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Local Power-to-Heat (P2H) district heating cooperatives

An exploration of the technical, economic, social and legal aspects of the establishment of a local P2H district heating cooperative in an existing residential area, particularly in the Netherlands.

Written by:	André Knol
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CSTM – the Department of Governance and Technology for Sustainability
Faculty of Behavioural, Management and Social sciences (BMS)

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Colophon

Student: A.F. (André) Knol
Programme: Master of Environmental and Energy Management (MEEM)
Specialisation: Energy Management
Student number: 2031493
Address: Aquamarijnstraat 553
9743 PN Groningen
Phone number: 06-15431964
E-mail address: andre-knol@hotmail.com

University: University of Twente
Department: Department of Governance and Technology for Sustainability (CSTM)
Faculty: Faculty of Behavioural, Management and Social sciences (BMS)
Address: Drienerlolaan 5
7522 NB Enschede

Supervisor: F.H.J.M. (Frans) Coenen
E-mail address: f.h.j.m.coenen@utwente.nl

Reader: Y. (Yoram) Krozer
E-mail address: y.krozer@utwente.nl

Client: Shell Nederland B.V.
Address: Carel van Bylandtlaan 16
2596 HR Den Haag

Contact person: P. (Peter) Breithaupt
E-mail address: peter.breithaupt@shell.com

Preface

While working on my master's thesis, day after day I began to realise more and more how topical and relevant the topic 'local Power-to-Heat (P2H) district heating (DH) cooperatives' is. The Netherlands is currently facing a major challenge: how are we going to transform our current energy system, which is largely based on fossil fuels, to a sustainable energy system based on renewable energy? However, it is very important to note that the question is no longer 'if' or 'when', but 'how'. As an illustration, on 29 March 2018, the national government decided to significantly reduce the extraction of natural gas in the province of Groningen and terminate it by 2030. This reflects the change of mindset that has already taken place.

Perhaps the biggest question of the entire energy transition is: how are we going to heat the seven million households in the Netherlands? During my thesis, I noticed that Dutch newspapers write about this question almost daily. Even many people in my social environment are wondering about this question. In the meantime, I had the privilege to think about this question daily, together with my supervisors and experts in the field. I hope that this master's thesis will be a valuable contribution to this question.

I want to express my gratitude to the people who have contributed to my master's thesis. First of all, I want to thank both of my supervisors: Peter (Shell New Energies) and Frans (University of Twente). Peter, I am very grateful for your involvement. You have invested so much valuable time and taught me important lessons. I admire your knowledge; you are a true inventor and forerunner in the energy transition. It has been a pleasure to get to know you and work together. Frans, thank you for your constructive feedback and useful advice. You really helped me to structure and focus my research. I also want to thank the experts who have invested their valuable time and were willing to give interviews. Their names are: Gerwin Verschuur (Thermo Bello), Fokko Reinders (Enexis), Jord Kuiken (TexelEnergie), Joep Broekhuis (Grunneger Power), Kees van Dalen (Enexis), Kevin Mooibroek (Reggefiber), Louis Hiddes (Mijnwater), Rie Krabsen (EBO Consult), and Wouter van Bolhuis (Gemeente Groningen). Everyone's contribution was very valuable for my thesis. Thanks again all!

To be honest, I really enjoyed writing my master's thesis! This thesis is not only a scientific report about local P2H DH cooperatives, but it also reflects a personal journey. This journey has contributed to my knowledge and understanding in many ways, but above all: it has opened my eyes to the valuable contribution that P2H DH cooperatives can make in the transition to a sustainable heat supply. I especially hope that this thesis will make a valuable contribution to Shell, Grunneger Power, and Stichting Paddepoel Energiek. Good luck with the establishment of the local P2H DH cooperative EcoGenie 2.0. I also hope that many others will read and use this thesis, and that it ultimately contributes to a more sustainable world. I have nothing more to say than: I hope you will enjoy reading!

André Knol

Groningen, 15 August 2018

Dutch summary

Door de uitputting van fossiele brandstoffen en klimaatverandering, maken energiesystemen wereldwijd een radicale transformatie door (Koirala et al., 2016). Wereldwijd proberen landen hun huidige afhankelijkheid van fossiele brandstoffen te minimaliseren en een energiesysteem op basis van hernieuwbare energiebronnen te ontwikkelen. Bovendien hebben in 2016 maar liefst 197 landen het Parijsakkoord ondertekend dat als doelstelling heeft om de opwarming van de aarde te beperken tot maximaal 2 °C ten opzichte van het pre-industriële niveau (UNFCC, 2015). Zo wil Nederland bijvoorbeeld in 2050 CO_2-neutraal te zijn (SER, 2013). De primaire energieverdeling van Nederland laat de omvang van de warmtevraag zien, namelijk 58% van het finale energieverbruik. Daarom is de transitie naar duurzame warmtebronnen cruciaal voor het bereiken van een CO_2-neutraal energiesysteem.

Veel wetenschapers (bijv. Bloess et al., 2018; Koirala et al., 2016 en Yilmaz et al., 2018) wijzen op de toenemende rol van elektriciteit voor een CO_2-neutrale warmtevoorziening. Ook in beleid, zoals de Europese Roadmap (ECF, 2010) en de Nederlandse Energieagenda (EZK, 2010), wordt voorspeld dat elektriciteit en bovendien stadsverwarmingssystemen een belangrijke rol zullen spelen in het tot stand brengen van een duurzame warmtevoorziening. Elektriciteit kan worden omgezet in warmte door de toepassing van P2H-technologie (het gebruik van (grote) warmtepompen of elektrische boilers) (Averfalk et al., 2017). De toepassing van P2H-technologie kent op individueel niveau drie grote belemmeringen: (1) onvoldoende capaciteit van het laagspanningsnet, (2) hoge investeringskosten ten gevolge van hoge isolatiegraat en (3) ruimtegebrek in bestaande huizen (Ecofys, 2015). Echter kunnen deze belemmeringen worden vermeden door de toepassing van P2H-technologie op collectief niveau (wijk). Bovendien is collectieve P2H een bewezen technologie, geschikt voor energieopslag, draagt het bij aan de reductie van CO_2-uitstoot en integreert het de elektriciteits- en warmtemarkt (Yilmaz et al., 2018).

Shell, de Nederlands-Britse olie- en gasmultinational, ondersteunt een coöperatieve startup die een pilot stadsverwarmingssysteem wil ontwerpen, bouwen en beheren. De pilot voor ongeveer 100-200 huishoudens is gebaseerd op P2H-technologie en beoogt een coöperatieve organisatiestructuur. De pilot is genaamd EcoGenie 2.0 en vindt plaats in Paddepoel-Noord, een bestaande woonwijk in de stad Groningen. Om te slagen moet vergeleken met de huidige situatie in Paddepoel-Noord het comfort worden verhoogd, de CO_2-uitstoot met minimaal 50% worden verminderd en de warmte 10-20% goedkoper worden geleverd. Thermo Bello in Culemborg is het enige Nederlandse voorbeeld van een lokale P2H-stadsverwarmingscoöperatie. Hierdoor is er in Nederland weinig (wetenschappelijke) kennis en ervaring met P2H-technologie in combinatie met een coöperatieve organisatiestructuur.

Yilmaz et al. (2018) stelt dat voor het opstellen van een haalbare businesscase en het oprichten van een lokale P2H-stadsverwarmingscoöperatie, het noodzakelijk is om alle aspecten van P2H-integratie gelijktijdig te ontwikkelen. Bovendien onderscheiden Yilmaz et al. (2018) vier ‘overkoepelende’ aspecten, namelijk: (1) technische aspecten, (2) economische aspecten, (3) sociale aspecten en (4) wettelijke aspecten. Deze thesis brengt de voornaamste technische, economische, sociale en wettelijke aspecten van het opzetten van een lokale (P2H) stadsverwarmingscoöperatie in een bestaande woonwijk in kaart (vooral gericht op Nederland). Daarnaast zijn de aspecten toegepast op de EcoGenie 2.0 pilot in Paddepoel-Noord en is de economische haalbaarheid beoordeeld door het opstellen van een businesscase. De hoofdvraag luidt:

Wat zijn de voornaamste technische, economische, sociale en wettelijke aspecten van het opzetten van een lokale Power-to-Heat (P2H) stadsverwarmingscoöperatie in een bestaande woonwijk, met name in Nederland?

Deze vraag is in vier opeenvolgende fasen beantwoord: (1) verkenning, (2) begrip, (3) ontwerp en (4) evaluatie, gebaseerd op Gonzalez & Sol (2012). Daarnaast zijn twee onderzoeksstrategieën gebruikt om deze vraag te beantwoorden, namelijk deskresearch en casestudies.

De verkenningsfase start met een wetenschappelijke literatuurstudie over de historische ontwikkeling en het huidige functioneren van het Nederlandse geliberaliseerde energiesysteem (elektriciteit en aardgas). De liberalisering heeft bijgedragen tot een aanzienlijke overcapaciteit aan geïnstalleerd vermogen voor elektriciteitsopwekking (IEA, 2014). Bovendien resulteert een toename van hernieuwbare energie in een daling van de elektriciteitsprijs en een toename van de prijsvolatiliteit op de groothandelsmarkt. Dit wordt gewoonlijk het merit-order effect of de hernieuwbare energie paradox genoemd (bijv. Cludius et al., 2014; Winkler et al., 2016 en Blazquez et al., 2018). Volgens veel wetenschappers (bijv. Bloess et al., 2018; Koirala et al., 2016 en Yilmaz et al., 2018) is het merit-order effect zeer gunstig voor de toepassing van P2H-technologie. De verkenningsfase is vervolgd met deskresearch naar de voornaamste aspecten van de oprichting van lokale (P2H) stadsverwarmingssystemen en lokale stadsverwarmingscoöperaties. Daarnaast is de Warmtewet geanalyseerd. De Warmtewet reguleert de warmtevoorziening voor consumenten met een aansluiting tot 100 kWt. De verkenningsfase is afgesloten met een conceptueel model dat de voornaamste (theoretische) aspecten samenvat (paragraaf 3.4).

De begripfase bestaat uit vijf casestudies, namelijk: (1) Thermo Bello in Culemborg, (2) Mijnwater in Heerlen, (3) TexelEnergie op Texel, (4) de customer journey van EBO Consult en (5) de marketingstrategie van Reggefiber. Thermo Bello, een kleinschalige P2H-stadsverwarmingscoöperatie, heeft bijgedragen aan alle vier aspecten en belangrijke lessen onthuld. Mijnwater is een P2H-stadsverwarmingsbedrijf en TexelEnergie een voormalige en kleinschalige stadsverwarmingscoöperatie. Beide casestudies hebben gezamenlijk bijgedragen aan alle vier aspecten en hebben belangrijke lessen opgeleverd. De customer journey van EBO Consult (Deens onafhankelijk administratiebedrijf gespecialiseerd in stadsverwarmingscoöperaties) en de marketingstrategie van Reggefiber (Nederlands glasvezelbedrijf) hebben gedetailleerde inzichten gegeven in het sociale aspect. Deze vijf case studies hebben geleid tot verificatie van de (theoretische) aspecten en hebben nieuwe (empirische) aspecten toegevoegd. Bovendien hebben de casestudies belangrijke lessen onthuld over de oprichting van lokale P2H-stadsverwarmingscoöperaties. De begripfase is afgesloten met een framework dat de voornaamste (theoretische en empirische) aspecten samenvat (paragraaf 5.3).

De ontwerpfase heeft de eerder gevonden aspecten toegepast op het pilotproject EcoGenie 2.0 in Paddepoel-Noord. Momenteel hebben de huishoudens een individuele gasgestookte ketel. Het huidige energieverbruik en de bijbehorende kosten en CO_2-emissies zijn berekend. Vervolgens is een exploitatiebegroting opgesteld om de kosten van EcoGenie 2.0 te ramen, waarna de kosten en de CO_2-emissies van de huidige situatie zijn vergeleken met de toekomstige situatie van EcoGenie 2.0.

Ten slotte wordt in de evaluatiefase de hoofdvraag beantwoord. Ook wordt er uitgezoomd om de bijdrage van lokale P2H-stadsverwarmingscoöperaties aan de transitie naar een CO_2-neutrale warmtevoorziening te bespreken. Er kan worden geconcludeerd dat lokale P2H-stadsverwarmingscoöperaties kunnen bijdragen aan een CO_2-neutrale energievoorziening, met name in de bestaande gebouwde omgeving. In aanvulling op de vier overkoepelende aspecten genoemd door Yilmaz et al. (2018), is het overkoepelende organisatorische/bestuurlijke aspect geïdentificeerd. De investeringskosten van EcoGenie 2.0 worden geschat op € 13.500/huishouden. Dit resulteert in een terugverdientijd van 31 jaar en een Return on invested capital (ROIC) van 1,85-2,00% (afhankelijk van de warmtetarieven). Een subsidie van € 5.000/huishouden leidt tot een terugverdientijd van 24 jaar en een ROIC van 4,58%. Zowel casestudies als eigen berekeningen voor EcoGenie 2.0 tonen het belang van hernieuwbare energie om de CO_2-uitstoot te verminderen. Wanneer EcoGenie 2.0 hernieuwbare energie omzet in warmte, wordt in vergelijking met de huidige situatie de (directe) CO_2-uitstoot met 77,8% verlaagd.

English summary

Due to the depletion of fossil fuels and climate change, energy systems across the globe are going through a radical transformation (Koirala et al., 2016). Countries around the world intend to minimise the current dependency on fossil fuels and develop an energy system based on renewable energy sources (RES). In addition, no less than 197 countries signed the Paris Agreement in 2016, which aims to limit the temperature increase to maximum 2 °C above pre-industrial level (UNFCC, 2015). The Netherlands, for example, aims to be CO_2-neutral by 2050 (SER, 2013). The primary energy breakdown of the Netherlands reveals the magnitude of the heat demand, namely 58% of the final energy usage. That is why the transition to sustainable heat sources is crucial in the transition to a carbon-neutral energy system.

Many scholars (e.g. Bloess et al., 2018; Koirala et al., 2016 and Yilmaz et al., 2018) point to the increasing role of electricity in the transition to a carbon-neutral heating sector. In addition, policies such as the European Roadmap (ECF, 2010) and the Dutch Energy Agenda (EZK, 2010), predict that electricity and DH systems will play an important role in establishing a sustainable heat supply. Electricity can be converted to heat by the application of P2H technology (the use of (large) heat pumps or electric boilers) (Averfalk et al., 2017). The application of P2H technology has three major obstacles at an individual level: (1) insufficient capacity of the low-voltage grid, (2) high investment costs as a result of expensive refurbishment and insulation, and (3) lack of space in existing houses (Ecofys, 2015). The application of P2H technology at a collective level (district), however, avoids these obstacles. Furthermore, collective P2H is a proven technology: it capable of energy storage, it contributes to the reduction of CO_2 emissions, and integrates the electricity and heat market (Yilmaz et al., 2018).

Shell, the Dutch-British oil and gas multinational, supports a cooperative start-up that aims to design, build, own, and operate a pilot DH system. The pilot for circa 100-200 households is based on P2H technology and a cooperative governance structure. This pilot is called EcoGenie 2.0 and will be located in Paddepoel-Noord, an existing residential area in the city of Groningen. In order to be successful, it needs to increase comfort, reduce CO_2 emissions with at least 50% and supply heat 10-20% cheaper based on the current situation in Paddepoel-Noord. Thermo Bello in Culemborg is the only Dutch example of a local P2H DH cooperative. As a result, there is little (scientific) knowledge and experience with P2H technology combined with a cooperative governance structure in the Netherlands.

Yilmaz et al. (2018) states that in order to create a feasible business case and to establish a local P2H DH cooperative, it is necessary to develop all aspects of P2H integration simultaneously. Furthermore, Yilmaz et al. (2018) distinguished four 'overarching' aspects, namely: (1) technical aspects, (2) economic aspects, (3) social aspects, and (4) legal aspects. This thesis has developed a framework that includes the main technical, economic, social and legal aspects of establishing a local (P2H) DH cooperative in an existing residential area, particularly in the Netherlands. In addition, the aspects have been applied to EcoGenie 2.0 in Paddepoel-Noord and examined the economic feasibility by drawing up a business case. The main research question was:

What are the main technical, economic, social, and legal aspects of establishing a local Power-to-Heat (P2H) district heating cooperative in an existing residential area, particularly in the Netherlands?

This question has been answered in four consecutive phases: (1) exploration, (2) understanding, (3) design, and (4) evaluation, based on Gonzalez & Sol (2012). In addition, two research strategies were used to answer this question, namely desk research and case studies.

The exploration phase starts with a scientific literature review about the historical development and the current functioning of the liberalised Dutch energy system (electricity and natural gas). The liberalisation has contributed to a significant overcapacity of installed capacity for electricity generation (IEA, 2014). Moreover, an increase of renewables results in a decrease of the electricity price and an increase in price volatility at the wholesale market. This is usually called the merit order effect or the renewable energy paradox (e.g. Cludius et al., 2014; Winkler et al., 2016 and Blazquez et al., 2018). According to many scholars (e.g. Bloess et al., 2018; Koirala et al., 2016 and Yilmaz et al., 2018), the merit order effect is highly beneficial to the application of P2H technology. The exploration phase continued with desk research on the main aspects of the establishment of local (P2H) DH systems and local DH cooperatives. In addition, the Heat Act has been analysed. The Heat Act regulates the heat supply for consumers with a connection up to 100 kWt. The exploration phase concludes with a conceptual model (paragraph 3.4) that summarises the main (theoretical) aspects.

The understanding phase consists of five case studies, namely: (1) Thermo Bello in Culemborg, (2) Mijnwater in Heerlen, (3) TexelEnergie on Texel, (4) the customer journey of EBO Consult, and (5) the marketing strategy of Reggefiber. Thermo Bello is a small-scale P2H DH cooperative and has contributed to all four aspects and revealed important lessons. Mijnwater is a P2H DH company and TexelEnergie a former small-scale DH cooperative. Both cases have contributed to all four aspects and revealed important lessons. The customer journey of EBO Consult (a Danish independent administration company specialised in managing DH cooperatives) and the marketing strategy of Reggefiber (a Dutch fibre optic networks company) have given detailed insights into the social aspect. These five case studies together have led to the verification of the (theoretical) aspects and have added new (empirical) aspects. Moreover, the case studies have revealed important lessons about the establishment of a local P2H DH cooperative. The understanding phase concludes with a framework that summarises the main theoretical and empirical aspects (paragraph 5.3).

The design phase applied the aspects found in the earlier stages of this research to the EcoGenie 2.0 pilot in Paddepoel-Noord. Currently, every household has an individual gas-fired boiler installed. The current energy consumption and associated costs and CO_2 emissions have been calculated. An operating budget was then drawn up to estimate the costs of EcoGenie 2.0. Finally, the costs and CO_2 emissions of the current situation were compared with the future situation of EcoGenie 2.0.

Finally, the evaluation phase answered the main research question and zoomed out to discuss the contribution of local P2H DH cooperatives to the transition to a carbon-neutral heating sector. It can be concluded that local P2H DH cooperatives can contribute to the transition to a sustainable heat supply, especially in the existing built environment. In addition to the four overarching aspects mentioned by Yilmaz et al. (2018), organisation/governance has also been identified as an overarching aspect. The investment costs of EcoGenie 2.0 are estimated at € 13,500/household. This results in a payback time of 31 years and an ROIC of 1.85-2.00% (depending on the heat tariffs). A subsidy of € 5,000/household leads to a payback time of 24 years and an ROIC of 4.58%. Both case studies and own calculations for EcoGenie 2.0 showed the importance of renewable energy to reduce CO_2 emissions. When EcoGenie 2.0 converts renewable power into heat, it reduces (direct) CO_2 emissions by 77.8% compared to the current situation.

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Terms and abbreviations

ACI	Aggregate carbon intensity
ACM	Authority for Consumers and Markets
ASHP	Air-sourced heat pump
CAPEX	Capital Expenditures
CHP	Combined Heat and Power
CO_2	Carbon dioxide
COP	Coefficient of Performance
DH	District Heating
DSO	Distribution System Operator
GHG	Greenhouse gas
GSHP	Ground-sourced heat pump
H-gas	High calorific gas
L-gas	Low calorific gas
NPV	Net Present Value
O&M	Operation & Maintenance
OPEX	Operating Expenses
P2H	Power-to-Heat
RES	Renewable Energy Sources
ROIC	Return on Invested Capital
SodM	State supervision of the Mines
TES	Thermal Storage Capacity
TSO	Transmission System Operator

1 Introduction

As a result of human activities, climate change (global warming and more extreme weather events) is one of the major challenges of the twenty-first century. The global temperature has been increasing significantly since the middle of the past decade due to greenhouse gas (GHG) emissions. Continued emissions of GHG will cause further global warming and increases the likelihood of severe, pervasive, and irreversible impacts for people and ecosystems (IPCC, 2014 and EPA, 2018). A very important step to reduce GHG emissions was taken in 1997, when the Kyoto Protocol was signed. This protocol is an international treaty – currently signed by 192 parties, including the Netherlands – committing the parties to reduce their GHG emissions to the level of the base year of 1990 (United Nations, 1998). The most recent step to fight global warming is the Paris Agreement, which entered into force on 4 November 2016. This agreement was signed by 197 countries and is currently ratified by 174 countries (UNFCC, 2018). The aim of the Paris Agreement is explained in article 2: *"holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels [...]"* (UNFCC 2015, p.2). In practise, this means a CO_2 reduction of 80-95% for the Netherlands compared to 1990 levels (SER, 2013).

Due to the depletion of fossil fuels and climate change, energy systems across the globe are going through a radical transformation (Koirala et al., 2016). The intended change is to minimise the current dependency on fossil fuels and to develop an energy system based on renewable energy sources (RES). This process is generally called the energy transition. Cities will play a big role in the energy transition, because currently 54% of the world population lives in urban areas. It is expected that urbanisation will continue, which means that 66% of the world population will live in urban areas by 2050 (UN, 2014). Therefore, cities are a major contributor of GHG emissions. On the other hand, cities could play a strategic role in the energy transition because cities are the heart of creativity and innovation (Ellen MacArthur Foundation, 2017).

The national government of the Netherlands also participates in the energy transition. The national government took a very important step in 2013, when more than forty governmental, societal, environmental, and private organisations signed the Energy Agreement for Sustainable Growth (in Dutch: *Energieakkoord voor Duurzame Groei*). The ultimate goal is to establish a carbon-neutral energy system by 2050, which basically means that there will be no CO_2 emissions unless they are compensated somewhere else (SER 2013, p.29). To achieve this goal, different short-term goals have been set based on different time frames. The most well-known goals are reducing the total energy consumption by 1.5% per year and increasing the share of renewables to at least 14% by 2020 and 16% by 2023 (SER 2013, p.11). Unfortunately, the first policy evaluation of the Energy Agreement showed that the targets of 2020 are not achievable anymore (KWINK groep, 2016). In comparison with other Western European countries, many experts in the field describe the Netherlands as the *'shameful laggard'* (OneWorld, 2018).

Another important step was taken in 2016, when the Dutch ministry of Economic Affairs introduced the Energy Agenda (in Dutch: *Energieagenda*), which provides a more accurate picture of the energy transition and the (policy) measures that will be taken. The vision for 2050 is: "*Electricity is then generated sustainably, buildings are mainly heated by geothermal heat and electricity, companies have adjusted their production processes, there is no longer heating on natural gas, and almost only electric cars are used"* (EZK 2016, p.5).

Recently, on 29 March 2018, the Dutch national government decided that low calorific gas (L-gas) production in Groningen should be terminated as quickly as possible because the natural gas extraction causes earthquakes in the local environment (EZK, 2018). This measure was taken on the basis of the advice of the State supervision of the Mines (in Dutch: *Staatstoezicht op de Mijnen, SodM*). Their advice was to reduce the natural gas extraction to at least twelve billion Nm^3, but the national government decided to completely terminate the natural gas extraction by 2030.

Likewise, the regional and municipal levels participate in the energy transition. In fact, many regional and local governments are much more ambitious and proactive towards the energy transition. Blokhuis et al. (2012) calls this phenomenon the bottom-up movement of regional and local governments. Furthermore, public awareness is increasing (Golušin et al., 2013). At the community and district levels, bottom-up initiatives such a community windmill or community solar PV are emerging (Arentsen & Bellekom, 2014 and Schoor & Scholtens, 2015). Even the individual level participates in the energy transition; households are no longer only end-users (consumers) of energy but also become producers of energy. In other words, households become prosumers, both on an individual level and a community level (Timmerman, 2017).

1.1 Problem statement

It is inevitable that all different sectors and applications of energy need a radical transformation to achieve the global and national climate and energy goals. The primary energy breakdown of the Netherlands reveals the major share of heat demand compared to the share of electricity and the share of transport (figure 1). 58% of the total primary energy consumption is used for heating, electricity, and transport applications. The other 32% is used for non-energetic purposes (e.g. producing plastics from oil), is consumed by the energy sector itself or is lost as a result of conversion loss. Furthermore, the built environment (space heating, hot tap water, and cooking) consumes 43% of the total heat usage, 47% is consumed by the industry, and 10% is consumed by the agricultural sector. In view of the total primary energy demand, heat (low- and high-temperature) has the largest share.

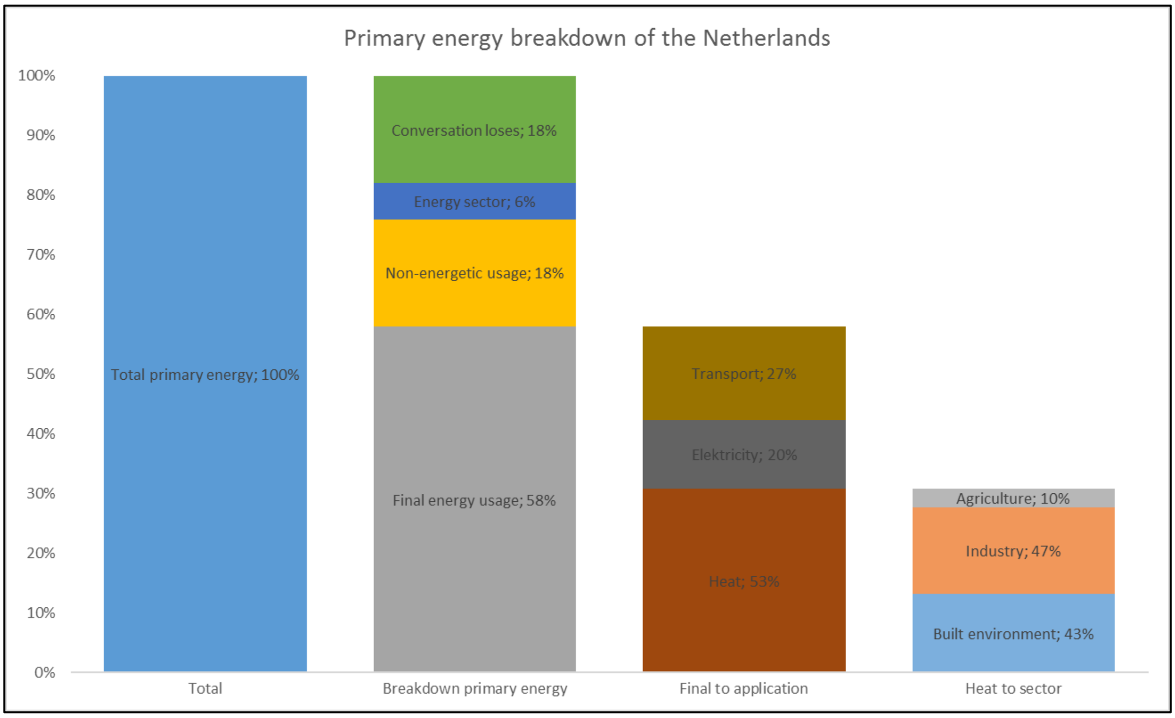

Figure 1. Primary energy breakdown of the Netherlands in 2015 (based on data from CBS, 2015).

Given the magnitude of the heat demand, the transition to sustainable heat sources is crucial in the transition to a carbon-neutral energy system. Currently, 90% of the built environment (consisting of residential and non-residential buildings) uses natural gas for space heating, hot tap water, and cooking. The other 10% of the built environment uses (industrial) residual heat, heat pumps, green gas, or other miscellaneous sources (EZK, 2016). Most of the houses in the Netherlands are equipped with an individual gas-fired boiler. In fact, about two-thirds of the total CO_2 emissions per household are caused by the combustion of natural gas.

The national government took a first step towards a sustainable heat supply by abolishing the connection obligation (in Dutch: *aansluitplicht)* to the natural gas network for new buildings (RVO, 2018a). In addition, this amendment of law should lead to new innovations supporting houses with a sustainable heat source instead of houses relying on natural gas.

However, according to the Energy Agenda, the disconnection and long-term heat supply of the existing built environment will be the biggest challenge of the transition towards renewable heat sources (EZK, 2016). The policies described above imply that roughly seven million Dutch households must switch to another (sustainable) heat source (VNG, 2016). In 2021, around 30,000-50,000 households will be disconnected which amounts to about 0.4-0.7% of the total number of households (EZK, 2018). In 2030, however, two million households need to be disconnected (34%) (Trouw, 2018). This implies that after 2021, 200,000 (2.9%) households must be disconnected annually in order to achieve the energy targets. In addition, existing DH systems are currently largely gas-fired and also have to switch to a sustainable heat source (e.g. residual heat of industries).

It is forecasted that electricity will have a predominant role in the energy transition, mainly caused by the increasing popularity of electrical vehicles and electrical heating (Koirala et al., 2016). According to the European Roadmap, electricity will double its share by 2050 compared to 2005 (ECF, 2010). Hers et al. (2015) investigated the potential options for heating in Northwest Europe and concluded that P2H is one of the most promising options. P2H converts electricity to (low-temperature) heat by means of industrial heat pumps and electric boilers. Also, the Dutch government considers heat pumps and DH systems as the preferred road towards a low-carbon energy system (EZK, 2016). On the other hand, Dutch society is suspicious and afraid of excessive prices and loss of comfort, even now that the Heat Act is in force (Ecorys, 2016 and FD, 2017).

However, installing individual heat pumps requires large investments in the low-voltage grid, because the current infrastructure can supply a peak load of circa 1.2 kW per household. For example, if all Dutch households switch to an air-sourced heat pump (ASHP) and thoroughly insulate their houses, still a tripling of the low-voltage grid power capacity is needed (Ecofys, 2015). In addition, individual heat pumps require high investments per households (insulation) and not every house has space to install a heat pump. On the other hand, collective DH systems with the application of industrial heat pumps and electric boilers can be connected to the medium-voltage grid. As a result, the obstacles mentioned above can be avoided. Other positive aspects are the significantly lower energy requirements (COP) and the rapidly growing shares of renewable electricity, mainly as a result of the increase of wind and solar energy. Furthermore, collective P2H is a proven technology: it is capable of energy storage, it contributes to CO_2 emissions reduction, and it integrates the electricity and heat markets (Yilmaz et al., 2018). Thermo Bello in Culemborg (near Utrecht) is the only P2H DH cooperative in the Netherlands. It supplies heat to 210 households and seven commercial buildings by means of an industrial heat pump.

Shell, the Dutch-British oil and gas multinational, supports a cooperative start-up that aims to design, build, own, and operate a pilot DH system for circa 100-200 households based on P2H technology and a cooperative governance structure. This pilot is called EcoGenie 2.0. Not only does Shell want to contribute to the energy transition by reducing its own carbon footprint, but also by developing and exploring new commercial energy models (Shell, 2018). For example, Shell is collaborating in the construction of wind farms in the North Sea, which will play an important role in the future energy supply (NOS, 2016). The project location of EcoGenie 2.0 will be Paddepoel-Noord, an existing residential area in the city of Groningen, built during the 1960s and 1970s. In order to be successful, the DH system needs to ensure lower costs, higher comfort, and cleaner supplies. It needs to increase comfort, reduce CO_2 emissions with at least 50%, and supply heat 10%-20% cheaper, all based on the current situation in Paddepoel-Noord. It is important to note that renewable electricity will be used to power an industrial ground-sourced heat pump (GSHP) and an electric boiler. In addition, EcoGenie 2.0 strives for intensive engagement of customers and stakeholders.

The EcoGenie 2.0 pilot contributes to the Dutch Energy Agenda, as well as to the local climate goals of the municipality of Groningen. In fact, the municipality of Groningen is even more ambitious because it aims to reduce 50% of its CO_2 emissions by 2025 and wants to become CO_2-neutral by 2035 (gemeente Groningen, 2011). Furthermore, the municipality of Groningen wants to be natural gas free by 2035 (gemeente Groningen, 2016) and to become an ‘Energy City’ by developing local knowledge and opportunities (gemeente Groningen, 2015).

In summary, the establishment of a local (P2H) DH cooperative requires at least four transitions:

1. From a conventional heat source (natural gas) to a sustainable heat source (P2H).
2. From an individual solution (gas-fired boiler) to a collective solution (DH).
3. From commercial (energy suppliers) to non-commercial (cooperatives).
4. From a national level to a community/district level.

1.2 Objective and research questions

The objective of this research is to design a framework that includes the main technical, economic, social, and legal aspects of establishing a local (P2H) DH cooperative in an existing residential area, particularly in the Netherlands. In addition, this research will apply these aspects to the EcoGenie 2.0 pilot in Paddepoel-Noord and examines the economic feasibility by drawing up a business case. Based on the problem statement and the objective, the following research question has been formulated:

What are the main technical, economic, social, and legal aspects of establishing a local Power-to-Heat (P2H) district heating cooperative in an existing residential area, particularly in the Netherlands?

1.2.1 Sub-questions

To answer the main research question as thoroughly as possible, the following sub-questions will be discussed:

1. How did the Dutch energy system (natural gas and electricity) develop and how does it function nowadays?
2. What is a (P2H) DH system, which types can be distinguished, and what are the main technical and economic aspects?
3. What is a local DH cooperative, which types can be distinguished, and what are the main social and legal aspects?

4. Which aspects can be found in existing (P2H) DH cooperatives and which lessons can be learned?
5. Does EcoGenie 2.0 reduce CO_2 emissions by at least 50% and supply heat 10-20% cheaper, based on the current situation in Paddepoel-Noord?

1.2 Scientific and social relevance

Thermo Bello in Culemborg is the only Dutch example of a local P2H DH cooperative. As a consequence, there is little (scientific) knowledge and experience with P2H technology combined with a cooperative governance structure in the Netherlands. This research contributes to the body of knowledge by collecting and reviewing knowledge of and experiences with this type of technology in combination with a cooperative governance structure. The framework with the main technical, economic, social, and legal aspects could also be the basis for further research. Moreover, P2H is a very interesting alternative for the current heating system in the Netherlands (Hers et al., 2015). Therefore, it could play an important role in the Dutch transition towards a CO_2-neutral energy system. In addition, the EcoGenie 2.0 pilot is in line with the national, regional, and local climate goals. When the pilot is successful, it will directly affect the residents of Paddepoel-Noord because it aims to ensure lower costs, higher comfort, and cleaner supplies. Because the heat will be produced by a renewable energy source (wind energy), the pilot contributes to the quality of life of present and the future generations. In case the pilot is not successful, which means that the three objectives cannot be achieved, the pilot and this research still contribute to the body of knowledge.

1.4 Demarcation

This study focuses on the establishment of a local P2H DH cooperative in an existing residential area, particularly in the Netherlands. The industrial GSHP and electric boiler will be powered mainly by wind energy. The potential of other applications (e.g. industry and horticulture) and other conversion and/or integration technologies (e.g. power-to-gas and smart grids) are acknowledged but not included, nor considered as an alternative. Also, other (renewable) fuels for DH systems (e.g. geothermal energy, biomass, residual heat or (the future possibility of) hydrogen) are not included, nor considered as an alternative. After all, the governance structure will be a cooperative.

1.5 Research methodology

A hypothetical-deductive approach will be used to meet the objective of this research. This approach derives a conceptual model from existing literature (theories), and then verifies whether the relationships in the model, i.e. the causal hypotheses, are not falsified by empirical data (Verschuren & Doorewaard, 2010). Furthermore, this methodology provides insights in how mechanisms work, in this case a ‘local (P2H) DH cooperative’. The research methodology consists of four consecutive steps: (1) exploration, (2) understanding, (3) design, and (4) evaluation (Gonzalez & Sol, 2012). Figure 2 is a visualisation of this methodology.

