost of heat pumps and electricity to operate the heat pump and cost for (complete) home insulation. As the maximum temperature supplied by natural water sources is 20 degrees Celsius, application of the ATES+ system requires that the houses are energy efficient and equipped with heat pumps (Alphen, 2015). With an energy-rating label of C, the houses in Maldenhof must be well insulated in order to be energy efficient. Costs for insulating houses range variously, depending on the type, material and size of insulation. However, a study by Sommers (2010) on a seasonal thermal energy storage project indicates that a house using this type of heating is on average €10,000 more expensive than a traditional house. This figure is used as average cost for complete home insulation. A heat pump of 6kWh to 12kWh capacity costs approximately €5,000 and has an average lifespan of 15 years. In table 20 the annual transitional costs for an average household are calculated.

Table 20 - Annual transitional costs for switching from gas to waste heat per average household (1500m³)

Category	Total costs (€)	Notes
Gas boiler depreciation cost	50	€1500/30 years
Electric stove depreciation cost	40	€600/15 years
Electricity cost for cooking	60	Costs for additional 400 kWh consumption (€0.15kWh)
Heat pump depreciation cost	333	€5000/15 years
Electricity cost for heat pump	990	Costs for additional 6,600kW consumption (6kW x 1100 hours/year) at €0.15/kWh
House insulation depreciation cost	333	€10,000/30 years
Total	**1806**	

A heat pump of 6kWh capacity can be used with the ATES+ to increase temperature to required standard (Biemond, 2015b). Assuming the use of a 6 kWh instead of a 12kWh heat pump as under the environmental sustainability results in less consumption of electricity and consequently less electricity cost. This lower assumption is chosen to compensate for possible overestimation of investment costs. According to Biemond (2015a), an ATES system for 300 households costs approximately €250,000, with annual maintenance cost of 2.2% of total investment. A surface water energy system costs approximately €200,000 with annual maintenance of 2.5% of total investment. Together an ATES+ system for 300 household costs around €450,000. However, cost for the main pipeline system and individual property connections are not included in this estimation. The estimation for a 3,200m length heat network by Alliander (Alliander, 2015c) is therefore used to estimate the cost of the pipeline network for the ATES+ system. According to Biemond (2015b), a flow of 165m3 per hour is required to supply heat to 300 households; the type of pipe needed for this flow rate is HDPE pipe with 200mm in diameter. The cost of 3200m of 200mm HDPE pipe is €640,000 based on Mol's (2015) estimation of €1 per millimetre per meter for HDPE pipe. However this is probably an overestimation because the pipe to connect the main grid with individual houses has a diameter of 12mm (Biemond, 2015b). The lack of data on the total length of the main grid and the total length of individual connection pipes make it impossible to estimate the cost of the pipeline system accurately. Therefore initial investment cost for the ATES+ system is crudely estimated at €1,090,000.

The source pumps for the ATES+ system should have similar capacity as the water pump for the waste heat system and, annual operating costs of the ATES+ system is calculated as shown in table 21.

Table 21 - Annual operating costs of the ATES+ system

Category	***Amount (€)***	***Note***
Annual maintenance costs (2.2% of €250,000 and 2.5% of €200,000)	10,500	€250,000 x 0.022 + €200,000 x 0.025
Electricity consumption for operating water pump at the source (28,980kW, €0,15/kWh)	4,347	28,980kW x 0.15/kWh
Total	**14,847**	

In other ATES and ATES+ projects that have been implemented, typically an energy corporation invests in the system and directly sells the heat to consumers. Annual earnings after tax of this energy corporation is estimated for five saving potentials as in table 22.

Table 22 - Annual earnings after tax for five saving potentials

Annual saving potential	**Annual heat consumption cost per household (€) (1)**	**Annual transitional cost per household (€) (2)**	**Annual revenue after tax for energy corporation per household (€) (3) = [(1) - (2)] x 0.79**	**Annual revenue after tax for energy corporation from 300 households (€) (4) = (3) x 300**	**Annual operating costs of energy corporation (€) (5)**	**Energy corporation's fix cost depreciation over 30 years (excluding interest and tax) (€) (6)**	**Energy corporation's annual earnings after tax (€) (7) = (4) - (5) - (6)**
Additional 20%	1,701.60	1,806	-82.476	-24742.80	14,847	36,333	-75922.80
Additional 10%	1,559.80	1,806	-194.498	-58349.40	14,847	36,333	-109529.40
Base case	1,418	1,806	-306.52	-91956.00	14,847	36,333	-143136.00
Savings of 10%	1,276.20	1,806	-418.542	-125562.60	14,847	36,333	-176742.60
Saving of 20%	1,134.40	1,806	-530.564	-159169.20	14,847	36,333	-210349.20

As indicated in table 22, investing in an ATES+ system does not make sense from an economic perspective since the energy corporation will not make any profit. This is due to the high cost of insulation, heat pump and annual electricity consumption to operate the heat pump. The ATES+ scenario is given a score of 1.

Our calculations most likely contain very high margins of errors. As previously mentioned, interest rate and inflation rate have been excluded from above calculations. The estimated investment cost for the ATES+ system is extremely crude, as cost data on similar projects is unavailable, and there is not yet an interested company such as Alliander in the waste heat case. Estimated cost of the pipeline system could be much larger than in reality. Calculations also rest on the assumption that all households need to fully insulate their houses, which may not be true. Furthermore, there are other factors that could possibly affect the cost such as investment subsidies and/or home insulation subsidies from the EFRO program (see section on institutional framework).

V) Social sustainability

Tsoutsos et al. (2009) take as an indicator for social impact the contribution to local development and welfare. The authors define this indicator as "the total social and economic impact that may become perceptible in the regions that house the sustainable energy system" (Tsoutsos et al., 2009, p. 1592). Review of similar literature helps expand this indicator into concrete sub-indicators such as job creation, standard of living, specific community benefits (Afgan et al., 2010), empowerment, social justice, and regional cohesion (Kowalski et al., 2009). However, due to the limited timeframe of this study and the difficulties of ex-ante assessment, this paper will only take into account more tangible sub-indicators such as job creation, standard of living, and specific community benefits. Specific community benefits can be creation of business opportunities, and health benefits derived from an environment free of hazardous emission (i.e. dust, NOx/NO2, SOx/SO2). Moreover, it is important to also take into account other possible disturbances that have immediate impacts on the daily lives and well-being of the residents in the neighbourhood, including noise disturbance, odour pollution, space obstruction, and aesthetic disturbance as the results of constructing, installing and operating the energy system. In sum, the social impact criterion is operationalized as *contribution to local development and welfare*, with the following sub-indicators: (i) creation of jobs, (ii) creation of business opportunities, (iii) improvement in living standards standard, (iv) emission of noxious substances, (v) noise pollution, (vi) odour pollution, (vii) space obstruction, and (viii) aesthetic disturbance.

RQ: What is the level of social sustainability of waste heat, and ATES+, in terms of contribution to local development and welfare?

The score scale of each sub-indicator ranges from 1 to 5 as illustrated in the following table:

Table 23 - Scoring method for indicators of social sustainability

(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	Score
No job created	No business opportunity created	No improvement in living standard	High emission of noxious substances	High level of noise pollution	High level of odour pollution	High level of space obstruction	High level of aesthetic disturbance	1
Creation of a few jobs	Creation of a few business opportunities	A little improvement in living standard	Sizable emission of noxious substances	Sizable level of noise pollution	Sizable level of odour pollution	Sizable level of space obstruction	Sizable level of aesthetic disturbance	2
Creation of some jobs	Creation of some business opportunities	Some improvement in living standard	Some emission of noxious substances	Some noise pollution	Some odour pollution	Some space obstruction	Some aesthetic disturbance	3
Creation of sizable number of jobs	Creation of sizable number of business opportunities	Sizable improvement in living standard	Little emission of noxious substances	Little noise pollution	Little odour pollution	Little space obstruction	Little aesthetic disturbance	4
Creation of many jobs	Creation of many business opportunities	Significant improvement living standard	No emission of noxious substances	No noise pollution	No odour pollution	No space obstruction	No aesthetic disturbance	5

Under each sub-indicator, the two technological scenarios under consideration will be assessed based on the above value scale. Creation of jobs, creation of business opportunities, improvement in standard of living, and emission of noxious substances are given equal weight because they are substantial impacts. Noise pollution, odour pollution, space obstruction, and aesthetic disturbance are less substantial impact and are therefore given a quarter of the weight of the other sub-indicators. The results will then be averaged to produce a final score for the level of contribution to local development and welfare of each technological scenario.

The data for assessment is obtained from interviews with Biemond and Hollanders.

(i) Creation of jobs

According to Hollanders (2015), Alliander representative in the Maldenhof initiative, Alliander would hire a third party to carry out construction and installation work. This third party will source personnel for constructing and installing the system. The chance that personnel will be sourced from within Maldenhof is very little. Therefore there will be no temporary jobs created for the neighbourhood during the construction and installation process.

The waste heat system, once set up, will operate automatically with little requirement for manpower. Technical work required to operate and maintain the system includes calibration of the part of the system located within the facilities of AMC and periodical maintenance work. Alliander intends to hire technicians who are already employed by AMC to perform calibration work, which will not be a full time job. Periodical maintenance work will be performed by Alliander's in-house technicians. Therefore the waste heat system will not create any job opportunity for the residents of Mandelhof during the operational phase (Hollanders, 2015). This scenario scores 1 for job creation.

Similarly, Biemond (2015a) confirms that the investor of the ATES+ system would contract a third party for construction and installation. Since this party will source its personnel, it is highly unlike that these personnel will be sourced from within Maldenhof. Hence, there will be no job created during the construction and installation process of the ATES+ system. Once installed, the ATES+ system will operate fully automatically. Periodical maintenance work is required to maintain the system, but such position requires technical skills and is not full time. It is thus unlikely that such position will be source from within Maldenhof. The ATES+ scenario also scores 1 for job creation.

(ii) Creation of business opportunities

The third party will purchase materials for constructing the infrastructure for the waste heat system. Alliander will also purchase equipment necessary for installation of the system. There are no businesses in Maldenhof that can supply these materials and equipment. During operations, the fuel supply for the system is waste heat, which will be purchased from AMC. Accordingly, there are no business opportunities created throughout the process of constructing, installing and operating the waste heat system (Hollanders, 2015).

There is one scenario in which residents of the neighbourhood may benefit financially from the waste heat system: that is, if they form an energy cooperative, that will act as an energy supplier that purchases heat from AMC, rents the grid system from Alliander and NUON to sell heat to the neighbourhood (Hollanders, 2015). As indicated under the section on social feasibility, the Maldenhof initiative is not considering the possibility of forming an energy cooperative. The waste heat scenario is therefore given a score of 1 for this sub-indicator.

Similar situation applied for the ATES+: materials and equipment required to construct, install and operate the system cannot be sourced from within the neighbourhood. The ATES+ scenario is thus given a score of 1.

(iii) Improvement in living standard

The living standards of the residents in Maldenhof are improved when the energy system installed directly enhances the quality of their daily experience in terms of personal comfort and wellbeing and/or when the financial benefits/savings derived from using the system contribute to an increase in their disposable income. Neither the waste heat system nor the ATES+ system would directly enhance the daily experience of Maldenhof residents or significantly increase their disposable income, as indicated by potential annual savings under the economic section. Each scenario is therefore given a score of 1.

(iv) Emission of noxious substances

There is no emission of particulate matters or noxious substances for both waste heat and ATES+ system (Koelemij). Each scenario is given a score of 5.

(v) Noise pollution

There will be some noise emitted during the process of constructing and installing both the waste heat and ATES+ systems due to construction work, drilling and transportation of construction material, but the magnitude is low and it is only temporary and. There will be no noise emitted from operating the system. Hence each scenario is given a score of 4.

(vi) Odour pollution

There will be no odour pollution for either system throughout the construction, installation and operation processes (Hollanders and Biemond, 2015a). Each scenario is therefore given a score of 5.

(vii) Space obstruction

There will be some temporary space obstruction when Alliander installs the grid system within the neighbourhood due to pipe duct excavation, and possibly storage of water pipes and other materials. However the occupied space for duct excavation is relatively small and temporary (Hollanders, 2015).

Similar situation applied for the ATES+ system. Accordingly, each scenario is given a score of 4.

(viii) Aesthetic disturbance

There will be no aesthetic disturbance to the neighbourhood throughout system construction, installation and operations. The grid system is buried underground. There is no protrusion for the waste heat system; and there is only one small structure required to house the heat exchanger and controller of the ATES+ system. As the result, each scenario is given a score of 5 for aesthetic disturbance.

Final results of social sustainability for both scenarios are indicated in table 24.

Table 24 - Final results of social sustainability

Waste Heat				ATES+			
Indicator	*Score*	*Weight*	*Average*	***Indicator***	*Score*	*Weight*	*Average*
Creation of jobs	1	1	2.5	**Creation of jobs**	1	1	2.5
Creation of business opportunities	1	1		**Creation of business opportunities**	1	1	
Improvement in living standard	1	1		**Improvement in living standard**	1	1	
Emission of noxious substances	5	1		**Emission of noxious substances**	5	1	
Noise pollution	4	0.25		**Noise pollution**	4	0.25	
Odour pollution	5	0.25		**Odour pollution**	5	0.25	
Space obstruction	4	0.25		**Space obstruction**	4	0.25	
Aesthetic disturbance	5	0.25		**Aesthetic disturbance**	5	0.25	

Integration

The goal of this report was to advise the Maldenhof initiative to determine whether waste heat from the AMC power plant or an ATES+ system is more sustainable and feasible as a heating solution for the Maldenhof neighbourhood. This report also gives an advice how to improve its popularity in the neighbourhood in order to enable a heating transition. Transition theory frames the initiative as a technological niche that needs further improvement for a transition to come about. To achieve an integrated result, all five disciplinary criteria as dealt with above are integrated by means of a PROMOTHEE weighted analysis, to advice on the preferred heating system. The transitional capacity of the neighbourhood was analysed as a condition for social feasibility and additionally serves as a basis to give advice on possible interventions and improvements of the neighbourhood's initiative. A schematic representation of this process is given in the flowchart in figure xviii.