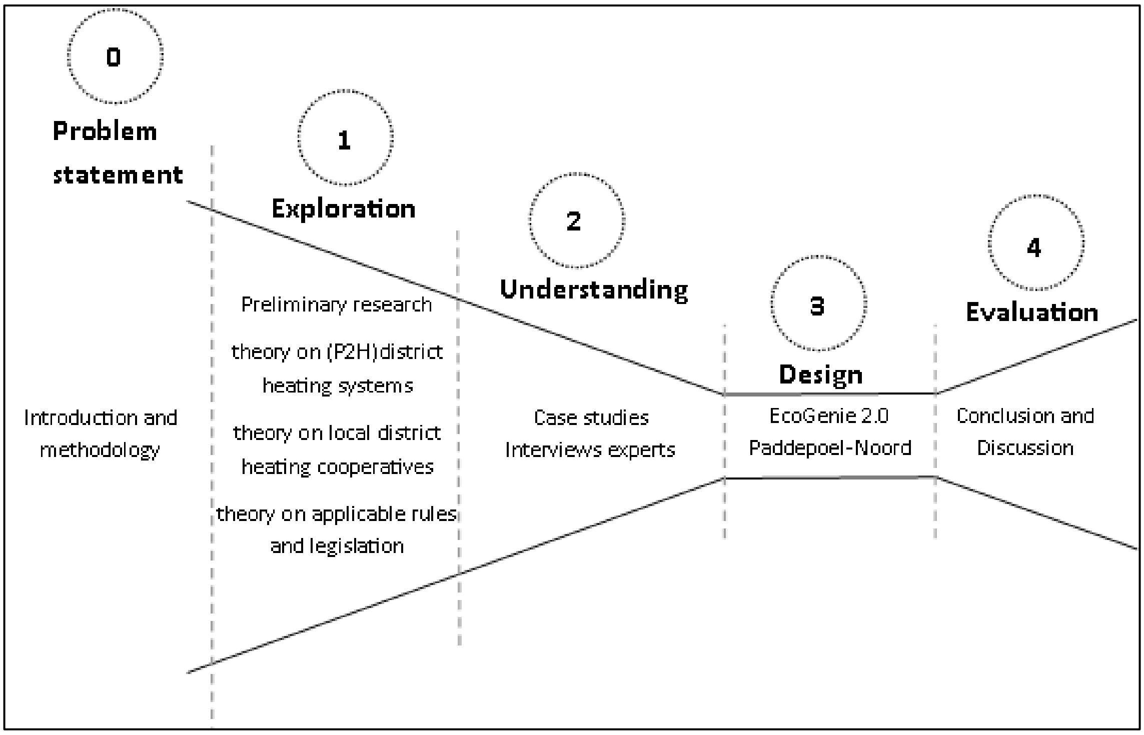

Figure 2. Research methodology local P2H DH cooperatives.

Below, the four steps are explained in more detail:

1. The exploration phase: the aim of this phase is to theoretically explore the key concepts of this research by a (scientific) literature review. The research strategy is desk research, which, according to Verschuren & Doorewaard (2010), is the art of reflecting on existing literature. Only (scientific) literature and (official) documents such as governmental reports or semi-governmental reports will be used. First of all, the historical development and the current functioning of the Dutch liberalised energy system will be reviewed. This is important in order to understand the four transitions mentioned in the problem statement (paragraph 1.1). Secondly, the key concepts 'local (P2H) DH systems' and 'local DH cooperatives' will be reviewed. The main technical, economic, social, and legal aspects will be examined. Furthermore, a special focus will be on applicable rules and legislation for heat supply (the Heat Act) in the Netherlands. The findings will lead to a conceptual model that summarises the main (theoretical) technical, economic, social, and legal aspects of the establishment of local P2H DH cooperatives. The conceptual model will be the 'heart' of this research. The exploration phase covers the answering of sub-questions 1 to 3.
2. The understanding phase: the aim of this phase is to gather empirical data in order to get an in-depth understanding of local P2H DH cooperatives. The research strategy is case studies, which will be carried out on local P2H DH cooperatives. The case studies will be used to verify the (theoretical) aspects of the previous phase and to find new (empirical) aspects. The findings will lead to a framework that summarises the main theoretical and empirical technical, economic, social, and legal aspects of the establishment of local P2H DH cooperatives. A detailed description and justification of the research methodology for the case studies is included in chapter 4. The case studies cover the answering of sub-question 4.
3. The design phase: the aim of this phase is to apply the previous findings to the EcoGenie 2.0 pilot in Paddepoel-Noord. The framework with the main technical, economic, social, and legal aspects of local P2H DH cooperatives will be applied to the EcoGenie 2.0 pilot. As mentioned earlier, the EcoGenie 2.0 pilot aims to reduce CO_2 emissions by at least 50%, supply heat 10-

20% cheaper, and increase comfort. The feasibility of these goals will be compared to the previous findings of this research. Specific information about the local situation in Paddepoel-Noord and detailed information on the EcoGenie 2.0 pilot will be derived from (official) documents and expert interviews. The findings lead to a business case and a comparison between the current energy situation in Paddepoel-Noord and the future situation with EcoGenie 2.0. The focus is on costs and CO_2 emissions. This covers the answering of sub-question 5.

4. The evaluation phase: the aim of this phase is first of all to draw conclusions based on the previous findings. The answers to the five sub-questions cover the answering of the main question. Furthermore, this phase zooms out to discuss the results in the light of the Dutch energy transition (introduction) and the problem statement (paragraph 1.1). Finally, recommendations for further research will be included.

1.5.1 Research strategies

Table 1 shows an overview of the different research strategies, the data sources, and the methods of assessing that will be used in this research. More detailed information on the research methodology for the case studies is included in chapter 4.

Table 1. Overview research strategies.

Research phase	Research strategy	Data sources	Assessing
1. Exploration	- Desk research	- (Scientific) literature - (Official) documents	- Search method - Content analysis
2. Understanding	- Interviews - Case studies	- Individual people - The media - (Scientific) literature - (Official) documents	- Search method - Content analysis - Questioning
3. Design	- Desk research - Interviews	- Individual people - The media - (Official) documents	- Search method - Content analysis - Questioning
4. Evaluation	Not applicable	Not applicable	Not applicable

1.6 Ethical statement

Research, and especially research involving human subjects or participants, can raise ethical issues. Newman & Jones (2006) emphasise the importance of authorship: not referring to the author has academic, social, and financial implications. Furthermore, referring implies responsibility and accountability for the published work. Every source that will be used for this research (official documents, peer-reviewed articles, newspaper articles, ideas of respondents etc.), will be referenced in a transparent and scientific way; credit where credit is due.

Several interviews with experts (participants) will be conducted. Therefore, it is important to identify the ethical considerations in advance. The ethical considerations are identified using the three ethical principles of the Belmont Report (1979): respect, beneficence, and justice. Beneficence and justice are in a sense interlinked. The two rules of beneficence are: (1) do not harm and (2) maximise possible benefits and minimise possible harms. Justice is about who bears the burden and who receives the benefits. It is unlikely that this study will be harmful to anybody or distribute benefits and harm unequally. According to the Belmont Report (1979), respect incorporates at least two ethical convictions: first, that individuals should be treated as autonomous agents, and second, that persons with diminished autonomy are entitled to protection. To mitigate the first ethical conviction, the interviewee: (1) will be informed in advance about the research objective/questions, (2) will always be allowed to stop during the interview without providing any reason, (3) permission will be asked to record the interview, and (4) the interviewee's information will be protected and anonymised (DiCicco-Bloom & Crabtree, 2006). The second ethical conviction is not applicable because it is not likely that the interviewees belong to a vulnerable group.

1.7 Reading guide

This master's thesis starts with general theories and narrows down to the specific EcoGenie 2.0 pilot in Paddepoel-Noord. The second chapter includes the historical development and the current functioning of the liberalised energy system of the Netherlands. The third chapter discusses the key concepts 'local (P2H) DH systems' and 'local DH cooperatives'. The main technical, economic, social, and legal aspects are distinguished based on (scientific) literature and (official) documents. The chapter concludes with a conceptual model summarising the main (theoretical) aspects of the establishment of local P2H DH cooperatives. The fourth chapter contains the research methodology. It describes and justifies the case studies and associated expert interviews. It offers transparency about why specific cases and respondents have been selected. The fifth chapter describes briefly the five case studies, namely: (1) Thermo Bello in Culemborg, (2) Mijnwater in Heerlen, (3) TexelEnergie on Texel, (4) the customer journey of EBO Consult, and (5) the marketing strategy of Reggefiber. The chapter verifies the theoretical aspects and adds empirical aspects. In addition, it contains important lessons from experts involved in the case studies. Chapter 5 concludes with a framework summarising the main theoretical and empirical aspects of the establishment of local P2H DH cooperatives. The sixth chapter discusses the EcoGenie 2.0 pilot in Paddepoel-Noord and applies the main aspects. It contains a business case and a comparison of the current energy situation and the future situation with EcoGenie 2.0, focused on costs and CO_2 emissions. Finally, chapter 6 concludes this thesis by answering the main research question, discussing the results, and setting the agenda for further research.

2 The liberalised energy system of the Netherlands

To understand the current liberalised energy system and the current challenges of the Netherlands, it is important to understand its history. Verbong & Geels (2007) analysed the energy transition of the Dutch electricity system between 1960 and 2004 from a socio-technical perspective. The following description of the historical development of the Dutch energy system is mainly derived from their findings.

In 1960, the electricity regime was quite stable and the dominant regime actors were regional and municipal utilities. Two main guiding principles were to provide cheap energy for large industries and grid reliability. Figure 3 shows the actors and networks in the electricity regime of the 1960s. Two actors played a role in the electricity regime, namely the utilities and the Arnhem organisations. The utilities were responsible for the production, transport, and sale of electricity. The Arnhem organizations were as a central body responsible for the inspection and certification of electrical appliances. Later this became the ‘KEMA-keur(merk)’, carried out by DERKA. An informal regime rule was to exclude the national government. However, the discovery of natural gas in Groningen and new developments with nuclear energy led to changes. The national government wanted more control over the electricity regime. The electricity regime was initially excluded from buying and using natural gas. That is why the national government has played an active role in the exploration of natural gas reserves. The government created a national monopoly on natural gas exploitation with the establishment of a public-private cooperation between the Dutch state, Shell and Exxon, and Gasunie. Their first focus was space heating for households and buildings.

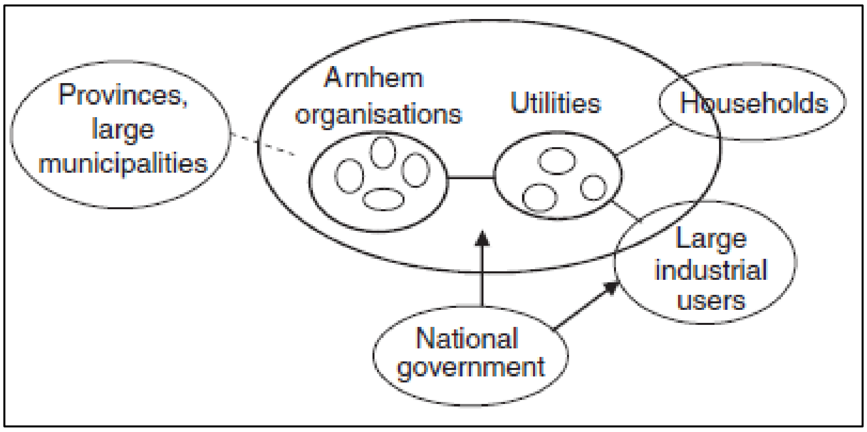

Figure 3. Actors and networks in electricity regime 1960s (Verbong & Geels 2007, p.1027).

In 1968, the gas turbines were introduced that changed the role of natural gas and with that the role of the national government in the electricity market. Compared to the steam turbines of that time, gas turbines had a lower fuel efficiency and smaller capacity but their advantage was the short start-up time. Natural gas rapidly became the main fuel. In the mid-seventies, the share of natural gas in the electricity sector rose to 80%. The policy was to quickly consume natural gas because it was expected that natural gas prices would fall as a result of the introduction of large-scale nuclear power plants by 2000. Large industrial users produced (decentralised) their own electricity and heat by combined heat and power (CHP) plants. Figure 4 shows the share of different fuel types in the Dutch electricity sector between 1955 and 1997.

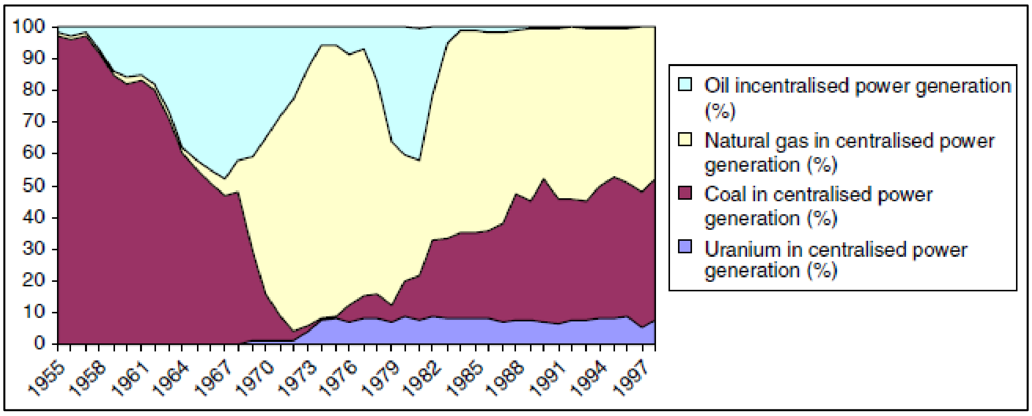

Figure 4. Fuel mix Dutch utility electricity production 1955-1997 (Verbong & Geels 2007, p.1028).

The first oil crisis in 1973 changed the landscape. The oil price suddenly increased by 70%, while the oil production decreased by 5% per month. The national government reacted with the first Energy White Paper (1974), which addressed the environmental impact of fossil fuels as well as the scarcity of fossil fuels. Natural gas was seen as a strategic resource and valuable commodity that was not to be used cheaply in power plants. Two main guiding principles were added: diversification of energy resources and energy efficiency to reduce environmental impact. The national government restricted the use of natural gas.

The second oil crisis in 1979 changed the landscape even further. The national government responded with the second Energy White Paper (1979), and energy saving became top priority. But there were two obstacles in reducing the environmental impact of the electricity generation: (1) low feedback tariffs and opposition from the electricity sector to include industrial CHP in their planning, and (2) the national gas policy, which limited the amount of natural gas available for steam generation in industry. To remove the first obstacle, the national government forced to connect industrial CHP plants to the grid and feedback tariffs were established (Raven & Verbong, 2007). To remove the second obstacle, the national government changed the gas policy to provide large industries with cheap natural gas for their CHPs in 1983. All this resulted in the reintroduction of coal (figure 2). The national government still favoured more nuclear power because it was clean. However, a societal debate between 1981 and 1984 and the Chernobyl accident (1986) ended this intention. Figure 5 shows the electricity regime of 1970-1980s.

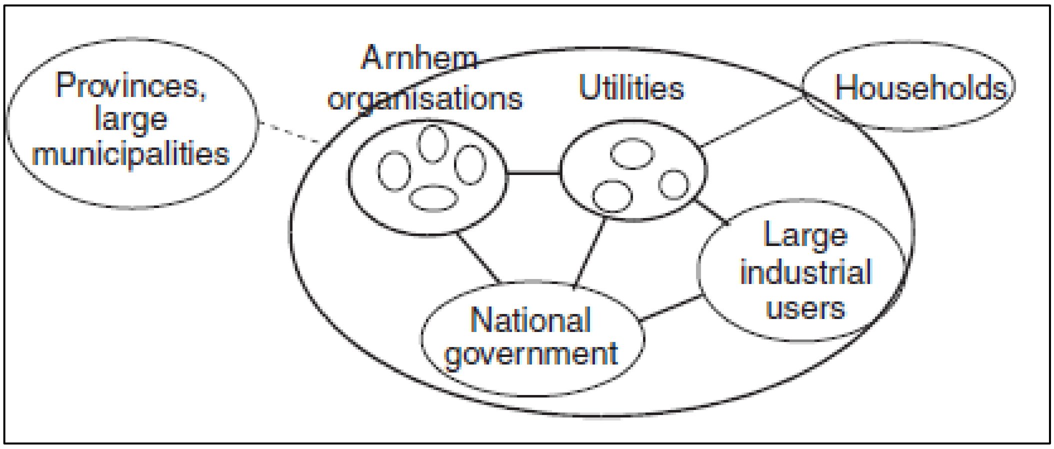

Figure 5. Actors and networks in electricity regime 1970-1980s (Verbong & Geels 2007, p.1029).

According to the national government, however, the large number of production and distribution companies was a barrier to efficiency. The national government proposed to merge all utilities into one national company, but the electricity sector responded proactively and introduced a national planning system in 1982. In this system, the most efficient power plant was connected to the national grid first. The different efficiencies per fuel type are shown in table 1 of appendix 1 (appendix 1, page 7). This was a major change, because previously each regional utility was responsible for balancing supply and demand in its own region. Another change was that Dutch utilities started to import electricity from abroad; especially nuclear power plants from Germany and France offered cheap electricity at night (Verbong, 2006). The national government wanted further restructuring and again the utilities responded proactively. The production facilities were reduced to four regional companies and also the number of distribution companies was reduced.

However, in 1989 the national government started to transform the electricity regime with the Electricity Act. The government aimed to enhance the dynamism and efficiency, it enforced the separation of electricity production and electricity distribution, and it created a new actor: the energy distribution company (EDC). New market mechanisms on the supply side were introduced and a standard base tariff for grid supply was established. In this new context, decentralised production (mostly CHP) increased rapidly because decentral producers got better access to the grid and had the possibility to sell excess electricity. Once again, CHP became the dominant form of electricity generation.

But decentralised feedback to the grid led to new problems with matching supply and demand; monitoring and balancing the electricity grid became extremely difficult. It also led to overcapacity and confusion about ownership. Around 1994, three out of the four centralised production companies were sold to international companies. Meanwhile, natural gas prices rose and electricity prices fell. Competition from large international suppliers brought the CHP expansion to a halt (Van Oostvoorn, 2003). Therefore, adjustments of the regulatory framework were needed. Liberalisation, privatisation, and deregulation became key words on national and European scale, supported by the Treaty of the European Union signed in Maastricht on 7 February 1992.

In 1998, the national government introduced a new Electricity Act, which extended the market mechanism to consumers and created a new actor: the Transmission System Operator (TSO). The TSO became responsible for the high voltage grid to take away the confusion about ownership. The EDCs transformed themselves into Distribution System Operators (DSOs) and commercial companies, buying electricity from suppliers (or generating it themselves) and selling it to consumers. Large industrial users where the first to choose their own supplier, followed by households in 2004. The government withdrew from the electricity regime and delegated responsibilities and supervision to a newly established regulator. Figure 6 shows the actors and networks in the electricity regime in the late 1990s.

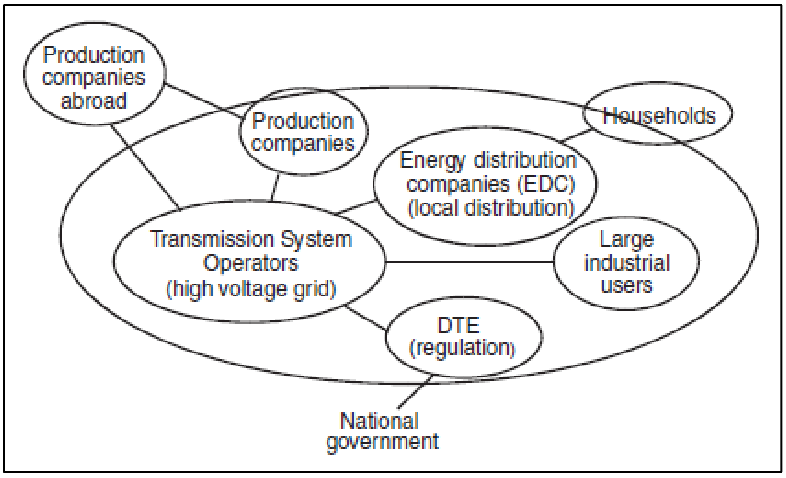

Figure 6. Actors and networks in electricity regime late 1990s (Verbong & Geels 2007, p.1031).

The current electricity regime has remained the same, the guiding principles being: (1) affordability, (2) reliability, and (3) sustainability (Sanders et al., 2016). Appendix 1 describes the current supply chain and main players on the liberalised electricity and gas markets. Furthermore, it explains that an increase of renewables results in a decrease of the electricity price and an increase in price volatility at the wholesale market, usually called the merit order effect or the 'paradox of renewable energy'.

2.1 Conclusion

This chapter described the historical development of the electricity and natural gas system between 1960 and 2004. In addition, it described the supply chain of electricity and the supply chain of natural gas from extraction/production and generation to supply to/consumption by households. It also described and analysed the effects of the increase of renewables on a liberalised market. Based on this, the first sub-question can be answered. The first sub-question is: '*How did the Dutch energy system (natural gas and electricity) develop and how does it function nowadays?*

In 1960, the two main guiding principles were to provide cheap energy for large industries and reliability of grid. The national government was originally not part of the electricity regime, but the discovery and exploitation of natural gas and new developments with nuclear energy led to changes. Gasunie, a public-private cooperation, was established and in a short period of time, Dutch households got connected to a reliable and cheap heat source. The first oil crisis of 1973 and the second oil crisis of 1979 impacted the energy regime. Two other main guiding principles were added: diversification of energy resources and energy efficiency in order to reduce environmental impact. In 1989, the national government started to transform the electricity regime with the Electricity Act, aiming to improve the dynamics and the efficiency. On 7 February 1992, the Treaty of the European Union was signed in Maastricht; liberalisation, privatisation, and deregulation became key words on national and European scale. In 1998, the national government introduced a new Electricity Act and in 2004, households could choose their own energy supplier for the first time.

The Dutch supply chain of electricity and the supply chain of natural gas have been analysed from extraction/production and generation to delivery and consumption by households. The liberalisation created competitive markets and regulated monopolies as well as wholesale markets and retail markets. In addition, liberalisation has contributed to a significant overcapacity of installed capacity for electricity generation (IEA, 2014). The overcapacity was 2.5 in 2016 and is expected to increase to 3.2 in 2035 due to the high increase of solar PV and wind energy. Moreover, it is predicted that the role of the Netherlands will change from a net importer to a net exporter of electricity. The aggregate carbon intensity (ACI) is a measure to calculate the direct CO_2 emissions per kWh. Ang & Su (2016) calculated the ACI for the Netherlands, which was 0.44 kg CO_2/kWh in 2013.

Natural gas can be categorised in H-gas and L-gas. H-gas is obtained in the North Sea or imported from foreign countries, while L-gas is extracted in the province of Groningen. Around 93% of the Dutch households are connected to the natural gas network and use L-gas for space heating, hot tap water, and cooking. On 29 March 2018, the national government decided that L-gas production in Groningen should be terminated as quickly as possible, because the natural gas extraction causes earthquakes in the local environment (EZK, 2018). This decision will a have a major impact on the Dutch energy system. In order to become independent of natural gas by 2050, new houses will not have a gas connection anymore. Moreover, after 2021, 200,000 existing houses must be disconnected from the natural gas network and switched to another energy source. This means that the role of the Netherlands will change from a net exporter to a net importer of natural gas. The energy content of L-gas has an upper value of 35.17 MJ/Nm^3 and an under value of 31.65 MJ/Nm^3. The heat content of 1 Nm^3 L-gas is 9.77 kWh. With an overall efficiency of 85-90%, the average CO_2 emission is 1.89 kg/Nm^3 (Klimaatplein, 2018). In addition, the total direct CO_2 emission of a reference boiler (HR107) is calculated at 2.01 kg/Nm^3.

In a conventional system, three different types of suppliers can be distinguished in order to provide: (1) the baseload, (2) the flexible load, and (3) the peak load. Competing generators and competing suppliers trade at the wholesale markets to provide the energy demand. Epex Spot and Pegas are respectively the electricity and natural gas platforms in Western Europe. An important aspect of the wholesale market is the merit order, which basically is designed to bring together supply and demand for the lowest price possible. The merit order is the ranking of all generation units from low to high marginal costs. However, when renewables are added to the generation mix, the merit order curve shifts to the right. This means that conventional plants with higher marginal costs are pushed out of the system when renewables are available. Moreover, an increase of renewables results in a decrease of the electricity price and an increase in price volatility at the wholesale market, usually called the merit order effect or the renewable energy paradox (e.g. Cludius et al., 2014; Winkler et al., 2016 and Blazquez et al., 2018). Germany is a good example to illustrate the merit order effect and shows that the increase of renewables in a liberalised market can lead to negative prices at the wholesale markets. In the Netherlands, it is forecasted that the electricity prices will increase slowly, despite the merit order effect. Furthermore, it is predicted that the wholesale price of natural gas will increase significantly (Schoots et al., 2017).

TSOs are responsible for the national high-voltage grid and high-pressure natural gas network. The Dutch TSOs are TenneT (electricity) and GTS (natural gas). DSOs are responsible for the regional and local medium- and low-voltage grids and the medium- and low-pressure natural gas networks. The DSO varies per region, which also means that network operating costs differ per region. ACM is the responsible body for the regulation of the TSOs and the DSOs in the Netherlands.

The retail market is the last phase of the energy chain, after which the energy is used in households to provide services. Based on data from *Klimaatmonitor*, it can be concluded that households living in apartments consume the lowest amount of energy, while households living in detached houses consume the most energy. In addition, the current energy bill consists of: (1) fixed supply costs, (2) variable supply costs, (3) network operating costs, (4) energy tax), (5) tax on Sustainable Energy (ODE), and (6) 21% VAT. A comparison of the tax on electricity and the tax on natural gas (in kWh) shows that the tax on electricity is significantly higher.

3 Power-to-Heat district heating systems and local district heating cooperatives

This chapter reviews scientific literature and official documents (governmental reports or semi-governmental reports) in order to determine the main aspects of 'local (P2H) DH systems' and 'DH cooperatives'. Yilmaz et al. (2018) analysed the potential of P2H technology in the European energy system. To create a feasible business case and to establish a local P2H DH cooperative, it is necessary to develop all aspects of P2H integration simultaneously. Yilmaz et al. (2018) distinguished four overarching aspects, namely: (1) technical aspects, (2) economic aspects, (3) social aspects, and (4) legal aspects. Figure 7 visualises the overarching aspects of establishing a P2H DH system. The term 'overarching' is used because the characteristics of the energy market differ per country. Moreover, the socio-political context differs per country and even by region and district. Therefore, a literature review has been carried out to determine the main aspects of establishment of local P2H DH cooperatives, particularly in the Netherlands. The literature review results in a conceptual model, a framework that covers the main aspects of local P2H DH cooperatives.

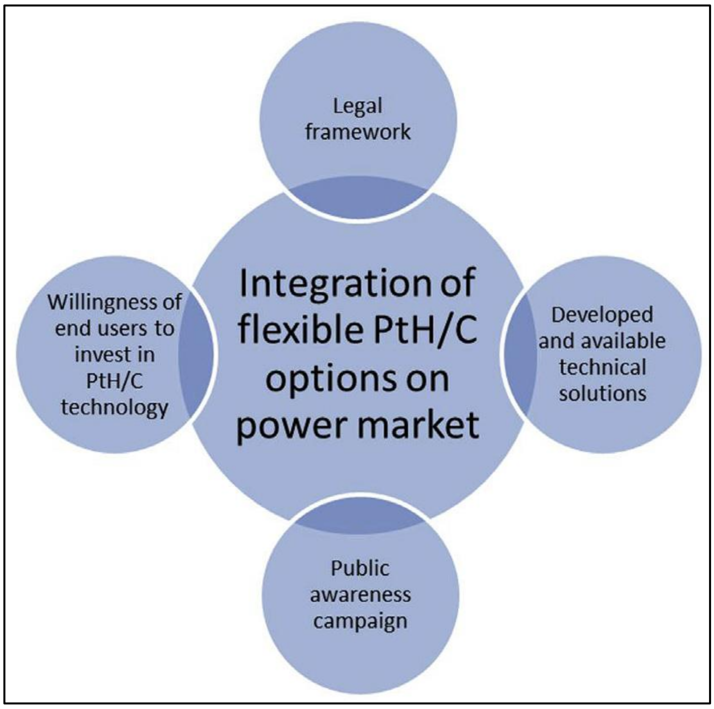

Figure 7. Conditions for deployment of business models P2H technologies (Yilmaz et al. 2018, p.9).

Paragraph 3.1 starts with the four generations of DH systems, which describe the historical development of DH systems. Furthermore, the different components of conventional DH systems are explained and the aspect of peak loads is described. Paragraph 3.2 explains how P2H systems operate and what their contribution is to the integration of the power and heat sector. In addition, the contribution to the decarbonising of the heat supply is described. These paragraphs include the main technical and economic aspects. Paragraph 3.3 defines local DH cooperatives and energy communities, and explains what makes them different from the traditional (centralised) energy supply approach. This paragraph includes the main social and legal aspects. Finally, paragraph 3.4 concludes with a conceptual model that summarises the main theoretical aspects of the establishment of local P2H DH cooperatives.

3.1 District heating systems

According to Lund et al. (2014, p.1), a DH system comprises *“a network of pipes connecting the buildings in a neighbourhood, town centre or whole city, so that they can be served from centralised plants or a number of distributed heat producing units*”. In other words, DH systems provide the services for the heat chain. In some EU countries, notably the Netherlands, DH suffers from the image that it is an outdated technique for space heating (Ecofys, 2014), but nothing could be further from the truth. A number of recent studies, including the *Heat Roadmap Europe*, conclude that DH systems will play an important role in future sustainable energy systems (e.g. Connolly et al., 2014 and Lund et al., 2014). The Dutch government also underlines the importance of DH systems in achieving their climate goals (EZK, 2016).

Paragraph 3.1.1 describes the four generations of DH systems, thereby briefly introducing the history of these systems. Paragraph 3.1.2 explains the basic operation of a conventional DH system. Finally, paragraph 3.1.3 shows how a DH system needs to be dimensioned based on heat profiles, degree of insulation, and simultaneously factor.

3.1.1 Four generations of district heating systems

Lund et al. (2014) analysed the historical development of DH systems across the world between 1880 and 2050. These systems are referred to as the first, second, third, and fourth generation of DH systems. The first generation (1880-1930) used steam as heat carrier. The primary motivations of society were to replace individual boilers in apartment buildings because of safety and to increase comfort. The second generation (1930-1980) used pressurised hot water with supply temperatures mostly over 100 °C as heat carrier. The societal and institutional reasons behind this technology differed per country, but in general, the primary motivation was to save fuel and increase comfort by utilising CHP. The third generation (1980-2020) uses pressurised hot water as heat carrier but the supply temperatures are often below 100 °C. Again, the societal and institutional differ per country, but the primary motivation was security of supply, especially considering oil crises of 1973 and 1979. Moreover, fuel efficiency and replacing oil with local and/or cheaper fuels such as coal, biomass, and waste became important. The third generation is sometimes referred to as ‘*Scandinavian DH technology*’, because many manufactures are Scandinavian. The fourth generation will be from 2020 until 2050 and uses low-temperature water between 30-70 °C as heat carrier. Figure 8 shows the characteristics of four generations of DH systems.

	1st Generation	2nd Generation	3rd Generation	4th Generation
Label	Steam	In situ	Prefabricated	4GDH
Period of best available technology	1880–1930	1930–1980	1980–2020	2020–2050
	Distribution and demand			
Heat carrier	Steam	Pressurised hot water mostly over 100 °C	Pressurised hot water often below 100 °C	Low-temperature water 30–70 °C
Pipes	In situ insulated steel pipes	In situ insulated steel pipes	Pre-insulated steel pipes	Pre-insulated flexible (possible twin) pipes
Circulation systems	Steam pressure	Central pumps	Central pumps	Central and decentralised pumps
Substations heat exchanger	No	Tube-and-shell heat exchangers	Without or with plate heat exchangers	Probably mostly with plate heat exchangers Introduction of flat-stations (decentralised supply of hot water in new buildings)
Buildings	Apartment and service sector buildings in the city	Apartment and service sector buildings 200–300 kWh/m^2	Apartment and service sector buildings (and some single-family houses) 100–200 kWh/m^2	New buildings: <25 kWh/m^2 Existing buildings: 50–150 kWh/m^2
Metering	Condensate meters in order to measure the amount of steam used.	Initially only flow meters in substations, later replaced by heat meters. Annual or monthly readings. Sometimes use of allocation meters on radiators for internal distribution of heat costs.	Heat meters and sometimes additional metering of flow in order to compensate for high return temperatures. Wireless readings introduced for more frequent readings.	As earlier but continuous reading used for continuous commissioning of customer heating system.
Radiators	High-temperature radiators (+90 °C) using steam or water.	High-temperature radiator (90 °C) using district heating water directly or indirectly.	Medium-temperature radiators (70 °C) using district heating water directly or indirectly. Floor heating.	Floor heating. Low-temperature radiators (50 °C). Indirect system.
Hot water	Hot water tanks heated directly with steam or from a secondary water circuit.	DHW tank heated to 60 °C. Circulation at 55 °C when needed.	Heat exchanger heating DHW to 50 °C. Domestic hot tank heated to 60 °C. Circulation at 55 °C when needed.	Very efficient local heat exchanger heating DHW to 50–40 °C. In district heating systems with supply temperature of 30 °C, a heat exchanger preheats DHW and a heat pump with buffer tank and heat exchanger increases DHW temperature to 40 °C by cooling down the return temperature.

Figure 8. Four generations of DH systems 1880-2050 (Lund et al. 2014, p.5).

The primary motivation of the fourth generation of DH systems is to contribute to decarbonising the heating sectors by replacing individual boilers (Connolly et al., 2014). In addition, the fourth generation must contribute to and benefit from the integration of fluctuating and intermittent renewables (Averfalk et al., 2017 and Lund et al., 2014).

3.1.2 Operation of a conventional district heating system

Although there are many different types of DH systems, each system basically consists of four components: (1) production, (2) transportation, (3) distribution, and (4) consumption (Sanders et al., 2016). Figure 9 shows an illustration of a conventional DH system.

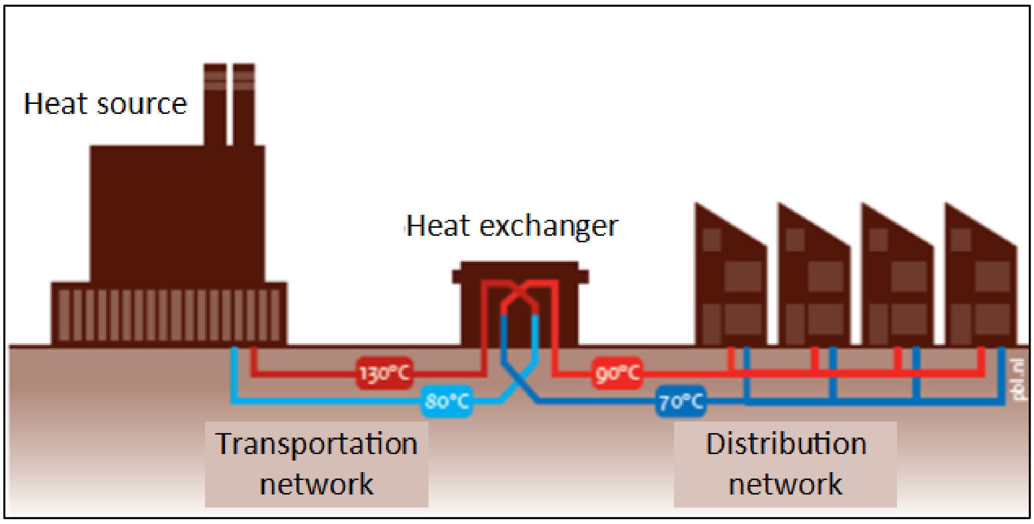

Figure 9. Conventional DH system (based on Hoogervorst 2017, p.65).

The first component of a DH system is the heat source or the fuel type. The heat source is an important aspect of DH systems, because it determines to a great extend the direct CO_2 emissions. Heat is produced by fossil fuels (cogeneration) or by renewables (Ten Donkelaar & Scheepers, 2004). The five main sources of renewable energy are solar PV, biomass, wind (onshore and offshore), geothermal, and hydropower (Golušin et al., 2013). Residual heat of industries can also be a (renewable) heat source. A distinction can be made between primary and secondary installation(s). The primary and the secondary installation can use a different type of fuel, which increases the reliability of the system. The primary installation produces the baseload and the secondary installation produces the peak load. The flexible load can be produced by both installations, depending on fuel type. In addition, the secondary installation(s) functions as back-up system while maintenance work is going on (Schepers & Van Valkengoed, 2009).

The second component of a DH system is transportation and distribution: carrying the heat from the production or supply site to the actual location of the heat demand. This consists of (mostly) underground pipelines to transport and distribute the heat. A distinction can be made between the primary transportation network and the secondary distribution network. In most cases both networks are separated by a so-called substation or heat exchanger (Schepers & Van Valkengoed, 2009). The transportation network transports the heat from the production site to the heat exchanger. This network typically consists of relatively large pipes and covers long distances. The distribution network distributes the heat from the heat exchanger to the end users and usually consists of relatively small pipes and covers short distances. In practise, the distribution network often has to be placed in a crowded subsurface, especially in an urban environment.

In the Netherlands, a distinction has been made between large-scale and small-scale district systems. A large-scale system has 5,000 or more consumers, while a small-scale system has less than 5,000 consumers (Schepers & Van Valkengoed, 2009). In addition, DH systems can be subdivided into regional or interregional systems (Schwencke, 2016).

3.1.3 Prediction of peak loads

Heat demand profiles show the heat demand in time. It is obvious that the heat demand of a household is never constant. For example, the heat demand is typically very high between 7.00 and 8.00 a.m., because many people wake up, take a shower, and heat their homes. At least four technical factors influence the heat demand: (1) weather conditions, (2) time, (3) type of house, and (4) degree of insulation. In addition to technical factors, the behaviour of people greatly influences the final heat demand profiles. The technology generating or supplying heat (e.g. a HR107 boiler or a DH system) must be designed based on peak levels. Nowadays, Gasunie is legally obliged to guarantee the heat supply of households to an average effective temperature of minus 17 °C (weather station De Bild) for at least 24 hours (Ecofys, 2015). This obligation originates from the extremely cold period during the winter of 1987. According to the Royal Dutch Meteorological Institute (KNMI), there are no indications that the probability of an average effective temperature of minus 17 °C for at least 24 hours has been reduced, despite climate change (KNMI, 2018). This means that the demand profile of 1987 is still normative in the design of a DH system. Figure 10 shows heat demand profiles for space heating based on the heat demand profile of the 1987 scenario. The different lines represent different types of houses, each with a low level of insulation.

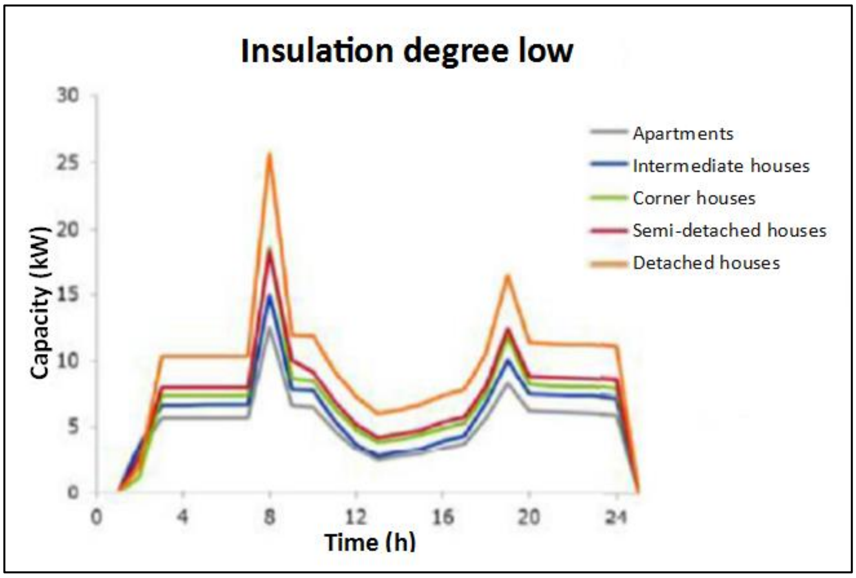

Figure 10. Heat demand profile space heating 1987 scenario (based on Ecofys 2015, p.13).

As mentioned previously, the degree of insulation influences the peak demand. Three categories are distinguished: (1) low, (2) medium, and (3) high. The lowest degree corresponds to energy label E, which means that the house basically has no roof, facade, and floor insulation. Medium corresponds to energy label B, which more or less comprises all houses built between 1992 and 2015. The highest degree corresponds to energy label A or higher, basically all houses built after 2015. Table 2 shows the technical specifications of these degrees.

Table 2. Degree of insulation (based on Ecofys 2015, p.8).

Degree of insulation	Rc rooftop (m^2 * K/W)	Rc facade (m^2 * K/W)	Rc floor (m^2 * K/W)	U glass (m^2 * K/W)
Low	0.86	0.43	0.17	Single glass 5.2 double glass 2.9
Medium	2.50	1.30	2.50	HR++ glass 1.8
High	5.00	5.00	5.00	Triple glass 0.5

Figure 11 shows the effect of the degree of insulation on the heat demand profile. It is worth noting that a low degree and a medium degree of insulation result in steep peaks, whereas a high degree of insulation results in a fairly constant and stable heat demand profile.

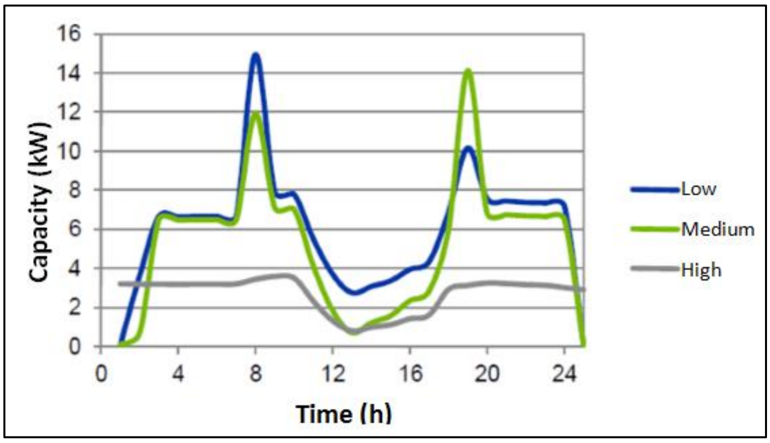

Figure 11. Heat demand profile space heating 1987 scenario (based on Ecofys 2015, p.13).

Table 3 gives an overview of the peak demands subdivided into type of technology and degree of insulation. A DH system in a residential area with a medium degree on insulation, for example, needs to provide on average at least 14.3 kWth per household. The efficiency due to distribution loss (in Dutch: *stilstandsverliezen*) of DH systems is similar to an individual HR107 boiler, namely 90% (Ecofys, 2015).

Table 3. Peak demand intermediate house 1987 scenario (based on Ecofys 2015, p.20).

Technologies	Degree of insulation		
	Low	**Medium**	**High**
HR107 boiler	16.8 KWgas	15.2 KWgas	4.2 KWgas
District heating	15.1 KWth	14.3 KWth	3.8 KWth
Air source heat pump	-	12.6 KWe	2.3 KWe
Ground source heat pump	-	-	1.0 KWe
Hybrid heat pump	-	12.2 KWgas 0.8 KWe	4.1 KWgas 0.5 KWe
Micro CHP	-	17.3 KWgas - 1.5 KWe	6.0 KWgas - 1.5 KWe

Heat demand profiles hot tap water and cooking

The patterns of hot tap water and cooking do not depend on the type of house, but on the size of the household and people's behaviour. The average annual natural gas consumption for hot tap water is 300 Nm^3 or 23% of the total natural gas consumption (Ecofys, 2015). The peak demand is between 7.00 and 8.00 a.m. and is 9.3% of the total daily demand (Friedel et al., 2014). The average annual natural gas consumption for cooking is 39 Nm^3 or 4%. In case of electric cooking, the average annual electricity consumption is 211 kWh (ECN, 2014). Figure 12 shows the heat demand profiles for hot tap water and cooking. Due to the risk of legionella contamination, the minimum supply temperature (hot tap water) is set at 60 °C (Van Vliet et al., 2016). The distribution loss of a DH system as well as the HR107 boiler is 62% (Ecofys, 2015).

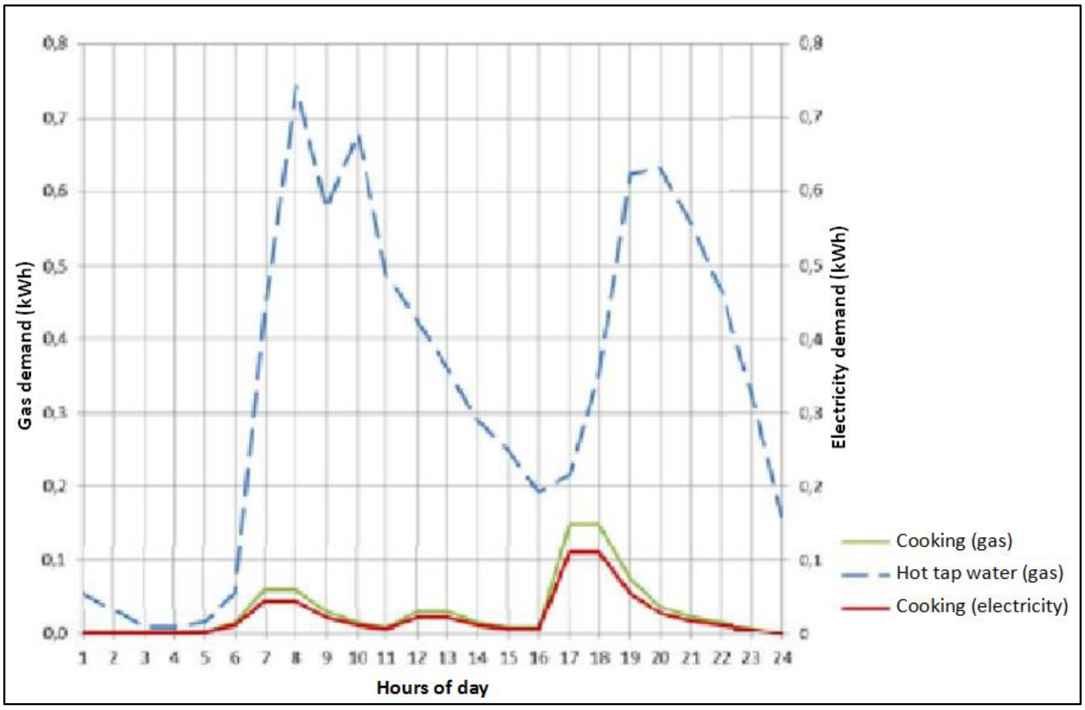

Figure 12. Heat demand profiles hot tap water and cooking (based on Ecofys 2015, p.15).

The simultaneity factor

The simultaneity factor (in Dutch: *gelijktijdigheidsfactor*) is the ratio of the simultaneous maximum load of a number of appliances or consumers for a given period of time, up to the sum of their individual maximum loads during the same period. Patterns and peaks differ per household and are distributed in time, because in practice not every household heats up their house or takes a shower between 7.00 and 8.00 a.m. Therefore, Gasunie calculated that the simultaneity factor is 0.53 (Ecofys, 2015). The simultaneity factor, however, can vary greatly at a local level. Figure 13 shows the aggregated effect of distribution of peak demand profiles.

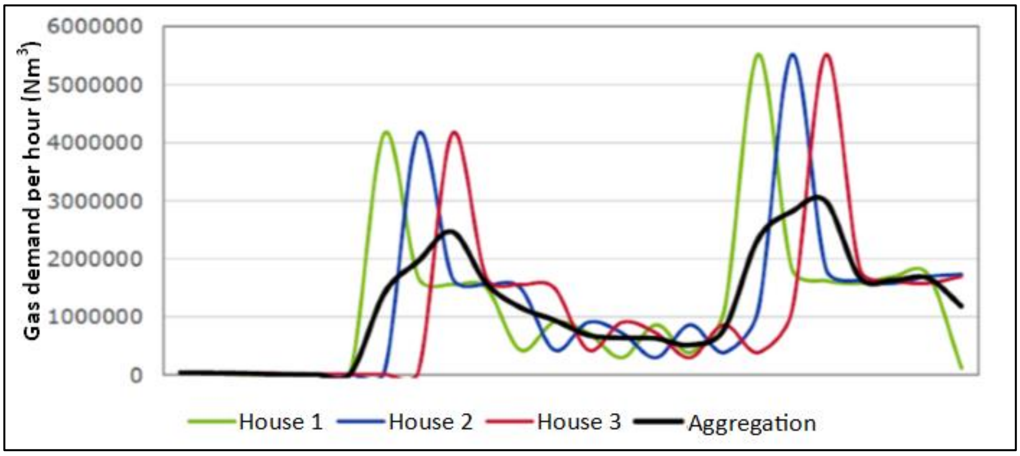

Figure 13. Effect aggregation of one day (based on Ecofys 2015, p.17).

3.2 Power-to-Heat

According to Averfalk et al. (2017, p.1276), the concept of P2H with respect to residential purposes comprehends "*the use of (large) heat pumps or electric boilers for covering heat demands*". The P2H concept is not entirely new because it has been applied several times during the past century (Averfalk et al., 2017). The main reason for installing P2H technology was a surplus of electricity, for example when conventional power plants were over-dimensioned due to the expected increase of demand. Because of the shortage of fossil fuels during World War Two, Switzerland installed three large heat pumps in 1942 with a total capacity output of 5.9 MW (Zogg, 2008). Interest in large heat pumps for DH systems increased during the first and second oil crises. Today, P2H is seen as an integration strategy to couple the power sector with the heat sector (Bloess et al., 2018).

Figure 14 shows a categorisation of the most important options of electrical heating for the residential sector. First of all, a distinction has been made between centralised and decentralised. Centralised refers to the situation that the conversion process does not take place at the location of the actual heat demand. In this case, the heat has to be transported by a DH network. Decentralised, on the other hand, refers to the situation that the heat is produced right at, or very close to, the location of the actual heat demand. Secondly, a distinction can be made between systems with and without thermal storage capacity (TES). Centralised systems always have thermal storage capacity to some extent. The storage capacity can be carried out internally (e.g. ceramic stones) and externally (e.g. hot water storage elements). Finally, a distinction can be made between (different types of) heat pumps and resistive heating.

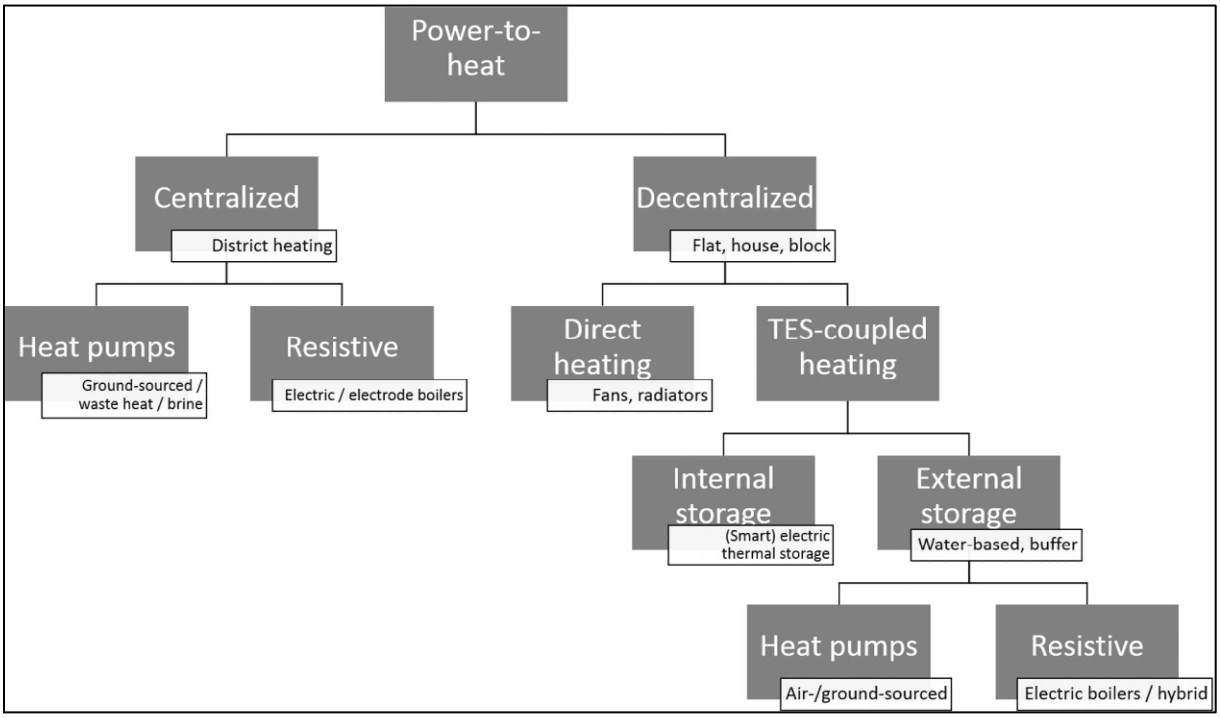

Figure 14. Categorisation of residential power-to-heat options (Bloess et al. 2018, p.1612).

3.2.1 (Industrial) heat pumps

As figure 14 illustrates, heat pumps can be used both centralised and decentralised. A heat pump is often compared to a refrigerator. A refrigerator extracts heat from the inside and releases the heat on the outside. This process decreases the temperature inside a refrigerator to the desired temperature. A heat pump uses a similar technique: it extracts heat from the outside of a house and releases the heat on the inside of a house. This process increases the temperature inside a house to the desired temperature. A heat pump consists of four main components: (1) evaporator, (2) compressor, (3) condenser, and (4) expansion device (De Klein, 2018). Figure 15 shows the operation cycle of a heat pump.

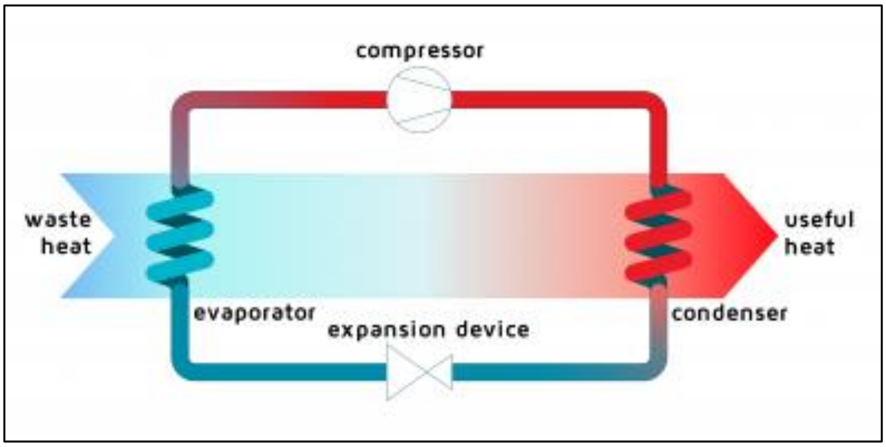

Figure 15. Operation cycle heat pump (De Klein, 2018).

The operating principle of a heat pump is based on the physical property that the boiling point of a fluid increases with pressure (De Klein, 2018). By lowering pressure, a medium can be evaporated while an increase of pressure will lead to condensation. Although there are different types of heat pumps, the mechanical heat pump is most commonly used (De Klein, 2018). It operates by the compression and expansion of a working fluid, the so-called 'refrigerant', which passes through all these four components. First, in the evaporator, the refrigerant (e.g. ammonia) absorbs heat from ambient sources that leads to evaporation of the liquid ammonia. Secondly, the compressor increases the pressure of the ammonia vapour, causing the temperature to rise. Then the vapour is condensed at high pressure and high temperature in the condenser and the heat is released to its destination. The liquid ammonia flows to the expansion device, which lowers the pressure. Finally, the ammonia with low temperature and low pressure flows to the evaporator and so the cycle repeats itself.

Heat pumps can be categorised by source, namely: (1) ground-sourced heat pumps (GSHP), (2) air-sourced heat pumps (ASHP), and (3) brine-sourced heat pumps or Heat/Cold Storage. The efficiency of a heat pump is expressed by the Coefficient of Performance (COP) which is the ratio between the energy consumption of the compressor and the useful extracted heat from the condenser (De Klein, 2018). A COP value of 5 means that 1 kWh of electricity is transferred to 5 kWh of heat. The COP value depends on several factors, but the most important one is difference between the condensation temperature and the evaporation temperature. The average COP values for market available heat pumps lie in the range of 3.2 and 4.5 for ASHP and between 4.2 and 5.2 for GSHP (Fischer & Madani, 2017). However, GSHPs usually have higher investment costs than ASHPs.

In addition, academic literature distinguishes between monovalent, mono-energetic, and bivalent systems (Fischer & Madani, 2017). Monovalent refers to a system where the entire heat demand is covered by a heat pump. In a mono-energetic system, a heat pump is combined with an electric (resistive) heating element, for example an electric boiler. A bivalent system complements a heat pump with a boiler fired on a different energy carrier, for example a gas-fired boiler or a (bio) diesel-fired boiler. Mono-energetic and bivalent systems allow for a smaller heat pump dimensioning, because the peak demand (paragraph 2.2.3) can be covered by the secondary system. Moreover, in the case of a DH system, a secondary system is required to ensure security of supply (Schepers & Van Valkengoed, 2009).

3.2.2 (Industrial) electric boilers

As said previously, industrial electric boilers can be used to complement the heat pump (mono-energetic) as ‘add on’ to the heat pump. An industrial electric boiler heats water through resistive heating. Resistive heating (also known as Joule heating or Ohmic heating) is the process of the passage of an electric current through a conductor to produce heat (Knirsh et al., 2010). Today, electric boilers are commercially available, typically with capacities of up to 50-70 MW and a steam output up to 45 bars at 260 °C (Hers et al., 2015). Electric boilers can be used as ‘economiser’ to take advantage of price fluctuations on the electricity market, which are currently caused by the merit order effect (Bloess et al., 2018; Connolly et al. and Hers et al., 2015). An electric boiler can absorb and store the surplus of electricity. Moreover, an electric boiler integrates the heat chain and the electricity chain, thereby contributing to the process of balancing (matching supply and demand). Figure 16 shows a hot water electric boiler with a circulation pump and a heat exchanger (left), and an electrode steam boiler (right).

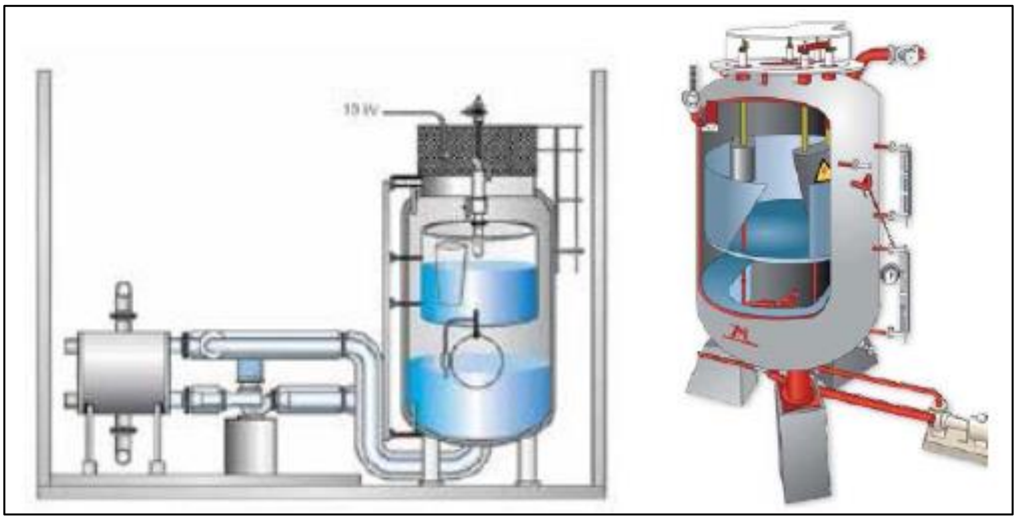

Figure 16. Electric boiler and electrode steam boiler (Hers et al. 2015, p.14).

3.2.3 Decarbonisation

P2H contributes to decarbonisation if the replacement of fossil fuels for heating leads to larger emissions reductions than potential emissions increase due to additional electricity demand (Bloess et al., 2018). Hers et al. (2015) and Yilmaz et al. (2017) state that P2H cannot only contribute to the required flexibility in the electricity systems, but can also contribute significantly to the EU’s and Dutch climate goals. Emissions from an energy carrier can be calculated using the following formula:

*Total CO_2 emissions per energy carrier = consumption of energy carrier * number of households per housing type * carbon intensity (Ecofys, 2015)*

Natural gas and electricity are to a large extent the current energy carriers in Dutch households. The consumption varies per household and per type of house. A household living in a detached house, for example, usually consumes more than a household living in an apartment. The carbon intensity is a measure of the amount of CO_2 emissions that is released into the atmosphere for every unit of electricity produced (Beggs, 2009). It is a measure of direct CO_2 emissions (during the usage phase) and does not consider the indirect CO_2 emissions (during the installation and decomposition phases). The ACI for electricity in the Netherlands is 0.44 kg CO_2/kWh (Ang & Su, 2016). The carbon intensity of natural gas depends on the efficiency of the burner. The carbon intensity of an HR107 boiler (standard reference boiler) with an overall efficiency of 85-90% has an average CO_2 emission of 1.89 kg/Nm^3 (Klimaatplein, 2018). However, the boiler uses around 0.28 kWh/Nm^3, which means an additional 0.124 kg/Nm^3 CO_2 emission (Schepers & Scholten, 2016). The total direct CO_2 emission of an HR107 boiler is 2.01 kg/Nm^3. The background of the mentioned carbon intensities and the average consumption per type of house are included in appendix 1.

3.2.4 Cost effectiveness

Bennink & Benner (2009) describe the cost drivers for DH systems. An operating budget (in Dutch: *exploitatiebegroting*), which basically distinguishes capital expenditures (Capex) and operating expenses (Opex), can demonstrate the economic feasibility. Numbers of EBO Consult show the costs of (industrial) heat pumps and electric boilers. Dominković (2016) shows similar amounts. Heat pumps generally have a high Capex and low Opex, mostly as a result of the COP. Electric boilers generally have a low Capex but high Opex, because the COP is 1. Table 4 gives an overview of different costs of a typical heat pump and a typical electric boiler.

Table 4. Overview costs (based on EBO Consult, 2018).

Category	Heat pump	Electric boiler
Investment (€/kWt)	700	100
Technical lifetime (years)	25	1.177
Fixed O&M (€/kW/year)	2.14	1.1
Variable O/M (€/kWh)	0.0018	0.0005

Various financial tools such as the Net Present Value (NPV) and Return on Invested Capital (ROIC) can support the decision-making process for DH systems. Figure 17 shows a typical cumulative cash flow of a DH system, which is characterised by high investment costs and a long payback period.

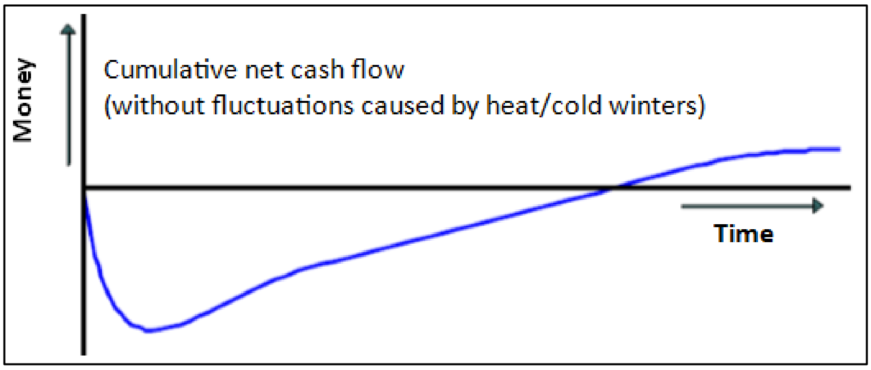

Figure 17. Typical cash flow DH system (based on Bennink & Benner 2009, p.15).

3.3 Local district heating cooperatives

According to Viadot (2013, p.757), cooperatives are "*autonomous associations of people who join voluntarily to meet their common economic, social, and cultural needs and aspirations through jointly owned and democratically controlled businesses*". Cooperatives are businesses owned and run by and for their members. The members, whether they are the customers, employees, or residents, all have an equal say in what the business does and a share in the profits (ICA, 2015). According to Wirth (2014), the term 'community energy' is an umbrella term for collectively organised projects for renewable energy, bearing in mind that related governance structures may differ. Communities are generally defined by the German word *Gemeinschaft*: "*aggregates of people who share common activities and/or beliefs and who are bound together principally by relation or affect, loyalty, common values, and/or personal concern*" (Brint, 2001, p.8).

Firstly, a cooperative is characterised by six values and seven principles that are included in paragraph 3.3.1. Paragraph 3.3.2 mentions different types of ownership and the aspect of liability is introduced. Paragraph 3.3.3 explains the two dimensions of citizen participation, namely process and outcome. Furthermore, the ladder of citizen participation and the aspect of conflicts about unequal distribution of benefits are discussed. The fourth paragraph discusses the three dimensions of social acceptance and underlines the importance of reciprocal trust. Paragraph 3.3.5 describes several motivations and (public) perceptions of DH systems and paragraph 3.3.6 includes the regulatory bodies and the relevant rules and regulations for heat supply in the Netherlands. Finally, paragraph 3.3.7 includes the conclusion of the analysis of the Heat Act.

3.3.1 Core values and principles

Across the world, cooperatives carry with them the same underlying social values and the same ethical principles (Viadot, 2013). In 1995, the International Co-operative Alliance, an independent, non-governmental organisation, adopted the revisited statement on the identity of a cooperative. The statement consists of six values and seven principles. These values are (1) self-help, (2) self-responsibility, (3) democracy, (4) equality, (5) equity, and (6) solidarity (ICA 2015, p.2). The seven core principles are (ICA 2015, p.2):

1. <u>Voluntary and open membership:</u> cooperatives are voluntary organisations, open to all persons able to use their services and willing to accept the responsibilities of membership, without gender, social, racial, political, or religious discrimination.
2. <u>Democratic member control:</u> cooperatives are democratic organisations controlled by their members, who actively participate in setting their policies and making decisions. Men and women serving as elected representatives are accountable to the membership. In primary cooperatives members have equal voting rights (one member, one vote) and cooperatives at other levels are also organised in a democratic manner.
3. <u>Member economic participation:</u> members contribute equitably to, and democratically control, the capital of their cooperative. At least part of that capital is usually the common property of the cooperative. Members usually receive limited compensation, if any, on capital subscribed as a condition of membership. Members allocate surpluses for any or all of the following purposes: developing their cooperative, possibly by setting up reserves, part of which at least would be indivisible; benefiting members in proportion to their transactions with the cooperative; and supporting other activities approved by the membership.

4. Autonomy and independence: cooperatives are autonomous, self-help organisations controlled by their members. If they enter into agreements with other organisations, including governments, or raise capital from external sources, they do so on terms that ensure democratic control by their members and maintain their co-operative autonomy.
5. Education, training, and information: cooperatives provide education and training for their members, elected representatives, managers, and employees so they can contribute effectively to the development of their co-operatives. They inform the general public – particularly young people and opinion leaders – about the nature and benefits of cooperation.
6. Cooperation among cooperatives: cooperatives serve their members most effectively and strengthen the cooperative movement by working together through local, national, regional, and international structures.
7. Concern for community: cooperatives work for the sustainable development of their communities through policies approved by their members.

3.3.2 Ownership and liability

Cooperatives can be either completely owned by the local community or developed in co-ownership (hybrids) with a commercial or public party (Yildiz et al., 2015). DH cooperatives can evolve from bottom-up initiatives as well as top-down initiatives. In case of a bottom-up initiative, residents of a certain neighbourhood or district take the initiative to form a cooperative. According to Schoor & Scholtens (2015), bottom-up initiatives usually start with informal meetings, but financial risks and legal difficulties are a big barrier for small initiatives. Small initiatives, therefore, often decide to align themselves with a larger energy company with a strong focus on sustainability. In case of a top-down initiative, a public or private party such as utilities or local governments take the initiative to establish a DH cooperative. The customers are not or only partially owner of the cooperative (Schwencke, 2016).

Two ownership models are important: (1) a limited partnership and (2) a civil partnership (Yildiz et al., 2015). The limited partnership separates the management (consisting of project-initiating investors) from other investors. This usually means that decisions are taken by a board of directors and corporate officers, who get a significant financial compensation for their work (ICA, 2007). A civil partnership is often an association consisting of elected board members. Decisions are taken through a democratic process: one member, one vote (ICA, 2007). The disadvantage here is the direct liability of the members. That is why this type of ownership model is only feasible for small projects (Yildiz et al., 2015).

A cooperative is a legal entity and therefore liable. The liability of cooperatives in the Netherlands can be spread in three ways: (1) all members are equally and personally liable (WA), (2) all members are liable to a certain limited extent (BA), or (3) none of the members can be held liable (UA) (NCR, 2017).

3.3.3 Citizen participation and conflicts

Community energy projects rely on the involvement and participation of their members (Kalkbrenner & Roosen, 2016). Empirical research shows that more direct involvement of local people in renewable energy projects contributes to increased acceptance and support of projects (Walker & Devine-Wright, 2008 and Yildiz et al., 2015). Moreover, it contributes to people's concern for the environment and their understanding of renewables (Rogers et al., 2008). In order to understand participation, Walker & Devine-Wright (2008) distinguish two dimensions, namely process and outcome. The process dimension is about who develops and operates a project, who is involved and who has influence. The outcome dimension is concerned with how the outcomes of a project are distributed spatially and socially (who receives the economic and/or social benefits from the project).

Figure 18 shows an abstract view of these two dimensions in order to position, categorise, and understand the participation within different projects. The utility wind farm at the bottom left is an example of a conventional approach, neither process nor outcome are locally focused. The wind farm is developed and operated by a distant and closed institution, with minimal (direct) involvement of local people. In addition, the energy is produced for the national grid rather than for the local environment which means that the economic returns go to distant shareholders instead of local people.

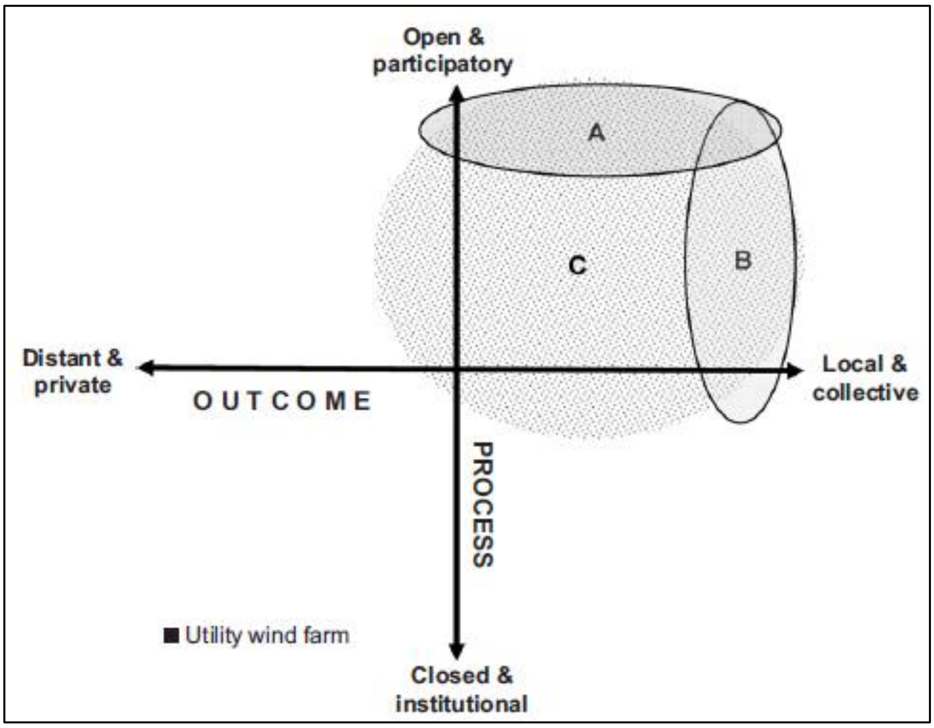

Figure 18. Community renewable energy projects (Walker & Devine-Wright 2008, p.498).

In the top right corner, one could put community projects that are driven and carried out by local people and which return the economic and social benefits to the local community. In other words, projects that are both by and for local people. There are, however, different views on how the process and the outcome of a community project should be distributed (Walker & Devine-Wright, 2008). The first viewpoint (A) is more focused on a high degree of involvement of local people, while the second viewpoint (B) is more concerned about how the benefits are distributed. The third viewpoint (C) takes a broader stance and comprises a variety of forms of community projects. People with this view are often less focused on the 'right' way of process and results, but are more concerned that it leads to something productive and that something useful happens.

Arnstein (1969) developed the well-known *ladder of citizen participation* to assess the degree of citizen participation in public administrative processes. The ladder can also provide insights in the participatory process within local energy communities (Rogers et al., 2008 & Yildiz et al., 2015). The ladder of citizen participation consists of eight rungs (figure 19). These eight rungs correspond with the degree of influence different inside and outside stakeholder groups have on the final outcome (Yildiz et al., 2015). The rungs can be further subdivided into three categories: nonparticipation, tokenism, and citizen power. On the lowest spot on the ladder (nonparticipation), the initiator tries to educate the participants rather than listen to them. In the middle category (tokenism), the initiator consults participants but they still do not have an influence on the project decisions. On the highest spot (citizen power), the citizens do have the power to influence the outcome and make decisions. Although the model is widely accepted, it has been revisited several times, for example because the emphasis was (too much) on the decision-making power (Tritter & McCallum, 2008). The main purpose of the ladder, however, was to illustrate that there is a significant graduation in citizen participation (Arnstein, 1969).

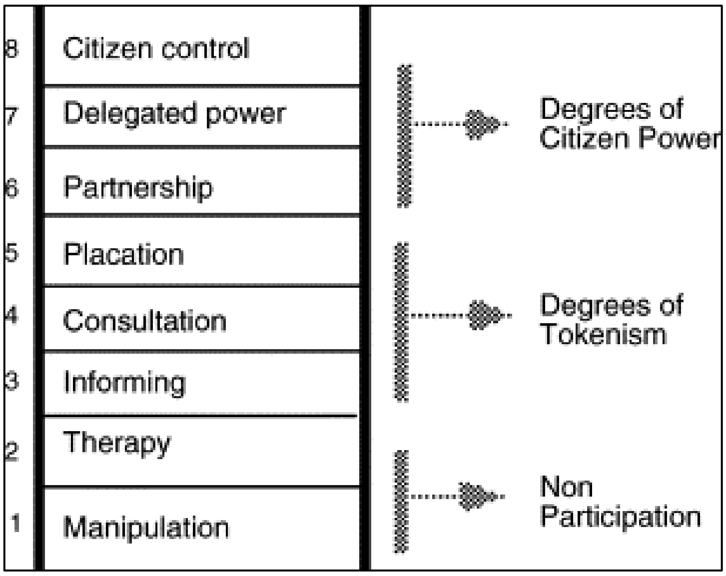

Figure 19. Ladder of citizen participation (Tritter & McCallum 2008, p.157).

Walker & Cass (2007) reported that local involvement in community tasks, such as attending meetings or construction work, was the key success factor in a renewable energy project in a village in Cumbria (England). On the other hand, not everyone wants a high degree of involvement because it is, for example, time-consuming (Walker et al., 2008).

Walker & Devine-Wright (2008) and Yildiz et al. (2015) warn for the possibility of conflicts within an energy cooperative. Conflicts within organisations can broadly be defined as the *"perception of incompatibility between values, needs, interests, or actions"* between individuals or groups (Zarankin 2008, p.167). According to Walker & Devine-Wright (2008), conflicts are mainly about how the outcome (profits and benefits) is divided among the members. Furthermore, new energy cooperatives usually face many struggles and have to overcome many barriers which can be a source of conflicts as well (Yildiz et al., 2015). That is why cooperatives need flexibility and adaptability from its members. A *'cooperative spirit',* which means a collectively shared vision, is vital for surviving in a constantly changing economic and political environment. An easy way to increase this shared vision is to organise formal and informal activities, for example information markets or excursions (Schoor & Scholtens, 2015).