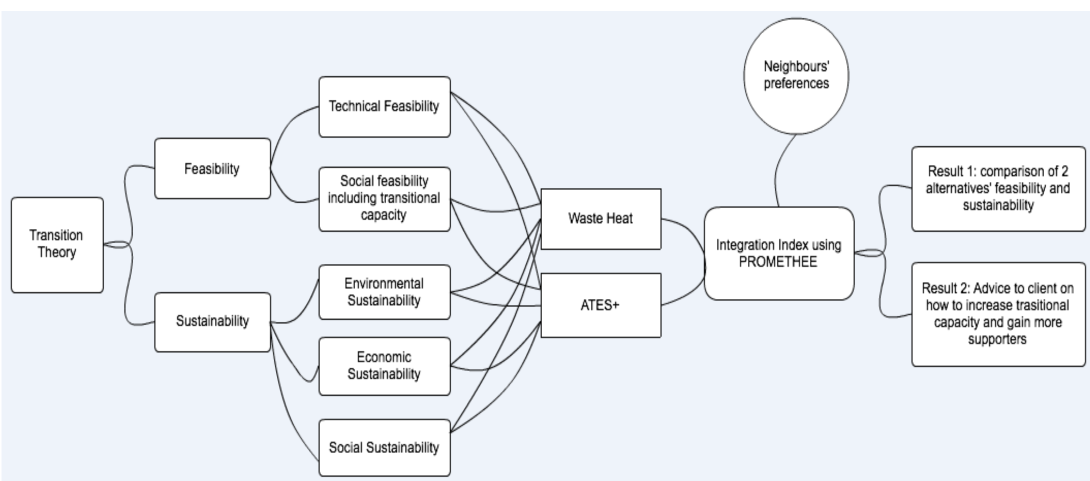


Figure xviii - Integration flow chart

The weights, scores, and standardized values of five criteria derived from surveys and the assessment are presented in table 25 and 26. The weight values determined by different respondent groups (initiative members and broader neighbourhood) and the separate criteria categories (feasibility and sustainability) are also shown here. For example, the total index for waste heat according to the initiative members (1.95) is the sum of all sub-indices of the five criteria (0.61+0.49+0.30+0.34+0.21). Each sub index is the product of the weight and the standardized value; for example the sub index of the technical feasibility of waste heat (according to the initiative members) is 0.61, calculated as: the criterion weight according to the initiative (0.70)*the standardized value of the technology's criterion value (0.88). Independent of the responding group, the first option (waste heat) is scoring higher on both feasibility and sustainability indices. The integrated end indices are also given in the stacked figure xix.

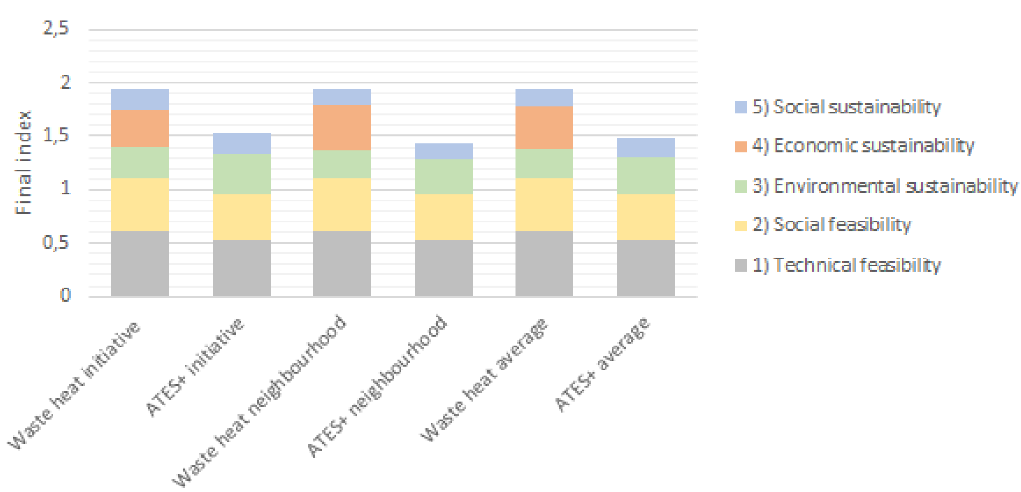
Table 25 - All weights and standardized criterion values and the calculated sub-indices.

	1) Technical Feasibility	2) Social feasibility	3) Environmental sustainability	4) Economic sustainability	5) Social sustainability
Weight initiative members	0.70	0.83	0.73	0.68	0.55
Weight neighbourhood	0.70	0.83	0.65	0.85	0.38
Average weight	0.70	0.83	0.69	0.76	0.46
Standardized score waste heat	0.88	0.60	0.75	0.50	0.38
Standardized score ATES+	0.81	0.53	0.43	0.00	0.38
Index waste heat initiative	0.61	0.49	0.30	0,34	0,21
Index ATES+ initiative	0.53	0.44	0.36	0.00	0.21
Index waste heat neighbourhood	0.61	0.49	0.27	0.43	0.14
Index ATES+ neighbourhood	0.53	0.44	0.33	0.00	0.14
Average index waste heat	0.61	0.49	0.29	0.38	0.17
Average index ATES+	0.53	0.44	0.34	0.00	0.17

Table 26 - The final indices, subdivided into feasibility and sustainability

	FEASIBILITY	SUSTAINABILITY	TOTAL INDEX
INDEX WASTE HEAT INITIATIVE	1.10	0.85	**1.95**
INDEX ATES+ FOR INITIATIVE	0.96	0.57	**1.53**
INDEX WASTE HEAT NEIGHBOURHOOD	1.10	0.84	**1.94**
INDEX ATES+ NEIGHBOURHOOD	0.96	0.47	**1.43**
AVERAGE INDEX WASTE HEAT	1.10	0.84	**1.95**
AVERAGE INDEX ATES+	0.96	0.52	**1.48**

Figure xix - Stacking graph with integrated results showing the final indices for both options on the different criteria for the two response groups.



Conclusion

Results of the assessment and the PROMETHEE analysis indicate that waste heat is a more feasible and sustainable heating solution for the neighbourhood of Maldenhof. On average, ATES+ scores better than waste heat on environmental sustainability, but waste heat scores slightly better in terms of technical and social feasibility, and much better in terms of economic sustainability. Both technologies score equally on social sustainability. The results of economic assessment contain substantial margins of error, especially for ATES+, due to highly limited cost data on ATES+ systems. However, it is certain that due to low energy efficiency, the houses in Maldenhof must be retrofitted (on varying scales depending on the state of each individual house) in order to be suitable for an ATES+ system. There are possibilities for reducing the costs of the waste heat system in order to improve annual cost savings when consuming heat from this system. Variables affecting cost factors include available subsidies, cost of purchasing waste heat from AMC, costs of renting grid system from NUON, and long-term commitment of households in the neighbourhood, which can help improve investor's confidence. Outcomes of these variables depend on the negotiations between involved parties.

This report recommends the Maldenhof initiative to investigate different venues to reduce the costs for transitioning into waste heat, and at the same time investigate decentralized solutions such as solar panels and hybrid heat pump (which can reduce gas consumption by 70%). Decentralized solutions may provide optimal tailor-made solutions for individual households.

Results of transitional capacity analysis show that the neighbourhood is generally positively minded towards sustainability. However, individual attitude toward sustainability issues associated with home heating and toward changes in energy infrastructure could be further improved to facilitate more forward thinking and stronger political will for energy transition. Individual attitude could be improved through sharing of sustainability related values. To do so, the Maldenhof initiative must further improves its organization and communication strategies. Analysis shows that 70% of non-initiative neighbours is not even aware that the initiative exists. This implies that communication and knowledge sharing beyond the initiative is suboptimal. Analysis also shows that communication and knowledge sharing among core members of the initiative is still limited. Moreover, the initiative could further strengthened its ties with other actors in the niche, including the municipality of Amsterdam and expert communities in sustainable energy in order to gain more knowledge and leverage on emerging opportunities. Finally, it is important that the initiative maintains unity and makes decisive actions following the result of this study. Transitioning into any form of sustainable heating solution requires effective communication and organization within the initiative and cooperation with the broader neighbourhood and local authorities.

Discussion

Conducting a multi-criteria analysis to compare two heating solutions for Maldenhof has been a complicated task. Despite the insights gained, the study entails some shortcomings and compromises as well. These are mainly methodological as well as related to data availability. Over the course of this study, indicators for each criterion have been averaged. This however bears the risk of introducing bias in the final results. The same holds true for the averaged answers given by the neighbours on similar questions. The response rate was equally rather small in the broader neighbourhood, which requires further investigation. Finally, the scale from 1 to 5 employed to assess all criteria can entail bias, in that it does not represent an ordinal scale. All calculations are in parts based on assumptions which brings along certain risk of errors as well.

Regarding the two technologies compared, at the beginning of the project there was great enthusiasm for especially the ATES+ solution as potentially more sustainable than waste heat, especially because the client indicated skepticism towards waste heat. With the present findings however, it becomes questionable whether this technology lends itself as a more feasible and sustainable alternative to waste heat. There are some limitations regarding the scale envisioned: as shown, investment in new infrastructure would be expensive for both alternatives, and both investor and neighbourhood will bear financial risks taking on such a project. Furthermore it is uncertain among experts whether ATES+ is more suited to insulated or new houses.

Our findings also have implications for neighbourhood initiative driven transitions more generally. The neighbourhood of Maldenhof is not extremely wealthy and as such exemplary for many regions in the Netherlands. There is a positive attitude towards sustainable energy among many respondents of the surveys: many neighbours have mentioned that they already use solar panels, are planning to use solar panels or are getting electricity from a green provider. However, budget constraints play an important role in the choice of heating system. Although a group of 25 motivated citizens seems a rather high number, it does not represent a feasible amount to undertake larger infrastructure projects especially when the price of energy plays a crucial role. A more in-depth study of the demographics of the whole neighbourhood would underpin this assumption with better facts. More structured political mechanism of support and a spreading of the investment risks for such initiatives would be necessary and desirable if technological niche-based transition to more sustainable energy is actually to be achieved.

Finally, the results favour waste heat as sustainable and feasible heating option, but this option and the related decision making process have been criticized by many initiative members. Larger infrastructure projects always require third party cooperation but in the case of Maldenhof this cooperation has not been satisfactory. To still improve the neighbourhoods sustainability, perhaps the initiative should shift focus toward more decentralized solutions, as these already enjoy great popularity within the neighbourhood.

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Annexes

Annex I: Maldenhof inhabitants 01-01-2015

Table 1 presents the demographic data of Maldenhof

Age	**Sex**					
Age	**Male**	**Female**	**Total**	**%**		
0-4	12	20	32	3 %	21 %	0-19 years
5-9	30	26	56	6 %		
10-14	29	20	49	5 %		
15-19	38	27	65	7 %		
20-24	32	26	58	6 %	12 %	20-29 years
25-29	44	18	62	6 %		
30-34	21	22	43	4 %	8 %	30-39 years
35-39	22	20	42	4 %		
40-44	22	25	47	5 %	9 %	40-49 years
45-49	21	22	43	4 %		
50-54	28	43	71	7 %	15 %	50-59 years
55-59	36	47	83	8 %		
60-64	48	67	115	12 %	22 %	60-69 years
65-69	53	47	100	10 %		
70-74	37	37	74	7 %	10 %	70-79 years
75-79	17	12	29	3 %		
80-84	9	10	19	2 %	3 %	80+ years
85+	5	5	10	1 %		
Total	504	494	998	100 %		

Annex II: Questionnaires

a) Questionnaire to the initiative members

Wie zijn we? Wat doen we? En waarom is het invullen van deze enquête van belang?
Wij zijn zes studenten van de Universiteit van Utrecht en zitten in het tweede jaar van de master in Duurzame Ontwikkeling. We komen van verschillende disciplines en zijn voor een vak in contact gebracht met Anne Stijkel om jullie te adviseren in een besluit over een eventueel centraal georganiseerd verwarmingssysteem in de buurt Maldenhof.

In ons onderzoek zullen we twee opties voor een centraal georganiseerd verwarmingssysteem met elkaar vergelijken aan de hand van verschillende criteria. Hiervan heeft Anne jullie al op de hoogte gebracht als het goed is. Door middel van deze enquête proberen wij een beeld te krijgen van welke criteria als meest belangrijk worden beschouwd door de buurt. Daarbij proberen wij een duidelijk beeld te krijgen van de relaties en interacties tussen buurtbewoners, om de sociale haalbaarheid te analyseren.

Kortom, uw antwoorden en meningen zijn enorm waardevol voor ons onderzoek en helpen ons Maldenhof een goed, weloverwogen advies te geven. Alvast bedankt voor uw tijd en moeite!

Deel 1: Schaalvragen

Het eerste onderdeel bestaat uit een aantal schaalvragen. De schaal loopt van 1 tot 5. Waarin:

1: Totaal niet belangrijk
2: Niet belangrijk
3: Neutraal
4: Belangrijk
5: Heel erg belangrijk

1. In welke mate is de hoogte van de vaste kosten van belang in uw keuze voor een bepaald verwarmingssysteem? (Met vaste kosten wordt bedoeld: de kosten die niet voortkomen uit energieverbruik.)

2. In welke mate is de hoogte van de variabele kosten van belang in uw keuze voor een bepaald verwarmingssysteem? (Met variabele kosten wordt bedoeld: de kosten die voortkomen uit energieverbruik.)

3. In welke mate is het reduceren van CO_2 emissies van belang in uw keuze voor een bepaald verwarmingssysteem?

4. In welke mate is de impact op het lokale milieu (bijvoorbeeld de flora & fauna en de lokale waterkwaliteit) van belang in uw keuze voor een bepaald verwarmingssysteem?

5. De aanleg van een nieuwe energie-infrastructuur kan voor tijdelijke hinder zorgen, in welke mate is dit van belang in uw keuze voor een bepaald verwarmingssysteem?

6. Hoe belangrijk is het voor u om makkelijk te kunnen wisselen van verwarmingssysteem?

7. In welke mate is het van belang dat een eventueel nieuw systeem een doorontwikkelde en bewezen technologie is in uw keuze voor een bepaald verwarmingssysteem?

Deel 2: Persoonlijke houding

Dit onderdeel bestaat uit vragen over uw persoonlijke houding ten opzichte van duurzaamheid.

8. In de winkel kies ik altijd voor de meest duurzame optie van een product (biologisch, lokaal geproduceerd of gerecycled). (1-5)

9. Ik heb geïnvesteerd in duurzame energie oplossingen in mijn huis (zoals zonnepanelen). (ja/nee)

10. Ik ben erg tevreden met de investering(en) in duurzame energie oplossingen in mijn huis. (1-5)

11. Ik ben van plan om te investeren in duurzame energie oplossingen in mijn huis.

Deel 3: Buurtnetwerk & Interactie

In dit onderdeel proberen we een duidelijk beeld te krijgen van hoe het onderwerp leeft in de wijk. In de vragen wordt regelmatig gerefereerd naar een initiatief, hiermee bedoelen wij het initiatief 'Slim Wonen Gaasperdam'. Verder bestaat dit onderdeel weer uit een aantal schaalvragen. De schaal loopt van 1 tot 5. Waarin:

1: Helemaal niet mee eens
2: Niet mee eens
3: Neutraal
4: Mee eens
5: Volledig mee eens

12. Ik ben goed op de hoogte van de verschillende opties voor een buurt georganiseerd duurzaam warmte systeem.

13. Ik ben erg tevreden over de huidige besluitvormingsprocessen voor een eventueel buurt georganiseerd duurzaam warmte systeem.

14. Er is voldoende sociale cohesie in de buurt Maldenhof om een dergelijk initiatief tot een succes te maken.

15. Mijn voorkeur gaat uit naar een onafhankelijke, zelfstandige duurzame oplossing voor een warmte systeem.

16. Ik vind het leuk om met een groep na te denken over het verduurzamen van onze wijk.

17. Ik heb met andere buurtbewoners, die nog niet betrokken zijn bij het initiatief, gesproken over onze plannen en ideeën over een eventueel buurt georganiseerd duurzaam warmte systeem.

18. Ik ben door andere buurtbewoners benaderd, die nog niet betrokken zijn bij dit initiatief, met vragen over dit initiatief.

19. Ik ben door andere buurtbewoners benaderd, die nog niet betrokken zijn bij dit initiatief, over andere duurzame oplossingen die ik in mijn eigen huis toepas.

20. De meeste mensen waarmee ik intensief contact heb in de buurt, zijn onderdeel van dit buurtinitiatief.
21. Ik denk dat het politieke klimaat gunstig is voor het implementeren van een buurt georganiseerd duurzaam warmte systeem.

22. Wanneer ik overtuigd ben van het potentieel succes van een dergelijk buurt georganiseerd duurzaam warmtesysteem, ga ik mijn best doen om andere buurtbewoners te overtuigen om ook deel te nemen.

23. Ik denk dat veel van mijn buren milieubewust denken en handelen.

24. Ik zou willen dat er meer politieke steun was voor dergelijke initiatieven voor buurt georganiseerde duurzame warmtesystemen.

25. Ik ken niet veel mensen uit de buurt, buiten de 25 geïnteresseerden in dit duurzaam buurtinitiatief.

26. Geslacht: Man/Vrouw

27. Leeftijdscategorie: 0 - 20 jaar, 21 - 40 jaar, 41 - 60 jaar, 60 +

28. Huishoudentype: Alleenstaand, Paar zonder kinderen, Paar met kinderen, Een-oudergezin

29. Bent u verantwoordelijk voor het betalen van de energierekening? Ja/Nee

Deel 4: Algemene informatie

Het laatste onderdeel bestaat uit wat algemene vragen over uw woonsituatie en dergelijke.

b) Questionnaire broader neighbourhood

1. Heeft u al eens gehoord van het initiatief BUURTzoektWARMTE? Of een ander buurtinitiatief dat zich richt op duurzaamheid (zoals zonnepanelen)?

2. Heeft u ooit gehoord van politieke initiatieven voor het verduurzamen van de energie voorziening voor centrale verwarming(hier in Amsterdam)?

3. Zou u graag meer te weten komen over dergelijke initiatieven?

4. Heeft u ooit informatie gezocht over hoe je duurzame energie kunt verkrijgen?

5. Would you be willing to pay a little more each month if you knew your heating was sustainably generated?

En nu wat vragen over uw eigen energie rekening en keuze voor een bepaald verwarmingssysteem. Stelt u zich voor, u kon opnieuw een keuze maken voor een geavanceerd energie systeem; waarop baseerd u uw keuze?

6. In welke mate is de hoogte van de vaste kosten van belang in uw keuze voor een bepaald verwarmingssysteem? (Met vaste kosten wordt bedoeld: de kosten die niet voortkomen uit energieverbruik.)
7. In welke mate is de hoogte van de variabele kosten van belang in uw keuze voor een bepaald verwarmingssysteem? (Met variabele kosten wordt bedoeld: de kosten die voortkomen uit energieverbruik.)

8. In welke mate is de impact op het lokale milieu (bijvoorbeeld de flora & fauna en de lokale waterkwaliteit) van belang in uw keuze voor een bepaald verwarmingssysteem?

9. De aanleg van een nieuwe energie-infrastructuur kan voor tijdelijke hinder zorgen, in welke mate is dit van belang in uw keuze voor een bepaald verwarmingssysteem?

Annex III: Conducted interviews

Overview of the conducted Interviews

No.	Date	Location	Name of interview	Company/ Organization	Position
a	12-oct-2015	Arnhem	Hans Biemond	If Technology	Specialist in ATES+
b	15-oct-2015	Amsterdam	Stefan Mol	Waternet	Researcher
			Otto Reinstra	Waternet	Researcher
			Maarten Ouboter	Waternet	Researcher
b.1	15-oct-2015	Amsterdam	Anne Stijkel	Maldenhof	Resident
c	16-oct-2015	Amsterdam	Niels van Alphen	Techneco	Specialist in heat pump; technology
d	19-Oct-2015	E-mail	Machiel Bakema	Alliander	Technical consultant
e	20-Oct-2015	Amsterdam	Shira Hollanders	Alliander	Heat Product Developer
f	22-Oct-2015	Amsterdam	Teun Koelemij	Municipality Amsterdam	Civil servant
g	28-Oct-2015	Email	Stefan Mol	Waternet	Energy specialist
h	02-Nov-2015	Email	Hans Biemond	IF Technology	Energy Specialist

a) Interview Biemond, 2015 (IF Technology)

Interview on October 12th, 2015 by: Hà, T. & Huizen, van M.
Followed by Email conversation on November 2nd, 2015 by Hà. T.
Short description of IF Technology:

IF Technology operates as an engineering company with main activities focusing on technical design, operation, maintenance and monitoring of ATES systems, surface water systems and geothermal systems. IF technology started 25 years ago with designing ATES systems and were involved in the first large scale ATES projects in the Netherlands, for example the ATES system for the hospital in Gouda.

- **How operates an ATES system?**

Thermal energy is stored in an aquifer system to conserve it and utilize it during times when it is really necessary. Storaging energy prevents waste of energy. One of the problems of ATES application in residential buildings is that there is disbalance in heat and cold demand. Raising or dropping soil temperature significantly is illegal and therefore a balance between heat and cold in the soil is required. For residential houses heating demand is five times higher than cooling demand. Therefore first ATES systems were only applied in utility buildings like offices or hospitals with a more balanced heating and cooling demand. By better insulating houses and application of floor heating ATES also become more suitable for residential buildings. In combination with a heat pump it is a reliable system. Regeneration of ATES with thermal energy from surface water have increased the reliability of the system. Surface water is almost everywhere in the Netherlands and stores a lot of potential energy. Thermal energy from surface can be regenerated at a high efficiency compare to other technologies, such as heat from the amposhere. Heat exchangers are used to exchange heat from surface water to the groundwater grid or directly to the houses whereby heat is further upgraded by a heat pump. A heat pump uses the principles of condensation and evaporation to upgrade thermal energy to a higher level via different fluid streams. Without a heat pump temperatures remain too low for heating purposes. Heat pump operates with the highest efficiency if temperature differences are small in the house. This requires for example heating systems, like floor or wall heating, that operate at a much lower temperature (35°C) than conventional heating panels.

- **What are the disadvantages of high temperature heating systems like waste heat?**

Waste heat requires expensive investments in infrastructure, whereby heat at a high temperature is transported to buildings that actually don't need that. AMC produces now waste heat because they are not able to use it in an efficient way, but if they are able to manage that properly within 20 years than the neighbourhood will have a problem if there is not sufficient supply. By making infrastructure for waste heat you actually say as a neighbourhood we want 'waste'. One of the largest waste heat networks in Amsterdam, called Westpoort Warmte, operates nowadays on waste heat that is produced by burning imported residential waste from London and Milano. This is because one of the waste heat producers has improved there system efficiency. Besides that most houses in Westpoort Warmte has become more efficient by insulation measures and implementation of floor heating. All-in all this means that this high temperature grid is actually not necessary anymore. This project also shows that waste heat loses a lot of energy in the grid; it was estimated that almost 50 percent of the heat is lost in the subsoil.

- **What are the possibilities for ATES application in Maldenhof?**

ATES is possible if there is a low temperature heating system in the house, like floor heating. Conventional heating panels cannot operate efficiently with this type of system. This needs be replaced first which can be a disadvantage. On the other hand there is a lot of surface water available in the neighbourhood, for example Gaasperplas or the canals. By ATES application water flow in the canals will be activated which is beneficial for the water quality. This prevents for example botulism, whereby upper water layers lose a lot of oxygen content.

Amsterdam has a excellent subsoil, one of the best in the world, for application of ATES. The heat storing properties are really good of this subsoil. Beside that there are no other operating ATES near Maldenhof which can intervene with a new ATES system in Maldenhof. Thermal interference of ATES could reduce efficiency, but this won't be an issue in this neigbourhoud since there is plenty of space for that. Overall, it's one of the best location to implement an ATES system because of the excelllent soil properties and the large availability of surface water. It's possible to extract and infiltrate water from this specific aquifer up to 250 m^3/hour.

- **What are the costs for an ATES system?**

This will cost around 200000 euros for the groundwater system alone, assuming a thermal power availability of 2.3 MW , a temperature differential of 8 degrees between wells and a normal house that can be heated with 5 kW, approximately 464 households can be heated. This is a very rough estimation because this only includes heating for houses, not showering. The number of households that potentially can be heated will reduce if we include that. Connecting with surface water requires an additional investment of around 250000 euros. Total investments costs for heat pumps depend on the amount of connected households, more connected households means cheaper heat pumps. Pipes for the ATES system are relatively cheap since well-insulated pipes are not necessary because of the low temperature of the water. Compare to waste heat which require expensive isolated pipes its more beneficial in terms of costs.

- **What other advices do you have to make ATES+ application succesfull in Maldenhof?**

-Investigate what Waternet is doing with water quality, maybe they have an incentive to join in this project because it also have benefits for them if there is some water quality improvement. Hans gave us the contact of Stefan Mol from Waternet.
- Contact a private energy service company (ESCO) like ETECK, one the biggest in the Netherlands. ETECK is focusing on the whole picture, not only on the infrastructural investments but also how to organize a fair price with the neighbourhood. Without a energy service company ATES+ can't be operated efficiently. It requires some expert knowledge for operation.
- Contact Greenspread for more information about currently operating ATES+ projects for residential areas. For example the project Ouverture in Goes.

b) Interview Mol, Reinstra, Oubouter, 2015 (Waternet)

Interview on October 15th, 2015 by: Hà, T., Land, P., Weerts, K. & Huizen, van M.
Short description of the participants:

Otto Reinstra: Strategic is invited to provide the perspective of Waternet to facilitate sustainable development and has knowledge to explain about Waternet as an investor in energy systems.

Maarten Ouboter: Focusses on system analysis and practical water management. He can help to give an idea of what permits are necessary.

Stefan Mol: Is a researcher at Waternet and has a lot of knowledge with regards to plans and experience with ATES+ systems

What is the actual case, what is the energy demand?

Average demand is 1500 cubic meter per household per year in Maldenhof (10-20 gigajoules) Maximum: 300 households, which would mean an average demand of 6000 gigajoules for the whole neighbourhood per year.

Comparable to another case: Diemen de Sniep. There is a generated ATES+ system, with approximately 200 cubic meter per hour in summer, which would also be necessary for Maldenhof so let's assume it's the same. In that case we will extract, 200 cubic meters per hour for 3 months and exchange it through a heat exchanger. We try to take it out of the lake at the highest temperature possible, which is approximately 20-21 degrees, and pump it back at 10 maybe 12 degrees. It however would be better if we could lower this even further back to 6 degrees. Pumping back water with a higher temperatures can be dangerous for the ecosystem of the lake because a lot of nutrients gather in the lower layers of the lake, but we will pump them back in the top layer which could lead to a higher production in the lake (like algae) which is not desirable.

At the Gaasperplas we would extract water from the top layer, and by doing so we have to be very sure not to make the system flip so it becomes unstable as it is also a recreational area. This demand of energy will however not flip the whole system. What is possible is that when you bring it back at a temperature of the intermediate layer between the top layer and the lower layer, the stable stratification is disturbed. So from a more double layered system so you would get a more continuous change in temperature over depth. But as said before, due to the low energy demand this is very unlikely to happen. We should however take into consideration how this interferes with the nutrients in the lake. This is quite complex and also very new as it has not been done before in an area that is under the supervision of Waternet. Interfering with Gaasperplas, which is one of the good lakes, with a stable water quality and a lot of recreation can be risky as a lot is at stake.