3.3.4 Social acceptance and trust

Renewables have different characteristics than conventional technologies, thus bringing new aspects to the debate on social acceptance (Wüstenhagen et al., 2007). Renewable energy plants usually need more space per MWh output. It also means that renewable energy plants tend to be closer to people's living environment (the 'backyard'), thereby bringing the visibility and environmental impact closer to the residents. However, even offshore wind energy has a NIMBY (Not in My Backyard) effect even though people do not hear or see it (Haggett, 2011). Wüstenhagen et al. (2007) distinguish three dimensions of social acceptance: (1) socio-political acceptance, (2) market acceptance, and (3) community acceptance. Figure 20 shows the triangle of social acceptance.

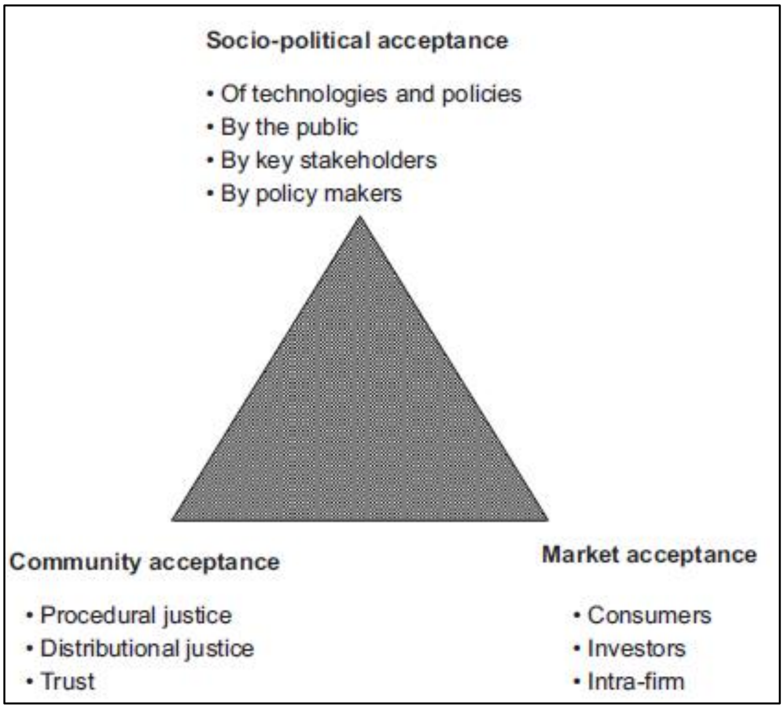

Figure 20. The triangle of social acceptance (Wüstenhagen et al. 2007, p.2684).

The triangle of social acceptance emphasises that acceptance is not only limited to the community itself, but that acceptance in a broader context is necessary for a successful implementation of a community energy project. In fact, DH goes 'behind the front door' (Schoor & Scholtens, 2015). Policies and tax schemes are indicators of the socio-political acceptance. In addition, it is important that the proposed renewable technology is supported by the local public authorities. Market acceptance is essential in order to attract investors, public, private, or consumers. Kalkbrenner & Roosen (2016) investigated that people are generally more willing to voluntarily participate in community energy projects than to support them financially.

A large body of literature states that the aspect of trust is essential for establishing a community energy project and gaining the acceptance of the community (e.g. Walker et al., 2010; Wüstenhagen et al., 2007 and Yildiz et al., 2015). Trust is relevant in all social relations, organisations, and in cooperative organisations in particular (Yildiz et al., 2015). Luhmann (1979) was one of the first scholars who conceptualised the phenomenon of trust. He described trust as "a *function that reduces social complexity by going beyond the available information, and generalising expectations of behaviour so as to replace missing information with a sense of an internally guaranteed security*" (Luhmann, 1979 in Yildiz et al. 2015. p.69).

Both trust between people and between people and local institutions within the communities is necessary to develop a distinctive, desirable, and attractive community energy project (Walker et al., 2010). Working for and with the local population, clear communication, and reciprocal commitment builds trust and results in consensus rather than division.

3.3.5 Motivations and (public) perceptions

A perception (positive and negative) can be defined *as "a thought, belief or opinion, often held by many people based on appearances*" (Cambridge Dictionary, 2018). Perception can exist among initiators as well as among participants of community energy projects. Walker & Cass (2008) have investigated the underlying assumptions of initiators. Firstly, it is assumed that the local population is willing to take on the role of participant in a community project. However, as mentioned before, not everyone is willing due to time concerns. Secondly, it is assumed that participation leads to more understanding of sustainable energy and thus to acceptance of a community project and even willingness to take individual measures. Moreover, it is assumed that the participants' attitudes towards large-scale renewable energy projects changes as well. On the other hand, the public perception of the local population determines the willingness to participate in a local community energy project. Rogers et al. (2008) emphasise the importance of getting to know the motivations and perceptions, the why and how, of (potential) participants. Surveys and/or in-depth interviews are ways to investigate these motivations and perceptions. An extended survey held in Thirlmere, a region in the United Kingdom, showed that motivations to participate in community energy projects can be categorised into social, economic, and environmental motives (Rogers et al., 2008). Figure 21 shows the result of the survey. It is important to keep in mind that these motivations can vary per country, region, and district.

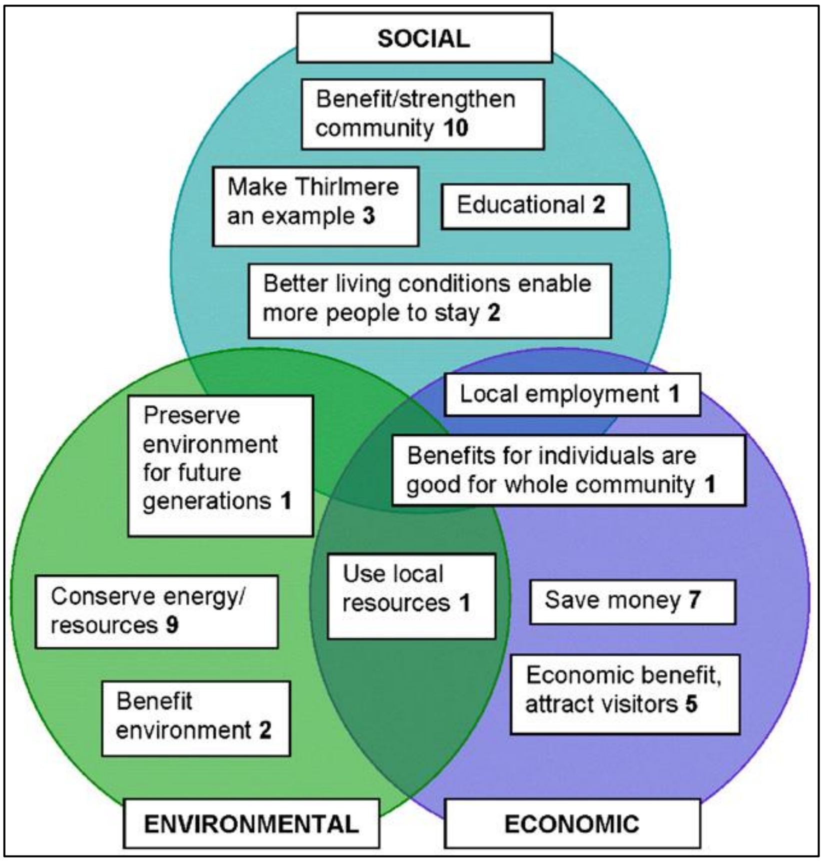

Figure 21. Benefits of a sustainable energy project for Thirlmere (Rogers et al. 2008, p.4222).

Ecofys (2014) investigated the perceptions of consumers and potential consumers of DH systems in Rotterdam, a city in the Netherlands. An extensive survey and in-depth interviews showed that the local population is particularly concerned about and afraid of high prices and loss of control over price and comfort. The majority believe that DH is more expensive than a gas-fired heating system. On the other hand, the local population thinks the DH technology is more environmentally friendly and that it is safer than a gas-fired boiler, especially in apartment buildings. In addition, homeowners are happy that maintenance will be done by the supplier. The final recommendation to win potential participants is to focus on comfort and usability rather than economic benefits, because people tend to distrust those.

3.3.6 Regulatory institutions and authorities

The Netherlands has various (national) authorities that are engaged in the energy transition and sustainable energy policies. These authorities are:

- The Ministry of Economic Affairs and Climate (in Dutch: *Ministerie van Economische Zaken en Klimaat, EZK*). It has the overall responsibility for the Dutch energy policy, including renewable energy policies and the energy transition. The Ministry of Infrastructure and Water Management (in Dutch: *Ministerie van Infrastructuur en Waterstaat, I&W*) is responsible for policies on environment, transport, water, and public works. These two ministries jointly coordinate the environmental impact assessments and permits for spatial planning, including maritime waters. The regional governments are responsible for granting environmental licences and permits (IEA, 2014).
- The Environmental Assessment Agency (in Dutch: *Planbureau voor de Leefomgeving, PBL*). The agency has a key role in implementing environmental policies. PBL monitors and implements national energy and climate objectives and develops long-term scenarios in cooperation with the Energy Research Centre of the Netherlands (IEA, 2014).
- The Dutch Authority for Consumers and Markets (In Dutch: *de Autoriteit Consument en Markt*, *ACM*). This is an independent administrative body under the ministry of EZK. ACM has regulatory powers to supervise electricity and natural gas markets as well as DH markets.
- The Dutch Enterprise Agency (in Dutch: *Rijksdienst voor Ondernemend Nederland*, *RVO*). RVO implements R&D policies and finances programmes with a focus on sustainability, innovation, and international cooperation. In addition, RVO facilitates market parties and other organisations to set up training and certification facilities for renewable energies and supports innovation contracts between private companies, universities, and R&D institutes (IEA, 2014).

3.3.7 Conclusion analysis Heat Act

The Heat Act was introduced in 2014 and regulates the heat supply of consumers with a connection up to 100 kWt. The Heat Act is related to four other regulations (delegated regulation): (1) decision invoice consumption and indicative cost overview energy, (2) arrangement to prove the source of renewable energy sources and HR-WKK electricity, (3) heat decision, and (4) heat regulation. The Heat Act applies to all suppliers, but it distinguishes permit holders and non-permit holders (articles 9 to 11). A supplier is legally obliged to apply for a permit unless the supplier (1) supplies heat to a maximum of ten consumers at the same time, (2) supplies a maximum of 10,000 GJ annually, or (3) is the owner or the lessor of the building. EcoGenie 2.0 aims to connect 100-200 households with an average heat demand of 56.8 GJ/year (without cooking). The break-even point is 175 households. Below 175 households, only the general provisions will apply. Above 175 households, both general and special provisions will apply. A permit can be obtained via an application form available on the ACM website.

The general provisions (articles 2 to 8B) apply to all suppliers. The special provisions (articles 9 to 12a) only apply to permit holders. Articles 9 to 11 prescribe three different criteria. The various organisational, financial, and technical requirements are stated in paragraph 3.1.1 and paragraph 3.1.2 of appendix 2. However, all requirements can be summarised as: to protect consumers, taking into account the importance of a reliable, sustainable, environmentally sound, and efficient heat supply (Warmtewet, 2017, article 2.1). Articles 12b to 12d regulate the heat supply in case a producer or supplier intends to terminate the heat supply or production. Article 13 enables ACM to request data and information from producers, suppliers, and consumers for the implementation of this law and for the preparation of the energy report. Full cooperation is required. Articles 15 to 46 regulate the role of ACM. Moreover, a supplier is legally obliged to reimburse consumers € 35 per disruption of 4-8 hours and an additional reimbursement of € 20 per extra four hours.

ACM annually sets the maximum tariffs for heat supply to ensure that consumers do not pay more than usual and to ensure that suppliers do not earn more than a reasonable rate of return. ‘Usual’ refers to a household with a G6 meter, an individual gas-fired HR107 boiler with a CW value of 4 for hot tap water. The CW value is a measure of the volume and temperature of hot tap water that must be delivered per minute to (1) the kitchen, (2) the shower, and (3) the bathtub. It is important to note that these three requirements (within the CW value) are not always equal to each other. Furthermore, the CW value can be used as a measure to determine comfort.

The costs of a supplier can be divided into supply costs and network operating/connection costs. The heat supply tariffs have increased by 4.26% between 2014 and 2018. Ecorys (2016) evaluated the Heat Act in 2016. On the basis of their evaluation, three main points of dissatisfaction came to light: (1) the calculation method of the maximum tariffs is not right, (2) tariffs for the delivery device and the supply of cold is not adequately regulated, and (3) consumers do not want be dependent on a monopolist from whom they cannot switch. On the positive side, consumers are generally happy about the usability and comfort offered by a DH system. An extensive description and analysis of the Heat Act is included in appendix 2.

3.4 Conclusion and conceptual model local P2H district heating cooperatives

According to Yilmaz et al. (2018), four overarching aspects are important to establish a local P2H DH cooperative. These overarching aspects are: (1) technical aspects, (2) economic aspects, (3) social aspects, and (4) legal/organisational aspects. Based on scientific literature and official reports, various aspects have been distinguished that have led to answering the second sub-question and the third sub-question. The second sub-question is: *'What is a (P2H) DH system, which types can be distinguished, and what are the main technical and economic aspects?'* According to Lund et al. (2014, p.1), a DH system comprises *"a network of pipes connecting the buildings in a neighbourhood, town centre or whole city, so that they can be served from centralised plants or a number of distributed heat producing units*". A DH system basically consists of four components: (1) production (primary and secondary installation), (2) transportation, (3) distribution, and (4) consumption. Historically, DH systems can be divided into the first, second, third, and fourth generation. Whereas the first generation (1880-1930) used steam as energy carrier, the fourth generation (2020-2050) will have a supply temperature of 30-70 °C. In addition, DH systems can be categorised into large-scale systems (>5,000 consumers) and small-scale systems (<5,000 consumers). From a technical perspective, a DH system must be dimensioned for the normative peak load of 1987. In addition, the historical energy consumption, the degree of insulation, the simultaneity factor, and the distribution loss are technical aspects for dimensioning a DH system.

According to Averfalk et al. (2017, p.1276), the concept of P2H with respect to residential purposes comprehends "*the use of (large) heat pumps or electric boilers for covering heat demands"*. A heat pump basically consists of an (1) evaporator, (2) compressor, (3) condenser, and (4) expansion device. Heat pumps can be divided into monovalent, mono-energetic, and bivalent systems. The COP value, which is the ratio between the energy consumption of the compressor and the useful extracted heat from the condenser, is an important technical aspect of heat pumps. An electric boiler heats water through resistive heating: the process of the passage of an electric current through a conductor to produce heat. Electric boilers can be used as 'economisers' to take advantage of price fluctuations on the electricity market, which are currently caused by the merit order effect. Moreover, P2H contributes to decarbonisation if the increase of CO_2 emissions as a result of the additional electricity demand is lower than the current CO_2 emissions caused by fossil fuels. The potential reduction can be calculated by means of the carbon intensities. An operation budget, which basically distinguishes Capex and Opex, can demonstrate the economic feasibility. In addition, financial tools such as NPV and ROIC can support the decision-making.

The third sub-question is: *'What is a local DH cooperative, which types can be distinguished, and what are the main social and legal aspects?'* According to Viadot (2013, p.757), cooperatives are "*autonomous associations of people who join voluntarily to meet their common economic, social, and cultural needs and aspirations through jointly owned and democratically controlled businesses*". Cooperatives across the world have one thing in common, namely the six values and seven principles adopted by the International Co-operative Alliance. Local DH cooperative can be classified according to the way ownership and liability are organised. A cooperative is a legal entity and can spread this liability in three ways: (1) all members are equally and personally liable (WA), (2) all members are liable to a certain limited extent (BA), or (3) none of the members can be held liable (UA). Moreover, the way in which citizens participate in local DH cooperatives can vary considerably. Walker & Devine-Wright (2008) differentiate process (the degree of involvement of local people) and outcome (how the benefits are distributed) in order to understand participation in community energy projects. In addition, the classic ladder of citizen participation of Arnstein (1969) can be used to classify citizen participation.

A large body of literature points to the importance of social acceptance and trust. Wüstenhagen et al. (2007) have distinguished three dimensions of social acceptance: (1) socio-political acceptance, (2) market acceptance, and (3) community acceptance. Trust is key to overcome (negative) perceptions local people might have and will increase their willingness to participate. The motivation of local people can be classified into (1) social, (2) environmental, and (3) economic reasons.

ACM is a Dutch independent administrative body under the ministry of EZK and has regulatory powers to supervise electricity and natural gas markets as well as DH markets. In January 2014, EZK introduced the Heat Act. It regulates the heat supply for consumers with a connection up to 100 kWt. Appendix 2 describes the way the Heat Act functions and which articles and obligations apply to local P2H DH cooperatives. Figure 22 shows a conceptual model that summarises the main theoretical aspects of the establishment of local P2H DH cooperatives.

Technical aspects P2H DH systems	Social aspects DH cooperatives
• Large-scale (>5,000) vs. small-scale (<5,000). • Primary and secondary installation: - monovalent, mono-energetic and bivalent systems. - Normative peak load of winter 1987. - Legionella contamination (60 °C) - Degree of insulation. - Simultaneity factor. - Coefficient of Performance (COP). - Decarbonisation. • Transportation and distribution: - Distribution loss. - Heat carrier and temperature. • Consumption: - Historical energy consumption. - Space heating and hot tap water. - Comfort (CW value). - Heat exchanger and meter.	• 7 core values and principles. • Process and outcome: - Open & participatory vs. closed and institutional. - Local & collective vs. distant & private. • Citizens participation: - nonparticipation, tokenism and citizen power. • Conflicts: - Values, needs, interests and actions. • Social acceptance: - socio-political acceptance, market acceptance and community acceptance). • Trust. • Motivations and perceptions: - Social, environmental and economic.
Economic aspects P2H DH systems	**Legal aspects DH cooperatives**
• Business to business: - Price (development) wholesale and retail markets). - Merit order effect. - Loans. • Business to customer: - Capex and Opex. - Taxes (Energy Tax, Tax on Sustainable Energy, VAT 21% and annual Tax discount).	• Ownership: - Community owned, co-ownership (hybrids) and commercial or public owned. - Limited partnerships and civil partnerships. • Liability: - WA, BA and UA. • Heat Act: - Permit obligation ACM. - Maximum tariffs (NMDA principle). - Compensation fee disruption. - Technical, financial and organisational requirements.

Figure 22. Conceptual model establishment of local P2H DH cooperatives.

4 Research methodology

This chapter describes the research methodology of the understanding phase of this study. The (theoretical) conceptual model, which is based on the four overarching of Yilmaz et al. (2008) forms the starting point of the empirical research. Expert interviews are used to gain an in-depth insight into the case studies and to draw up a business case for the EcoGenie 2.0 pilot in Paddepoel-Noord. Case studies can verify the theoretical aspects as well as lead to the empirical acquisition of new aspects and important lessons.

Paragraph 4.1 contains a detailed description of the research methodology for the case studies. It starts with a brief theoretical introduction to case studies. Next, it describes how the cases have been selected and accessed, so how the case studies have been carried out. Paragraph 4.2 contains a detailed description of the expert interviews, starting with a brief theoretical introduction to (expert) interviews and paying attention to important weaknesses. It contains a list of respondents and explains how the obtained data has been processed.

4.1 Case studies

According to Yin (2014, p.16), a case study is an "*empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident".* This definition is twofold, both the 'contemporary phenomenon' and its 'real-world context' are important. Therefore, a case study relies on multiple sources of evidence, known as triangulation (Yin, 2014). Detailed observation, conducting interviews, and studying all sorts of documents could provide a profound insight into the way various processes take place and the reasons behind those processes (Verschuren & Doorewaard, 2010). Yin (1984) distinguishes three types of case studies: (1) exploratory, (2) explanatory, and (3) descriptive. This study uses exploratory and descriptive case studies; questions that are likely to be answered are 'what', 'how' and 'why'. In addition, multiple case studies have been carried out to get a more comprehensive understanding. Verschuren & Doorewaard (2010) call this the 'hierarchic method', which means that cases are first described and examined individually. Then the cases are combined to investigate similarities and differences. As a result, cases not only offer individual insights, but also provide shared insights.

4.1.1 Case selection

The research unit is 'a local P2H DH cooperative'. Initially, the following four criteria were used to select cases:

1. A local P2H (industrial heat pump and electric boiler) DH system.
2. Cooperative organisation structure.
3. Small-scale system (<5,000 consumers, preferably around 200 consumers).
4. Accessibility of data (Yin, 2014).

In practice, however, it turned out to be difficult to select cases based on these four criteria. Hers et al. (2015) and Agora (2014) recently provided an overview of P2H DH systems in Denmark and Germany. This overview seemed very promising in the beginning, but only concerns the application of electric boilers as add-on to a fossil-fuelled boiler. Various sources such as (relevant) scientific articles, official reports, web pages, newspapers, and Google have been examined and experts in the field have been consulted to find suitable cases. The local P2H DH cooperative Thermo Bello in Culemborg is the only case that could be found that meets all four criteria. On the one hand, this underlines the uniqueness of the establishment of a local P2H DH cooperative. Yet on the other hand, the four selection criteria needed to be enlarged. As a result, the DH system of Mijnwater in Heerlen and the energy/DH cooperative TexelEnergie on Texel were investigated. Both cases complement each other (table 5). Due to the low availability of suitable cases, no cases are excluded. In addition, the customer journey of EBO Consult and the strategy of Reggefiber to recruit participants for fibre optic networks were added.

4.1.2 Data sources and assessment method

The five selected cases have been analysed in close relation to the aspects of the conceptual model (paragraph 3.4, figure 22). The conceptual model includes four overarching aspects, namely (1) technical aspects, (2) economic aspects, (3) social aspects, and (4) legal aspects, based on Yilmaz et al. (2018). Various sources have been used to obtain data: (scientific) literature, (official) documents, web pages, media, and expert interviews. Table 5 shows the relation between the four (theoretical) overarching aspects and the five selected (empirical) cases.

Table 5. Relation between theoretical aspects and empirical case studies.

Aspects / **Case studies**	**Technical**	**Economic**	**Social**	**Legal**
Thermo Bello in Culemborg	X	X	X	X
Mijnwater in Heerlen	X	X		
TexelEnergie on Texel			X	X
The customer journey of EBO Consult			X	
The recruitment strategy of Reggefiber			X	

Each case starts with an introduction and a brief description of its history and motivations. This helps to understand the real-world context of each case individually. Then the overarching aspects that apply to a specific case are analysed. In the Mijnwater case, for example, only the technical and economic aspects apply. On the one hand, it verifies the theoretical aspects and on the other hand it can contribute to the empirical acquisition of new insights and new aspects. Finally, each case study concludes with a list of lessons drawn from that case. Subsequently, the cases are combined to investigate similarities and differences.

4.2 Expert interviews

According to Dunn (2005, p.71, cited in Clifford et al. 2010, p.105), interviews "*are verbal interchanges where one person, the interviewer, attempts to elicit information from another person*". Clifford et al. (2010) distinguish three types of interviews: (1) structured, (2) unstructured, and (3) semi-structured. This study uses semi-structured interviews, because it allows to ask predetermined and standardised questions as well as asking for opinions of respondents (Flowerdew & Martin, 2005). Interviews can be conducted face-to-face, via the internet (e.g. Skype), or via the telephone.

Verschuren & Doorewaard (2010) point to four weaknesses of expert interviews: (1) bias due to poorly articulated questions, (2) expert bias, (3) inaccuracies due to poor recall, and (4) reflexivity (the interviewee gives the answer the interviewer wants to hear).

4.2.1 Respondent selection and data processing

The respondents (experts) were selected in close relations to the case studies and to the EcoGenie pilot in Paddepoel-Noord. One interview per case study was conducted to increase the knowledge and understanding. Moreover, a variety of data sources contributes to the validity (Verschuren & Doorewaard, 2010). In addition, five interviews were conducted for EcoGenie 2.0 in Paddepoel-Noord. Table 6 shows an overview of the respondents and their position.

Table 6. Overview respondents.

Name	**Position**
Fokko Reinders	Relation Manager and advisor sustainability at Enexis
Gerwin Verschuur	Managing Director of Thermo Bello
Joep Broekhuis	Project Manager sustainable energy at Grunneger Power
Jord Kuiken	Project Manager at TexelEnergie
Kees van Dalen	Strategic Advisor at Enexis
Kevin Mooibroek	Former Sales Manager at Reggefiber and entrepreneur
Louis Hiddes	Director of Mijnwater
Peter Breithaupt	Senior Technical Advisor at Shell New Energies
Rie Krabsen	Market Officer at EBO Consult
Wouter van Bolhuis	Programme Manager energy transition at the municipality of Groningen

Potential respondents were contacted by telephone or e-mail. They received a brief introduction to the research objective and EcoGenie 2.0, and a request to give an interview. If they responded positively, they received a letter with a more elaborate explanation and a questionnaire by e-mail. The letter covers three out of four strategies (paragraph 1.6) to mitigate the first ethical conviction. Moreover, the letter is a way to reduce the possibility of reflexivity during the interview. Before the actual interview began, permission to record the interview was asked. This was the fourth strategy to mitigate the first ethical conviction.

In order to prevent the weaknesses of interviews mentioned by Verschuren & Doorewaard (2010), interviews were preferably held face-to-face. If a face-to-face interview was not possible due to a large travel distance, a Skype or telephone interview was preferred. The interviews were summarised as quickly as possible and sent to the respondent. The respondent was given the opportunity to change information, to add information, and to withdraw information. This helped prevent bias and inaccuracies.

5 Results case studies

This chapter contains the results of the five case studies. The case studies are: (1) Thermo Bello in Culemborg, (2) Mijnwater in Heerlen, (3) TexelEnergie on Texel, (4) the customer journey of EBO Consult, and (5) the marketing strategy of Reggefiber. Thermo Bello is a small-scale P2H DH cooperative that withdraws heat from a drinking water basin in Culemborg, the Netherlands. Thermo Bello currently supplies heat to 210 households and seven commercial buildings. Mijnwater is a small-scale P2H DH company that supplies heat and cold from abandoned mining fields in Heerlen, the Netherlands. Mijnwater currently supplies heat to 270 households and nine commercial buildings. Because Mijnwater does not have a cooperative governance structure, only the technical and economic aspects are included. TexelEnergie is an energy cooperative and a former small-scale DH cooperative that generated heat from biomass on Texel, the Netherlands. It supplied heat to 193 households. The customer journey of EBO Consult (a Danish independent administration company specialised in managing DH cooperatives) is a tool to understand and optimise the customer experience during a DH project. The marketing strategy of Reggefiber (a Dutch fibre optic networks company) shows the best practice for recruiting participants for a DH project. An extensive description and analysis of these cases are included in appendix 4.

Paragraph 5.1 includes the important lessons that the involved experts have learned from their specific situations. Paragraph 5.2 contains the analysis and description of the technical, economic, social, and legal/organisational aspects. It verifies the (theoretical) aspects and adds new (empirical) aspects. Finally, paragraph 5.3 concludes with a framework that summarises the main (theoretical and empirical) aspects of local P2H DH cooperatives.

5.1 Lessons

The experts who were involved in the case studies have learned important lessons from their specific situations, which can be of great value to establishing local P2H DH cooperatives. However, it is very important to consider that the real-world context always varies (Yin, 2014). To acknowledge their real-world contexts, the lessons are discussed separately. Paragraphs 5.1.1 until 5.1.4 show these lessons. The lessons as well as the real-world contexts are included in appendix 3.

5.1.1 Lessons Thermo Bello

Below is an overview of lessons learned from the establishment and operation of Thermo Bello.

- There is a big gap between the design phase, the construction phase, and the operation phase of a DH system. Various contractors and consultancy companies design and construct different parts without having an overview of the total system, which can easily lead to mismatches between various parts of the DH system. This makes that the owner remains responsible for the integration of all aspects. To avoid this situation, it might be better to purchase a certain service instead of a certain product. Installations really need to be checked before completion and operation (G. Verschuur, appendix 5).
- The debate about the legal form has once again made clear local residents ultimately trust people, not structures (Verschuur 2010, p.15).
- It was very important that we (the initiators) did not request permission for acquisition in the early stages of the feasibility study. We only asked permission to carry out an in-depth feasibility study and acknowledged the option that it would not be realistic to take over (Verschuur 2010, p.34).

- Good communication is vital. Embrace resistance of local residents, because in most cases, resistance is based on knowledge and previous experiences. Residents want to see their problems and fears (risks) reflected and dealt with in the business plan (G. Verschuur, appendix 5).
- The ratio between fixed and variable costs can be used as a financial incentive for consumers to save energy, ultimately contributing to (national) climate goals (Verschuur 2010, p.29).
- In the establishment of Thermo Bello, four phases can be distinguished (exploration, feasibility study, business development, and start-up). It is important to finish each phase with a milestone, thus keeping the focus on what has been done and what needs to be done. It also helps people who are less involved to keep track of the process (Verschuur 2010, p.38).

5.1.2 Lessons Mijnwater

Below is an overview of lessons learned from the establishment and operation of Mijnwater.

- Be very careful with the advice/advisory reports of installers/installation companies. Heating and cooling are very complex matters. Therefore, an understanding of the entire system and the entire process is required (L. Hiddes, appendix 5).
- It is important to be aware that in the current situation (individual gas-fired boiler), efficiency losses (in Dutch: *rendementsverliezen*) of space heating and hot tap water occur behind the meter. In contrast, efficiency losses in a DH system occur before the meter (L. Hiddes, appendix 5).

5.1.3 Lessons TexelEnergie

Below is an overview of lessons learned from the establishment and operation of the DH system in Wijk 99.

- An energy cooperative has to be able to pay its bills (in Dutch: *de schoorsteen moet roken*). Projects must be economically viable or become economically viable within a reasonable period of time. Both the innovative and the commercial aspects are equally important (J. Kuiken, appendix 5).
- Choose your partner organisations carefully. Because the primary organisation is always the contact of the customer and responsible, even if a partner organisation (secondary organisation) makes a mistake. In addition, cooperation with partners often decreases the recognisability of the primary organisation (J. Kuiken, appendix 5).
- Document all agreements with third parties, because it can prevent disagreements later on in the project (J. Kuiken, appendix 5).

5.1.4 Lessons customer journey of EBO Consult

Below is an overview of lessons learned from the customer journey mapping of EBO Consult.

- Customers prefer personal contact and visibility. It is important to visit each customer individually in order to understand their situation and to adapt the installation process to their personal situations and preferences (EBO Consult 2016, p.3).
- Respect the private space of people and restore private spaces (e.g. garden) to their original state. If you carefully treat their private space, trust increases (R. Krabsen, appendix 5).
- Communicate directly and honestly, even if something went wrong. Mistakes occur because often many contractors and subcontractors are involved during the execution of a DH project. People may not like it at first, but it builds trust in the long run. In addition, follow-up. Keep people informed and stay (in person) in contact with the customers (R. Krabsen, appendix 5).

5.1.5 Lessons marketing strategy of Reggefiber

Below is an overview of lessons learned from the marketing strategy of Reggefiber.

- A marketing campaign requires a flexible organisation and clear communication. Flexibility is important, because decisions have to be made quickly as time is limited. Clear communication with the community is important, and home visits in particular should be announced in advance (K. Mooibroek, appendix 5).
- Being present is very important to gain acceptance and trust from the community. Setting up a temporary store or office at a central place where people can ask their questions and share their concerns is a good example of being physically present (K. Mooibroek, appendix 5).
- People like to have a choice between two or three options. A lack of choice often leads to resistance (K. Mooibroek, appendix 5).
- Visualisation often helps people to understand, for example a demonstration model illustrating the conventional connection and the new home connection (K. Mooibroek, appendix 5).
- Empathise with people, try to understand their feelings and thoughts (e.g. suspiciousness), because then people are more inclined to participate (K. Mooibroek, appendix 5).
- Create necessity because necessity makes people decide. A typical sales curve has the shape of a hockey stick. The majority of people sign up close to the deadline. Therefore, limit the timeframe of the campaign (e.g. three months) and announce a clear deadline (K. Mooibroek, appendix 5).

5.2 Analysis aspects

Paragraphs 5.2.1 until 5.2.4 contain the analysis of the technical, economic, social, and legal/organisational aspects. These paragraphs discuss and verify the (theoretical) aspects and add new (empirical) aspects. The aspects as well as their real-world contexts are included in appendix 3.

5.2.1 Technical aspects

Thermo Bello and Mijnwater can be regarded as small-scale P2H DH systems. In both cases the primary installation consists of brine-sourced heat pumps and a secondary installation has been installed, consisting of respectively a gas-fired boiler and the use of residual heat. Both DH systems can be considered bivalent. As mentioned by Schepers & Van Valkengoed (2009), the secondary installation not only complements the primary installation (during peak loads), but also functions as a back-up (during maintenance or breakdowns). The case of Mijnwater illustrates how a local data centre or refrigerators and freezers in a supermarket can be used as a (secondary) heat source. Not only does this contribute to the sustainability, according to L. Hiddes (appendix 5), it is also financially attractive for both parties (the supplier and the client).

Contrary to the theoretical requirement of an average effective temperature of minus 17 °C, Thermo Bello is dimensioned at an average effective temperature of minus 10 °C. According to G. Verschuur (appendix 5) DH systems are usually dimensioned at minus 10 °C. Thermo Bello used a simultaneity factor of 0.53 and calculated their average distribution loss at 13.3% in 2016. Both values are similar to the values mentioned by Ecofys (2015). In addition, G. Verschuur (appendix 5) mentioned the distribution pumps that are needed to pump the hot water through the pipelines. Similar to generation, a secondary (back-up) distribution pump is required.

It is very interesting to note that in both cases the heat used for space heating is generated collectively, while the heat used for hot tap water is generated individually. This results in a reduction of the total heat demand, because only hot tap water requires a supply temperature of 60 °C. In addition, both cases use a so-called variable heating curve which is related to the outside temperature. In case of Thermo Bello, the supply temperature varies between 20 °C and 50 °C. Various solutions are available to generate hot tap water at an individual level, for example the booster heat pump. The booster heat pump uses the low-temperature heat for space heating and increases the temperature to the required 60 °C, resulting in a (high) COP of around 5-5.5. The investment costs amount to approximately € 3,000 per household.

The average annual COP of Mijnwater for space heating is 6, which is very high compared to the theoretical COP values mentioned by Fischer & Madani (2017) and the COP values of Thermo Bello. Thermo Bello had an average annual COP of 3.64 in 2016 and their target is to achieve an average annual COP of 4.7. This difference can largely be attributed to the extraction temperature. Mijnwater extracts water that already has a temperature of 28 °C. However, the COP values confirm that the average COP values mentioned by Fischer & Madani (2017) are accurate.

Both G. Verschuur and L. Hiddes (appendix 5) mentioned the importance of the input of renewable energy to reduce CO_2 emissions. A recent calculation revealed that the CO_2 emissions of Thermo Bello's P2H DH system is similar to the CO_2 emissions of individual gas-fired boilers. The only way to drastically reduce CO_2 emissions is by installing renewable energy devices (e.g. solar PV) or purchasing renewable energy (e.g. wind energy).

Interestingly, G. Verschuur and L. Hiddes (appendix 5) learned the same lesson: a (P2H) DH system is very complex, which can easily lead to mistakes and mismatches between theory (advisory reports and design) and practise. L. Hiddes (appendix 5) points to the importance of understanding the entire system. G. Verschuur (appendix 5) mentions that it might be better to purchase a certain service instead of a certain product and stresses the importance of a final mechanical check before the P2H DH system starts operating.

5.2.2 Economic aspects

The initiators of Thermo Bello and Mijnwater were not motivated by the price development on the wholesale markets (merit order effect) to establish a P2H DH system. In fact, in both cases the environmental and social motivations were leading. As derived from the literature review, P2H DH systems require high investment costs (Capex) that must be covered by loans and sufficient incomes. The DH cooperatives Thermo Bello and TexelEnergie have, in addition to bank loans and private investors, issued depositary receipts to raise sufficient investment capital. As a result, according to G. Verschuur (appendix 5), the benefits become circular: local profits remain local and can be invested locally. Moreover, J. Kuiken (appendix 5) mentions the importance of economic viability, because the lifetime of DH systems is generally very long. In addition, J. Kuiken (appendix 5) adds the aspect of the default risk (in Dutch: *debiteurenrisico*), which can be a major burden, especially for small DH cooperatives.

Heat tariffs are obviously used to invoice the services that heat supplier provides to its customer. However, heat tariffs can also be used as a financial incentive. The ratio between fixed and variable tariffs can be used as a financial incentive for consumers to save energy, ultimately contributing to (national) climate goals (Verschuur 2010, p.29). Mijnwater uses the connection fee as a financial incentive to stimulate consumers to insulate their houses. This is a win-win situation for both parties, because a higher degree of insulation decreases the required production capacity and lowers the consumers' energy bills (L. Hiddes, appendix 5).

5.2.3 Social aspects

The DH cooperatives Thermo Bello and TexelEnergie, as well as the customer journey of EBO Consult and the marketing strategy of Reggefiber show the importance of social aspects. After all, without consumers it is impossible to establish a local P2H DH cooperative. The six values and seven principles adopted by the International Co-operative Alliance are not directly used by Thermo Bello and TexelEnergie. However, indirectly (underlying) each of these values and principles were found, which is in line with Viadot (2013).