Another option would be to take the surface water from the surrounding canals, and not from the Gaasperplas. If you take it from the canals, this is an opportunity to improve their water quality as you will be pumping it from one place to another. These canals are often neglected.

Would this be economically more interesting than for example take it from the drinking water?

Depends: it has plusses and minuses:

- When using drinking water you need a double wall heat exchanger, which is expensive.
- If you take it from the surface water, you also need a heat exchanger but also need to do some effort to keep it clean. You probably need some salt electrodes system and use a little chlorine to prevent the growth of algae and biofills. If you do it well, it is claimed there is no effect. But Waternet is scared that it will have an effect, and they will always see this is a risk. However, this system is actually already used for quite some canals and lakes, but Waternet would prefer not to. 'We need to be convinced'. Taking heat from a surface water might be cheaper as an investment, however less worthwhile investing for waternet in the case of the Gaasperplas;

If there are no benefits is Waternet also interested in investing in energy?

Back to the case study in Diemen. The implementation of the ATES+ systems start now and they should be running before next summer. The conceptual design is done by Waternet and another company does the installation. Their partner is ENECO who wants to buy all generated energy. The project was started 7 years ago, but quiet for about 5 years because of the financial crisis. Another important feature of this project is that the houses are newly built.

What are the chances for implementing this in an already existing neighbourhood?

It will be more difficult as the system that you are helping with an ATES+ system is a low temperature system. So instead of receiving water through your radiators at a degree of 60 degrees, you now receive water of 35 degrees. The capacity of your radiators will however not change, so your house needs to be well insulated otherwise your house will be cold in winter. So there are three options to make such a system work for Maldenhof:

- Houses need to be insulated well.
- They need to invest either in another heating system or in better radiators; there are high performance radiators on the market nowadays.
- Put a heat pump in your house to higher the temperature to 55-60 degrees.

People have already invested in a system, because it is an already existing neighbourhood, which would make this a long term project.

In an ATES+ system, you would have a district heating network, which is not run by the free market anymore as there is only one owner of that network. Waternets role in the implementation would be to grant a permit. Energy companies can use the heat without any charge and sell it to their customers which they like to have their customers bound in a long term contract. A critical not is that: This is an already existing neighbourhood, which is connected to gas, you cannot oblige them to connect to that network and without that obligation… the establishment of such a system can be very hard. Neighbours can come up with their own idea for a contract and then it is upto the energy company to decide whether to invest in it or not. People in the neighbourhood do not want to be bound for such a long time, this makes it difficult because such an investment you do for a period of 30-50 years. This is a big difference, which can be hard to overcome.

In the Netherlands these energy providers are all privatised, which makes them not so willing to invest in long term projects. ENECO, in the case of Diemen has already indicated that this is the last time they will invest in such a project, because they learned from this crisis. The risk of investing and nobody is living there is just too big. So the market is failing at the moment, it would be good if we have a public energy company again that has the guts to invest in such projects.

That brings us to the question whether Waternet can play a role in this?

No, because we are not an energy company, we are a public company and we cannot just choose a different type of business. But; there is an opportunity because there can be energy taken out of water, with which we can help society. Therefore we are actually interested in the implementation of ATES+ systems. We are looking for opportunities to cooperate with other parties, to start maybe a public system but we don't have any concrete plans. But for us to invest in it is really difficult because of legal obstructions. As a water company we are on a special tax regime, which we would jeopardize if we would step into another market. We are interested in partnerships. Public investors that you are interested in would be more parties like Alliander.

If Alliander decides to implement an ATES+ system they would need permission from one of Waternet's boards. If you start with a good idea and explain there is a mutual benefit; it can be organised. It should however not conflict with the water quality of the lake, if it does we try our best to prevent the implementation. For the Ouderkerkerplas project where we cooperate with NUON, we received 1 million euro subsidy to do research for a period of 6 years. For the Gaasperplas, another study like this would be necessary. If we think it is a good idea, we would like to help with the application for subsidy. The opportunity of using the canals would be really good to investigate and could also become an example for other canals. This increases the chances of receiving subsidy! Generally the Province is responsible for the ground water. But in this case, waternet is also concerned with ground water so Waternet would also be dealing with the shallow ground water.

b.1) Interview with Stijkel, Anne October

Interview on October 15th, 2015 by: Ha, T.,

Q: What is the average cost of a gas boiler the neighbours typically pay for?

A: A gas boiler costs from 1,200 to 1,800 euros. The average is 1,500 euros.

Q: Does the gas boiler require maintenance work and how much does it cost annually for maintenance?

A: Gas boiler should be maintained annually. The average cost for maintenance is 100 euros per year.

Q: What is the average lifespan of a gas boiler?

A: A gas boiler typically lasts from 12 to 15 years.

c) Interview Van Alphen, 2015 (Techneco)

Interview on October 19th, 2015 by: Hà, T., Huizen, van M. & Oever, van den I.

Q: What is the capacity and the price of heat pump typically use for the ATES+ system?

A: The pump used for the ATES+ has a capacity of 12kWh and typically costs from 5,000 to 7,000 euros. However this only works if the houses have high levels of energy efficiency.

Q. The houses in Maldenhof have energy label rating of C, does the ATES+ system work with these houses if the heat pumps are also use?

A: Houses with energy label of C are not suitable for the ATES+ system because the energy efficiency is too low. If using a heat pump, the lifespan of the heat pump will be reduced significantly. For this type of house, a hybrid heat pump is more suitable. Hybrid heat pump is used with the existing gas system, but it can reduce gas consumption by 70%. This solution is flexible and can be adapted to the needs of individual houses.

d) Interview Bakema, 2015 (Alliander)

Structured interview through e-mail on technical questions considering the waste heat network, with Bakema, M., an employee of Alliander who is involved in the project at Maldenhof. Interview is translated from Dutch. Unanswered questions are left out.
Interview on October 19th, 2015 by: Berg, van den C. & Oever, van den I.

1. ***Construction of the heat network:***

- *What is the depth of the underground pipe network?*
  80-100 cm.

- *What is the length of the underground pipe network?*
  3200 meters for 425 households, excluding connecting pipes.

- *How will the households be connected?*
  By means of a delivery kit that converts waste heat water into heating water and hot tap water.

- *What type of materials are used for the pipes?*
  ST/PUR/PE.

- *In the business model made by Alliander, was the already existing underground pipe network taken into account, or was a complete new heat network presumed?*
  A part of the length is included to make the connection, but how this is done exactly is not yet determined.

- *How long does it take to construct the complete waste heat network?*
  The implementation phase takes 26 weeks.

2. **The flexibility of the system:**

- *What kind of adaptations are required in the homes?*
  Removal of the boiler, hanging of the delivery kit, connection to the current pipelines (mainly in the crawl space) and calibration of the heating system.

- *How will households be treated if they want to disconnect from the new heat network?*
  To be determined.

- *Could the system also be used for the heat network of minister Kamps, or even for another heat technology like geothermal energy in the future?*
  Yes, that is exactly the intention for the future. In principal every source of 70^{o}C is suitable.

3. **The security of supply:**

- *What is the chance that waste heat will not be delivered?*
  A backup system of gas fired (peak) boilers will be installed to guarantee the security of supply.

4. **Environmental impact:**

- *Are there any effects on the water quality? If so, what are the differences between waste heat and the conventional boiler technology?*
  No significant differences.

- *What is the impact on for example: flora and fauna, noise pollution, the landscape?*
  The implementation phase of the system is 26 weeks, which will lead to some disturbance in the area.

- *What is the amount of carbon dioxide emissions during the construction of the waste heat system? Like: generators at the constructions site, or the required energy for construction?*
  Compared to CO2 savings during the use phase (which could last a hundred years with proper maintenance and management) these amounts are negligible. You might be able to find more information at the producers of certain systems (www.logstor.com).

e) Interview Hollanders, 2015 (Alliander)

Interview on October 20th, 2015 by: Hà, T

Q: Is 100 households the minimum number required to make the investment viable? If not, what is the number?

A: Yes

Q: Does the investment costs cover waste heat cost (that Alliander purchases from AMC) and annual maintenance costs? Or only the grid infrastructure? Will Alliander pay for the upfront investment and then recover this investment through energy bills to consumers?

A: Investment costs cover expenses for installation at the source, and the grid infrastructure in Maldenhof (including connection to individual property). It is not certain whether Alliander will pay for all the investment upfront. This depends on financing possibilities. Alliander does not sell energy directly to consumers. An energy company must be engaged to take this role. Alliander will provide and operate the grid network.

Q: So Alliander will sign a contract with this energy corporation and earn profit from renting out heat grid? What does Alliander typically earn as a grid operator?

A: Yes, Alliander will sign a contract with this energy corporation. Alliander's transportation earning is typically per household. We have no reference for a project like Maldenhof so it is hard to give you a tarAgeted transportation earning per household that makes sense. However, I have done my research and for this project I can give you an estimation of where the money from the households (after tax) goes to:

- 15-20% for the use of the NUON transport pipe from AMC to Maldenhof plus making the heat available for district heating (still don't know the proper word for it, google translate doesn't know it eather). The transport fee to NUON is included in the number at B4 in 'Inkoop Warmte' in the Excel sheet.
- 25-35% for the heat supplier. This includes buying heat from the AMC as buying gas to provide for the peak in heat demand, administration (billing) and profit.
- 50-55% for the grid operator. This includes earnings for investing in back-up power (gas heaters for the peak), infrastructure in Maldenhof, net management and maintenance and profit.

Q: Can you elaborate more on NUON and the role NUON would play?

A: NUON is heat supplier, grid operator and heat producer and owns a district-heating grid near Maldenhof, see the red line in the picture below. The investment of Alliander is the 'uitkoppelingsinstallatie' (I have a better word in English: heat exchanger) at AMC, plus the grid in Maldenhof itself. In this setting, we would use the pipe of NUON that is already there and pay a fee for it. It would not make any sense that Alliander would build a second pipe from AMC to Maldenhof, and it would not be financial feasible.

Q: Will Alliander or the energy corporation sign a contract with NUON?

A: The energy corporation.

Q: Are there any subsidies available for this type of project and what are the forms of these subsidies?

A: Subsidies available are with the EFRO program, they can take the form of subsidies for investment and/or lower interest or government guarantee (if the project fails, the government cover the costs for the project), but these are only possibilities.

Q: In the business case, the assumption made is that a household now pays 65 cents per m3 of natural gas. Is it the average price that the residents in Maldenhof have been paying or is based on national average? Does this price already include energy taxes, delivery price, national transport and regional charges and BTW (tax)?

A: Yes it's what the residents in Maldenhof have been paying (but I am sure that's more or less equal to the national average). This price already includes energy taxes, and regional charges and BTW (tax) yes but not delivery price and, national transport.

f) Interview Koelemeij, 2015 Municipality Amsterdam

Summary of most important questions with regard to the political background and the role that the Amsterdam municipality can play in here and about possible implications during other projects. Interview on October 22th, 2015 by: Land, P., Oever, van den I. & Weerts, K.

Introduction of two technical options under study.

- Question: Maldenhof is not one of the seven "Referentiegebieden"?
  Answer: From what he knows, it is not, but we can look online.

- Q: Is it thus easier to get permission for the construction of any kind of infrastructure in the ground?
  A: Yes and now. It only means that in this area it is less likely that a similar system already exists. But for an open heat cold exchanger system it is necessary to get permission from the province authority, not the municipality. Doesn't know if it's harder or easier.

- Q: but this is about water, right?
  A : it is about how much groundwater you might be using. Mutual benefit is not necessary as long as it does not harm the lake.

- Q: there are also canals in the area, what are the regulations applying to this?
  A: not sure, but there are definitely laws. About the little ditches, it could be easier to use them. Potentially it is allowed, cause those are much smaller, but we'd have to figure out whether they are connected to the lake. The Stadsdeel also has a say for works in public spaces.

- Q: The Oudekerkplas has received a lot of funds for research, who did this come from?
  A: Possibly EFRO.

- Q: What about other subsidies?
  A: They have been given, but not sure. He himself is working for the Jaap Edebaan, to get funding for this project. There is no Stadswarmtenet, but around the AMC there is already one from NUON, but this then has to be done via NUON, they have to be on board as well. NUON would like to buy the heat and sell it again. But of course they set their own tariffs. This causes the big search, and raises the question how sustainable the heat of AMC is.

- Q: You would actually well isolated houses, but this is not the case in Maldenhof. What about subsidies for isolation works? Does this take place in Amsterdam?
  A: There used to be a subsidy for homeowner, as partial subsidy and partial loan for a good condition. At the moment the municipality is working out how to continue this project. But now there is nothing. But within a year there should be something. But it is a legitimacy and bidget problem, the question is why would you give money away? It will at least take until next summer until the municipality council to decide on this. But for now there are only loans.

- Q: Are we missing anything in our research, what is important?

A: A reason of worry is how many people are actually involved and how much would they invest? Cause you need at least 80% of the community to join. But in the end the question is if it's more or less expensive. But you really need a concrete offer.

- Q: So how did you convince people in your roject to join? Is it mandatory?
  A: At a certain point there is a contract, and then people can join. At Jaap Ede Baan, the group still needs to grow

- Q: What are you exactly doing to support them?
  A: We are looking into subsidies from EFRO. And the stadsdeel does the publicity and networking.

- Q: Can your experience help for other projects?
  A: Yes of course!

- Q: How do you think the odds are for this project (Jaap-Ede-baan?) to come true?
  A: It changes all the time. It is difficult to make those projects come true, it needs a lot of dedication. The relation with NUON in this case is until now non-existent as there is no NUON network in that neighbourhood. Alliander is in both cases the initiative taker.

- Q: Are there any other options than NUON?
  A: Around Jaap Ede baan there is no Warmth network, but around Maldenhof there is already infrastructure of the larger warmth network. There is no real way around NUON in this sense.