In both cases (Thermo Bello and TexelEnergie), the two dimensions of participation (process and outcome) mentioned by Walker & Devine-Wright (2008) were to a large extent distributed to the local community. The DH projects were driven and carried out by local people (process). The economic and social benefits were partially distributed among the community (outcome). Thermo Bello, for example, started with the distribution of economic benefits when they were able to repay their loans by issuing certificates and being financially stable. In view of the ladder of citizen participation developed by Arnstein (1969), the citizens participate on the highest rung because they have the power to influence the outcome and make decisions.

Various scholars (e.g. Walker & Devine-Wright, 2008 and Yildiz et al., 2015) warned for the possibility of conflicts within an energy cooperative. Such conflicts have indeed been found in the investigated cases. However, G. Verschuur (appendix 5) proposes to embrace local resistance because it is in most cases based on knowledge and previous experiences. K. Mooibroek (appendix 5) emphasises the importance of showing empathy, trying to understand the community's feelings and thoughts (e.g. suspiciousness). People tend to participate more in a DH cooperative when their fears, feelings, and thoughts are taken seriously and discussed in for example the business plan. Moreover, K. Mooibroek (appendix 5) states that a lack of choice often leads to resistance. That is why it is important to let people (potential customers) choose between two or three options.

A large body of literature (e.g. Walker et al., 2010; Wüstenhagen et al., 2007 and Yildiz et al., 2015) mentions that social acceptance and trust are essential for establishing a community energy project. All the investigated cases underline this statement, and reciprocal trust in particular is an aspect mentioned often. Different strategies can be used to gain social acceptance and trust. K. Mooibroek and R. Krabsen (appendix 5) both pointed to the importance of being visible and physically present. Setting up a temporary store or office at a central place where people can ask their questions is a good example of being physically present. Both respondents also mentioned that visualisation (e.g. videos or demonstration models) and creating necessity are key strategies to gain acceptance and recruit participants. R. Krabsen (appendix 5) stresses the importance of direct and honest communication. People may not like it at first, but it builds trust in the long run. Finally, K. Mooibroek and R. Krabsen (appendix 5) mentioned that so-called local influencers or local ambassadors as a key strategy to convince the local community.

R. Krabsen (appendix 5) states that P2H DH not only goes 'behind the front door' but also 'behind the garden gate'. First of all, it is important to visit people's houses individually in order to understand their situation and to adapt the installation process to their personal situation and preferences. Secondly, it is important to restore for example the garden to its original state after construction work is done. Careful handling of people's private property increases trust.

J. Kuiken (appendix 5) pointed to a strong social benefit of a local energy cooperative compared to a major energy supplier. A local (P2H) DH cooperative can protect and assist vulnerable people because it knows its customers more personally and knows when people face problems with paying their energy bills.

5.2.4 Legal/organisational aspects

Thermo Bello and TexelEnergie are both DH cooperatives that are owned by the community. Thermo Bello illustrates the possibility of a hybrid between a limited partnership and a civil partnership. The management consists of project-initiating investors, but decisions are taken by a democratic process. Both DH cooperatives evolved from the bottom-up with informal meetings, as was mentioned by Schoor & Scholtens (2015). Both DH cooperatives have a paid board of directors and staff members. G. Verschuur (appendix 5) emphasises the importance of a supervisory board. A small-scale DH cooperative is financially not capable of hiring sufficient staff members and a lack of time can lead to big mistakes. A supervisory board consisting of volunteers is a way to prevent this.

Schwenke (2016) mentioned that small initiatives align themselves with larger energy companies with a strong focus on sustainability. This is more or less also the case with Thermo Bello and TexelEnergie. In both cases the invoicing of heat is outsourced. According to J. Kuiken (appendix 5), this is because many rules and legislation apply, making it too complicated for a small energy supplier. Also, maintenance of the installations and pipelines is outsourced to specialised companies. J. Kuiken (appendix 5) emphasises the importance of documenting all agreements with third parties, even if it seems unnecessary. This can prevent many problems.

Both cases are cooperatively organised with excluded liability (UA), which means that the members cannot be held liable. People can join the cooperative by buying at least one share. All members (above the age of eighteen) have the right to vote. There are no exceptions: one vote per person in accordance with the values and principles adopted by the International Co-operative Alliance. It is important to keep in mind that a cooperative structure requires statutes that include at least the name, purpose, and obligations of the cooperative.

Thermo Bello, Mijnwater, and TexelEnergie all use the maximum heat tariffs set by ACM. The Heat Act does not prescribe a maximum tariff for a delivery device (e.g. heat exchanger), but it has to be a 'reasonable amount'. Thermo Bello invoiced € 77.22/household for renting the delivery device in 2015, which apparently meets the criteria 'reasonable amount'.

5.3 Conclusion and framework local P2H DH cooperatives

In total, five case studies have been carried out: (1) Thermo Bello in Culemborg, (2) Mijnwater in Heerlen, (3) TexelEnergie on Texel, (4) the customer journey of EBO Consult, and (5) the marketing strategy of Reggefiber. The (theoretical) aspects found in the literature review have been verified by these case studies. The (theoretical) aspects were not always found separately, but usually in one or two cases. Moreover, the case studies have brought new (empirical) aspects to light. Based on this, the fourth sub-question can be answered. The fourth sub-question is: '*Which aspects can be found in existing (P2H) DH cooperatives and which lessons can be learned?'*

Technically, both Thermo Bello and Mijnwater use a variable heating curve and (partly) booster heat pumps. The aspect of distribution pumps (primary and secondary) was found as well. Both cases mentioned the importance of the input of renewable energy to reduce the CO_2 footprint. The most important lesson learned from Thermo Bello and Mijnwater is that a (P2H) DH system is very complex, which can easily lead to mistakes and mismatches between the theory (advisory reports and design) and practise. Economically, both Thermo Bello and TexelEnergie use depositary receipts. Depositary receipts have the advantage that benefits become circular: local profits remain local and can be invested locally. In addition, the aspect of default risk was found. The most important lesson learned from Thermo Bello and Mijnwater is that the heat tariff and connection fee can be used as a financial incentive to save energy.

Socially, the aspect of local resistance was found in Thermo Bello, TexelEnergie, Reggefiber, and EBO. Resistance is related to trust and needs to be embraced. Three important measures/aspects were found to increase trust: (1) empathy, (2) visibility and being (physically) present, and (3) local influences and ambassadors. The aspect of protection and assisting vulnerable people was found in the case of TexelEnergie. A DH cooperative generally knows its customers on a more person level, which means that many (financial) problems can be prevented. The most important lesson is that P2H DH not only goes ‘behind the front door’ but also goes ‘behind the garden gate’. Legally, the ‘overarching’ aspect of organisation/governance was found in the cases of Thermo Bello and TexelEnergie. Four organisational aspects were found: (1) board of directors and staff members, (2) supervisory board, (3) invoicing, and (4) statutes. The most important lesson is the importance of documenting all agreements with third parties, even if it seems unnecessary. The empirical aspects found in the case studies are added to the theoretical aspects found in the literature review. Figure 23 shows a framework summarising the main (theoretical and empirical) aspects of the establishment of local P2H DH cooperatives. The empirical aspects are underlined.

Technical aspects P2H DH systems

- Large-scale (>5,000) vs. small-scale (<5,000).
- Primary and secondary installation:
  - monovalent, mono-energetic and bivalent systems.
  - Normative peak load of winter 1987.
  - Legionella contamination (60 °C)
  - Degree of insulation.
  - Simultaneity factor.
  - Coefficient Of Performance (COP).
  - Decarbonisation (RES).
  - Variable heating curve.
  - Booster heat pump.
- Transportation and distribution:
  - Distribution pumps.
  - Distribution loss.
  - Heat carrier and temperature.
- Consumption:
  - Historical energy consumption.
  - Space heating and hot tap water.
  - Comfort (CW value).
  - Heat exchanger and meter.

Social aspects DH cooperatives

- 7 core values and principles.
- Process and outcome:
  - Open & participatory vs. closed and institutional.
  - Local & collective vs. distant & private.
- Citizens participation:
  - nonparticipation, tokenism and citizen power.
- Conflicts:
  - Values, needs, interests and actions.
  - Resistance.
- Social acceptance:
  - socio-political acceptance, market acceptance and community acceptance).
- Trust:
  - Empathy.
  - Visibility and presence.
  - Local influencers/ambassadors.
- Motivations and perceptions:
  - Social, environmental and economic.
- Protect and assist vulnerable people.

Economic aspects P2H DH systems

- Business to business:
  - Price (development) wholesale and retail markets).
  - Merit order effect.
  - Loans.
- Business to customer:
  - Capex and Opex.
  - Depositary receipts.
  - Taxes (Energy Tax, Tax on Sustainable Energy, VAT 21% and annual Tax discount).
  - Default risk.

Legal and organisational aspects DH cooperatives

- Ownership:
  - Community owned, co-ownership (hybrids) and commercial or public owned.
  - Limited partnerships an civil partnerships.
- Liability:
  - WA, BA and UA.
- Heat Act:
  - Permit obligation ACM.
  - Maximum tariffs (NMDA principle).
  - Compensation fee disruption.
  - Technical, financial and organisational requirements.
- Organisational:
  - Board of directors and staff members.
  - Supervisory board.
  - Invoicing.
  - Statutes.

Figure 23. Framework establishment of local P2H DH cooperatives.

6 EcoGenie 2.0 pilot in Paddepoel-Noord

Paddepoel Energiek (resident's initiative) and Grunneger Power (green energy cooperative) are investigating the possibility of establishing a local pilot P2H DH cooperative. The pilot is called EcoGenie 2.0. and will be located in Paddepoel-Noord. Shell, the Dutch-British oil and gas multinational, supports this cooperative start-up. This chapter applies the main technical, economic and social aspects to this pilot and compares the current (energy) situation to the future situation with EcoGenie 2.0, focused on costs and CO_2 emissions. However, the real-life context in Paddepoel-Noord is briefly described in advance.

Paddepoel-Noord is a residential area in the northern part of the city of Groningen. Paddepoel-Noord is surrounded by the residential areas Vinkhuizen, Selwerd, and Paddepoel-Zuid, as well as the university complex Zernike Campus. Paddepoel-Noord was built in the 1960s and 1970s, and is characterised by monotonous terraced single-family houses, wide streets with lots of parking space and little greenery. In addition, Paddepoel-Noord has a modern indoor shopping centre with many amenities. Figure 24 shows the geographical location of Paddepoel-Noord.

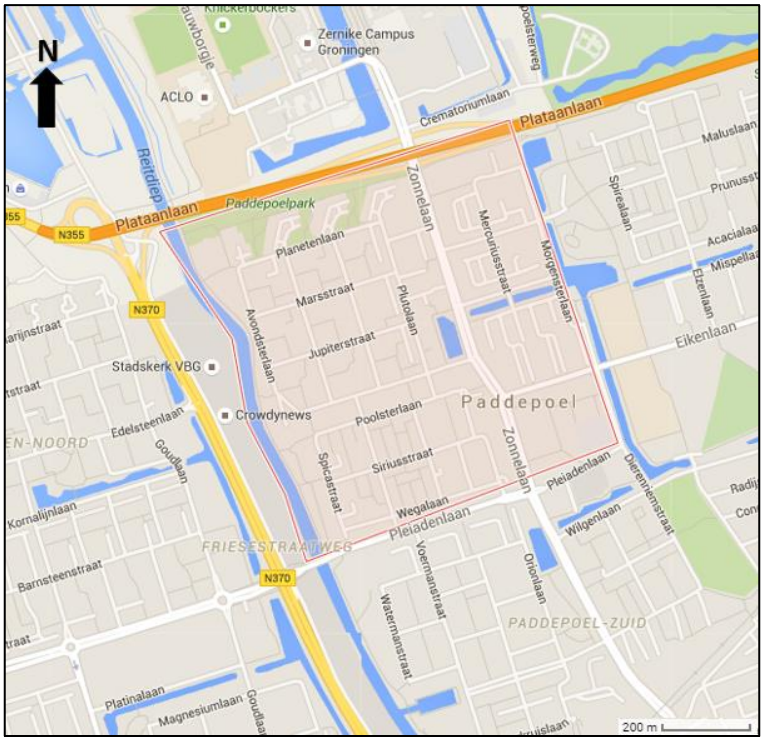

Figure 24. Location Paddepoel-Noord (Google, 2018).

The province of Groningen, the city of Groningen, and especially the residential area Paddepoel-Noord have progressive ambitions. The province of Groningen wants to take the lead in the energy transition of the Netherlands (provincie Groningen, 2018). This is because the province of Groningen suffers from earthquakes caused by the extraction of natural gas. F. Reinders (appendix 5) referred to the great disaster in the province of Zeeland: the flood of 1953. In response to the flood, they built the Delta Works as protection, and as a result, the province of Zeeland is known nationally and internationally because of these Delta Works. Likewise, the earthquakes make the province of Groningen a very good testing ground (in Dutch: *proeftuin*) for sustainable energy solutions, hopefully making the province of Groningen known nationally and internationally because of its sustainable energy solutions (F. Reinders, appendix 5).

Also, the municipality of Groningen is ambitious. Their environmental goal is to reduce 50% of its CO_2 emission by 2025 and to become carbon-neutral by 2035 (gemeente Groningen, 2011). Furthermore, Groningen wants to be natural gas-free by 2035 (gemeente Groningen, 2016). According to Wouter van (appendix 5), there are basically three sustainable heat sources to replace natural gas: (1) DH systems, (2) all-electric systems, and (3) hybrid systems with green gas, combined with hydrogen. DH systems are the preferred alternative for the existing built environment. In addition to its environmental goals, the municipality of Groningen also has economic goals. The municipality wants to become an 'Energy City' by developing local knowledge and opportunities (gemeente Groningen, 2015) in order to profit from the Dutch energy transition in twenty years' time (Wouter van Bolhuis, appendix 5)

Even the community in Paddepoel-Noord is ambitious. In 2012, a bottom-up movement started and the association Paddepoel Energiek was established. Paddepoel Energiek consists of energetic residents who want to make their own neighbourhood more sustainable. Their vision is: "*In 2035, Paddepoel must be an energy neutral neighbourhood generating its own energy"* (Stichting Paddepoel Energiek, 2018). Their effort led to (collective) energy saving measures and (collective) procurement of solar PV. In addition, the realisation of two local and community owned windmills is at an advanced stage.

The municipality of Groningen wants to start the transition towards a sustainable heat supply in Paddepoel (consisting of North and South) and the adjacent neighbourhood of Selwerd (Stadszaken, 2018). Their reasons are twofold: Paddepoel's and Selwerd's ambitious residents, and the need to have the natural gas network replaced before 2023 (RVO, 2018b). Both neighbourhoods participate in the so-called natural gas free neighbourhoods (in Dutch: *aardgasvrije wijken*) of the national government. The national government made € 90 million available to transform twenty (pilot) neighbourhoods into natural gas free neighbourhoods. The state has received 75 applications (including from Paddepoel-Noord) and on 1 October 2018, they will announce which neighbourhoods have been selected (RVO, 2018c). In addition, Paddepoel Energiek is one of the six energy initiatives in the province of Groningen selected by the regional government. This results in support consisting of sharing knowledge, investigating the financial possibilities, and generating (media) attention (provincie Groningen, 2017).

Paragraph 6.1 describes the current energy situation (reference situation) in Paddepoel-Noord. It examines the current energy costs and the associated CO_2 emissions of the residents of Paddepoel-Noord. Paragraph 6.2 describes the EcoGenie 2.0 pilot and examines future energy costs and associated CO_2 emissions of the residents. Finally, paragraph 6.3 concludes this chapter and answers sub-question five.

6.1 Current energy situation in Paddepoel-Noord

Households in Paddepoel-Noord currently use natural gas for space heating, hot tap water, and cooking. The local DSO for both electricity and natural gas is Enexis. Each household has an individual gas-fired boiler. According to ACM (2018), it can be assumed that this is an HR107 boiler. In addition, it is assumed that each household has a single-phase power connection, while induction cooking requires a three-phase power connection.

The average energy costs (electricity and natural gas) are calculated based on the (aggregated and allocated) historical energy consumption between 2014 and 2016. The average electricity consumption is 2,902 kWh/household and the average natural gas consumption is 1,690 Nm^3/household (16,103 kWh). The monthly electricity costs amount to € 40.93/household (incl. VAT) and the monthly natural gas costs amount to € 110.57/household (incl. VAT). The average CO_2 emission is calculated based on carbon intensities. The electricity consumption causes 1,072 kg/household CO_2 emissions and the heat consumption causes 3,399 kg/household CO_2 emissions. An extensive calculation and description is included in appendix 4. Figure 25 shows the results of the calculation of the current energy costs and CO_2 emissions of an average household in Paddepoel-Noord in percentages. It shows that the costs and the associated CO_2 emissions of natural gas are significantly higher compared to electricity. Natural gas is responsible for more than three quarters of the costs and CO_2 emissions per household.

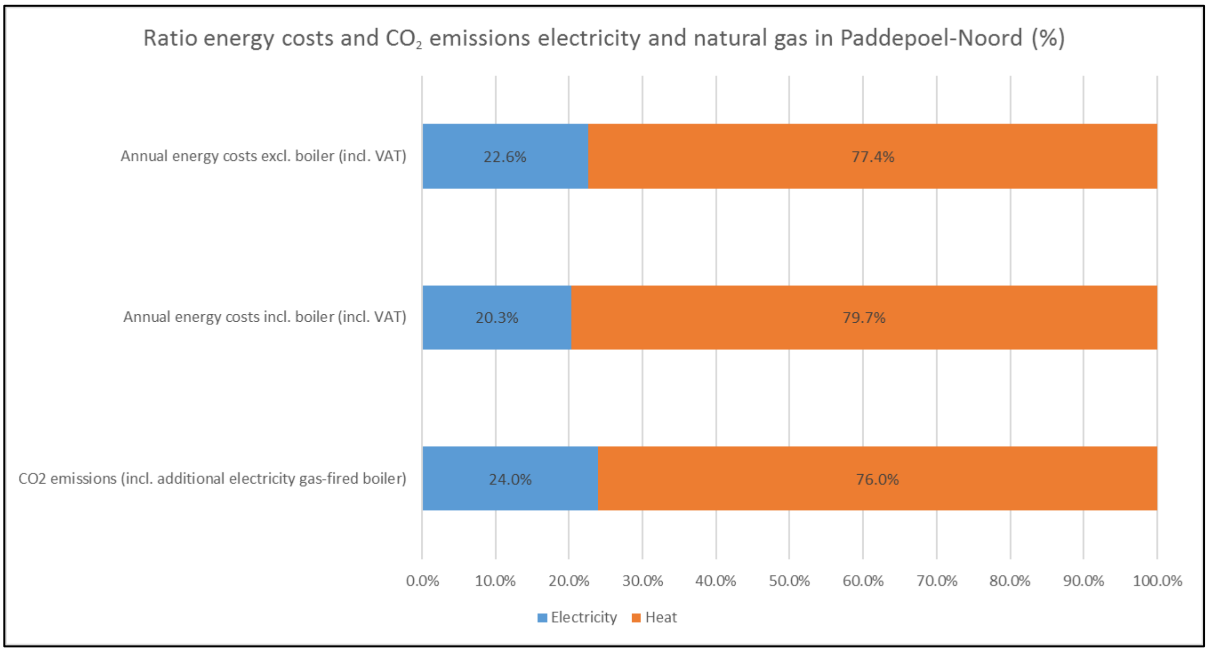

Figure 25. Calculated energy costs and CO_2 emissions in Paddepoel-Noord.

The current natural gas costs are used as reference situation for the calculation of the future heating tariff for consumers of EcoGenie 2.0 in Paddepoel-Noord. The current natural gas costs result in a heat tariff of € 25.90/GJ (excl. VAT). However, because EcoGenie 2.0 aims to reduce the costs by at least 10%, the heating tariff is set at € 23.31/GJ (excl. VAT). The maximum heat tariff is calculated at € 29.81/GJ (excl. VAT), which means that it is legally permitted to charge € 23.31/GJ. An extensive calculation and description is included in appendix 4.

6.2 Future energy scenario with EcoGenie 2.0 in Paddepoel-Noord

EcoGenie 2.0 is the successor of EcoGenie 1.0. EcoGenie 1.0 aimed to understand how low-carbon technologies such as solar PV and heat pumps work together. Shell installed state-of-the-art technologies in a 1930s house in The Hague. The house functioned as a living lab. The aim of the pilot was to "*learn how homeowners can make the biggest cuts in their carbon dioxide emissions at the lowest cost*" (Shell, 2015). Although the pilot has successfully reduced GHG emissions by more than 50%, two restrictions have also been identified. The first restriction is that large-scale changes at the individual level (e.g. a house) require significant investment costs, especially in an existing built environment. The second restriction was the lack of space for additional heating appliances (or for energy storage installations). The typical Dutch house is too small and has no basement to install the low-carbon technology.

Therefore, with the EcoGenie 2.0 pilot Shell aims to "*develop and test "last mile" smart heat and power solutions and customer value propositions*". Although Shell initially started the EcoGenie 2.0 pilot, it will be carried out in close collaboration with Grunneger Power and Stichting Paddepoel Energiek. In addition, Shell will finance the development costs. EcoGenie 2.0 will consist of an industrial GSHP, an industrial electric boiler, and an oil-fired boiler (as hybrid back-up) to supply heat for circa 100-200 households. This system can store both electricity and heat. The EcoGenie 2.0 pilot aims to reduce GHG emissions by at least 50% and supply heat 10-20% cheaper. In order to be successful, it needs to increase comfort, reduce GHG emissions by at least 50%, and supply heat 10-20% cheaper based on the current situation in Paddepoel-Noord. Figure 26 shows the concept of EcoGenie 2.0. Important to note is that hydrogen and EV charging will not be realised in the beginning. However, this can be considered as important features in the future.

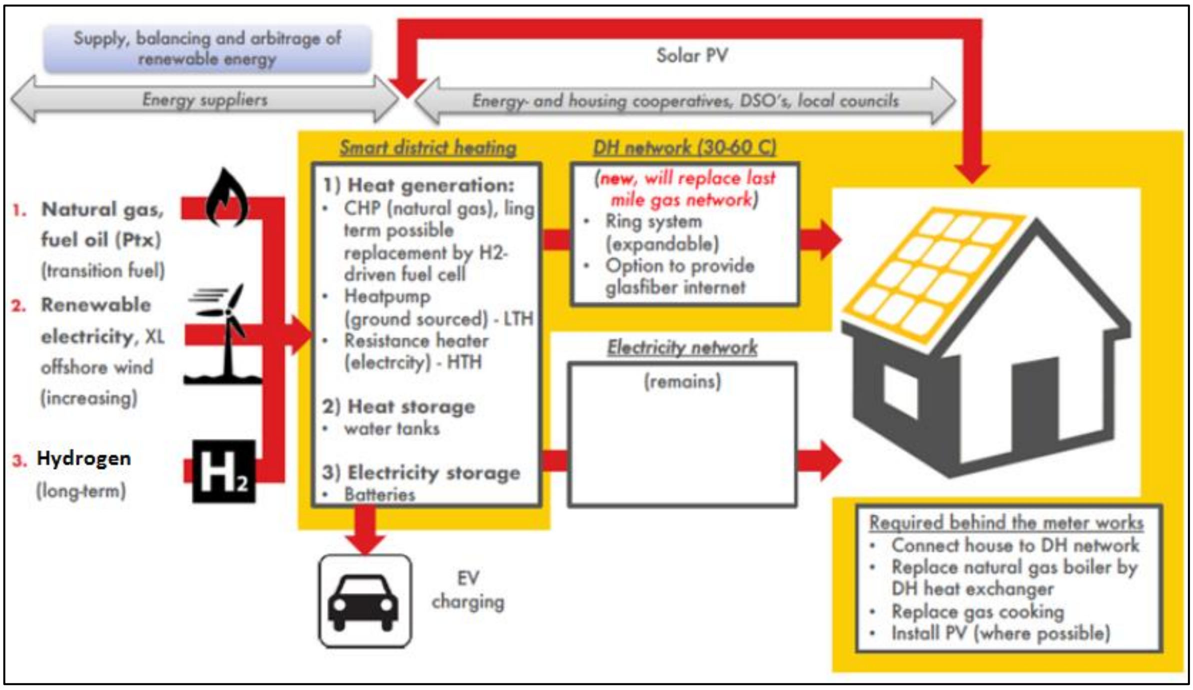

Figure 26. EcoGenie 2.0 pilot overview (Breithaupt, 2018).

6.2.1 Costs EcoGenie 2.0

Appendix 4 includes three operating budgets. These operating budgets are based on the main technical, economic, and legal/organisational aspects derived from this study. The investment costs of EcoGenie 2.0 are calculated at € 13,500/household. The first operating budget is based on the current heat tariff in Paddepoel-Noord minus 10%, because EcoGenie 2.0 aims to supply heat at least 10-20% cheaper. The heat tariff (-10%) is € 23.31/GJ (excl. VAT). This results in a payback time of 31 years and an ROIC of 1.85%. The second operating budget is based on the maximum heat tariff, set by ACM. The maximum heat tariff is € 25.05/GJ (excl. VAT). This results in a payback time of 31 years and an ROIC of 2.00%. The third operating budget includes a subsidy of € 5,000/household. This leads to a payback time of 25 years and a ROIC of 4.58%. Extensive calculations and descriptions are included in appendix 4.

6.2.2 CO_2 emissions EcoGenie 2.0

Figure 27 shows a comparison of the CO_2 emissions in the current situation in Paddepoel-Noord and the desired EcoGenie 2.0 situation. The associated CO_2 emissions of natural gas consumption is calculated at 3,399 kg/household. If EcoGenie 2.0 operates on fossil electricity, CO_2 emissions increase to 3,405 kg/household (100.2%). If EcoGenie 2.0 operates on renewable electricity (e.g. offshore wind energy), CO_2 emissions decrease to 755 kg/household (22.2%). The remaining CO_2 emissions is caused by the secondary installation (oil-fired boiler). An extensive calculation and description is included in appendix 4.

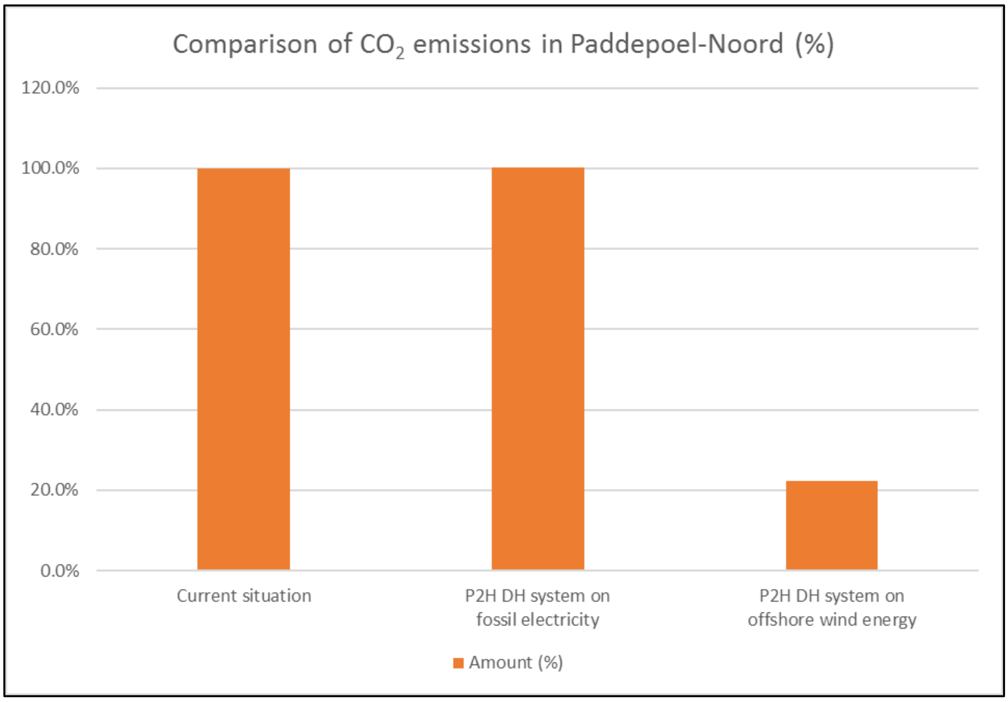

Figure 27. Calculated CO_2 emissions of EcoGenie 2.0 in Paddepoel-Noord.

6.3 Conclusion

Paddepoel-Noord can be viewed as an energetic community. Residents have been working on saving energy and generating their own (renewable) electricity since 2012. The next step is to become natural gas free. Their efforts are recognised by the local and regional governments. Both governments also have ambitious goals themselves and want to be precursors in the Dutch energy transition. It can be predicted with caution that Paddepoel-Noord will be one of the first existing neighbourhoods in the Netherlands to become natural gas free. In addition to these conclusions, the current energy consumption, associated costs, and CO_2 emissions have been calculated. Based on these findings, two operating budgets have been drawn up, and with all this information, the fifth sub-question can be answered. The fifth sub-question is: '*Does EcoGenie 2.0 reduce CO_2 emissions by at least 50% and supply heat 10-20% cheaper, based on the current situation in Paddepoel-Noord?*'

It has been calculated that if EcoGenie 2.0 converts renewable power into heat, it reduces the (direct) CO_2 emissions by 77.8% compared to the current situation. However, if EcoGenie 2.0 converts fossil power into heat, it increases the (direct) CO_2 emissions by 100.2%. Yet EcoGenie 2.0 supplies heat without natural gas, thus EcoGenie 2.0 can be considered as (more) sustainable, even without the input of renewable energy because it is more future-proof. The investment costs of EcoGenie 2.0 are calculated at € 13,500/household. This results in a payback period of 31 years and an ROIC of 1.85-3.79% (depending on the heat tariffs). A subsidy of € 5,000/household leads to a payback time of 24 years and an ROIC of 4.58%.

7 Conclusion and discussion

Above all, it must be clear that the concept of local P2H DH cooperatives is very interesting and that it can contribute to the transition to a sustainable heat supply, especially in the existing built environment. The application of P2H technology at the individual level has three major obstacles: (1) insufficient capacity of the low-voltage grid, (2) high investment costs as a result of high insulation, and (3) lack of space in existing houses. By using P2H technology (industrial heat pumps and electric boilers) at district level, these obstacles can be avoided. Furthermore, collective P2H is a proven technology, it is capable of energy storage, it contributes to CO_2 emissions reduction, and it integrates the electricity and heat markets (Yilmaz et al., 2018). In addition, many scholars (e.g. Bloess et al., 2018; Koirala et al., 2016 and Yilmaz et al., 2018) point to the increasing role of electricity in the heating sector. Also, policies such as the European Roadmap (ECF, 2010) and the Dutch Energy Agenda (EZK, 2010) predict that electricity and DH systems will play an important role in establishing a sustainable heat supply.

The liberalisation of the Dutch energy system (electricity and natural gas) has contributed to a significant overcapacity of installed capacity for electricity generation (IEA, 2014). Moreover, an increase of renewables results in a decrease of the electricity price and an increase in price volatility at the wholesale market. This is usually called the merit order effect or the renewable energy paradox (e.g. Cludius et al., 2014; Winkler et al., 2016 and Blazquez et al., 2018). According to many scholars (e.g. Bloess et al., 2018; Koirala et al., 2016 and Yilmaz et al., 2018), the merit order effect is highly beneficial to the application of P2H technology.

As far as is known, Thermo Bello in Culemborg is the only P2H DH cooperative in the Netherlands. In addition to Thermo Bello, the energy company Mijnwater in Heerlen also uses a P2H DH system. Other countries only provide examples concerning the application of electric boilers as add-ons to fossil-fuelled boilers, which illustrates the uniqueness of P2H DH cooperatives. In addition to the conclusions above, the main technical, economic, social, and legal aspects of the establishment of local P2H DH cooperatives have been investigated. Based on a scientific literature review, case studies, and expert interviews, the main research question can be answered. The main research question is: '*What are the main technical, economic, social, and legal aspects of establishing a local Power-to-Heat (P2H) district heating cooperative in an existing residential area, particularly in the Netherlands?'*

The framework in paragraph 5.3 summarises the main (theoretical and empirical) aspects. In addition to the four overarching aspects mentioned by Yilmaz et al. (2018), organisation/governance has also been identified as an overarching aspect. The case studies and expert interviews generally confirmed the theoretical aspects and even added several aspects. Technically, an individual booster heat pump enables a variable heating curve that significantly reduces the supply temperature for space heating. Economically, a P2H DH cooperative generally has a high Capex and a low Opex (Bennink & Benner, 2009). However, issuing depositary receipts and a cooperative governance structure can lead to circular benefits: local profits remain local and can be invested locally. Socially, it is concluded that DH does not only go 'behind the front door' but also 'behind the garden gate'. This is especially important to realise in order to win trust of the consumers. The case studies highlighted three measures to increase trust: (1) empathy, (2) visibility and presence and (3) local influencers/ambassadors. In addition, a local (P2H) DH cooperative can protect and assist vulnerable people because it usually knows its customers more personally. Legally, the Heat Act (for consumers with a connection up to 100 kWt) is the most important legislation that applies to heat supply in the Netherlands.

The case studies and calculations for EcoGenie 2.0 pilot showed the importance of renewables to reduce CO_2 emissions. If EcoGenie 2.0 converts renewable power into heat, it reduces the (direct) CO_2 emissions by 77.8% compared to the current situation. However, if EcoGenie 2.0 converts fossil power into heat, it increases the (direct) CO_2 emissions by 100.2%. Nevertheless, P2H DH systems supply heat without natural gas. Therefore, P2H DH systems can be considered as (more) sustainable, even without the input or renewable energy because it is more future-proof. The investment costs of EcoGenie 2.0 are estimated at € 13,750/household. This results in a payback time of 31 years and an ROIC of 1.85-2.00% (depending on the heat tariffs). A subsidy of € 5,000/household leads to a payback time of 24 years and an ROIC of 4.58%.

The aspects (summarised in paragraph 5.3) are in principle focused on the Dutch context. In addition, four of the five investigated case studies and the EcoGenie 2.0 pilot have a Dutch real-world context. The aspects (except from the Heat Act) can be applied in other countries as well, preferably Western European countries because its real-world context is fairly similar (Yilmaz et al., 2018).

7.1 Discussion

The main research question was based on the four overarching aspects mentioned by Yilmaz et al. (2018). However, the (empirical) case studies and expert interviews have identified organisation/governance as another overarching aspect. Although this is a good research result, it also means that organisation/governance is not included in the scientific literature review.

Initially, three comparable case studies would be carried out on local P2H DH cooperatives. However, it turned out that only Thermo Bello in Culemborg met this criterion. Therefore, Mijnwater was used as the second case study on local P2H DH systems, while TexelEnergie was used as the second case study on local DH cooperatives. Two other case studies were added to deepen the social aspect. Nevertheless, all cases were different and had a different real-world context. Because of these differences, it was difficult to combine the case studies and to analyse the similarities and differences, as was the initial plan.

The case studies (and indirectly the expert interviews) validated and confirmed most of the (theoretical) aspects that were derived from the literature. In addition, several new aspects came to light. However, this validation and confirmation and these new aspects must be handled with care. For example, the aspect of trust was not only emphatically emphasised in literature, but also in every case study. In other words, all cases confirm the literature. Most aspects (e.g. simultaneity factor and distribution loss) were only confirmed once or twice in the case studies. This implies that the conclusions of this research, although very interesting as an exploration, cannot be used to back up far-reaching conclusions.

The technical, economic, and legal aspects that were necessary to develop a business case have been applied to the EcoGenie 2.0 pilot. However, it was too early to apply the social aspects at this time. That is why the focus was on costs and CO_2 emissions.

7.2 Recommendations further research

It is worth mentioning that this study was an exploration of the main technical, economic, social, and legal aspects of local P2H DH cooperatives. This implies that many of the aspects mentioned in this thesis can be studied more thoroughly, especially organisation/governance. More case studies and expert interviews could lead to a better understanding and could bring new aspects to light. In particular, it is recommended to conduct interviews with technical experts who have experience with the engineering of (P2H) DH systems. For example, it is not clear whether a (P2H) DH system should be dimensioned at an average effective temperature of minus 17 °C or minus 10 °C. Finally, it is recommended to compare the differences in investment costs, operational costs, and CO_2 emissions between generating hot tap water at a district level (the current situation) and at an individual level (booster heat pump).

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Appendix 1

The Dutch energy chain

Contents

1 Introduction

This appendix describes, as part of the literature review, the (current) Dutch energy chain to position the role of local (P2H) DH cooperatives in the (future) energy chain. The focus is on the electricity supply chain and the natural gas supply chain because these chains are the most relevant for the existing built environment. The oil chain, which is in particular relevant for the mobility sector, is not discussed. However, it is important to note that the oil prices influence natural gas prices.

The second chapter describes the electricity supply chain and the third chapter the natural gas supply chain. These chapters also include the carbon intensity of natural gas and electricity. In the fourth chapter is about wholesale markets and the predicted price developments of the Dutch energy markets. An important aspect is the merit order and the merit order effect. The fifth chapter is about the network and distribution operators and their cost tariffs. The sixth chapter elaborates on the retail markets and the Dutch energy tax. Finally, chapter 7 summarises both the electricity and natural gas chain. In addition, it contains various aspects that are relevant for the establishment of a local P2H DH cooperative.

2 The supply chain of electricity

The supply chain of electricity consists of different players, each with their own responsibility. Today, six independent parties can be distinguished: (1) generation, (2). Trading, (3) transmission, (4) distribution, (5) metering and (6) supply, as illustrated is figure 1.