- Q: How are you getting EFRO, what is a good reason get EFRO?
  A: It contributes to a more sustainable city and to community building. The initiative can also apply for EFRO without the municipality, but they can also become partner and d some of the work to make a subsidy plan. The chances are high that the municipality will help, technically for both options. But it depends on what the municipality really has to do and how much time and money needs to be invested in this.

- Q: How much money is at stake for this?
  A: about 1,5 million, but this is not an exact number.

- Q: Are there any other policies that could be relevant?
  A: The water quality is important. For ATES+, but aside no special policies. There would not be much hindrance, other than for a second heat network next to the pipes that already existed. But a different network from the Gaasperplas would be possible.
  -Before 2017, there is no definite decision on the future of heat networks to be expected, but it is under discussion.
    - There are no other environmental impacts to be expected, Maldenhof seems to be pretty well suited.

g) Interview with Mol, Stefen

Email interview on October 28th, 2015 by: Ha, T.

Q: In the regeneration project by Waternet what is the unit price per GJ that customers of this system is paying? What are the terms of their contract with the energy company? Are there any other upfront investment the customers have to pay (i.e. insulation cost for the house, cost for heat pump, cost for individual pipeline connection, etc...), and what is total investment and annual operation and maintenance cost the investor (energy corporation?) has to pay?
A: I have a cost calculation on the regeneration of the ATES system, and tariffs from 2012. I do not have insight in the current energy contract that Eneco has with the house owners. You could ask for this at Eneco or at one of the owners. Or maybe it is available on the internet? For sure you will find information on the 'warmtewet', the heat law that protects customers from too high heat prices.

I also found a report by Monica Sommers. On page 32 she claims that the houses in this project cost about € 10.000,- more than traditional houses, due to the sustainable energy system.
Q: What is the diameter of the pipe typically used for the ATES system? And what is the unit price of the pipe?
A: The diameter of the pipe depends on the water flow which depends on the total energy demand. This type of pipe costs 1 euro per mm per 1m (1m of 1mm pipe costs 1 euros)

h) Interview with Biemond, Hans

Q: A while back we met with a heat pump supplier: he told us that the type of heat pump used for ATES should have a capacity of 12kW - this type of pump costs 5,000 to 7,000 euros. Do you know if this information is correct? Do you know what is the type and diameter of the pipes used to transfer the water to the houses (both the pipe for the main grid and the pipe for connecting each individual houses to the grid)? What is the capacity of the source pumps for a combined ATES system and how many hours do the pumps operate per year.

A: The heatpump needed for a household depends mainly on the level of building insulation and the warm water consumption needed. This could be much less than 12 kW for a modern house too. A widely used heatpump like this is produced from 6kW heating capacity. A price of 5-7 k€ for a heat pump seems right to me although when bought and installed in larger quantities I guess it can be cheaper.

Assuming the average house needs 10 kW of heat at peak demand and the COP = 3,5. This means the heat demand on the evaporator side is 7,14 kW. When the dT between the hot/cold distribution grid is 10 K, the water flow needed is 0,62 m^3/h. This can be done with a tiny (uninsulated!) 12mm inner diameter connection (max flow speed 2 m/s).

When you want to do an estimation of the cumulative capacity needed you can assume for example a maximum capacity for 1 household of 0,7 m^3/h. Because there will never be the situation that all households connected demand at maximum you can introduce a simultaneity factor, for example 80%. In that case the netto household demand is ± 0,55 m^3/h (q_h).

For the size of the distribution grid it is a simple matter of the number of households connected times q_h=total flow needed (q_t).
Then in order to know the size of pipe needed you have to calculate the flow speed and inner diameter needed.
For example when you connect 80 households. The q_t will be 0,55*80=44 m^3/h. This means (in commercially available HDPE piping) you need a 110 mm pipe (SDR 17 HDPE) which will give a maximum flow speed of 1,66 m/s.

Q: As for the main pipe grid, if we need to connect 300 households (with average gas demand of 1,450m3 per year, equivalent to 45.9 GJ), how big should the diameter of the pipe is?

A: For the grid distribution size the annual gas demand and energy consumption does not matter. It's the actual power demand which determines the flow. In case of 300 houses it's simply multiplying my example.
So 0,55*300=165 m^3/h total flow. So the main pipes to the ATES system will be 200mm size (SDR 17 HDPE pipe).

Annex IV: Group discussion

Translation of the guideline of the group discussion (held in Dutch)
Discussion on October 10th, 2015 by: Land, P., & Weerts, K.

- **Guideline**

Three aspects of transitional capacity:
1. Personal attitudes towards sustainability and transitions: knowledge, interest, preference for independence or cooperation.

2. Organizational structure: Network, interaction, knowledge transfer, communication channels and practices

3. Legal situation: support of local authorities (and knowledge thereof), clear guidelines, or messiness? Perception of institutional support frameworks or their absence.
Introduction:

Hello everyone, thank you very much for participating in this group discussion. It's great help for us so we better understand the situation and can shape our research better. First we will introduce our research topic, although you might already know it, cause in fact, you are the research topic. We want to find out which sustainable heating solution there are for your area, Maldenhof, and specifically for the group of the 25 people who were interested. We are looking into technical and practical aspects like costs, but we also want to find out which legal barriers or opportunities there are and how you as a group can move forward. Therefore it's of course important to hear you opinion.

1. We would like you to introduce yourselves and let everyone know why you are here and what interests you about sustainable heating.
Possible follow up questions: So are there other things you do in your life to live more sustainably? Is this important to you? Do you feel it's time consuming? Do you like to spend money on sustainability?

2. We have handed out paper and pencil and we would like each of you to draw a sketch of all the people you are in touch with about sustainable housing projects. It can include people that you have asked advice from, but also people that have approached you with questions or just friends that you discuss these issues with. Maybe you can point out who of those lives in Maldenhof and is part of the project group and who lives beyond.

... they are writing down and drawing...

Do you want to share real quick what you've sketched out?
Do you feel like people are interested in these topics?

Now we would like to discuss the decision making process in your group: How did you find out about the heating initiative?
Do you think it is heading in the right direction?
Did you enjoy the group discussions so far?
What would you like to change?

Would you like other people to join?
Do you think it is attractive for external people to join? If yes why? If no, what would you change?

3. Finally, we would like to discuss the political situation:
Which organizations or companies support you, if any?
How do you feel about this support: is it helpful?
Do they understand your problems?
What kind of support would you like to have for the initiative to be successful?
Where do you think are the local authorities failing? What is going ok?
Did you acquire any information/was information from the municipality available?

4. Finally, is there anything that we should know about the group process and the heating that we didn't discuss yet?

Thanks a lot for giving us your time, we appreciate it and will continue working hard on this

- **Summary Group discussion**

The discussion was held in Dutch, the summary is a translation.

- Introduction of both alternatives: waste heat from the AMC and ATES+
- Mentioning of "Stadsverwarming: It already goes along the A9, a NUON pipeline. This would be very close to the neighbourhood.
- Discussion whether NUON is sustainable as they now also produce heat and scepticism towards NUON
- Presentation round: guest 1 only comes to listen and to get information. Sustainability to her is manifest in avoiding waste. Guest 2 has been part since the very beginning: was very invested but the last 2 months hasn't been too active. Wasn't happy with Alliander's role in the process, as they seemed to pursue only their interest and should be rather working towards the initiative's interest. Guest 3 has been part of the group since the very beginning. Is sustainability advisor of the "Stadsdeel": that's why she likes to follow it and play a role in sustainability in the neighbourhood.
- 3 is less negative about Alliander. Maybe they are too early to want sth like this in a neighbourhood like this: costs? Do we want to get more people on board as investors or people who support the initiative as planners?
- 3 want more precise data and security. If you want to convince people you need a good story and low prices. Initiative needs to define if that's what they want and what the expectations are. Not more expensive then now!!
- 1 wants green electricity, 2 already has it and also invests in Greenchoice. All think that almost everyone get electricity from Greenchoice.
- Sketches about who are you in contact with?
- 2 talks a lot about solar panels with their neighbours and also people beyond the neighbourhood, and also the board of her company.
- 3 mostly talks about her house and the experiences with making it more sustainable. Is very connected in Amsterdam and other initiatives, also Pakhuis de Zwijger.
- 2 & 3 both have solar panels and actively advocate for them in their friend circles, they also see a difference in their energy bills.

- Decisionmaking process:
- 3 found it a bit strange that some members of the group stepped back because AMC is not sustainable enough. 3 wants a reliable and experienced source of energy. Many people were surprised. There was still a long process of discussion
- 2 &3 liked the group discussion process. New people brought new dynamics. 6 to 10 people attend meetings, but getting less and less. Some people just got a new kettle (minimal 3)
- Reasons some people stepped out: busy with other things. Contact with Alliander on hold also surprised some people and made them feel like the cooperation was stopped. People think it takes too long and people maybe don't have the patience anymore. The group dynamic shifted.
- When a solution is found, Alliander made it sound like everyone has to convince 10 people to join the project, 2 thinks that this could be a problem, for her and in general.
- 3 really wants a onvincing story and mentions a neighbourhood association "de Laagbouw" but very little people are active. An activity at this place would be nice to get more people interested
- Discussion about two options. Participants get excited about ATES+. They also like that they already do it at Oudekerkplas. They are wondering how big the generation facilities will be.
- Political situation: Zuidoost made this project possible by paying Anne. Also all the people who signed the intetieverklaaring to make Maldenhof more sustainable. In the municipality of Amsterdam there have been a lot of changes because the city has a lot less discretion and less money to support projects and no say anymore in such things, there is an increased dependency on federal authorities. But policy makers at national level are more interested in big projects
- They discuss the possibility of the project being a "primeur"
- 2 doesn't have a good overview of the political situation. Does not feel too much support. There has only been an intention but not too much action.
- The wonder about NUON reaction and if they will oppose the project as they are very influential. They are in a power position.
- Independence? They would like to be a little more independent. But an energy cooperation would not be possible, only with support from different small organizations

c) Summary BuurtZoektWarmte (2015) meeting neighbourhood heating Maldenhof July 1st 2015

Verslag bijeenkomst buurtwarmte Maldenhof 1 juli 2015 Aanwezig:

- Bewoners/initiatiefnemers: Gerda Menkveld, Marjon Parson, Eugenie Baatsen, Anne Stijkel, Auke van Nie
- Alliander DGO: Carina Dijkhuis, Shira Hollanders

Afwezig: Erik de Wolf, Alison Bennett, Piet Jan Paul, WaiYing Guman, Margriet Koomen, Gilles Beydals Frank Boon

1. Terugblik / lopende zaken

- Een aantal mensen heeft het gasverbruik doorgegeven, zie tabel in presentatie (eerder toegezonden). We denken dat dit niet (helemaal) representatief is voor meedenkgroep en zeker niet voor de gemiddelde buurtbewoner. Daarom nogmaals de vraag om gasverbruik door te geven.

- Locatie warmwaterleidingen: Gerda heeft nogmaals gekeken en gezien dat warm water op 2 plekken in badkamer komt, van boven uit cv-ketel (douche) en via leiding uit slaapkamer (kraan/bad). Haar woning is (qua leidingen) nog grotendeels zoals bij oplevering. **Marjon** zal foto's maken van haar situatie. Auke geeft aan dat leidingen in 'kruipruimte' op zolder zitten, achter stapels boeken. Graag info sturen naar Machiel.bakema@alliander.com. Dit onderwerp is o.a. van belang omdat 'slim aansluiten' zorgt voor minder overlast voor bewoners en lagere kosten.

- Anand Joti: Margriet heeft contact gehad met André Bohla (vz. Bew.cie). Hij was geïnteresseerd. Daarop heeft Carina contact gehad met Marjolein van Zanten van Stadgenoot (eigenaar pand). Zij waren in eerste instantie geïnteresseerd om meer te horen. *Update 6 juli*: bij uitzoeken door Stadgenoot bleek dat de cv-ketels zijn vervangen in 2013, waardoor Stadgenoot de komende jaren geen nieuwe maatregelen wil nemen.

- Anne: heeft afspraak gemaakt met Universiteit Utrecht, studenten gaan in september/oktober onderzoek doen naar buurtwarmte Maldenhof, in het kader van de Transdisciplinary Case Study. **Actie**: **Anne** stuurt informatie rond hierover. Als mensen nog vragen hebben voor de studenten, dan kunnen ze die doorgeven aan Anne.

- Propositie: op de vorige bijeenkomst heeft Shira, aan de hand van het model HEAT, laten zien hoe het netwerk eruit kan zien, en wat de gevolgen zijn van keuzes voor de kosten van het netwerk en dus de kosten per woning en haalbaarheid. Daarbij is gerekend met de volgende uitgangspunten: een bedrag van €443 aan vaste lasten per jaar, en gelijke variabele kosten minus een korting zodat een huishouden met gemiddeld verbruik er 5% op vooruit gaat als men op gas blijft koken en 10% als men overstap op elektrisch koken. Bij sommige bewoners is hierdoor de indruk ontstaan dat dit een propositie is van Alliander. Shira legt uit dat deze propositie is ontstaan in een gesprek met Auke, Piet Jan, WaiYing en Gilles, waarbij de huidige vaste lasten in beeld zijn gebracht door Auke (zie verslag 8 juni) en besproken is wat aantrekkelijk zou zijn voor een grotere groep buurtgenoten,namelijk 5-10% lagere kosten dan in de huidige situatie. Het is daarom een propositie van buurtgenoten aan buurtgenoten. Er ontspint zich een discussie rondom thema's kosten/ duurzaamheid/ rol overheid.

- Anne herkent zich niet in propositie, vindt dat vastrecht zo laag mogelijk moet en hogere lasten voor variabel kosten, dat prikkelt energiebesparing. Ook wil ze graag lage drempel voor aan- of afsluitkosten. Ze vindt deze propositie ouderwets, en wil een ander businessmodel, dat een prikkel geeft voor verduurzaming van zowel huishoudens als warmtebron.
- Auke: als je een heel laag vastrecht stelt en hoge variabele kosten dan krijg je de onzuinige bewoner juist niet mee (want voor hem wordt het duurder) terwijl het aansluiten van de onzuinige bewoner de grootste duurzaamheidswinst levert. Met laag vastrecht verkleinen we de kans om de massa mee te krijgen.

- Carina: vraagt zich af hoe dan de bijdragen aan de kosten voor het netwerk geregeld moeten worden als woningen weinig bijdragen aan vaste lasten?

- Anne: Risico moet Alliander niet dragen maar de overheid, in lijn met warmtevisie van minister Kamp.

- Anne: twijfelt aan duurzaamheidsgehalte, wil liefst z.s.m. 100% duurzame energie. We gaan als

- bewoners het gas afsluiten maar we krijgen warmte die vrijkomt bij met gas opgewekte elektriciteit. Goed voor nu maar per 1 jan 2020 moet bron AMC geheel verduurzaamd zijn. Wil prikkel om te verduurzamen, bij bewoners en warmteleverancier.

- Gerda: heeft geen vertrouwen dat overheid nu een grote bijdrage gaat geven. Dus als je deze eis houdt dan kom je nergens. Heeft behoefte algemeen verhaal met duidelijk zicht op verder verduurzaming, maar niet als voorwaarde vooraf.

- Shira: de elektriciteit die wordt opgewekt hoeft niet meer ingekocht te worden dus er hoeft minder elektriciteit opgewekt te worden. AMC wekt elektriciteit om veiligheid in ziekenhuis te borgen, in dat opzicht is de warmte die daarbij vrijkomt 100% restwarmte.

- Eugenie: voor mij is de duurzaamheid niet het allerbelangrijkst en ik denk voor de massa ook niet. Met zulke scherpe eisen maken we geen voortgang. Geeft aan dat zij en Anne 2 zijden van het spectrum vertegenwoordigen, en dat de rest van de buurt daar tussen zit. Hoe houd je beide kanten aan boord en heb je en goed verhaal dat een groot deel van de buurt aanspreekt?

- Carina: Stelt voor dat bewoners/initiatiefnemers de zomer gebruiken om onderling van gedachten te wisselen over mogelijk businessmodellen, wensen m.b.t. verduurzaming, delen van kosten. **Actie:** alle bewoners/initiatiefnemers.

- Carina/Shira: bieden aan dat Alliander in beeld brengt welke besparing op gas/CO_2 wordt gerealiseerd met een warmtenet, rekening houdend met het feit dat AMC ook gas gebruikt bij de productie van elektriciteit waarbij de restwarmte vrij komt.

2. Projectgroep

- Anne vertelt over stadexpeditie op 23 juni jl. Ze heeft 'geflirt' met AMC en NUON, ook aanwezig waren Alliander, waternet, stadsdeel, gemeente en warmteregisseur. Ook waren Auke en Gerda van de partij. Korte samenvatting in filmpje van Pakhuis De Zwijger: *https://dezwijger.nl/programma/update-nieuw-amsterdam. (net voor 1.00.00)* - **Afspraak**: er komt projectgroep met genoemde organisaties, bewoners/initiatiefnemers en Alliander DGO. Op

- verzoek van Anne wordt Vandebron (potentiële leverancier) ook uitgenodigd. Doel: bespreken en afspraken maken over mogelijkheden voor realiseren buurtwarmte. Namens deze groep nemen Gerda, Anne en Auke deel. Zij zorgen voor afstemming met de overige bewoners (input vooraf en terugkoppeling achteraf). *NB projectgroep op 9 juli is niet doorgegaan omdat er veel afzeggingen waren*.

- De volgende opmerkingen worden gemaakt, als input voor projectgroepleden: o Wens: organisaties dienend aan wensen bewoners; o Wens: geen 30 jaar vastzitten o Wens; breed perspectief → veel mensen moeten kunnen instappen

- Angst: te veel voor de troepen uitlopen!
- Wens: maak een plan waarmee iedereen tevreden is.

3. Communicatie

- Eugenie, Erik en Carina hebben overleg gehad in werkgroep communicatie. Doel van de buurtcommunicatie is dat andere Maldenhof bewoners, m.n. huiseigenaren van de oneven huisnummers, horen over het buurtwarmteproject en enthousiast worden. In september/oktober kan er dan een tweede buurtbijeenkomst worden georganiseerd waar mensen meer info krijgen en kunnen mensen een intentieverklaring tekenen.

- Zie ook sheets in presentatie: zie bijlage.

- *NB i.v.m. het feit dat er nog geen overeenstemming is bij de bewoners in deze groep over de boodschap naar buiten en het aanbod aan buurtgenoten, is het verstandig om op dit moment nog niet actief de buurt in te gaan. Wel is hieronder een overzicht opgenomen van gemaakte afspraken, zodat als de tijd rijp is hierop verder gebouwd kan worden.*

- **Boodschap**: - bron noemen, bijv. restwarmte uit de buurt, zoals AMC - bewoners kiezen samen leverancier en hebben invloed op keuze bron en leveringsvoorwaarden - Warmtelevering ten minste even betrouwbaar als gas **Doelgroep**: Carina heeft gegevens ontvangen van stadsdeel over samenstelling bewoners Maldenhof. Zie bijlage en sheets. - Huishoudens zonder kinderen 33% , huishoudens met kinderen 35%, alleenstaand 31% - Leeftijd: 37% 50-70 jaar, 17% 30-50 jaar -Afkomst: 46% autochtoon, 27% van Surinaamse afkomst. **Aandachtspunt**: hoe bereiken we de groepen die maar beperkt of niet vertegenwoordigd zijn in deze bewonersgroep, zoals gezinnen met kinderen of mensen van Surinaamse afkomst? **Auke** zal met zijn Surinaamse buurman contact opnemen. **Middelen**: persoonlijk contact is het belangrijkste, dat kan worden ondersteund met communicatiemiddelen die informatief zijn of de aandacht trekken. Aanwezigen geven voorkeuren aan met stickers, zie foto.

- *Green graffitti*: met natuurlijke materialen worden afbeeldingen op straat aangebracht, zoals kalk of door het wegspuiten van vuil. Zie o.a. http://www.natuurlijkadverteren.nl / voor voorbeelden.

- *Website*: Anne geeft aan dat we website Slim Wonen Gaasperdam kunnen gebruiken. Beheerder is Frank Boon. Erik heeft eerder aangeboden om website en Facebook bij te willen houden. Op website o.a. lijst veel gestelde vragen (FAQ-lijst), informatie over project, contactpersonen. **Afspraak**: Erik stemt af met Frank over gebruik Slim Wonen-website. Carina nodigt Frank uit voor werkgroep communicatie. Eugenie heeft contact gehad met webbeheerder Cor Hagen van De Laagbouw: we mogen een stukje aanleveren voor de website, hierop kunnen we doorverwijzen naar de website Slim Wonen. Cor stuurt buurtgenoten een berichtje dat er nieuwe info op website De Laagbouw staat. **Actie**: Carina, Eugenie, Erik
- *Facebook*: Erik beheert FB-pagina Slim Wonen Gaasperdam. Waarschijnlijk is het handig om voor buurtwarmte een eigen FB-pagina te maken. Overleg in wg communicatie. **Actie**: Erik. *Brief*: Eugenie wil graag brief of kaartje bij mensen verspreiden, zodat ze een aantal dagen later aan kan bellen en daarna kan verwijzen. Idee: kaartje met uitnodiging/info over project, kan ondertekend worden door de uitdeler met persoonlijke boodschap. **Actie**: Carina en Eugenie.

- **Actie:** Eugenie en Gerda willen in elk geval langs de deuren gaan van de geïnteresseerden v.d. eerste bijeenkomst . *Digitale nieuwsbrief*: om contacten die we al hebben n.a.v. eerste bijeenkomst te informeren over stand van zaken. Moment:nader te bepalen. **Actie**: Carina en wg communicatie.

- **Anne**: wil contact opnemen met Urwin Vyent, portefeuillehouder duurzaamheid van stadsdeel Zuidoost en bewoner Maldenhof.

5. Actielijst
Wie
Wat
Wanneer

- Marjon (en anderen):

foto's warmwaterleidingen sturen naar
Machiel.bakema@alliander.com
Juli/augustus

- Anne

Informatie rondsturen over transdiciplinary case study (TCS) van studenten univ. Utrecht.
juli

- alle bewoners/ initiatiefnemers.

In de zomer onderling van gedachten wisselen over mogelijke businessmodellen, wensen m.b.t. verduurzaming, delen van kosten.
Juli-augustus
Shira (+ Alliander- collega's)
In beeld brengen welke besparing op gas/CO2 wordt gerealiseerd met een warmtenet.
juli

- Anne, Auke, Gerda

Deelnemen aan projectgroep met AMC, NUON, stadsdeel, Vandebron en Alliander, en afstemmen hierover met andere bewoners
Nieuwe datum in aug/sep.

Communicatie-acties
Nader te bepalen (n.t.b.)

- Auke

Contact met Surinaamse buurman: hoe kunnen we andere mensen van Surinaamse komaf bereiken?
Erik + Frank: wg communicatie
Informatieve tekst over buurtwarmteproject, stand van zaken op website Slim Wonen Gaasperdam
Juli

- Carina, Eugenie

Informatieve tekst aanleveren voor website De Laagbouw
n.t.b.
Erik + wg communicatie
Facebookpagina
Opzet juli, invulling n.t.b.

- Eugenie en Carina

Opzet brief/kaart voor bewoners over buurtwarmte
n.t.b.

- Eugenie en Gerda

Langs deuren bij mensen die in maart op bijeenkomst zijn geweest
n.t.b.

- Carina en wg. comm.

Dig. nieuwsbrief aan bestaande contacten (o.a. bezoekrs bijenkomst maart)
Sep?

- Carina

Frank uitnodigen voor volgende overleg wg communicatie (en Erik, Eugenie, Margriet)
n.t.b.

- Anne

contact opnemen met Urwin Vyent

d) Results surveys

- Results Survey neighbourhood Maldenhof

Data arrived by Email

No	1	2	3	4	5	6	7	8	9	Additional Comments
1	2	1	1	2	1.5	3	5	3	5	Just bought new heating
2	1	2	2	1	2	4	4	2	2	Has solar panels, thinks they are better, is part of the 25, thinks project is unrealistic and impossible
3	1	1	1	1	1	4	5	4	5	very sceptical, thinks politics has to set up a project without risk with the citizens, solarpanels are more lucrative
4	1	2	1	1	1.5	5	5	5	3	Got the flyers, is wondering if it works
5	2	2	1.5	2	1.5	5	5	4	5	Has solar panels
6	1	2	1	1	1.5	4	4	4	3	Got the flyer, wants to install solar panels for cost reasons
7	2	1	1	1	1	4	4	5	1	Likes solar panels, but too expensive, has green electricity
8	2	1	2	2	1.5	5	5	3	3	Wants everything to stay the way it is
9	2	1	2	2	2	5	5	1	4	
10	2	1	2	2	1	5	4	5	3	Rental house
11	2	1	2	2	1.5	4	4	5	3	Rental house, municipality should do something
12	2	2	2	2	1	4	4	5	3	Very old, not interested in change
13	2	2	2	2	2	5	5	1	1	Very old, not interested in change
14	2	2	2	2	1	5	5	5	1	
15	2	1	2	2	2	4	4	3	1	Not interested in change, doesn't use much anymay
16	2	2	1	1	1	5	5	2	1	
17	2	1	1	1	2	5	5	5	1	Rental house

18	2	2	1	1	1	3	3	4	5	Has invested in insulation and gets green electricity
19	2	1	2	1	2	5	5	3	1	Has looked into solar panel: too expensive
20	2	1	1	1	1	4	3	4	1	Has invested in insulation and solar panels
22	2	2	2	1	1	3	3	4	1	
23	2	2	1	1	1	5	5	3	1	Has solar panels to save money
	1.8	**1.5**	**1.5**	**1.5**	**1.4**	**4.4**	**4.4**	**3.6**	**2.5**	
							1	yes		interested but skeptical
							2	no		seriously thinking about investments
							1.5	may be		has invested in green options but not heard of initiative
										knows initiative and has invested
										not options for change
										very little options change

1	Heeft u al eens gehoord van het initiatief BUURTzoektWARMTE? Of een ander buurtinitiatief dat zich richt op duurzaamheid (zoals zonnepanelen)?
2	Heeft u ooit gehoord van politieke initiatieven voor het verduurzamen van de energie voorziening voor centrale verwarming(hier in Amsterdam)?
3	Zou u graag meer te weten komen over dergelijke initiatieven?
4	Heeft u ooit informatie gezocht over hoe je duurzame energie kunt verkrijgen?
5	Would you consider paying a litle more for sustainable solutions?
6	De hoogte van de vaste kosten
7	De hoogte van de variable kosten
8	De impact op het lokale milieu
9	De aanleg van een nieuwe energie-infrastructuur

- ## Results Survey among initiative members

By land, P. & Weerts, K.