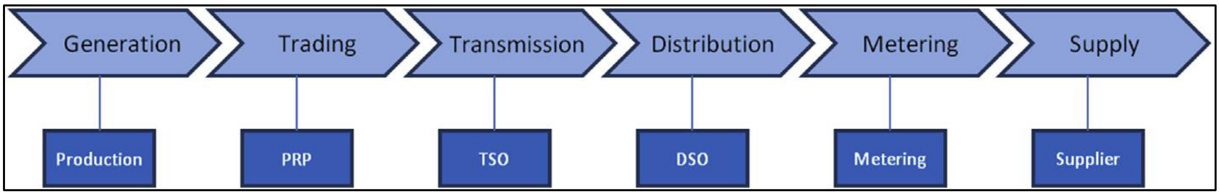


Figure 1. Electricity supply chain (Tanrisever et al. 2013, p.248).

However, the real supply chain is, especially due to the liberalisation, much more complicated. Figure 2 shows the Dutch liberalised electricity market. It differentiates competitive markets and regulated monopolies as well as wholesale markets and retail markets.

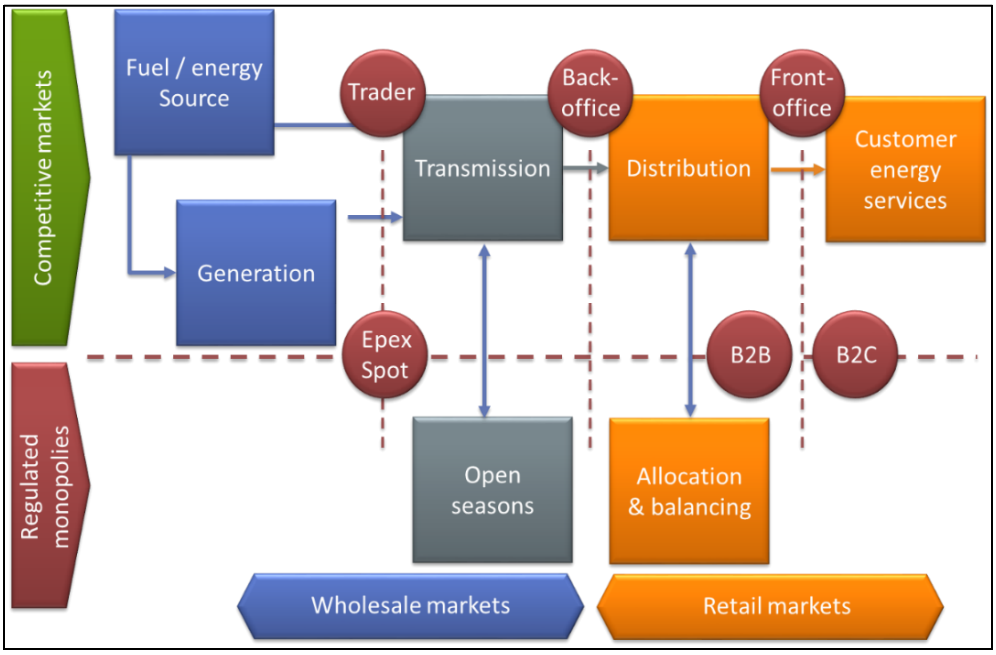


Figure 2. The Dutch liberalised electricity market (adapted from Breithaupt, 2011).

2.1 Electricity generation

Today, electricity is generated from fossil fuels (mainly coal and natural gas) and renewables (biomass, wind energy and solar PV). Electricity is produced by large centralised power plants (e.g. gas turbines) as well as small decentralised power installations (e.g. solar fields). As can be derived from the history, originally only a few centralised parties were responsible for the generation of electricity, but nowadays it becomes an interplay of centralised and decentralised parties. A distinction can be made between installed capacity (how much can be produced) and generated electricity (how much is actually produced). Current market conditions have led to significant overcapacity (IEA, 2014). Figure 3 shows the current installed capacity and plots the forecasted installed capacity till 2035.

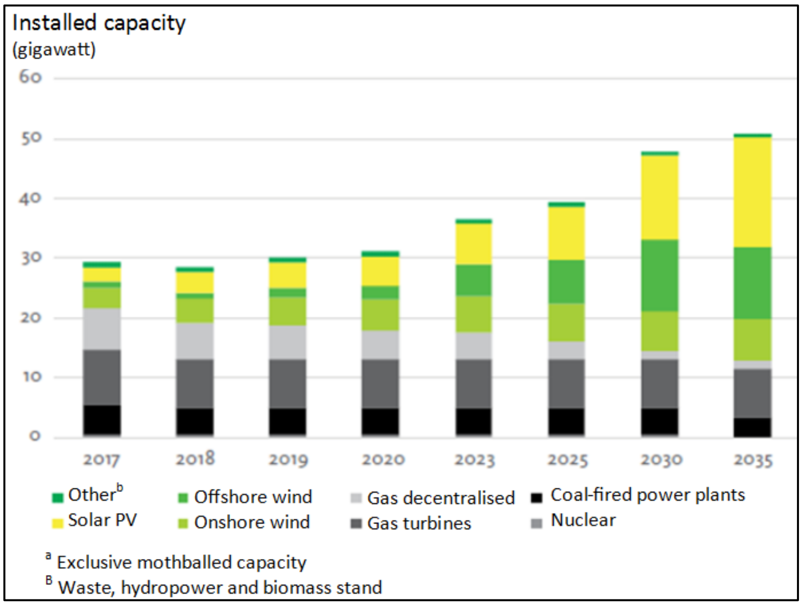


Figure 3. Installed capacity 2017-2035 (based on Schoots et al. 2017, p.119).

The energy sources are: coal, natural gas (centralised and decentralised), nuclear, offshore wind, onshore wind, solar PV and miscellaneous sources (e.g. waste incineration, biomass and stand-alone). The installed capacity will continue to grow, mainly due to increasing capacities of wind energy and solar PV. In contrast, the installed capacity of coal and natural gas will decrease. In fact, the installed capacity is even higher because some companies have so-called mothballed capacity (in Dutch: *gemottebalde capaciteit*). For example, a power station disconnects (partly) their production capacity because it is not economic viable at the moment but still maintains their capacity to reconnect it in better times.

Figure 4 shows the actual electricity production and the forecasted electricity production till 2035. In 2016 was the total electricity production 115 TWh which is significantly higher compared to 2017. This can be explained by the closing of the last two coal-fired power plants from the 1980s (Maasvlakte I and II) on 1 July 2017 (Schoots et al., 2017). The total electricity demand of the Netherlands is relatively stable in recent years, namely 120 TWh per year.

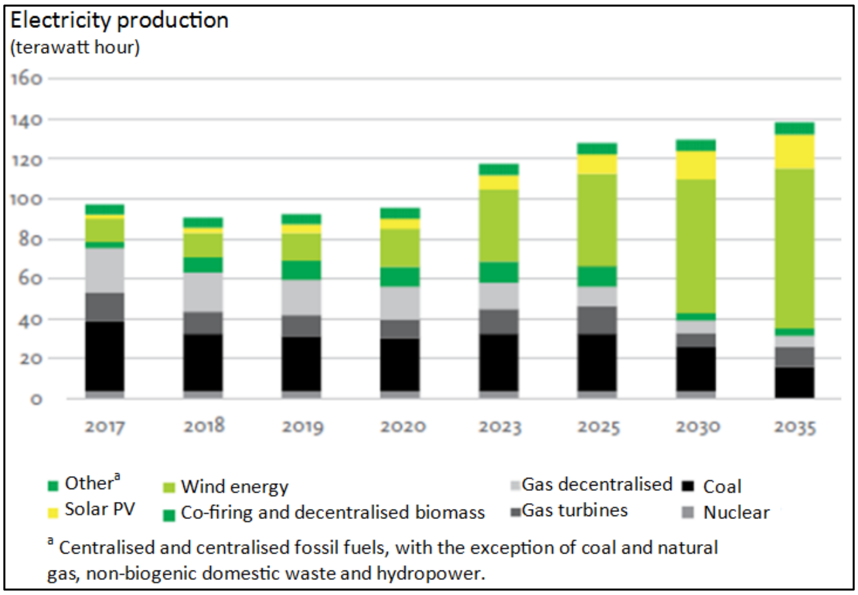


Figure 4. Electricity production 2017-2035 (based on Schoots et al. 2017, p.121).

The installed capacity of 2016 was 33 GW, which can theoretically produce 289,080 GWh/per year. The electricity production of 2016 was 115,000 GWh and the electricity consumption was 120,000 GWh. The net import capacity was 5,000 GWh. The overcapacity is determined by dividing the installed capacity by the electricity production, the overcapacity was 2.5 in 2016. The installed capacity will be 51 GW, which is 446,760 GWh in 2035. The electricity production will be 139,000 GWh in 2035. Interesting to note is that the capacity of solar PV will significantly increase, yet wind energy will become the main producer of electricity. The forecasted overcapacity will be 3.2 in 2035.

The electricity network of the Netherlands is connected with the following surrounding countries: Belgium, Denmark, Germany, Norway, and the United Kingdom. Figure 5 shows the physical electricity flows from and to the Netherlands. Germany is a main country of electricity import and Belgium the main country of export of electricity. As the figure shows, it is predicted that the role of the Netherlands will change from a net importer to a net exporter.

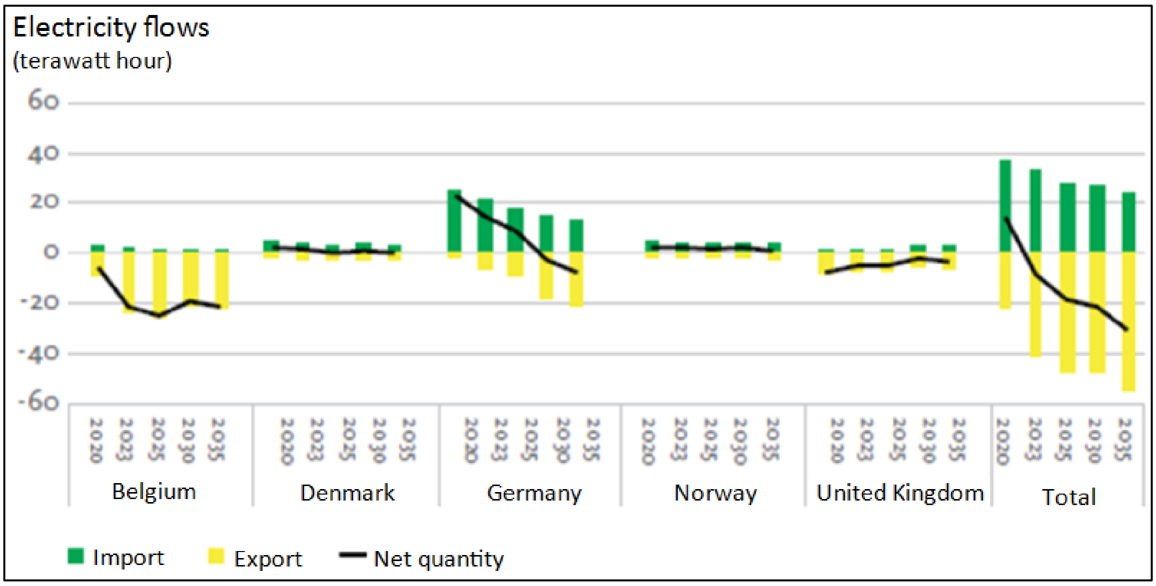


Figure 5. Physical electricity flows from and to the Netherlands 2020-2035 (based on Schoots et al. 2017, p.21).

2.2 Carbon intensity of electricity

The carbon intensity is a measure of the amount of CO_2 emissions that is released into the atmosphere for every unit of electricity produced (Beggs, 2009). The amount of CO_2 emissions depends on the fuel type and the efficiency of the plant. Table 1 shows the typical CO_2 emissions for three different fuel types. It reveals that the CO_2 emissions of a typical Combined Cycle Gas Turbine (CCGT) compared to a typical coal-fired power station is 2.4 times lower. The average CO_2 emissions of (grey) electricity is 0.65 kg CO_2 emissions/kWh in The Netherlands, based on the current fossil fuel mix in the energy production (Klimaatplein, 2018). However, this does not consider renewable energy sources. Ang & Su (2016) investigated the aggregate carbon intensity (ACI) for electricity at the global and country levels. The ACI is determined by four factors: (1) the proportion of electricity produced from fossil fuels, (2) the fossil fuel mix in the electricity production, (3) the thermal efficiency of electricity generation by fossil fuel type and (4) the carbon emissions factors for fossil fuels. In 2013, was the Dutch ACI 0.44 kg CO_2 emissions/kWh whereas is was 0.58 CO_2 emissions/kWh in 1990 (Ang & Su, 2016).

Table 1.CO_2 emissions per kWh of delivered electrical energy (Beggs 2009, p.18).

Primary fuel	Kilograms of CO_2 emissions per GJ of primary energy	Average gross efficiency of power plants (%)	Kilograms of CO_2 emissions per GJ of delivered electrical energy	Kilograms of CO_2 emissions per kWh of delivered electrical energy
Coal	90.7	35	259.1	0.93
Oil	69.3	32	216.6	0.78
Gas (CCGT)	49.5	46	107.6	0.39

Nuclear power plants emit almost no CO_2 emissions, but nuclear power plants unfortunately have the side-effect of radioactive waste. Renewables (e.g. wind energy, solar PV and hydropower) do not have direct CO_2 emissions (during the usage phase) but still have indirect CO_2 emissions (during the installation and decomposition phase). Pehnt (2006) investigated the indirect CO_2 emissions of different renewable technologies and compared it to conventional systems through a Life Cycle Analysis (LCA). It concluded that the indirect environmental impact of renewables is still very low compared to conventional systems.

3 The supply chain of natural gas

The supply chain of natural gas and of electricity has much in common, however, the big difference is that natural gas is extracted, and electricity is generated. Figure 6 shows an example of a typical supply chain of natural gas which is extracted on an offshore platform.

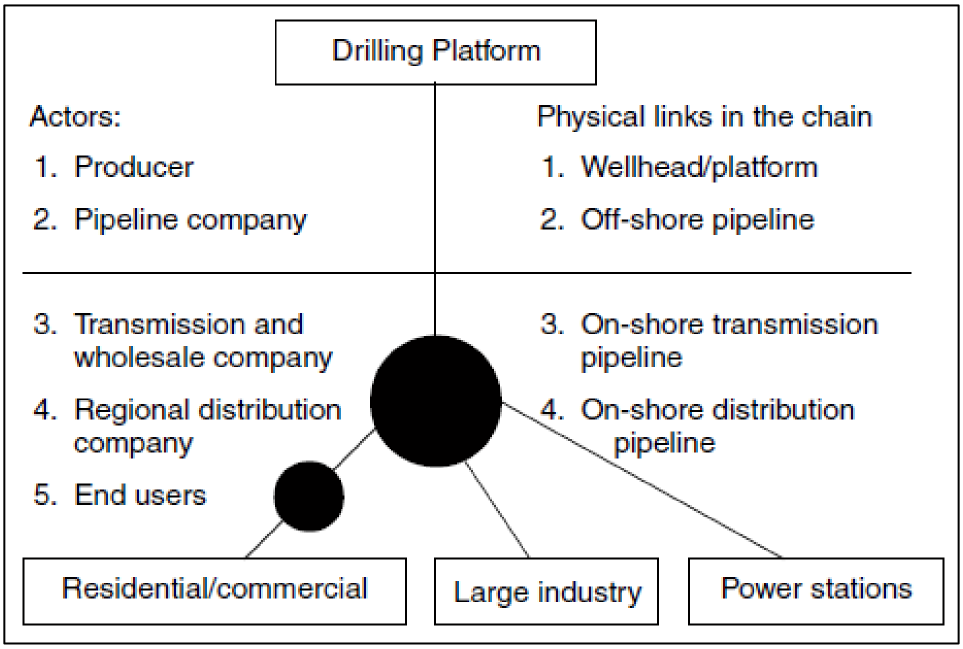


Figure 6. Gas supply chain (Beggs 2010, p.43).

The supply chain of natural gas consists of eight steps: (1) exploration and production, (2) transmission and processing, (3) storage, (4) trading, (5) transportation, (6) distribution, (7) metering and (8) supply. Figure 7 shows the supply chain of Gasunie from upstream till downstream.

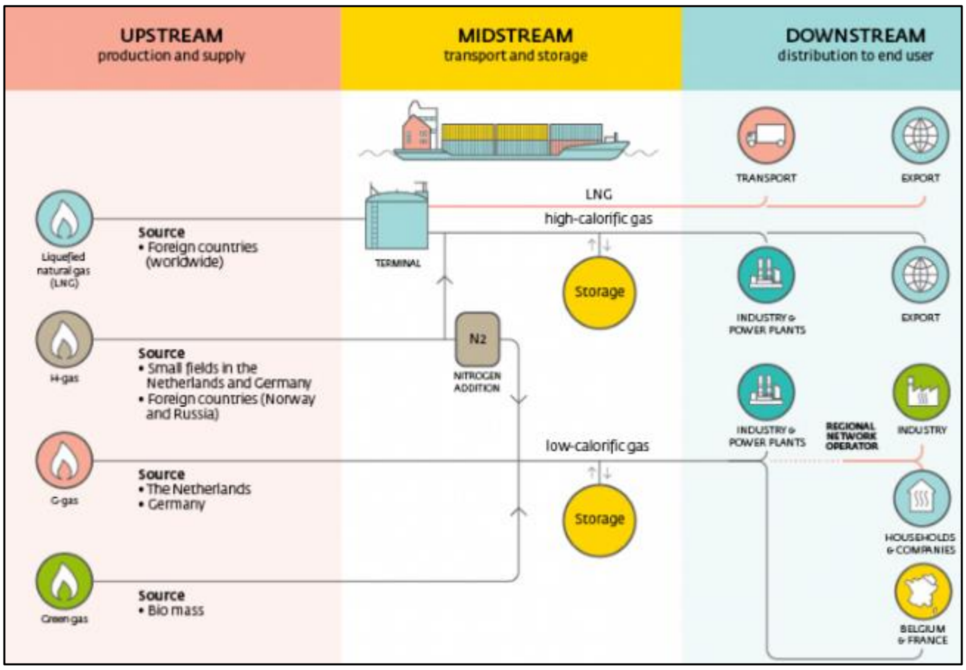


Figure 7. Supply chain Gasunie (Gasunie 2016, p.19).

Upstream, natural gas is extracted at onshore and offshore production facilities. Furthermore, two main types of natural gas can be distinguished: high calorific (H-gas) gas and low calorific gas (L-gas or G-gas). L-gas is extracted from the wells in Groningen while H-gas is mostly imported from foreign countries. The difference is the hydrocarbon and nitrogen content. Another emerging type of gas is green gas produced, for example, by digesters.

Midstream, extracted natural gas is processed. Extracted natural gas is almost always mixed with impurities such as water, acid gases, nitrogen and helium. These impurities cause corrosion in the transmission and distribution lines, therefore, these impurities need to be removed. This process usually takes place at onshore gas treatment facilities. Due to the difference in hydrocarbon and nitrogen content, blending stations are required to mix the various different gases into a blend whose calorific value is within the tolerance of the end users' appliances (Beggs, 2010). Nowadays, most of the appliances (in Dutch households) can only run on L-gas and cannot burn a gas with a different calorific value. Natural gas is transported by pipelines or it is liquified (LNG) and transported by ship or tanker. Compared to electricity, it is much more common to store natural gas. The Netherlands has six underground storage facilities, for example in empty gas fields or in salt caverns. Storage is needed for peak shaving during cold weather events but also allows trading in gas.

Downstream, the natural gas is transported to the final consumer. H-gas is used in industries, power plans or exported. L-gas is used in households and commercial buildings as well as industries, power plants or exported to surrounding countries.

3.1 Natural gas extraction and production

Figure 8 shows the previous and predicted gas production and demand of the Netherlands from 2000 to 2035. It shows that the onshore L-gas fields of Groningen contribute significant as well as the offshore H-gas fields at the North Sea. Other small-scale onshore gas fields contribute only a small part of the final consumption.

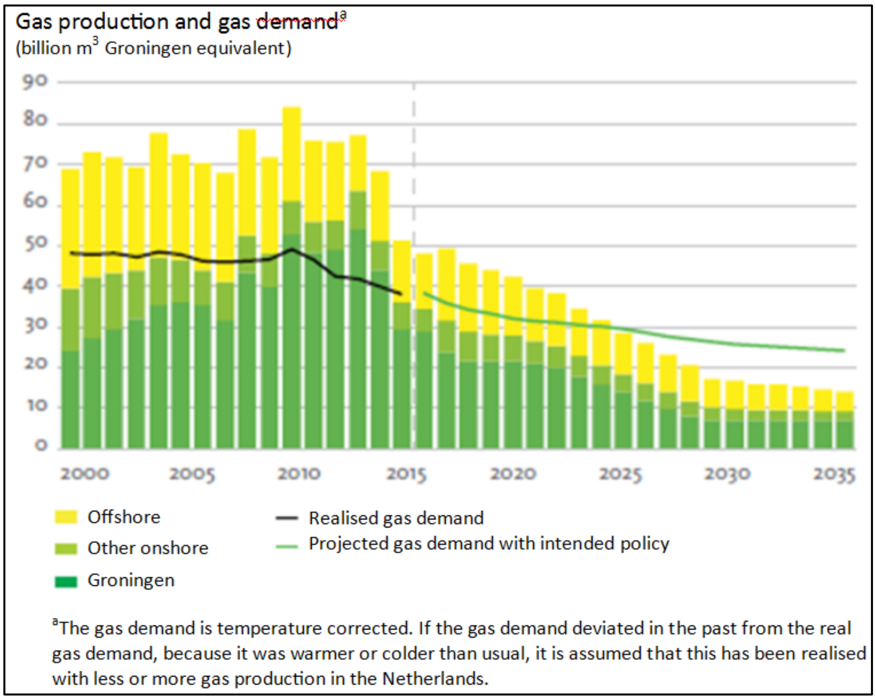


Figure 8. Natural gas production and demand of the Netherlands 2000-2035 (based on Schoots et al. 2017, p.129).

On 29 March 2018, however, the national government decided that L-gas production in Groningen should be terminated as quickly as possible because the natural gas extraction causes earthquakes in the local environment (EZK, 2018). This measure was taken on the basis on the advice of the State supervision of the Mines (in Dutch: *Staatstoezicht op de Mijnen, SodM).* Their advice was to reduce the natural gas extraction at least to twelve billion Nm^3, however the national government decided to completely terminate the natural gas extraction in 2030. Figure 9 shows the intended pathway of the completion of L-gas extraction and production in Groningen. The reduction of natural gas production depends on the weather conditions: cold winters automatically lead to more natural gas extraction and vice versa.

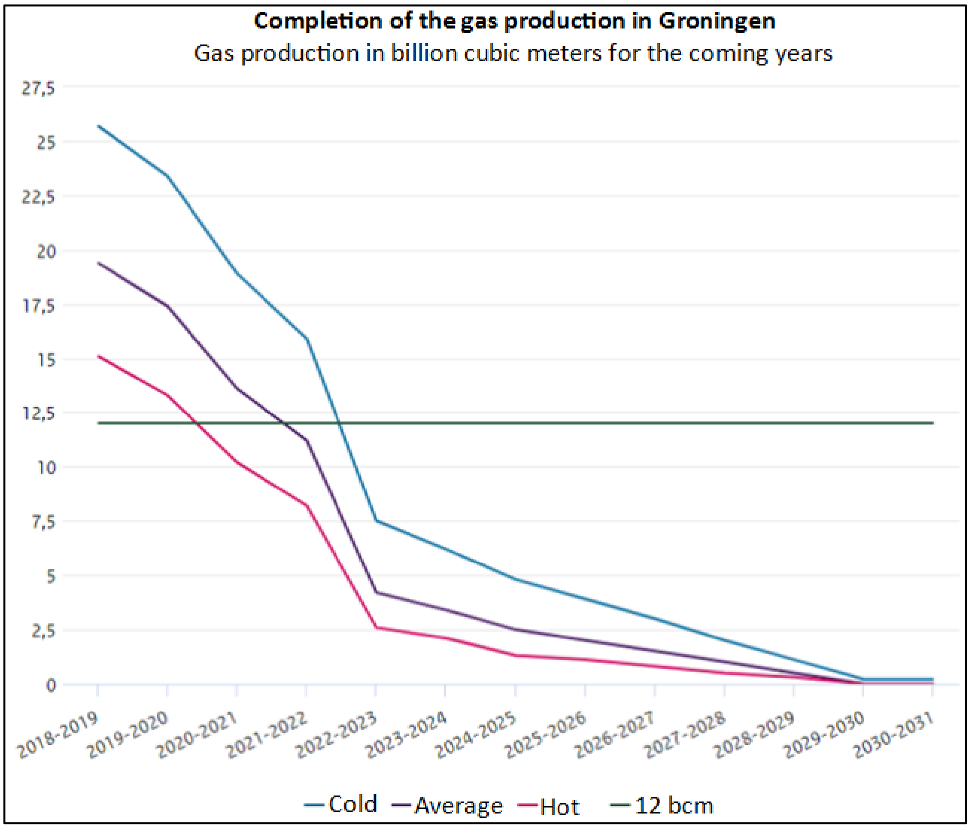


Figure 9. Completion of L-gas extraction in Groningen (based on Rijksoverheid, 2018a).

The reduction and termination of the extraction and production of L-gas will have a major impact on the heat supply for households. A short-term measure is to expand existing nitrogen plants to increase the capacity of converting H-gas into L-gas, which also means that the Netherlands are going to be a net importer instead of natural gas (Rijksoverheid, 2018b). Another short-term measure is to disconnect large industrial consumers of the L-gas network within four years. The biggest challenge, however, is the long-term heat supply. Almost all new houses and new residential areas are being built without a natural gas connection anymore, using heat pumps/electricity to generate their own. This should result in 30,000-50,000 households without natural gas in 2021, which is about 0.4-0.7% of the total households. After 2021, 200,000 (2.9%) households must be disconnected of the natural gas network every year. Existing DH systems must be connected to sustainable sources (e.g. residual heat of industries). In addition, new DH systems can provide an alternative heat supply when households are disconnected from the natural gas network (EZK, 2018).

3.2 Energy content and carbon intensity of natural gas

The energy content or calorific value of natural gas is expressed in MJ/ Nm^3. The calorific value indicates how quickly a fuel can heat a kilo of water at atmospheric pressure from 14.5 to 15.5 ^0C. The energy content of L-gas (from Groningen) has an upper value of 35.17 MJ/Nm^3 and an under value of 31.65 MJ/Nm^3 (ECN,2016). The under value represents the calorific value without the heat of condensation of water vapour while the upper value includes the heat of condensation of water vapour.

The Wobbe index is the ratio between the calorific upper value divided by a square root of the relative density, expressed in MJ/Nm^3 (Regeling gaskwaliteit, article 1, 2014). It is a measure for the interchangeability of gases with a different composition for specific appliances. In other words, it can be used to compare the combustion energy output of different compositions of combustion gases and its thermal capacity (GTS, 2018).

To convert Nm^3 to kWh, the energy content in MJ needs to be divided by 3.6 MJ (60 minutes times 60 seconds). Therefore, the heat content of 1 Nm^3 L-gas is 9.77 kWh. According to an official calculation of the Gasunie is the CO_2 emissions of burning gas 1.681 kg/Nm^3. With an overall efficiency of 85-90%, the average CO_2 emissions is 1.89 kg/Nm^3 (Klimaatplein, 2018).

Approximately 93% of Dutch households have an individual gas-fired boiler for space heating and hot tap water. It is important to note that the boiler also uses electricity, mainly to pump the water through the system. Schepers & Scholten (2016) calculated the electricity use for a reference boiler, the so-called HR107-ketel. This boiler uses around 0.28 kWh/Nm^3, which means an additional 0.124 kg/Nm^3 CO_2 emissions. This means that the total direct CO_2 emissions of an HR107 boiler is 2.01 kg/Nm^3.

4 Wholesale markets

The Dutch energy market is, as a result of the introduction of the 1998 Electricity Act, one of the most liberalised in the world (Tanrisever et al., 2013). Parties can trade freely at the Dutch electricity market. Figure 10 shows a horizontally integrated electricity supply chain. The competing generators trade on the wholesale markets and the competing suppliers on the retail markets (figure 14).

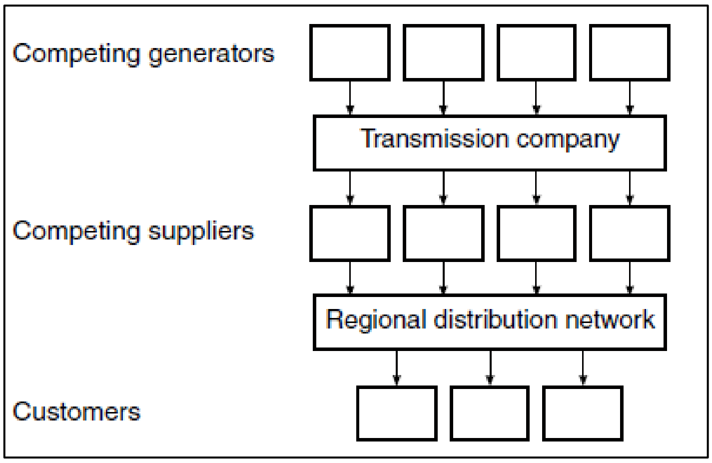


Figure 10. A horizontally integrated electricity supply chain (Beggs 2009, p.52).

In the past, the Netherland had two wholesale markets for electricity, namely the European Energy Derivates Exchange (ENDEX) and the Amsterdam Power Exchange (APX). Futures were traded on the Endex market, which are long-term contracts. The APX was the spot market, were parties could sell electricity 24 hours before delivery. The APX consists of two separate markets: The Day-Ahead Market (DAM) and the Intra-day market (IDM) (Tanrisever et al., 2015). The DAM is the larger of the two, agreements are made between generator and supplier to deliver the physical electricity for every 24 hours the next day. The DAM opens at midnight and closes at 12.00 p.m. the day before delivery. The DAM is a two-sided double-blind auction: the participants can make bids and offers for the delivery of electricity anonymously.

However, incidents may take place between the closing of the DAM and the next day. For example, a coal-fired power station stops operating or a wind farm generates more electricity due to strong winds. Therefore, generators and suppliers can trade at the IDM up to five minutes before the physical delivery of electricity to bring the market back in balance. But it is important to realise that the prices at the IDM are generally higher than at the DAM. Since 2015 are Endex and APX merged in order to become a big player in Western Europe and Great Britain, their new name is Epex Spot (Energeia, 2015).

The operation of the wholesale markets for natural gas is comparable to the wholesale markets for electricity. Since the beginning of the discovery of natural gas, Gasunie was not only the TSO but the trader as well. This has changed since 2005 as a result of liberalisation. Gasunie became a 100% state-owned company and became responsible for transport and storage. GasTerra, a new company, became responsible for trade in natural gas. GasTerra is owned by three shareholders, namely Shell (25%), ExxonMobil (25%) and the Dutch state (50%). Pegas Trading is the central platform of the European Energy Exchange Group (EEX), operated by Powernext. At this single platform, traders of Austria, Belgium, Denmark, the Netherlands, Germany, Italy and the UK can trade in natural gas (EEX, n.d.).

4.1 The merit order and levelized costs of energy

The merit order is the ranking of all generation units from low to high marginal costs. Marginal costs are the flexible costs, for example fuel costs. On the other hand, there are fixed costs, for example wages and investment costs. The merit order is basically designed to bring together supply and demand for the lowest price as possible. Because demand of electricity changes over time, supply of electricity change over time as well. Supply follows demand otherwise there will be a shortage in the grid. In a conventional system, three different types of suppliers can be distinguished in order to provide: (1) the baseload, (2) the flexible load and (3) the peak load. The baseload is usually provided by nuclear power plants and coal-fired power plants because their marginal costs are relatively low. Important to realise is that these types of supplier cannot provide the flexible load because long start-up times. Therefore, the flexible load is usually provided by gas-fired power plants. The marginal costs of gas fired power plants are higher but it is profitable because higher demand leads to higher electricity prices. In case of a peak load, for example when air-conditioning systems are running at full speed during hot weather, usually oil-fired power plants start operating.

Lazard, a financial advisory and asset management firm, calculates the net present value of a unit-costs of electricity over the lifetime of a generating asset annually. This is called the levelized costs of energy (LCOE) which is the sum of costs over lifetime divided by the sum of electrical energy produced over lifetime. Figure 11 shows the most recent LCOE. It includes flexible costs and fixed costs but it does not include taxes and subsidies. The blue bars illustrate the price range in dollar per generated MWh electricity. Currently, Gas Combination Cycle Power Plants (GCC) are the cheapest conventional energy suppliers. Wind energy is currently the cheapest of all the renewables.

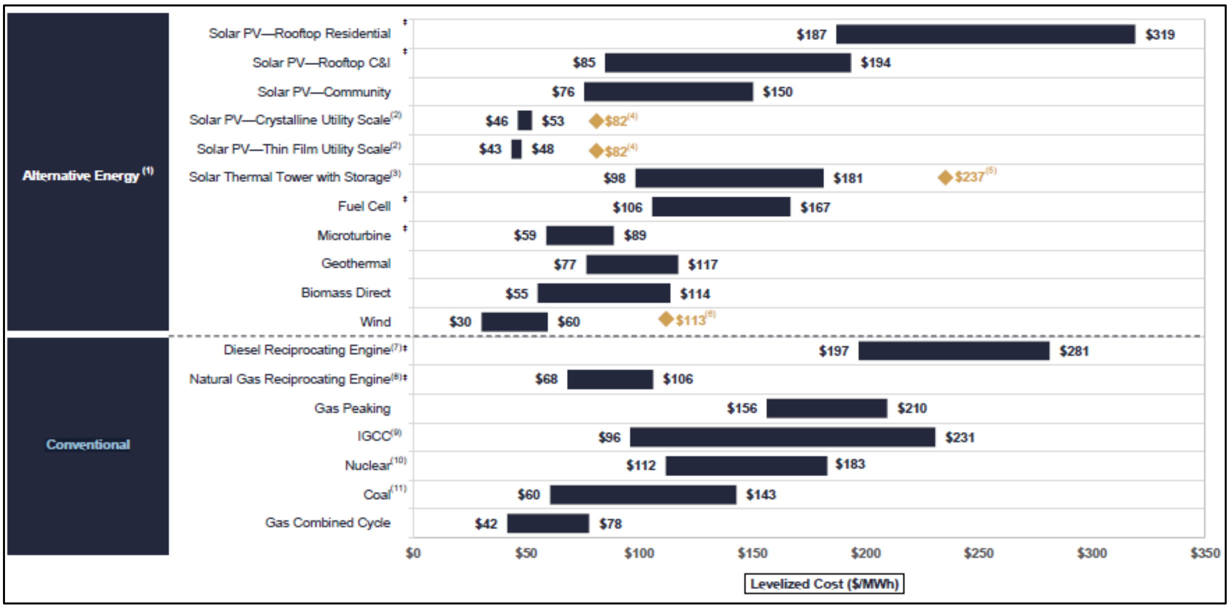


Figure 11. Levelized costs in $/MWh (Lazard 2017, p.2).

The LCOE is a tool to predict the merit order curve because it ranks different sources based on marginal costs. Figure 12 shows a typical merit order curve of the electricity market in Germany.

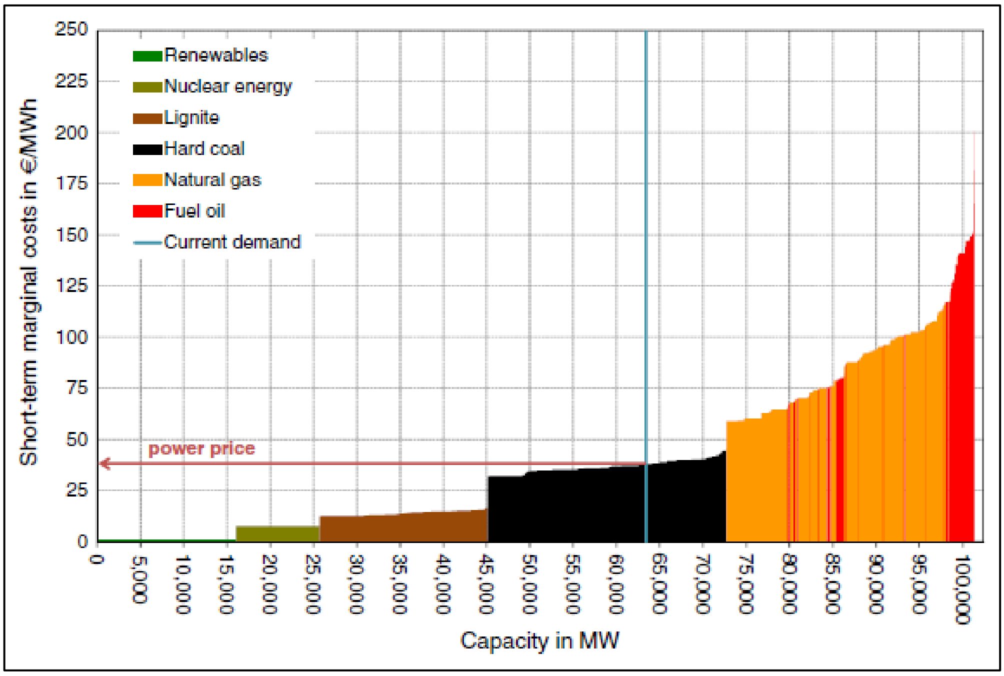


Figure 12. Merit order curve Germany (Cludius et al. 2014, p.303).