1. Ec	2. E	3. Du	4. Di	5. Sc	6. Fl	7. Te	8.	9.	10	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.
4	5	5	4	4	4	4	5	Ja	4	4	4	3	4	3	5	5	1	5	5	4	4	4	4	2	Vrouw	41 - 60 jaar	Alleenstaand	Ja
5	3	3	4	4	4	5	4	Ja	5	5	3	3	2	4	4	4	2	5	3	5	5	3	5	2	Man	60 +	Paar zonder kinderen	Ja
5	5		5	3	5	4	4	Ja	5	4	4	4	4	5	4	3			4	4	4	4	4	3	Vrouw	41 - 60 jaar	Alleenstaand	Ja
4	4	4	4	2	4	5	3	Ja	5		3	2	3	4	5	5	1	2	3	5	4	2	4	4	Vrouw	60 +	Paar zonder kinderen	Ja
3	4	5	5	3	4	4	4	Ja	4	4	3	3	2	4	4	4	2	2	4	4	4	3	4	4	Vrouw	41 - 60 jaar	Alleenstaand	Ja
3	3	4	4	1	5	4	3	Ja	5	4	5	3	3	3	5	5	2	4	4	4	4	3	4	2	Man	41 - 60 jaar	Paar met kinderen	Ja
3	3	4	4	2	4	4	2	Nee		3	2	1	2	1	3	4	1	1	4	3	3	4	2	4	Vrouw	60 +	Paar zonder kinderen	Ja
3	3	4	4	3	3	3	3	Ja	4	4	3	3	3	3	4	4	3	3	4	3	4	4	4	3	Vrouw	41 - 60 jaar	Paar met kinderen	Ja
4	2	4	3	2	4	4	4	Ja	4	4	3	2	2	4	4	3	2	1	1	2	4	3	3	2	Vrouw	60 +	Alleenstaand	Ja
3	3	4	4	3	3	4	3	Ja	4	3	3	3	4	4	3	1	1	1	3	3	3	3	3	1	Man	60 +	Paar zonder kinderen	Ja
4	4	4	4	3	4	4	3	Nee		5	4	4	3	3	4	3	2	3	3	4	4	4		1	Vrouw	41 - 60 jaar	Paar met kinderen	Nee
3	4	4	3	2	4	4	3	Nee		3	3	1	3	3	3	4	4	2	3	3	5	4	4	3	Vrouw	41 - 60 jaar	Paar met kinderen	Ja
2	4	4	5	2	2	4	4	Nee		1	2	2	4	2	4	1	1	1	1	2	3	3	4	2	Man	60 +	Alleenstaand	Nee
2	4	4	5	2	2	4	4	Nee		1	2	2	4	2	4	1	1	1	1	2	3	3	4	2	Man	60 +	Alleenstaand	Nee
5	3	1	1	3	5	3	1	Nee	2	1	2	2	1	4	2	1	1	1	1	1	2	1	3	5	Man	60 +	Paar zonder kinderen	Ja
5	5	4	4	2	2	4	3	Ja	4	4	4	3	2	2	2	2	4	2	2	2	3	3	3	4	Man	60 +	Paar zonder kinderen	Ja
4	4	4	3	2	3	4	4	Nee		3	3	3	3	3	4	1	5	3	5	3	4	3	2	1	Man	60 +	Paar zonder kinderen	Ja
3.6	3.7	3.88	3.9	2.5	3.6	4	3.4		4	3	3.1	3	2.9	3.2	3.8	3	2.1	2.3	3	3.18	3.7	3	3.6	2.6				
	3.7		3.9	2.5		3.8																						

d) Ooijenvaar, A. & Boon, F. (2015)Summary Presentations Expertsession „Warmtenet 2.0“

Huizen, M., Land, P., Oever van den I., & Weerts, K. were atending the meeting.

Verslag Expertsessie: Warmtenet 2.0

Samenvatting van de presentaties

Datum: 17 september 2015 – Verslag van ackeline Ooijenvaar en Frank Boon

Auke van Nie – Buurtwarmtenet Gaasperdam

- Via actieve buur Anne Stijkel onderzochten bewoners uit de wijk Gaasperdam de mogelijkheid om hun woningen naar 0-op-de-meter te renoveren. De conclusie was hun woningen net iets te goed gebouwd waren om hiermee aan de slag te gaan. Maar de buurt was wel 'warm' geworden en in het project Slim Wonen Gaasperdam is i.s.m. de gemeente Amsterdam en het bedrijfsleven het project Slim Wonen Gaasperdam gestart.
- Hieruit kwamen een aantal duurzame thema's naar voren waar de buurt en partners verder aan werken. Een thema is een collectief warmtenet voor Maldenhof (wijk in Gaasperdam).
- Reden om voor een warmtenet in de bestaande bouw te onderzoeken is dat er veel restwarmte aanwezig is uit bijvoorbeeld Datacentra en het AMC. Maar ook het feit dat er al een warmtepijp ligt (+/- 40 meter van de wijk).
- Uit dit proces is gebleken dat de schaal minimaal 100 tot 150 woningen moet zijn om het financieel enigszins te bolwerken. De wijk bestaat uit 470 woningen inclusief 100 huurwoningbouw. 150 woningen aansluiten betekent dat een groot deel van de wijk zal moeten deelnemen.
- In het verlengde hiervan hebben de woningen op dit moment allemaal een eigen systeem met gasketel. Sommige buren hebben recent een ketel aangeschaft, anderen zullen dit in de komende paar jaar gaan doen. Hoe kun je deze mensen die in de nabije toekomst gaan investeren in hun warmtevoorziening (maar nog niet op een collectief warmtenet aangesloten zijn) of dat recent hebben gedaan, verleiden of compenseren?
- En hoe wordt de straks de prijs voor warmte en de infrastructuur bepaald? Op dit moment worden het vervangen of onderhoud van de centrale verwarming door veel mensen niet gezien als energielasten maar als woninglasten. Toch worden deze kosten wel meegenomen in het berekening van de tarieven.

Maartje Romme – Wetering Verbetering

- Het is een bijzondere puzzel om in de Wetering buurt met veel monumentale panden eigen energie op te wekken (en te leveren). Het Maison Descartes biedt hier wellicht een oplossing voor. Het Maison Descartes in momenteel in Fransen handen maar die willen het verkopen.
- En de buurt heeft er een goede bestemming voor. Het kan tijdens de broodnodige renovatie namelijk worden voorzien van een WKO die meer dan genoeg produceert voor het gebouw zelf en ook de buurt van energie kan voorzien.
- Een bijkomend aspect is dat er een zeer verouderde maar bestaande infrastructuur reeds aanwezig is in de achtertuinen. Hier loopt namelijk een oud riool wat niet alleen voor de distributie van warmte kan zorgen maar ook de afwatering van de tuinen zal verbeteren.

Gerwin Verschuur – Thermo Bello

- Gerwin is medeoprichter en directeur van Thermo Bello. Thermo Bello levert warmte die gewonnen wordt uit drinkwater aan bewoners en bedrijven in de buurt. Bijzonder van Thermo Bello – wat het 2.0. maakt – is dat het een bedrijf is van, door en voor bewoners.
- Thermo Bello heeft de kans gekregen om een bestaande infrastructuur te kopen. De vorige eigenaar was waterbedrijf Vitens die besloot de infrastructuur te verkopen. Het nieuw aanleggen van de infrastructuur had Thermo Bello €1,5 miljoen gekost. De bestaande infrastructuur is voor €150.000 gekocht. Had Thermo Bello de infrastructuur niet zo goedkoop kunnen overnemen waren ze er nooit aan begonnen.
- De omzet van Thermo Bello bedraagt ongeveer €250.000 waarvan €30.000 winst. Kanttekening is dat de winst niet zo hoog zou zijn geweest als vrijwilligers niet een grote

2

bijdrage zouden leveren (in o.a. het optimaliseren van het systeem, ook bij mensen thuis).

- Belangrijke aspecten van een warmtenet zijn:
  - Tijdsplan: de aanleg is duur en wordt over een lange periode terugverdiend
  - Hoe duurzaam is de bron? Letterlijk ook in de zin hoe lang je hiervan op aan kunt. In het geval van Thermo Bello was er even sprake van dat Vitens misschien zou stoppen waardoor Thermo Bello haar bron zou verliezen. En belangrijk hierbij is wie draagt dit risico?
- Vraag is dus of je voor de oplossing niet beter op individueel niveau kunt kijken. In het geval het individuele niveau wordt overstegen is een samenwerking met grote en/of sterke partners nodig (om de bijvoorbeeld het risico van het verdwijnen van een bron op te kunnen vangen).

Shira Hollander - Alliander Duurzame Gebiedsontwikkeling (DGO)

- Om de SER-doelstelling voor 2050 te realiseren moeten alle zeilen bijgezet worden en is alles nodig. Daarmee ook warmtenetten.
- Maar wel op een manier waar de gebruiker op zit te wachten. Dat is een warmtenet 2.0.
- Alliander DGO leert via nieuwe processen en projecten om te zien wat wel en niet werkt. Hierbij wordt o.a. onderzocht of en hoe eindgebruikers zelf kunnen investeren in een warmtenet. Ook de leveranciersrol (Alliander als netbeheerder) is open en zou eventueel door de buurt zelf opgelost kunnen worden.
- Alliander DGO onderzoekt momenteel op verschillende plekken wat wel en niet werkt. Een aantal overeenkomsten tussen deze projecten is:
  - Het begrip "duurzaamheid" betekent voor iedereen weer wat anders. De een vind restwarmte bijvoorbeeld wel duurzaam en de ander totaal niet.
  - Het Tastbaar en/of zichtbaar maken is belangrijk
  - Er zijn veel praktische vragen waar een antwoord op moet komen, zie bijvoorbeeld de punten die Auke van Nie noemt.
- Een ander aspect is dat voor nieuwbouw – goed geïsoleerde panden – een warmtenet met een relatief lage temperatuur voldoende is. Voor de bestaande bouw die relatief slecht geïsoleerd zijn kan een woning doorgaans niet op temperatuur worden gebracht met een lage temperatuur maar is minimaal 80 graden nodig.

Niels van Alphen - Techneco

- Techneco is bouwer en importeur van warmtepompen.
- Warmtepompen worden veel toegepast in nieuwbouw. Maar het grootste gedeelte van de markt bestaat uit reeds bestaande gebouwen. Hiervoor heeft Techneco een hybride warmtepomp ontwikkeld die i.c.m. bestaande infrastructuur (een gasketel of aansluiting op stadswarmte) toegepast kan worden.
- In Amsterdam loopt nog niet zo hard warm voor warmtepompen. Een waarschijnlijke oorzaak is dat alle nieuwbouw in Amsterdam verplicht aan de stadswarmte moet. Uitzondering hierop is dat monumenten vaak wel worden voorzien van een warmtepomp.
- Warmtepompen worden hoofdzakelijk ingezet voor het verwarmen (en koelen) van ruimte. Inmiddels zijn er ook oplossingen voor het verwarmen tap- en douchewater. Ook in de bestaande bouw.
- Kaswoning is zoals het doet vermoeden een woning in een kas. De Kaswoning is een tegengeluid voor het steeds verder isoleren van woningen. Hoe beter je isoleert, hoe meer aandacht er nodig is voor ventilatie. Men maakt nu woningen die hermetisch dicht worden gemaakt en laten de woning ademen via een 'rietje'. Je kunt dit ondervangen door een woning op te bouwen uit laagjes.

Verslag Expertsessie: Warmtenet 2.0

Samenvatting van de presentaties

Datum: 17 september 2015 – Verslag van ackeline Ooijenvaar en Frank Boon

- De glazen schil bestaat uit enkel glas maar zorgt ervoor dat er in de woning reeds een derde wordt bespaard op de warmtevraag. Daarnaast wordt de benodigde energie (warmte en elektra) opgewekt op het dak via zonenpanelen en zon-thermische panelen. De laatste kunnen met behulp van een buffervat de kaswoning (2 appartementen en 2 werkruimten) voor 80% van het jaar voorzien van warmte. De overige warmte wordt opgewekt via een houtpellet ketel of Sterling motor (zowel elektra als warmte maakt).
- Basisprincipe is dat laagwaardige energie direct wordt gebruikt. Dus niet elektra – hoogwaardige vorm – gebruiken om warmte te maken maar opgewekte warmte gebruiken.
- Warmte collectoren en zonnepanelen (PV) concurreren niet met elkaar. Door de warmte collectoren op de gevel te plaatsen (i.p.v. het dak) staan deze in de winter beter op de zon gericht (wanneer je de warmte het hardst nodig hebt) dan op het dak en kunnen de zonnepanelen wanneer de behoefte aan warmte lager is elektra opwekken.
- Een nieuwe ontwikkeling uit Zwitserland is TVP. Een gamechanger want dit paneel is in staat bij -10 graden nog steeds 75 graden warm water te leveren. Prognose van de kosten voor dit paneel worden geschat op 300 euro per m2. Voor de Kaswoning zou van dit type 30m2 voldoende zijn om het hele jaar door over voldoende warmte te beschikken. Het TVP paneel is waarschijnlijk over 3 jaar beschikbaar voor toepassing op huishoudelijk niveau.

Cas Bol – Zelfbouw project Nautilus

- Nautilus is een collectief zelfbouw project op het Zeeburger Eiland. Planning is dat het complex in mei 2016 klaar is. Energie is een belangrijk element maar het collectief gaat verder dan allen energie. Het doel is om sociale woningen te realiseren die net onder de liberale huur grens – minder dan €750 p.m. – vallen. Dit om de doorloop in de sociale huur te bevorderen. Een ander bijzonder aspect van dit project is dat het Nautilus is gelukt om de verplichte aansluiting op het warmtenet te weigeren.
- Een snelle rekensom: de eenmalige aansluitkosten aan het warmtenet bedragen per woning €2.500. Het Nautilus project bevat 43 woningen wat daarmee neerkomt op ruim een ton. Daarnaast bedraagt het vastrecht (jaarlijkse kosten om warmte af te mogen nemen) ook €470. De conclusie is dat het warmtenet duur is en het veel goedkoper kan!
- Nautilus gaat gebruik maken van een hybride systeem van een warmtepomp, zonnepanelen en zonnecollectoren. Via dit systeem is uitgerekend dat er minimaal 60% minder CO_2 wordt uitgestoten dan wanneer het complex zou zijn aangesloten aan het warmtenet. Deze besparing is vanaf de eerste dag dus aantoonbaar duurzamer en goedkoper.