The various energy suppliers are ranked on the basis of marginal costs, low marginal costs on the left and high marginal costs on the right. The current demand is in this case 64,000 MWh, which means that the gas-fired power plant and oil-fired power plants do not have to operate to meet the demand. The merit order simply includes the cheapest suppliers that are needed to meet the demand and exclude all other suppliers. In case of the DAM, this means that each supplier first has to predict the electricity demand for the next day. Tanriserver et al. (2013) distinguish four main factors that influence the electricity demand: (1) calendar data, (2) meteorological data, (3) economic data and (4) demographic data. Figure 13 shows an explanation of these factors. Suppliers collect and combine as much data as possible to predict the electricity demand.

Factors influencing electricity demand.

Calendar data	Hour of the day, day of the week, holidays, bridge days, daylight saving time and school holidays.
Meteorological data	Temperature, humidity, cloud cover, luminosity, earth's position in the eclipse, sun's altitude, wind speed, solar radiation and climate change.
Economic data	GDP (gross domestic product), per capita GDP, consumer price index, average salary earnings, production plans of companies, electricity price and industrial expansion.
Demographic data	Number of households, population growth and local area development.

Figure 13. Factors influencing electricity demand (Tanrisever et al. 2013, p.249).

Subsequently, each supplier indicates at the auction the amount of electricity they are able to supply and at what price they willing to supply. The intersection of the demand and the supply curve determines the wholesale price and volume, called the cleaning price and the clearing volume. This means that all the suppliers will receive an (equal) clearing price for the electricity they will inject to the grid (Next Kraftwerke, n.d.). The merit order leads to strategic bidding. If a supplier offers (too) low, it runs the risk that its marginal costs are higher than its incomes and therefore has to take a loss. If a supplier offers (too) high, this could result in higher profits, but there is also the risk of being excluded from the merit order, which means that on that day there will be no income from the DAM. In practice, suppliers offer different quantities of electricity at various prices, which are ranked from cheapest to most expensive (Blazquez et al., 2018).

4.2 The merit order effect

As said previously, the merit order is the ranking of all generation units from low to high marginal costs. Therefore, renewables stand at the bottom (left) in the merit order because renewables have almost no marginal costs. When renewables are added to the generation mix, the merit order curve shifts to the right. This means that conventional plants with higher marginal costs are pushed out of the system when renewables are available. Moreover, an increase of renewables results in a decrease of the electricity price and an increase in price volatility at the wholesale market, usually called the merit order effect (e.g. Cludius et al., 2014; Winkler et al., 2016 and Blazquez et al., 2018). Figure 14 shows the effect of solar and wind energy on the feed-in tariffs on the EPEX Spot market in Germany.

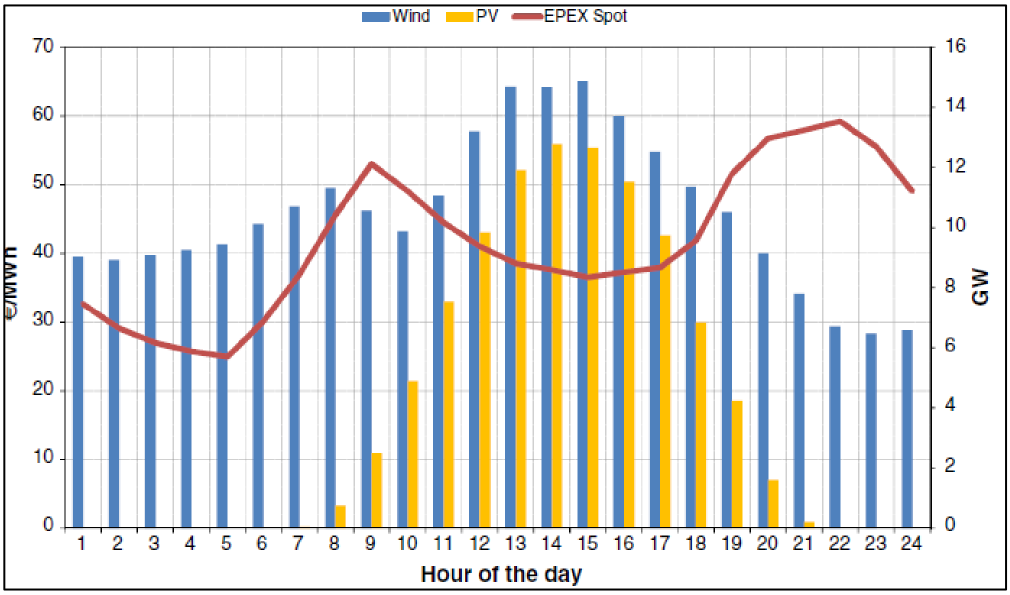


Figure 14. Wind and solar feed-in on 26-04-2012 (Cludius et al. 2014, p.303).

The German electricity market is suitable to illustrate the merit order effect because it is highly liberalised and it has a high penetration rate of renewables. In fact, already in 2017, 33% of the German electricity demand was supplied by renewables (Morris, 2018). Figure 18 shows that high availability of solar and wind energy results in lower feed-in tariffs and vice versa. Blazques et al. (2018) call the merit order effect the 'renewable energy paradox'. They say the following: "*promoting renewables – in liberalised power markets– creates a paradox in that successful penetration of renewables could fall victim to its own success"* (Blazquez et al. 2018, p.1).

This paradox results from the interaction between several factors, including:

1. The (almost) zero marginal costs of renewables.
2. The intermittent nature of renewables.
3. The interplay between price volatility and renewable technologies.

A liberalised market, on the other hand, is based on two assumptions: positive marginal costs and dispatchability of power, neither of these two assumptions is applicable to renewables. Ultimately, this paradox can even lead to negative electricity prices (e.g. Winkler et al., 2016 and Blazquez et al., 2018). This is not only theoretical, but it also happens in reality. Figure 15 shows the annual curve of the DAM in Germany between 2017 and 2018, the price fell five times below zero. Negative prices arise because baseload suppliers are willing to take a loss to keep their plants operational (Winkler et al., 2016). According to Cludius et al. (2014) was the average effect of wind energy and solar PV a reduction of the spot market price of € 0.8-2.3/MWh per additional GW installed capacity. In 2012, the average total effect of wind energy and solar PV on the feed-in tariff was between € 6-10/MWh. It is forecasted that these price effects will continue. The absence of dispatchable renewables or storage for conventional plants to make sudden adjustments in order to keep the system in balance. This in turn leads to sharp changes in the electricity prices (Blazquez et al., 2018).

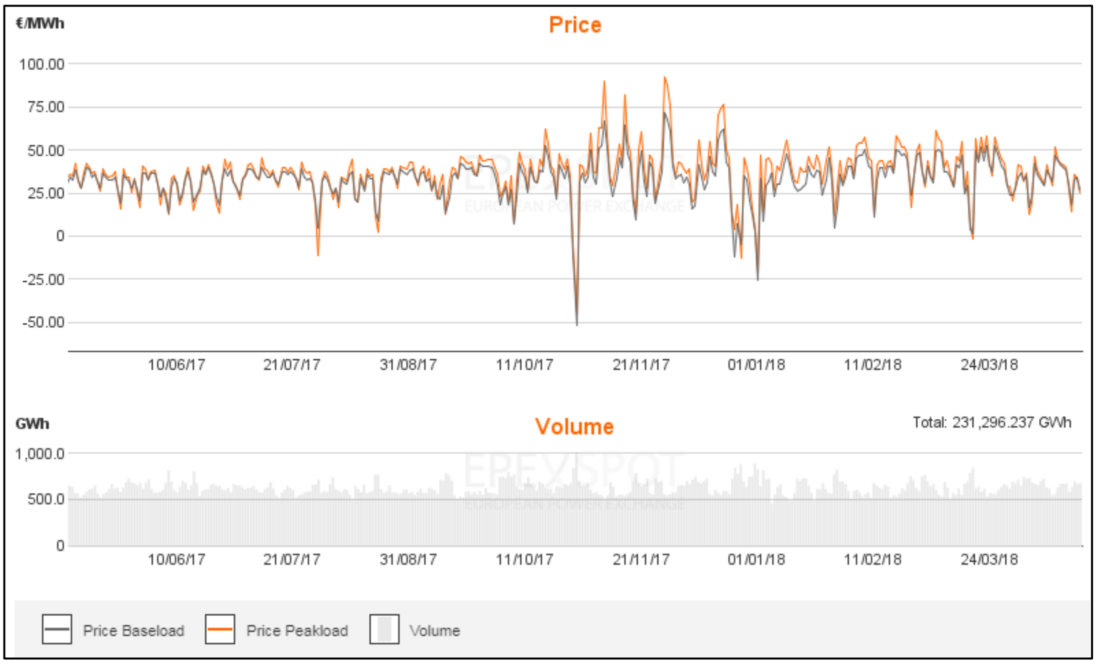


Figure 15. Annual curve of the DAM in Germany 2017-2018 (EPEX SPOT SE, 2018).

4.3 Expected energy price development in the Netherlands

Mulder & Scholtens (2013) investigated the impact of renewable energy on electricity prices in the Netherlands. Their conclusion is that the Dutch electricity price is still largely based on the marginal costs of conventional power plants. However, the increase of installed capacity in surrounding countries/connected markets, also affects the Dutch markets (Schoots et al., 2017). It is, moreover, important to note that price developments are strongly correlated to other factors, such as fossil fuel prices, political developments, natural disasters and so on (Cludius et al., 2014). Schoots et al. (2017) have predicted the price development of the wholesale prices in the National Energy Outlook.

Figure 16 and figure 17 show the historical price development of electricity and natural gas between 2000-2017 and the forecasted price development of electricity and natural gas up to 2035. It is predicted that the lowest prices will occur between 2018 and 2020, thereafter the prices will rise. The bandwidth (in Dutch: *bandbreedte*) reflects different price scenarios mainly due to unknown CO_2 emissions prices and fossil fuel/oil prices (Schoots et al., 2017). In 2017, the natural gas price was € 15.4/MWh which means that electricity costed twice as much.

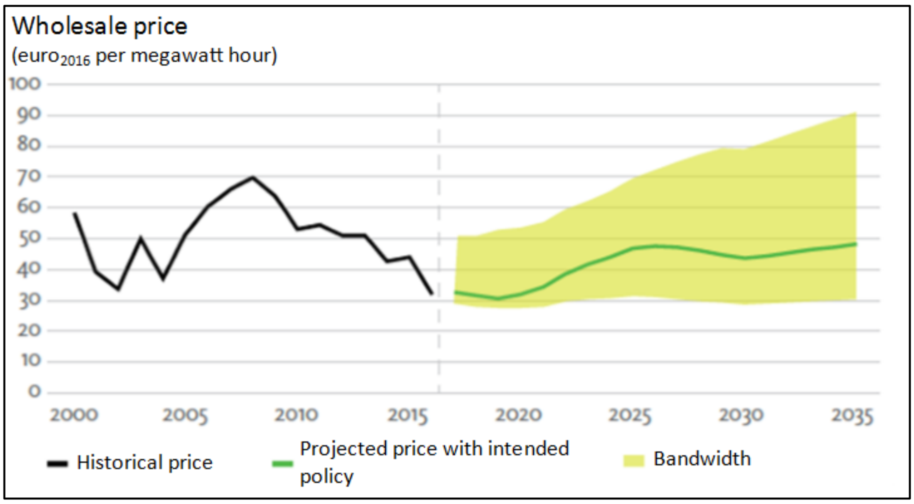


Figure 16. Development wholesale price of electricity 2000-2035 (based on Schoots et al. 2017, p.126).

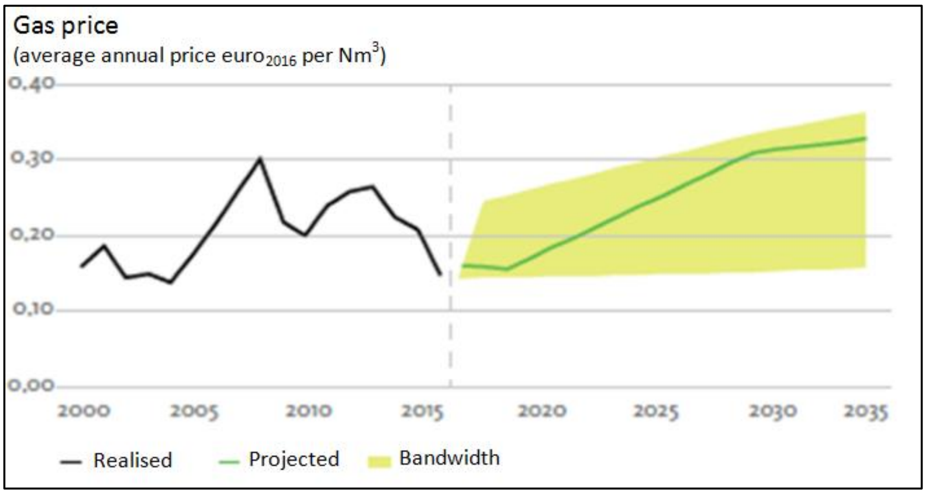
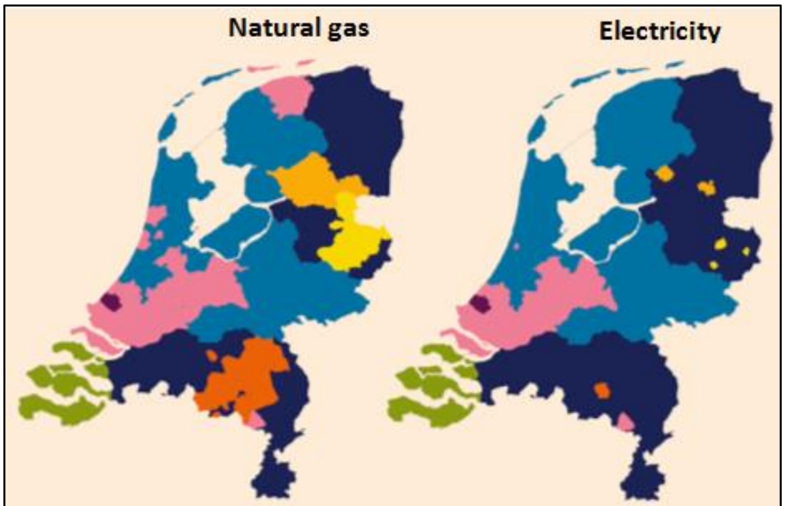


Figure 17. Development wholesale price of electricity 2000-2035 (based on Schoots et al. 2017, p.44).

5 Transmission, distribution, and metering

The transmission system operator (TSO) plays an important role in the electricity grid. The European Network Transmission System Operator Electricity (ENTSO-E) represents 46 TSOs from 36 countries across Europe. The TSO of the Netherlands is TenneT which is according to Tanrisever et al. (2015) the backbone of the Dutch electricity market, it manages the 110 kV, 150 kV, 220 kV and 380 kV high voltage grids. The company is an independently regulated state-shareholding. The distribution parties (DSOs) are responsible for the low voltage grids (below 110 kV) and the connections to the consumer. The DSOs have a regional monopoly.

There are two types of natural gas in the Netherlands, high calorific (H-gas) gas and a low calorific gas (L-gas). Therefore, two networks are needed. Both natural gas networks consist of: (1) a national high-pressure network (up to 67-80 bar), (2) a regional medium pressure network (up to 40 bar) and (3) a local low-pressure network (around 8 bar). It is important that the pressure in the natural gas network will remain above the atmospheric pressure because otherwise oxygen can enter the pipelines. The owner of the network is Gasunie and the TSO that manages the national and regional network is Gasunie Transport Services (GTS). The company is a state-controlled company. The DSOs are responsible for the local network and the connections to the consumer. The DSOs have a regional monopoly. Figure 18 shows the DSOs and its operation areas.



Network operators	Connections natural gas	Connections electricity
Cogas Infra en Beheer B.V.	138.989	52.930
Enduris B.V.	189.423	211.262
Edinet*	399.927	108.591
Enexis B.V.	2.074.234	2.647.300
Liander N.V.	2.243.915	2.938.787
Rendo Netbeheer B.V.	103.341	31.974
Stedin B.V.	1.947.767	2.055.520
Westland Infra Netbeheer B.V.	52.930	55.745
TenneT TSO B.V.**		
Gasunie Transport Services***	1.100	
Totaal	7.151.626	8.102.109

* Integrated with Enexis B.V. from 1 January 2017.
** TSO electricity.
*** TSO natural gas.

Figure 18. Overview network operators (ECN 2016, p.65).

The responsibilities of the TSOs and DSOs are described in the Dutch Electricity Act and Gas Act. The TSOs and DSOs are tasked with the transportation and distribution of electricity and natural gas in an efficient, safe, and secure manner. Secondly, they have the responsibility to establish and maintain connection points with other (foreign) networks and consumers. TSOs are also responsible for allocating and balancing the system, to ensure the stability of the grid and the network. Moreover, TSOs and DSOs have a responsibility to share all relevant information in order for consumers and producers to make efficient decisions. But above all it is their job to guarantee the security of the networks (ACM, 2017).

5.1 Network operation costs

Because the network operators have a regional monopoly, their tariffs are regulated by the state. The Dutch Authority for Consumers & Markets (In Dutch: *Autoriteit Consument & Mark*t, ACM) is the responsible body for the regulation of the TSOs and the DSOs in the Netherlands. The goal is incentivising TSOs and DSOs to operate efficiently by setting the revenue of the operators before the start of the next regulatory period (ex-ante revenue cap or ex ante price cap). If a system operator operates more efficiently, the cap becomes bigger witch results in higher profits. Figure 19 shows the process of tariffing at ACM. Three steps can be distinguished: (1) method decision, (2) x-factor decision and (3) tariff decision.

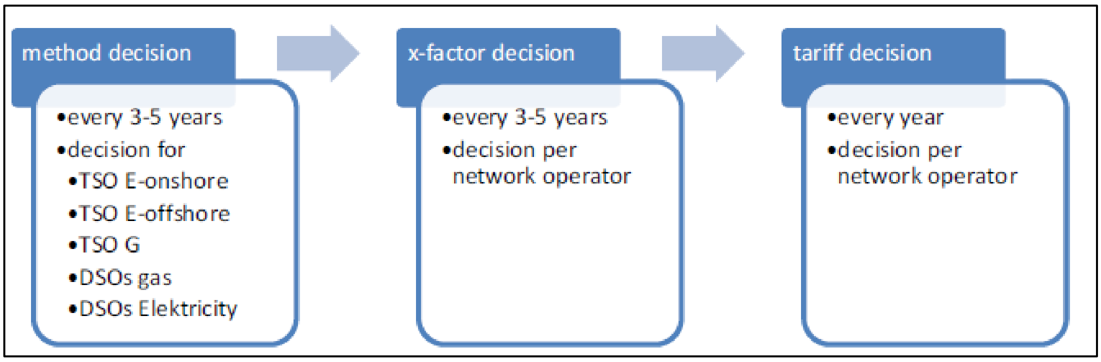


Figure 19. Process of tariffing at ACM (ACM 2017, p.4).

In the first step, ACM consults each individual DSO and TSO to determine the tariffs for the next 3-5 years. Simultaneously the x-factors for the coming 3-5 years are determined. The x-factor is a percentage by which the tariff will be increased or decreased over the next 3-5 years. Part of the x-factor is the q-factor. The q-factor is the percentage by which the tariff will be increased or decreased depending on the quality offered by a network operator. Finally, each year ACM takes a tariff decision for each individual network operator. This tariff is the maximum amount of money a network operator can charge of its consumers for their provided services. These tariffs are published publicly. Consumers automatically pay these tariffs to the network operators because this is part of the energy bill provided by the retailer. Important to note, these tariffs only apply to small consumers which means a maximum electricity connection of 3x80 Ampere and a natural gas connection that allow not more than 40 Nm^3 gas per hour (ACM, 2018).

Paddepoel-Noord is located in the region of Enexis, both the gas network and the electricity grid. The tariff is composed of four services: (1) connection services (in Dutch: *Aansluitdienst*), (2) fixed charge transport service (in Dutch: *Vastrecht transportdienst*), (3) transport service (in Dutch: *Transportdienst*) and (4) metering service (in Dutch: *Meetdienst).* Table 2 shows the network operating costs for electricity in 2018 and table 3 shows the network operating costs for natural gas in 2018.

Table 2. Network operating costs of electricity in 2018 (based on Enexis, 2018a).

Service	€/per day	€/per month	€/per year
Connection services	€ 0.0486	€ 1.4773	€ 17.7281
Fixed charge transport services	€ 0.0493	€ 1.4998	€ 17.9982
Transport services	€ 0.3314	€ 10.0798	€ 120.9574
Metering services	€ 0.0785	€ 2.3889	€ 28.6671
Total:	€ 0.5078	€ 15.4459	€ 185.3507
Total inc. 21% VAT:	€ 0.6145	€ 18.6895	€ 224.2743

Table 3. Network operating costs of natural gas in 2018 (based on Enexis, 2018b).

Service	€/per day	€/per month	€/per year
Connection services	€ 0.0761	€ 2.3147	€ 27.7765
Fixed charge transport services	€ 0.0493	€ 1.4998	€ 17.9982
Transport services	€ 0.1988	€ 6.0465	€ 72.5584
Metering services	€ 0.0574	€ 1.7465	€ 20.9583
Total:	€ 0.3816	€ 11.6076	€ 139.2913
Total inc. 21% VAT:	€ 0.4618	€ 14.0452	€ 168.5425

It can be observed that the transport service is the largest cost item in both tables. Moreover, the costs for operating the electricity grid are considerably higher compared to the operating costs of the natural gas network. Especially the transport service of electricity is significant higher. These higher costs reflect the sophisticated process of operating an electricity grid because its needs to be continuously balanced.

5.1.1 Disconnection of energy supply

Suppliers and consumers have, under certain circumstances, the right to disconnect a house from the natural gas, electricity grid or heat. On the one hand, a supplier is allowed to disconnect a household if: the consumer commits fraud or abuse; the situation is unsafe or in case of default (ACM, n.d.). On the other hand, if a consumer no longer wants to be connected to natural gas, electricity or heat, the local DSO is legally obliged to remove the connections. The tariffs for disconnecting differ per DSO, table 4 shows the tariffs of Enexis in 2018.

Table 4. Removal tariffs Enexis 2018 (Based on Enexis, 2018c).

Activities	Excl. VAT	Incl. VAT
Removal connection natural gas	€ 289.89	€ 350.77
Removal connection electricity	€ 418.78	€ 506.72
Removal cable or conduit	€ 15.51	€ 18.77
Surcharge urgent (within 5 days)	€ 203.12	€ 245.78

In addition, additional costs can be expected when a technician has to inspect the situation in advance or underground cables/conduits need to be removed. On the positive side, a household no longer has to pay the annual operating costs.

6 Retail markets and energy consumption

The retail market is the last phase in the energy chain after which the energy is used in households to provide services. The retail market consists of energy suppliers that form the link between the households and the rest of the energy chain. Since 2004, each household can choose its own energy supplier on the basis of its own preferences. In 2018, 39 energy suppliers are active in the retail market (ECN, 2016). Households pay a monthly deposit to the energy supplier. This deposit is usually based on historical data (three years) about the energy consumption of that household. In return, the energy supplier delivers electricity and natural gas to a household. The energy supplier takes stock after one year, this means that a household gets money returned or needs to do an additional payment. Furthermore, the energy supplier is responsible to pay the network operators and the energy taxes. These costs are part of the energy bill. In addition, ACM plays an important role in this phase in protecting the rights of consumers.

Paragraph 6.1 describes the energy consumption per type of house. The next paragraph, paragraph 6.2, elaborates on the Dutch energy tax. Finally, paragraph 6.3 describes the compensation fine by switching from supplier within the term of the contract.

6.1 Energy consumption per type of house

The National database Klimaatmonitor provides data about the historical energy consumption in the Netherlands. The database is operated by the Ministry of Infrastructure and Water Management. Klimaatmonitor first aggregates data at a national level from the Central Bureau for Statistics (in Dutch: *Centraal Bureau voor de Statistiek, CBS*). Thereafter, the data distributed to a local level in the Netherlands. This process is called allocation. This means that this database gives a good indication of the local situation, but only real-time measurements can provide the exact data. Table 5 and table 6 show the average electricity and the average natural gas consumption per type of house in 2016.

Table 5. Average consumption electricity in 2016 (based on Klimaatmonitor, 2018).

Category	**Netherlands (kWh)**	**Groningen (kWh)**	**Paddepoel-Noord (kWh)**
Apartments	2,070	1,940	1,540
Corner houses	3,180	2,970	3,010
Detached houses	4,120	3,970	2,830
Intermediate houses	3,060	2,790	2,760
Semi-detached houses	3,500	3,440	3,080
Average	2,910	2,330	1,960

Table 6. Average consumption natural gas in 2016 (based on Klimaatmonitor, 2018).

Category	**Netherlands (Nm^3)**	**Groningen (Nm^3)**	**Paddepoel-Noord (Nm^3)**
Apartments	870	1,100	1,110
Corner houses	1,480	1,610	1,960
Detached houses	2,300	2,350	2,400
Intermediate houses	1,240	1,400	1,710
Semi-detached houses	1,750	1,670	2,160
Average	1,300	1,250	1,330

Both tables show a similar pattern: households living in apartments consume the lowest amount of energy while households that live in detached houses consume the most energy. This pattern can be explained in several ways but very important here is the size of the house itself and the family size (Tanrisever et al., 2013). Another reason is that detached houses, semi-detached houses and corner houses have more exterior walls and therefore more heat losses (Ecofys, 2015).

Households use natural gas to provide three types of services: (1) space heating, (2) hot tap water and (3) cooking. Figure 20 shows the average division of natural gas to type of service. Most of the natural gas is used for space heating, a significant amount is used for hot tap water and only a small amount for cooking.

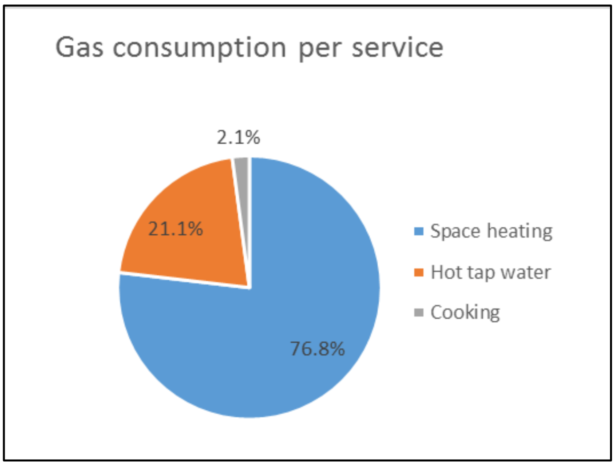


Figure 20. Division of natural gas to type of service (based on Menkveld et al., 2017).

The price paid by a household per kWh or Nm^3 varies per energy supplier. They price for energy consist of two parts: fixed supply costs and variable supply costs. The fixed supply costs are usually displayed per day and per product. This means that a household that uses both natural gas and electricity has to pay the fixed supply costs twice. The variable supply costs are expressed in kWh of Nm^3. In addition, consumers can choose to pay a single tariff of a double tariff for electricity. In case of a double tariff, electricity which is used during peak hours is more expensive than electricity used during off-peak hours.

In the Netherlands, the energy supplier is legally obliged to publicly publish its annual energy prices, enabling consumers to compare energy prices (IEA, 2014). In practice, energy suppliers offer quite similar prices for comparable products because the competitive energy market. Table 7 shows the price level of Essent in 2018 (excl. VAT), the largest retail energy supplier of the Netherlands. The natural gas tariff includes a regional surcharge which is an extra fee to cover the transport costs of natural gas. The regional surcharge is related to the transport distance, this means that households in the province of Groningen have to pay less than households in the province of Zeeland (ACM, 2018). The natural gas tariff is shown in Nm^3 and kWh which reveals that electricity is twice as expensive as natural gas.

Table 7. Price level of Essent in 2018 excl. VAT (based on Essent, 2018).

Category	Electricity (kWh)	Natural gas (Nm^3)	Gas (kWh)
Variable supply costs (single tariff)	€ 0.0527	€ 0.2576	€ 0.0264
Fixed supply costs per day	€ 0.1138	€ 0.1138	€ 0.1138

6.2 Energy taxes

The Dutch energy taxation consists of three parts: (1) Energy Tax (in Dutch: *Energiebelasting*), (2) Tax on Sustainable Energy (in Dutch: *Opslag Duurzame Energie*) and (3) VAT. The tax rates are publicly available at the webpage of the Dutch tax authority (Belastingdienst, 2018). Moreover, the tax is divided on the basis of the amount of consumption. Households, for example belong to the first category: 0 to 10,000 kWh electricity per year and 0 to 5,000 Nm^3 natural gas per year. The first category has the highest tax rates. In this way, energy-intensive companies or industries need to pay less tax for their energy consumption. The main reason for this system is according to Verbong & Geels (2007) that energy-intensive companies or industries of The Netherlands van compete with their competitors.

In 2018, the Energy tax for households is for electricity is € 0.1046/kWh electricity and for natural gas € 0.26001/Nm^3 (€ 0.0266/kWh). In 2013 came a new tax into force, namely the Tax on Sustainable Energy. The national government uses the yield of this tax to stimulate companies and (non-profit) organisations to invest in renewable energy production (RVO, 2017). This is the so-called SDE+ subsidy of the Ministry of Economic Affairs. In 2018, the Tax on Sustainable Energy for households for electricity is € 0.00132/kWh electricity and for natural gas € 0.0285/Nm^3 (€ 0.0029/kWh). The VAT has been set at 21%. Figure 21 shows the development of tax rates of the Energy Tax and the Tax on Sustainable Energy for the period 2011-2018. The effect of the Tax on Sustainable Energy is clearly visible in the diagram. For comparison: in 2016, average household payed € 17/year on this tax, but will pay € 77/year in 2020 (Schoots et al., 2017). On the other hand, the Energy tax has been reduced with € 0.02/kWh in 2016 and will remain more or less the same until at least 2020.

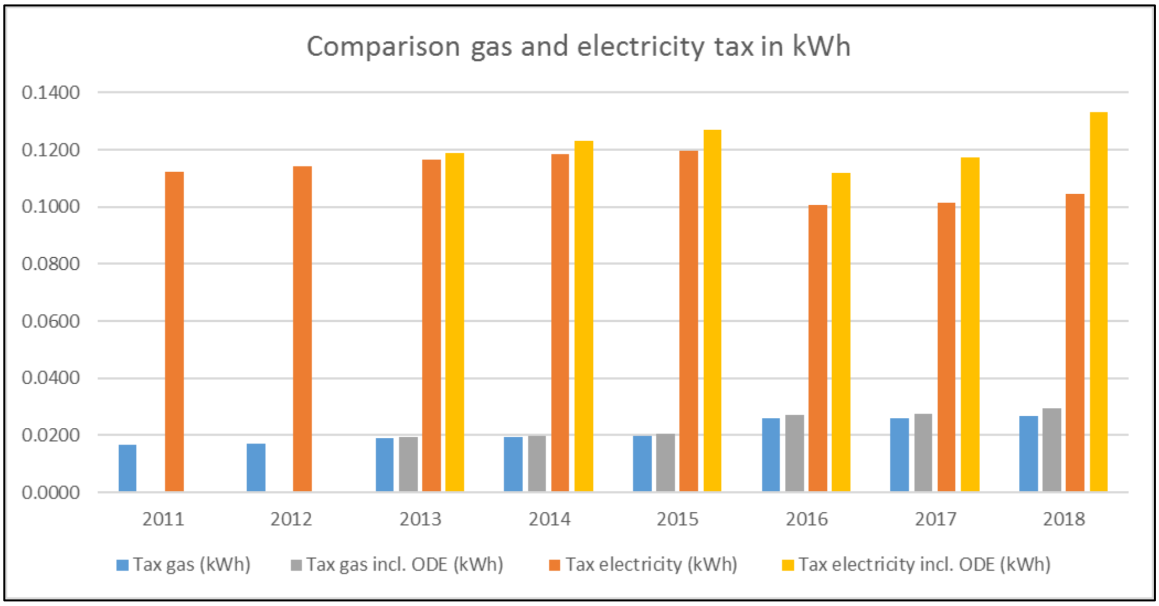


Figure 21. Comparison natural gas and electricity tax 2011-2018 (based on data Belastingdienst, 2018).

According to the national government is energy and sufficient energy a basic need. Therefore, the Energy Tax is reduced with an annual tax discount (In Dutch: *belastingsvermindering of heffingskorting*). In 2018, the energy tax credit is determined on € 308.54/year (excl. VAT) per electricity connection (Rijksoverheid, 2018c). This rate has been fairly constant over the years.

6.3 Compensation fines

In the liberalised Dutch energy market households can freely choose their energy supplier. Usually, energy suppliers and households sign a contract for a period of one, three or five years. A household is still allowed to switch from energy supplier during the term of the energy contract, however, the previous energy supplier is allowed to charge a compensation fine (in Dutch: *opzegvergoeding*) from the household for breaching the contract. The maximum compensation fine depends on the contract term and the remaining contract term. The rates for the maximum compensation fines are included in the law 'Richtsnoeren Redelijke Opzegvergoeding Vergunninghouders' article 4.1 and are shown in table 8. The maximum compensation fine is per product, which means that a household can get a maximum total compensation fine of € 250.

Table 8. Maximum compensation fines (Richtsnoeren Redelijke Opzegvergoeding Vergunninghouders, article 4.1, 2008).

Contract term	Remaining contract term	Maximum rates per product
1 year	< 1 year	€ 50
> 1 year	< 1.5 years	€ 50
	< 1.5 - 2 years	€ 75
	2 - 2.5 years	€ 100
	> 2.5 years	€ 125

7 Conclusion

The Dutch supply chain of electricity and the supply chain of natural gas have been analysed from extraction/production and generation to delivery and consumption by households. The liberalisation created competitive markets and regulated monopolies as well as wholesale markets and retail markets. In addition, liberalisation has contributed to a significant overcapacity of installed capacity for electricity generation (IEA, 2014). The overcapacity was 2.5 in 2016 and is expected to increase to 3.2 in 2035 due to the high increase of solar PV and wind energy. Moreover, it is predicted that the role of the Netherlands will change from a net importer to a net exporter of electricity. The aggregate carbon intensity (ACI) is a measure to calculate the direct CO_2 emissions per kWh. Ang & Su (2016) calculated the ACI for the Netherlands, which was 0.44 kg CO_2 emissions/kWh in 2013.

Natural gas can be categorised in H-gas and L-gas. H-gas is obtained in the North Sea or imported from foreign countries, while L-gas is extracted in the province of Groningen. Around 93% of the Dutch households are connected to the natural gas network and use L-gas for space heating, hot tap water, and cooking. On 29 March 2018, the national government decided that L-gas production in Groningen should be terminated as quickly as possible, because the gas extraction causes earthquakes in the local environment (EZK, 2018). This decision will a have a major impact on the Dutch energy system. In order to become independent of natural gas by 2050, new houses will not have a natural gas connection anymore. Moreover, after 2021, 200,000 existing houses must be disconnected from the natural gas network and switched to another energy source. This means that the role of the Netherlands will change from a net exporter to a net importer of natural gas. The energy content of L-gas has an upper value of 35.17 MJ/Nm^3 and an under value of 31.65 MJ/Nm^3. The heat content of 1 Nm^3 L-gas is 9.77 kWh. With an overall efficiency of 85-90%, the average CO_2 emission is 1.89 kg/Nm^3 (Klimaatplein, 2018). In addition, the total direct CO_2 emission of a reference boiler (HR107) is calculated at 2.01 kg/Nm^3.

In a conventional system, three different types of suppliers can be distinguished in order to provide: (1) the baseload, (2) the flexible load, and (3) the peak load. Competing generators and competing suppliers trade at the wholesale markets to provide the energy demand. Epex Spot and PEGAS are respectively the electricity and natural gas platforms in Western Europe. An important aspect of the wholesale market is the merit order, which basically is designed to bring together supply and demand for the lowest price possible. The merit order is the ranking of all generation units from low to high marginal costs. However, when renewables are added to the generation mix, the merit order curve shifts to the right. This means that conventional plants with higher marginal costs are pushed out of the system when renewables are available. Moreover, an increase of renewables results in a decrease of the electricity price and an increase in price volatility at the wholesale market, usually called the merit order effect or the renewable energy paradox (e.g. Cludius et al., 2014; Winkler et al., 2016 and Blazquez et al., 2018). Germany is a good example to illustrate the merit order effect and shows that the increase of renewables in a liberalised market can lead to negative prices at the wholesale markets. In the Netherlands, it is forecasted that the electricity prices will increase slowly, despite the merit order effect. Furthermore, it is predicted that the wholesale price of natural gas will increase significantly (Schoots et al., 2017).

TSOs are responsible for the national high-voltage grid and high-pressure natural gas network. The Dutch TSOs are TenneT (electricity) and GTS (natural gas). DSOs are responsible for the regional and local medium- and low-voltage grids and the medium- and low-pressure natural gas networks. The DSO varies per region, which also means that network operating costs differ per region. ACM is the responsible body for the regulation of the TSOs and the DSOs in the Netherlands. The annual network operating costs of Enexis (region 4) of 2018 are € 224.27 for electricity and € 168.54 for natural gas (incl. VAT) (Enexis, 2018a). In case a household will be connected to a DH system, the natural gas connection can be removed for at least € 350.77 (incl. VAT) (Enexis, 2018c). On the positive side, a household no longer has to pay the annual operating costs.

The retail market is the last phase of the energy chain, after which the energy is used in households to provide services. Based on data from *Klimaatmonitor*, it can be concluded that households living in apartments consume the lowest amount of energy, while households living in detached houses consume the most energy. In addition, the current energy bill consists of: (1) fixed supply costs, (2) variable supply costs, (3) network operating costs, (4) energy tax), (5) tax on Sustainable Energy (ODE), and (6) 21% VAT. A comparison of the tax on electricity and the tax on natural gas (in kWh) shows that the tax on electricity is significantly higher. One other aspect that has to be considered by switching to a DH system: the compensation fine. An energy supplier can charge a household maximum € 250 by breach of contract.