Cardo Nerders – de Alliantie

- Cardo zijn uitgangspunt is dat het gebruik van restwarmte duurzaam is omdat het verspillen enkel al zonde is. Cardo heeft in kaart gebracht welke belangen – van woningbouwcorporaties, huurders en energieleveranciers – er spelen.
- Voor een woningbouwcorporatie is het interessant om haar woningvoorraad aan een warmtenet te koppelen. Dit omdat het minder zorgen en onderhoud zijn bij een aansluiting op het warmtenet t.a.v. een individueel systeem. Bij een aansluiting op het warmtenet is de energieleverancier namelijk verantwoordelijk voor het systeem in huis waar bij individuele systemen de woningbouwcorporatie verantwoordelijk is en deze moet onderhouden. Daarnaast is er ook een verborgen financieel voordeel. Normaliter zouden de vermeden kosten voor onderhoud – die nu aan de energieleverancier worden betaald – in minder gebracht moeten worden op de huur. In de praktijk gebeurt dit echter niet.
- Voor een energieleverancier is het voornaamste belang dat de investering in het warmtenet. Omdat het om grote investeringen gaat die over een lange periode worden terugverdiend is

Annex V: Area specific criteria Maldenhof for developing ATES+

Quickscan bodemenergie

De belangrijkste voordelen en randvoorwaarden uitgewerkt

Kan het?

Bodemenergievariant:	**Open systeem**
Bodemgeschiktheid:	**zeer geschikt**
Grondwaterkwaliteit	**zoet-/brakgrensvlak**

Mag het? - verbodsgebieden

bescherming voor drinkwater	O	-
specifiek provinciaal beleid	O	-

Mag het? - aandachtsgebieden

open systemen	?	-
gesloten systemen	O	-
grondwateronttrekkingen	O	-
verontreinigingen (puntlocatie)	O	-
verontreinigingen (contour)	O	-
natuur	O	-
aardkundige waarden	O	-
archeologie	O	-
bodemenergieplannen	O	-
overige aandachtsgebieden	O	-
bodemonderzoek & -sanering	O	-
open systemen	?	-
gesloten systemen	O	-
interferentiegebieden	?	-
masterplangebieden bodemenergie	O	-

O omgevingsbelang niet aanwezig op locatie of in omgeving
● omgevingsbelang aanwezig op locatie
◐ omgevingsbelang aanwezig in omgeving
? geen informatie beschikbaar

Kaart restrictie- en aandachtsgebieden

Legenda

Op de locatie en in de omgeving zijn geen omgevingsbelangen aanwezig en/of bekend.

Milieuvoordeel - wat levert het op?

Energiebesparing [%]:	**57**
CO_2-emissiereductie [%]:	**51**

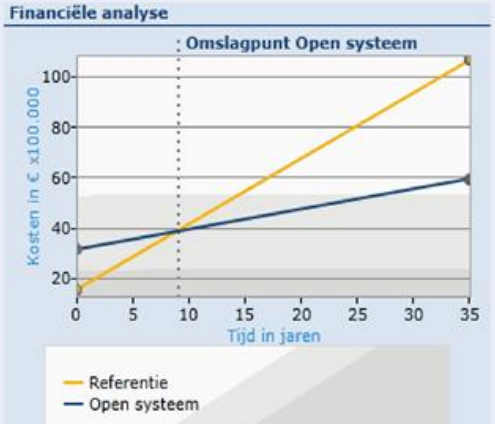
Financieel - wat levert het op?

Meerkosten investering [€]:	**1.639.000**
Exploitatievoordeel [€/jaar]:	**180.000**
Terugverdientijd [jaar]:	**7 - 11**

Financiële kentallen

Prijs CV-ketel huis [€/stuk]	**3.500**
Prijs CV-ketel collectief [€/stuk]	**100**
Prijs warmtepomp huis [€/stuk]	**5.500**
Prijs warmtepomp collectief [€/kW]	**250**
Prijs koelmachine huis [€/stuk]	**800**
Prijs koelmachine collectief [€/kW]	**225**
Electriciteitsprijs [€/kW]	**0,15**
Gasprijs [€/m³]	**0,55**
Opgave van subsidievoordeel [€]	**0**
Inkomsten uit koeling [€/jaar]	**240**

Financiële analyse



Disclaimer

Deze webapplicatie is bedoeld om op quickscan-niveau een indruk te krijgen van de kansen voor de toepassing van open en gesloten bodemenergiesystemen - al dan niet in combinatie met een warmtepomp - op een bepaalde locatie. Indien met de webapplicatie interessante terugverdientijden berekend worden, kan in de volgende fase een

Bodemenergie kansrijk voor uw locatie

Projectinformatie

Plaats:	
XY-coördinaat:	126.375 ; 479.643
Bouwvolume:	350 huizen

Kan en

- Bodem is zeer geschikt
- Wettelijk toegestaan

Wat levert het op?

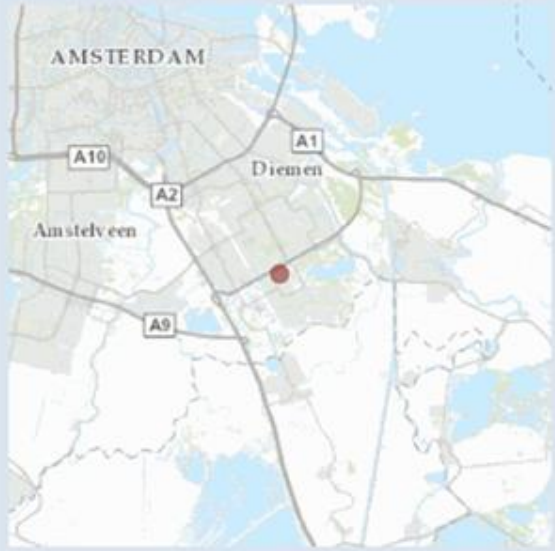
- Korte terugverdientijd van 7 - 11 jaar
- Energiebesparing tot 57%

Het vervolgtraject

Stap 1: Voer haalbaarheidstudie uit voor go/no go besluit

Stap 2: Ontwerp systeem en vraag vergunningen aan

Overzichtskaart



Detailkaart

Disclaimer

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Annex VI: Information Calculations ATES+

a) Components of the heat balance equation

Component [W m^{-2}]	**Method**	**With:**
Solar radiation	*Data from KNMI for specific location*	ε = emissivity of the atmosphere [-] σ_{SB} = constant of Stefan-Boltzmann [W m^{-2} K^{-4}] p_a = atmospheric vapour pressure [Pa] p_s = saturation vapour pressure [Pa] T_a = air temperature [°C] T_w = water temperature [°C] V_{wind} = wind velocity [ms^{-1}]
Atmospheric radiation	$H_a = \varepsilon\sigma_{SB}(T_a + 273)^4$	
Lake radiation	$H_l = -\varepsilon\sigma_{SB}(T_a + 273)^4$	
Evaporation and condensation heat flux	$H_e = (3.68 + 2.65\, v_{wind})(p_a - p_s)$	
Heat conduction to/from atmosphere	$H_c = (2.02 + 1.46\, v_{wind})(T_a - T_w)$	

Source: Graaf et al., 2012

b) Main empirical relations for each heat balance component

Summary of the main empirical relations that will be used for each heat balance component. Since the water system under consideration is a nearly closed system (no large water movements occur) heat Hf resulting from inflowing and outflowing water from the surface water is equal to zero

Year 2014

	Januari	Februari	March	April	May	June	July	August	September	Oktober	November	December
Solar radiation, Hsl	25,3	54,4	126,8	161,2	201,7	232,1	216,8	173,1	143,1	68,2	37,8	21,4
Atmospherical radiation, Ha	285,2	284,9	290,5	305,6	317,2	329,7	346,4	340,4	332,5	324,9	303,2	284,1
Lake radiation, Hl	-289,79096	-283,209637	-290,872168	-313,551036	-326,56342	-341,345467	-358,859216	-340,933672	-344,354383	-331,0748535	-310,205436	-289,58743
Evaporation, He	-36,828039	-21,8589221	-23,9913535	-48,4902008	-63,0083458	-71,6184011	-98,3348661	-49,9481902	-68,5784129	-60,35335488	-42,7603334	-41,81369
Conduction, Hc	-12,187404	4,95773184	-0,75903118	-15,1054903	-17,6662477	-18,5744439	-20,5825742	-0,97458169	-16,9015437	-12,54069161	-13,2975269	-15,540951
Htotal (W*m2)	-28,3	39,2	101,7	89,6	111,6	130,2	85,5	121,7	45,7	-10,9	-25,2	-41,4
excess heat in kWh	-1282863,5	1773866,16	4602268,76	4057491,55	5052908,72	5893051,5	3867512,81	5506289,03	2070464,9	-492764,2228	-1140597,75	-1875725
excess heat storing potential in GJ	-356,35	492,74	1278,41	1127,08	1403,59	1636,96	1074,31	1529,52	575,13	-136,88	-316,83	-521,03
translated to max. amount of households per month		129	334	295	367	428	281	400	150			

lake surface	62000	m2
conversion kWh to MJ	0,27777778	MJ/kWh
energy consumption per household per month	3,825	GJ/month

Components heat balance surface water

	formulas		With			
Solar radiation, Hsl	KNMI data		**ε**	emissivity		[-]
Atmospheric radiation, Ha	Ha = ε * σsb*(Ta + 273)^4		σsb	constant of Boltzmann	5,67E-08	W*m^-2*K^-4
	ε = 0,74 *(1+0,17*Cc)+0,0045*(1-Cc)*pa		Ta	Air temperature		degrees C
	Pa = 6,122*10^(7,5*Ta/273,7+Ta)	Unit	Cc	Cloud coverage as fraction of 1		[-]
Back radiation from lake, Hl	Hl = -ε*σsb*(Tw+273)^4	**All-in W*m^-2**	**Pa**	atmospheric vapour pressure		Pa
Evaporation heat flux, He	He = f(vwind)*(ps-pa)		Tw	water temperature		degrees C
	f(vwind) = 3,68+2,65*vwind		f(vwind)	empirical wind function		W*m^-2*Hpa^-1
	Ps = 23,4*1,062^(Tw-20)		vwind	wind velocity		ms^-1
Conduction heat flux	Hc = (2,02+1,46*vwind)*(Ta-Tw)		**Ps**	saturation vapour pressure		Pa
			Asw	area surface water		

Specific data per component per month

	Januari	Februari	March	April	May	June	July	August	September	Oktober	November	December
Ta	5,6	6,3	8,4	10,9	13,3	15,6	18,7	17,6	16,3	14,3	9,9	5,4
Hsl	2,53	5,44	12,68	16,12	20,17	23,21	21,68	17,31	14,31	6,82	3,78	2,14
vwind	6,0	7,0	4,8	4,2	4,4	3,7	4,1	4,9	3,2	4,9	4,3	6,6
Cc	0,6	0,5	0,4	0,5	0,5	0,5	0,5	0,5	0,4	0,6	0,6	0,6
Tw	6,71	5,89	8,52	12,7	15,4	18,1	21,25	17,7	18,9	15,7	11,5	6,7
Pa	8,646589	9,02713242	10,2596741	11,8347043	13,6339105	15,5126072	18,4426843	17,3731409	16,204137	14,46368538	11,1783164	8,530655
ε	0,835	0,826	0,817	0,830	0,833	0,838	0,844	0,842	0,837	0,841	0,835	0,835
Ps	10,520	10,014	11,730	15,084	17,744	20,873	25,227	20,376	21,902	18,067	14,033	10,514
f(vwind)	19,656935	22,1542857	16,3145161	14,9248333	15,3314516	13,3613333	14,4937097	16,6308065	12,0363333	16,75048387	14,9778333	21,084516

c) Numbers for heat- and cold storage

Tabel 4.6.2 Kentallen koude- en warmteopslag

Toepassing	Warmte			Koude			Opmerking
	ΔT (°C)	β_{warmte}	$E_{kental, warmte}$ (MJ/m^3)	ΔT (°C)	β_{koude}	$E_{kental, koude}$ (MJ/m^3)	
Agrarisch zonder koeling	7,4	0	0	8,8	0	0	Altijd WP
Agrarisch met koeling	7,4	0	0	8,8	0,5	19,8	
Industrie	1,2	0	0	3,2	1	3,5	Alleen koeling
Utiliteit zonder WP	5,7	0,3	23,0	4,1	1	9,3	
Utiliteit met WP	4,4	0	0	3,8	1	8,4	
Woningbouw met WP	3,6	0	0	3,9	0	0	Altijd met WP

ΔT= temperatuurverschil (°C)
β = de benuttingsfactor voor warmte respectievelijk koude
E_{kental} = kental voor warmte respectievelijk koude benutting (MJ/m^3)

Source: Agentschap NL, 2010, p.33

d) Numbers for heat pumps

Tabel 4.6.3: Kengetallen voor warmtepompen[15],[16]

Warmtepomp	Ruimte-verwarming		Tapwaterverwarming	
	V_r (h/jr)	SPF_r	$Q_{wp,t}$ [GJ/j]	SPF_t
Lucht-Lucht ≤ 12 kW SPF >3,6	550*	3,0	n.v.t.	n.v.t.
Lucht-Lucht > 12 kW SPF > 3,6	550*	3,0	n.v.t.	n.v.t.
Lucht-Water ≤ 12 kW SPF > 3,6	1100	3,2	8,940	1,9
Lucht-Water > 12 kW SPF > 3,6	1100	3,2	8,940	1,9
Bodem-Water ≤ 12 kW	1100	4,1	8,940	2,2
Bodem-Water > 12 kW	1100	3,8	8,940	2,2
Bodem-Lucht ≤ 12 kW	1100	3,5	n.v.t.	n.v.t.
Bodem-Lucht > 12 kW	1100	3,2	n.v.t.	n.v.t.
Water-water ≤ 12 kW	1100	4,3	8,940	2,4
Water-water > 12 kW	1100	4,3	8,940	2,4
Water-lucht ≤ 12 kW	1100	4,0	n.v.t.	n.v.t.
Water-lucht > 12 kW	1100	3,7	n.v.t.	n.v.t.
Gas-absorptie ≤ 12 kW	3500	1,2	8,940	1,2
Gas-absorptie > 12 kW	3500	1,3	8,940	1,3
Gas-motor ≤ 12 kW	1100	1,5	8,940	1,5
Gas-motor > 12 kW	1100	1,6	8,940	1,6
Warmteterugwinning bij melkkoeling (per melkkoe)			0,5	4,0

Source: Agentschap NL, 2010, p.35