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Appendix 2

Analysis Heat Act

Contents

1 Introduction

In January 2014, the Heat Act (in Dutch: *Warmtewet*) was introduced which regulates the heat supply of consumers with a connection up to 100 kWt. The main reason for the introduction of the Heat Act was to protect consumers, considering the importance of a reliable, sustainable, environmentally sound and efficient heat supply (Warmtewet, 2017). In 2016, the functioning of the Heat Act was assessed by an international consultancy firm called Ecorys (Ecorys, 2016). The evaluation was commissioned by the Ministry of Economic Affairs and led to a modification of the Heat Act in 2017. The Heat Acts consists of ten chapters and 46 articles.

It is important to notice that a law or regulation usually does not stand alone but that it is part of a larger scope. The same applies to the Heat Act, although the 'family name' is Heat Act, the following four regulations are related to the Heat Act (delegated regulation):

1. Besluit factuur, verbruiks- en indicatief kostenoverzicht energie (in English: *Decision invoice, consumption and indicative cost overview energy*): contains specific rules for energy suppliers for the compilation of invoices.
2. Regeling garanties van oorsprong voor energie uit hernieuwbare energiebronnen en HR-WKK-elektriciteit (in English: *Arrangement to prove the source of renewable energy sources and HR-WKK electricity*): contains regulations for natural gas, electricity and heat from renewable energy sources and HR-WKK electricity.
3. Warmtebesluit (in English: *Heat decision*): contains the calculation method and formulas to set the maximum delivery tariffs for heat supply and to set the maximum connection fees.
4. Warmteregeling (in English: *Heat regulation*) contains parameters that do not change quickly for the formulas of the Warmtebesluit such as the investment costs of a gas-fired boiler.

Finally, the Boetebeleidsregel ACM 2014 (in English: *Penalty policy ACM 2014*) applies to the Heat Act. With this policy, ACM can impose a fine on a heat supplier if it violates the law.

Chapter 2 starts with the introduction and definition of regular used concepts in both this analysis and the Heat Act. Chapter 3 then explains the distinction in the Heat Act between permit holders and non-permit holders. In addition, the responsibilities of a permit holder and a non-permit holder are described. Finally, chapter 4 describes the maximum supply tariffs and the maximum connection fees heat suppliers are allowed to charge. Furthermore, it analyses the price development of supply costs and describes the most important results of the evaluation of the Heat Act in 2016.

2 Concept definitions

The Heat Act (Warmtewet, 2017) starts in article one with defining concepts used throughout the law. A description of concepts that are often used in this analysis is shown in alphabetical order in table 1. A complete overview of all concepts and a (Dutch) description can be found in first article of the Heat Act.

Table 1. Terminology.

Concept	Description	Source
Connection fee (*aansluitbijdrage*)	In case a supplier charges a one-time connection fee from an individual customer for an unforeseen connection to an existing DH network, this fee is at least equal to the price a natural gas consumer pays for a connection to the natural gas network.	Article 6, section 2.
Consumer (*verbruiker*)	A person that takes heat from a heating network and which has a connection of maximum 100 kilowatt.	Article 1, section g.
Developer (*ontwikkelaar*)	A person who develops a construction project in an area where space heating is or will be provided by means of a DH network.	Article 1, section f.
Heat (warmte)	Hot water or tap water used for space heating, sanitary purposes and domestic consumption.	Article 1, section d.
Heat from renewables (*warmte uit hernieuwbare energiebronnen*)	Heat generated in a production plant that uses only renewables or is generated from renewables by a hybrid production plant which also uses fossil fuels.	Article 1, section n.
District heating network (*warmtenet*)	The whole of, connecting pipes, associated installations and other auxiliary equipment with the purpose of serving the transport of heat, except insofar as these pipes, installations and auxiliary equipment are located in a building or work of a consumer or of a producer, used for supply or return of heat for that building or work	Article 1, section c.
Heat supply (*levering van warmte*)	The delivery of heat to consumers.	Article 1, section e.
Producer (*producent*)	A person who produces heat.	Article 1, section i.
Representative organisation (*representative organisaties*)	A legal entity that represents the interests of producers, suppliers or consumers in the heating sector.	Article 1, section k.
Supplier (*leverancier*)	A person who supplies heat.	Article 1, section h.

3 Permit obligation

In principle, the Heat Act applies to all suppliers, but it distinguishes permit holders and non-permit holders (G. Verschuur, appendix 5 of the main report). This is enclosed in articles 9 to 11. A supplier is legally obliged to apply for a permit from ACM, unless one of the following criteria is not applicable (Warmtewet 2017, article 9):

1. The supplier supplies heat to maximum 10 consumers at the same time.
2. The supplier supplies maximum 10,000 GJ annually.
3. The supplier is the owner or the lessor of the building.

To illustrate: if criteria one and two are answered with 'more' and if criterion three is answered 'no', the supplier is obliged to apply for a permit. If criterion one is answered with ‘more’, criterion two is answered with ‘less’ and criterion three is answered with ‘no’, the supplies not obliged to apply for a permit (ACM, 2014). In addition, the Heat Act is applicable for the entire heat chain. Figure 1 shows that the Heat Act is applicable to producers and wholesale suppliers as well as retail suppliers.

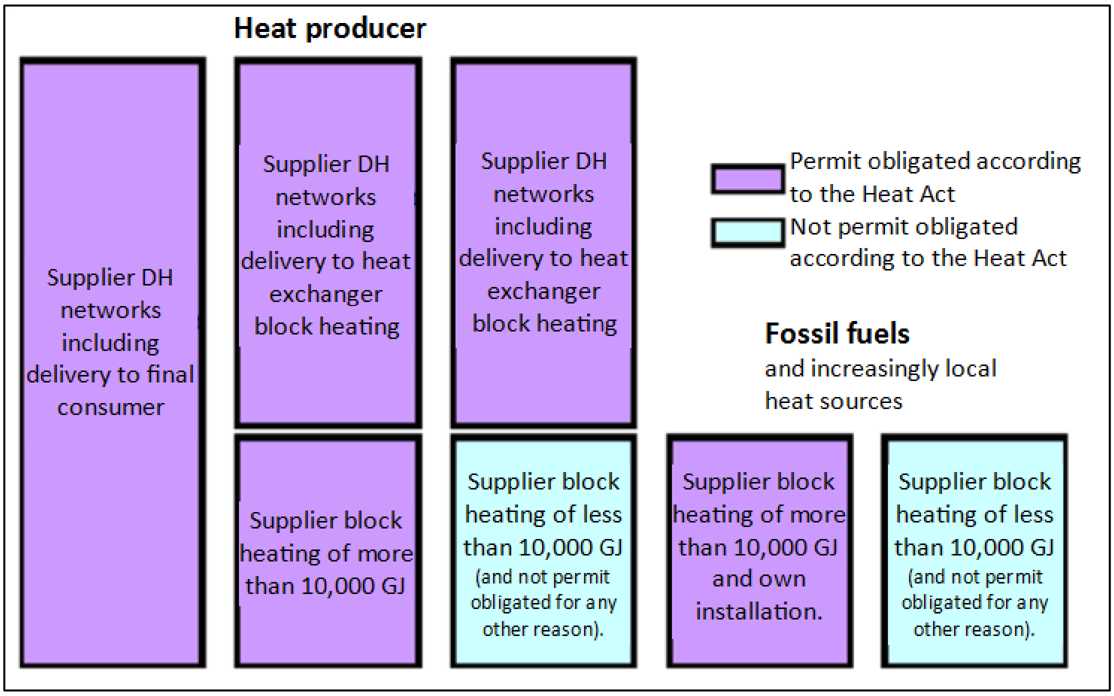

Figure 1. Permit obligation heat supply (based on Bennink & Benner 2009, p.12).

A (potential) supplier can apply for a permit via an application form which is available on the ACM website. According to the Warmtewet (2017, article 10), an applicant will get a permit when he sufficiently proves that he has:

1. The required organisational, financial and technical qualities.
2. Can meet the legal obligations for heat suppliers.

The Minister is allowed to withdraw the permit if the permit holder does not comply with the regulations or the restrictions imposed on the permit. Furthermore, the Minister is allowed to withdraw the permit if, for one reason or another, they regard the permit holder as incapable to meet the obligations of the permit. (Warmtewet 2017, article 11).

EcoGenie 2.0 aims to connect 100-200 households with an average heat demand of 56.8 GJ/year (without cooking). The first criterion can be answered with ‘more’ and the third criteria with ‘no’. In this case, the second criterion is crucial whether or not EcoGenie 2.0 should apply for a permit. This can be determined by the break-even point that can be found by dividing 10,000 GJ by the average annual heat demand. Based on an average heat demand of 56.8 GJ/year, the break-even point is 175 households. Below 175 households, only the general provisions will apply. Above 175 households, both general and special provisions will apply.

3.1 Organisational, financial and technical requirements

The responsibility of each supplier can be summarised as: to ensure a reliable supply of heat for reasonable terms and considering a good quality of service (Warmtewet 2017, article 2.1). The Heat Act regulates various organisational, financial and technical aspects.

3.1.1 General provisions

Article 2 to article 8b are general provisions which apply to both permit holders and non-permit holders. The following organisational, financial and technical requirements are applicable:

- A supplier must provide at least once a year a specified cost overview with all services provided to the customer (Warmtewet 2017, article 2.2).
- A supplier is restricted to (1) the maximum tariffs for heat supply, is only allowed to charge a (2) reasonable fee for the heat exchanger and is restricted to the (3) maximum measurement fee (Warmtewet 2017, article 2.3). These requirements are further explained in chapter 4.
- A supplier refrains from any form of unjustified discrimination against his consumers (Warmtewet 2017, article 2.4).
- A supplier shall adequately inform consumers of any change in supply tariffs or any intention to change conditions of the supply contract (Warmtewet 2017, article 2.5).
- A supplier’s accounting contains reliable and transparent information about the integral costs and revenues of heat supply and the realisation of connection (Warmtewet 2017, article 2.6).
- A supplier keeps track of disruptions of the heat supply and publishes it annually in an appropriate manner (Warmtewet 2017, article 7).
- A producer connected to a DH network is obliged to negotiate at the request of the supplier about the availability of heat at reasonable prices and conditions (Warmtewet 2017, article 2.8).
- A supply contract (between supplier and consumer) is put into writing and contains at least the following information: (1) personal details and address of the supplier, (2) a clear and complete description of the goods and services to be delivered and the agreed quality levels, (3) the conditions for suspension or ending the agreement and (4) a description of the applicable reimbursements (Warmtewet 2017, article 3.1).
- A supplier shall make a reasonable effort to prevent disconnection and interruption of heat supply, and in case of an interruption of the heat supply occurs, it must be solved as soon as possible. In particular disconnection of consumers between 1 October and 1 April need to be prevented (Warmtewet 2017, article 4.1).
- A supplier shall inform a consumer as least three days in advance of planned activities, (e.g. maintenance), whereby the heat supply to consumers will be disrupted (Warmtewet 2017, article 4.2).

- In case a one-time connection fee is charged by a supplier to an individual customer for an unforeseen connection to an existing DH network, this contribution will be maximum the amount that a natural gas consumer would pay (Warmtewet 2017, article 6.1).
- A supplier needs to provide a heat exchanger within a reasonable period of time and at a reasonable rental tariff in case the existing heat exchanger need to be replaced or in case of a new building (Warmtewet 2017, article 8.1).

3.1.2 Special provisions regarding to permit holders

Articles 9 to 12a are special provisions which apply only to permit holders. The following organisational, financial and technical requirements are applicable:

- A permit holder offers consumers a wide choice of payment methods (Warmtewet 2017, article 12.1).
- A permit holder ensures good accessibility for consumers. The permit holder replies to correspondence from consumers within ten working days. If a solution is not possible during this period, the consumer needs to receive at least a message within five working days within which period an adequate response can be expected (Warmtewet 2017, article 12.2).
- A permit holder uses the information provided by consumers exclusively to carry out the obligations of the Heat Act itself (Warmtewet 2017, article 12.3).
- A permit holder must keep separate records with regard to the supply of heat and, if applicable, the supply of cold (Warmtewet 2017, article 12a.1).
- A permit holder publishes an annual account and an annual report. The annual report contains reliable and transparent information about the integral costs and revenues of the permit holder. The information of the annual report is provided with an audit's opinion (Warmtewet 2017, article 12a.2).

3.2 Other provisions and reimbursements

Articles 12b to 12d regulate the heat supply in case a producer or supplier intends to terminate the supply or production of heat. Article 13 enables ACM to request data and information from producers, suppliers and consumers for the implementation of this law and for the preparation of the energy report. Full cooperation is required. Articles 15 to 46 regulate the role of ACM.

A supplier is legally obliged to record all disruptions of the production installations, the start and end times have to be noted. This does not include disruptions in a household, caused by for example the heat exchanger, measurement device or radiators. Also, disruptions caused by maintenance works are excluded when these activities are announced at least three days in advance (Warmtewet 2017, article 4). A heat supplier is legally obliged to reimburse to consumers € 35 per disruption of 4-8 hours and an additional reimbursement of € 20 per extra four hours. The reimbursement must be paid within six months, even to consumers who do not ask for it themselves (ACM, 2018c).

4 Maximum tariffs

A supplier is legally obliged to adhere to the maximum tariffs for heat supply, set by ACM. The maximum tariffs regulate the maximum price customers pay for their energy, as well as the maximum rate of return a supplier/producer can achieve by supplying heat. The maximum tariffs for consumers are based on the so-called NMDA principle which is an abbreviation for 'Niet-Meer-Dan-Anders' (in English: *Not More Than Usual*). This means that a customer connected to a DH network, does not pay more than a household with an individual gas-fired boiler. In addition, ACM (2018b) annually adjusts the tariffs for heat supply to the price increase or price reduction of natural gas.

ACM monitors according to the Heat Act (2017, article 7) the rate of return heat suppliers achieve by supplying heat. Every two-year ACM publishes a report, the so-called *Rendementsmonitor* (in English: *Rate of return monitor*). Ecorys (2017) has developed a methodology to calculate the reasonable rate of return on heat supply and to calculate the average rate of return on heat supply. Only large-scale DH systems (> 5000 connections) are included. The most recent report was published in 2017. The reasonable rate of return is set at 5.1%-6.6%. The average rate of return was 7.7% in 2013, 2.1% in 2014, 2.2% in 2015, and 4.8% in 2016 (ACM, 2017).

4.1 The 'usual' consumer

'Usual' refers to a household with a G6 meter, an individual gas-fired HR107 boiler with a CW value of 4 for hot tap water (ACM, 2018b). A G6 meter has a capacity of up to 10 Nm^3 of gas per hour (Enexis, n.d.). The CW value expresses the hot tap water debit of a gas-fired boiler. In addition, the CW value can be used as a measure to determine comfort. A CW value consists of three requirements for supplying domestic hot water: (1) kitchen at 60 °C, (2) shower at 40 °C and (3) bathtub at 40 °C. The supply temperature for each CW value is the same, but the time and volume differ. A gas-fired boiler with a CW value of 4 must supply at least 7.5 l/min of 60 °C, 12.5 l/min of 40 °C and fill a bathtub of 120 litres within 11 minutes. There are in total six different CW values, these are shown in Figure 2.

CW value	Application	Kitchen (60 °C) Minimum tap flow rate (l/min)	Shower (40 °C) Minimum tap flow rate (l/min)	Bathtub (40 °C) Minimum tap flow rate (l/min)
1	Kitchen	≥ 2,5	-	-
2	Kitchen or shower	≥ 3,6	≥ 6	-
3	Kitchen or shower or bathtub (100 l)	≥ 6	≥ 10	≤ 12
4	Kitchen or shower or bathtub (120 l)	≥ 7,5	≥ 12,5	≤ 11
5	Kitchen or shower or bathtub (150 l)	≥ 7,5	≥ 12,5	≤ 10
6	Kitchen and shower or kitchen and bathtub (150 l) Bathtub (200 l)	≥ 7,5 ≥ 7,5 -	≥ 12,5 - -	- ≤ 10 ≤ 10

Figure 2. CW values (based on Nuon 2013, p.6).

The three requirements of CW 4 are equal. To illustrate, mixing 7.5 litres hot tap water of 60 °C with 5 litres of 10 °C domestic water results in 12.5 l/min of 40 °C in the shower. The three requirements of CW 5 are different. To illustrate, to fill a bathtub of 150 litres within 10 minutes, 15 l/min of 40 °C is required. Mixing 9 litres hot tap water of 60 °C with 6 litres of 10 °C drinking water results in 15 l/min of 40 °C in the shower. Therefore, 9 l/min of 60 °C is normative instead of 7.5 l/min. Gas-fired boilers with CW value 6 are the only boilers that can simultaneously deliver to the kitchen and the shower/ bathtub without interrupting (Nuon, 2013).

4.2 Cost breakdown heat supply

ACM annually publishes the maximum tariffs for heat supply, the prices apply from 1 January to the following year with that date (Warmtewet 2017, article 5). However, suppliers are obviously allowed to charge lower tariffs. The maximum price of heat is determined by the integral costs of a typical natural gas consumer to obtain the same amount of heat by using natural gas as heat source (Warmtewet 2017, article 5). This means, for example, that depreciation costs of an individual gas-fired boiler are included in the maximum price. The maximum price consists of a fixed tariff which is expressed in euros and a variable tariff which is expresses in euros per gigajoule.

Moreover, in contrast to electricity and natural gas suppliers, heat suppliers do not only have supply costs but also network operation costs (Bennink & Benner, 2009). Currently, these network operation costs are paid to DSO's and TSO's which are responsible for a reliable and stable network. In the case of a DH system, suppliers become responsible for both the network and the supply of heat. In order to cover the (high) investment costs of connecting customers to a DH network, the supplier is allowed to charge a one-time connection fee. These connection costs consist of two parts, a basic fee and an additional fee per meter that only applies if more than 25 metres of tube has to be laid to connect a household. These maximum tariffs are based on the amount of money that a natural gas consumer must pay to be connected to the natural gas network (Warmtewet 2017, article 6). A heat supplier is allowed to charge a fee for the rent of a measurement device. These costs are comparable with the costs of a G6 meter. The Heat Act does not prescribe a maximum tariff for a delivery device (e.g. heat exchanger), but it must be a 'reasonable amount'. Table 2 shows an overview of the tariffs from 2014-2018.

Table 2. Tariffs heat supply 2014-2018 (based on data of ACM, 2018b).

Category	**2014**	**2015**	**2016**	**2017**	**2018**
Tariffs heat supply					
Fixed tariff heat supply (annually)	€ 254.00	€ 281.78	€ 276.13	€ 299.16	€ 309.52
Variable tariff heat supply (per GJ)	€ 24.03	€ 22.64	€ 22.66	€ 22.69	€ 24.05
Network operating costs					
Connection fee (one-time)	€ 911.78	€ 928.01	€ 962.95	€ 1,011.73	€ 1,037.78
Additional fee (one-time per meter tube)	€ 31.31	€ 32.51	€ 33.87	€ 32.27	€ 33.77
Fee delivery device (e.g. heat exchanger)	NA	NA	NA	NA	NA
Fee measurement device (annually)	€ 24.54	€ 24.78	€ 24.97	€ 25.02	€ 25.36

4.3 Price development of heat supply

The average natural gas consumption of a Dutch household was 1,300 Nm^3 in 2016 (Klimaatmonitor, 2018). L-gas has an upper value of 35.17 MJ/Nm^3 and an under value of 31.65 MJ/Nm^3, which results in approximately an average heat demand is 44.6 GJ per household. This means that an average household paid in addition to € 309.52 fixed supply costs, also € 1072.46 on variable supply costs. Figure 3 shows the development of the fixed tariff and the variable tariff for an average Dutch household between 2014 and 2018 (incl. VAT). The green line represents the total annual costs per household. Interestingly, prices fell slowly in the first three years after the introduction of the Heat Act. However, this pattern changed in 2018. In conclusion, heat supply tariffs increased by 4.26% in the last four years.

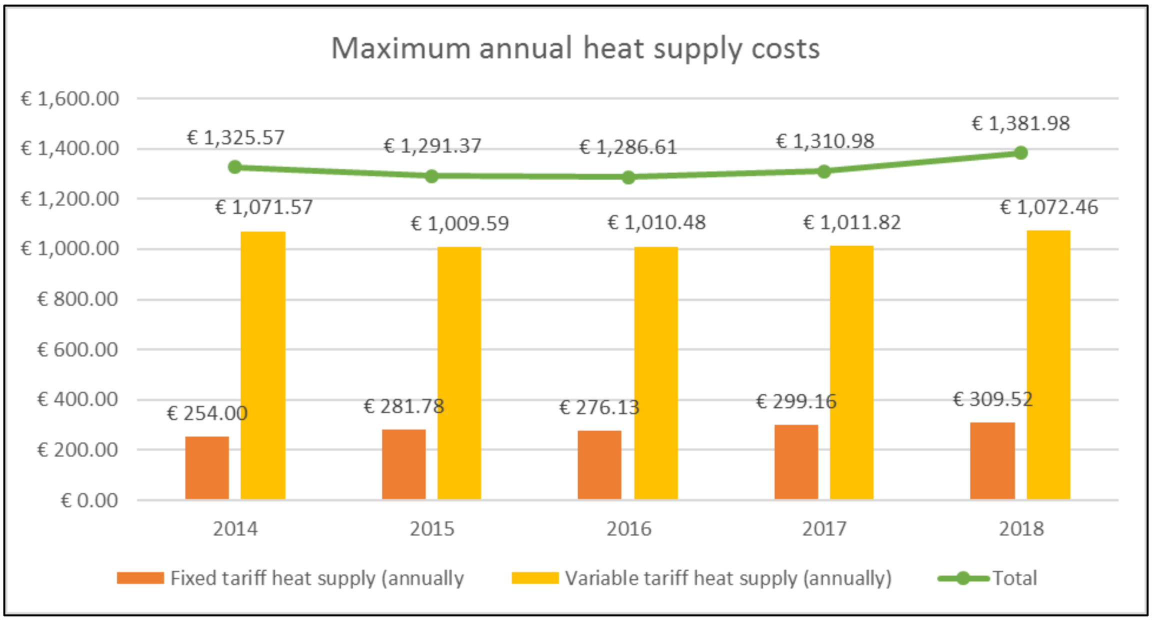

Figure 3. Price development annual heat supply 2014-2018 (based on data ACM, 2018b).

4.1.1 Evaluation Heat Act 2016

Ecorys (2016) assessed the instruments of the Heat Act on effectiveness and efficiency. The primary goal of the Heat Act was to protect customers, mainly by setting maximum tariffs and regulating the security of supply. The evaluation of Ecorys (2016) concludes that consumers with a connection up to 100 kWt are better protected after the introduction of the Heat Act than before. However, consumers are not totally satisfied with the Heat Act. Firstly, consumers disagree with the calculation method of maximum tariffs. The maximum tariff is based on the average natural gas consumer and not on their own specific situation. For this reason, many consumers perceive the tariffs for heat supply as too high. Secondly, consumers mention that aspects such as supply of cold and the tariffs for a delivery device (e.g. heat exchanger) are not adequately regulated. Thirdly, consumers are dissatisfied because they depend on a monopolist from whom they cannot switch. On the positive side, consumers are generally positive about the user-friendliness and comfort offered by a DH system.

5 Conclusion

The Heat Act was introduced in 2014 and regulates the heat supply of consumers with a connection up to 100 kWt. The Heat Act is related to four other regulations (delegated regulation): (1) decision invoice consumption and indicative cost overview energy, (2) arrangement to prove the source of renewable energy sources and HR-WKK electricity, (3) heat decision, and (4) heat regulation. The Heat Act applies to all suppliers, but it distinguishes permit holders and non-permit holders (articles 9 to 11). A supplier is legally obliged to apply for a permit unless the supplier (1) supplies heat to a maximum of ten consumers at the same time, (2) supplies a maximum of 10,000 GJ annually, or (3) is the owner or the lessor of the building. EcoGenie 2.0 aims to connect 100-200 households with an average heat demand of 56.8 GJ/year (without cooking). The break-even point is 175 households. Below 175 households, only the general provisions will apply. Above 175 households, both general and special provisions will apply. A permit can be obtained via an application form available on the ACM website.

The general provisions (articles 2 to 8B) apply to all suppliers. The special provisions (articles 9 to 12a) only apply to permit holders. Articles 9 to 11 prescribe three different criteria. The various organisational, financial, and technical requirements are stated in paragraph 3.1.1 and paragraph 3.1.2. However, all requirements can be summarised as: to protect consumers, considering the importance of a reliable, sustainable, environmentally sound, and efficient heat supply (Warmtewet, 2017, article 2.1). Articles 12b to 12d regulate the heat supply in case a producer or supplier intends to terminate the heat supply or production. Article 13 enables ACM to request data and information from producers, suppliers, and consumers for the implementation of this law and for the preparation of the energy report. Full cooperation is required. Articles 15 to 46 regulate the role of ACM. Moreover, a supplier is legally obliged to reimburse consumers € 35 per disruption of 4-8 hours and an additional reimbursement of € 20 per extra four hours.

ACM annually sets the maximum tariffs for heat supply to ensure that consumers do not pay more than usual and to ensure that suppliers do not earn more than a reasonable rate of return. 'Usual' refers to a household with a G6 meter, an individual gas-fired HR107 boiler with a CW value of 4 for hot tap water. The CW value is a measure of the volume and temperature of hot tap water that must be delivered per minute to (1) the kitchen, (2) the shower, and (3) the bathtub. It is important to note that these three requirements (within the CW value) are not always equal to each other. Furthermore, the CW value can be used as a measure to determine comfort.

The costs of a supplier can be divided into supply costs and network operating/connection costs. The heat supply tariffs have increased by 4.26% between 2014 and 2018. Ecorys (2016) evaluated the Heat Act in 2016. On the basis of their evaluation, three main points of dissatisfaction came to light: (1) the calculation method of the maximum tariffs is not right, (2) tariffs for the delivery device and the supply of cold is not adequately regulated, and (3) consumers do not want be dependent on a monopolist from whom they cannot switch. On the positive side, consumers are generally happy about the usability and comfort offered by a DH system.

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Appendix 3

Analysis case studies

Contents

1 Introduction

This appendix contains case studies to 'local P2H DH cooperatives' and related cases. As mentioned in chapter 4, the case studies one the one hand verify the theoretical aspects which are theoretically derived. On the other hand, new insights and new aspects are empirically derived from these case studies. Additional information of the process of case selection and the assessment method is included in paragraph 4.1 of the main report. Important to note, however, is that the selected cases are analysed in close relation to the aspects of the conceptual model that can be classified into four overarching aspects: (1) technical aspects, (2) economic aspects, (3) social aspects and (4) legal aspects. Table 1 shows the relation between the four (theoretical) overarching aspects and the five selected (empirical) cases.

Table 1. Relationship between theoretical aspects and empirical case studies.

Aspects / Case studies	Technical	Economic	Social	Legal
Thermo Bello in Culemborg	X	X	X	X
Mijnwater in Heerlen	X	X		
TexelEnergie on Texel			X	X
The customer journey of EBO Consult			X	
The recruitment strategy of Reggefiber			X	

Thermo Bello is a small-scale P2H DH cooperative that withdraws heat from a drinking water basin in Culemborg, the Netherlands. Thermo Bello currently supplies heat to 210 households and seven commercial buildings. Thermo Bello has been selected because it meets all selection criteria and serves as an example to EcoGenie 2.0. Mijnwater is a small-scale P2H DH company that supplies heat and cold from abandoned mining fields in Heerlen, the Netherlands. Mijnwater currently supplies heat to 270 households and nine commercial buildings. Mijnwater has been selected because the technical and economic aspects are related. Because Mijnwater has not a cooperative governance system, only the technical and economic aspects are included. TexelEnergie is an energy cooperative and a former small-scale DH cooperative that generated heat from biomass on Texel, the Netherlands. It supplied heat to 193 households. Because TexelEnergie used biomass instead of P2H technology, only the social and legal/organisational aspects are included. Because the case study on Mijnwater and the case study on TexelEnergie complement each other, two 'complete' case studies have been carried out.

Two other cases were added to get a better understanding of the social aspect. First of all, the customer journey of EBO Consult (Danish independent administration company specialised in managing DH companies) and secondly the marketing strategy of Reggefiber (a Dutch company that lays fibre optic networks). The customer journey is a tool to understand and optimise the customer experience during a DH project. The marketing strategy for fiber optic networks of Reggefiber can be used as a best practice for involving participants for a DH project.

The second chapter contains the case study on Thermo Bello in Culemborg. The third is about the case study on Mijnwater in Heerlen and the fourth chapter is about the case study on TexelEnergie on Texel. The fifth chapter describes the customer journey of EBO Consult and the sixth chapter the marketing strategy of Reggefiber. Finally, the seventh chapter concludes with the similarities and the differences. Moreover, it compares the theoretical aspects derived from literature with the empirical aspects found in the case studies.

2 Thermo Bello in Culemborg

Thermo Bello is a local DH cooperative owned by residents in the district Lanxmeer or EVA-Lanxmeer. EVA-Lanxmeer is located in Culemborg, a small town near Utrecht, the Netherlands. Dóci & Vasileiadou (2015) describe EVA-Lanxmeer as a very strong community where people know each other and collaborate to improve their local environment. For example, they manage their own public greenery, share cars and have their own decentralised water treatment and energy generation. Figure 1 shows a geographical overview of the neighbourhood.

Figure 1. Location EVA-Lanxmeer (Based on Google, 2018a).

Thermo Bello has grown into a company that supplies heat to 210 households and seven commercial buildings. The annual heat supply currently amounts to 1,245 MWh for households and 1,092 MWh for commercial buildings (Verschuur, 2018c). The total annual heat production is 2,660 MWh, which 9,576 GJ.

Paragraph 2.1 provides a brief introduction to the history and motivations of the district EVA-Lanxmeer and Thermo Bello. Paragraph 2.2 analyses the technical, economic, social and legal/organisational aspects of the DH cooperative Thermo Bello. Finally, paragraph 2.3 mentions some lessons that have been drawn from the establishment and operation of Thermo Bello.

2.1 History and motivations

In 1994, the foundation Ecological Centrum for Education, Information and Advice (in Dutch: *Ecologisch Centrum voor Educatie, Voorlichting en Advies, EVA*) took the initiative to realise an ecological living and working area. Moreover, they wanted to be a "*living example in development*" by sharing the acquired knowledge and experiences to others (BEL Lanxmeer, n.d.). The main motivation behind this initiative was the publication of the Brundtland report (1987) and the increasing environmental awareness. The foundation formulated three goals (BEL Lanxmeer, n.d.):

1. An environment where people are concerned with their environment, which can help to shape their own existence.
2. An environment where solutions for environmental issues are visible and healthy ecosystems can emerge.
3. An environment where more conscious lifestyles can arise.

The municipality of Culemborg was receptive for the EVA concept because it was very innovative and sustainable. This resulted in an early collaboration between EVA and the municipality. From 1996 the EVA foundation was not only the initiator and advisor of the municipality, it became the 'hinge' between top-down and bottom-up planning (BEL Lanxmeer, n.d.). In 2000, the first phase of the neighbourhood was realised, the realisation of the other four phases followed quickly. At the moment about 800 people (300 households) live in Eva-Lanxmeer (Dóci & Vasileiadou, 2015).

Originally, the *Trias Energetica* concept was used in the development of the neighbourhood. The maximum required energy consumption of households was set at 40 GJ per year (BEL Lanxmeer, n.d.). Furthermore, households installed solar PV at their rooftops to generate their own electricity. The first two construction projects (Nesciohof and Vasalishof), were built with an individual gas-fired boiler for space heating. In 2002, the water company Gelderland and Core International took initiative to develop a DH system. This was done in collaboration with the municipality and residents, all houses and even some commercial buildings built after 2002, are connect to this DH system. However, after the water company merged with NUON water (which became Vitens), it wanted to sell its subsidiary. Although Vitens was willing to sell the DH system below its market value, they could not find any buyers, even the municipality did not show any interest (Nesciohof and Vasalishof).

Fortunately, four local residents saw the potential of the DH system and decided to investigate the possibility of acquiring and establishing a local DH heating cooperative. A first step was taken by setting up of a business development association (in Dutch: Vereninging Ontwikkeling Explotatie Warmtenet, VOEW). Local inhabitants could become member of this association. 68 people joined this association and four working groups (financial, organisational, communication and technology) of each 5-6 people worked on a feasibility study and a business plan (Nesciohof and Vasalishof). This group consisted of very positive people as well as people who were really sceptical (Verschuur, 2010). In 2008, the association presented their plans to the community and the large majority was very positive. In the same year, Thermo Bello BV was founded, which acquired the DH system from Vitens on 1 April 2009 (Verschuur, 2010). Thermo Bello started with the heat supply of 170 households and seven commercial buildings. Thermo Bello formulated three goals (Thermo Bello, 2018):

1. To supply heat in the neighbourhood EVA-Lanxmeer without interruptions by sustainable exploitation and optimisation of installations that produce or distribute heat at costs that are less than or equal to a competitive method of heat generation.
2. To develop, exploit and optimise the application of sustainable energy and energy saving in Culemborg.
3. Collecting and sharing knowledge of local energy production and energy saving.

2.2 Analysis technical, economic, social and legal/organisational aspects

Paragraph 2.2.1 describes the technical aspect and starting points of the DH system. Paragraph 2.2.2 explains how the DH system is financed and describes the supply tariffs. Paragraph 2.2.3 describes the social aspects, in particularly how the initiators raised trust among local residents. Finally, paragraph 2.2.4 describes the legal and organisational aspects. It describes the legal form, the voting structure and how the work/roles are divided among staff members and volunteers.

2.2.1 Technical aspects

Thermo Bello only supplies heat supply for space heating because by the time Thermo Bello started only low-temperature heat pumps existed. The primary installation is an industrial water-sourced heat pump that withdraws heat from a drinking water basin of Vitens. The drinking water basin of Vitens is located in the middle of EVA-Lanxmeer and used to supply drinking water. The total capacity of the water basis is two million m^3 water per year, with a maximum of 300 m^3 water per hour. The total capacity of the heat pump is 780 kWth at full load. The peak load is dimensioned on -10 ˚Celsius and a simultaneity factor of 0.53 is applied (G. Verschuur, appendix 5 of the main report). The heat pump can operate from 20% of the total capacity (Verschuur, 2010). The average annual COP was 3.64 in 2016 while the target is to achieve an average annual COP of 4.7 (Verschuur, 2011 and Verschuur 2018c). Figure 2 shows how the installation operates.

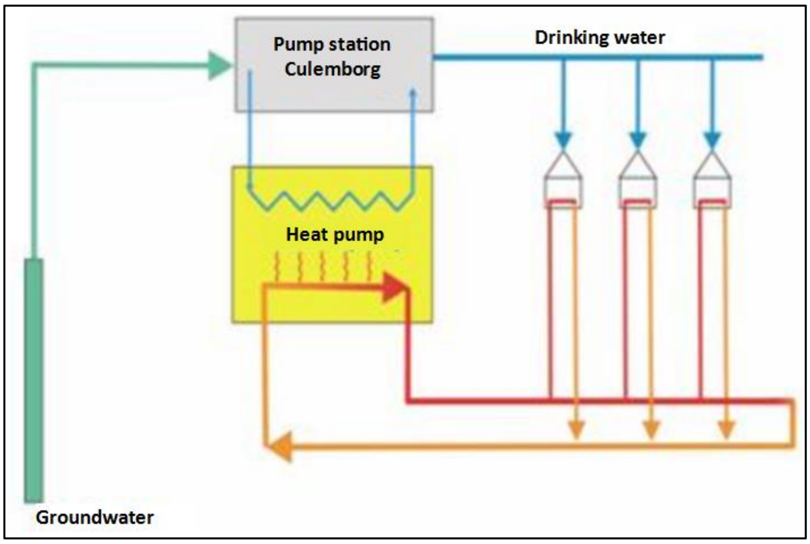

Figure 2. Operation water-sourced heat pump Thermo Bello (based on Thermo Bello, 2018).

The heat pump is complimented with two industrial gas-fired boilers with a capacity of each 500 kWth, the secondary system. The boilers start operating when the heat demand exceeds the capacity of the heat pump or in case of maintenance work (Thermo Bello, 2018). The system is bivalent because it operates with a boiler which is fired on a different energy carrier. In 2016, the heat pump supplied 2,347 MWh (87.1%) and the gas-fired boilers supplied 349 MWh (12.9%). The annual gas consumption was 37,758 Nm^3, which caused 501 tonnes CO_2 emissions (Verschuur, 2018c).

The heat is produced on a variable heating curve that is related to the outdoor temperature. The maximum water temperature is 50 °C at an outdoor temperature of -10 °C (Verschuur, 2010). On the other hand, the heat temperature is usually below 50 °C due to the variable heating curve, which means that consumers need another source (gas-fired) to supply heat for hot tap water. In addition, Thermo Bello invested in solar PV to contribute to the energy transition (Verschuur, 2010). The generated electricity is sold to a local urban farm, called Caetshage.

Different (individual) systems are used to generate hot tap water. At this moment Thermo Bello experiments with (individual) booster heat pumps that raise the temperature from 50 to 60 °C. The booster heat pumps operate with an average COP of 5 and the investment costs are around € 3,000 (G. Verschuur, appendix 5 of the main report). In addition, commercial parties use the DH network to release heat during hot weather to cool their buildings.

The electricity supplier of Thermo Bello is Vitens because Vitens is a large-scale consumer of electricity and able to purchases their electricity at the wholesale market without the intervention of a trader. Thermo Bello and Vitens agreed that Thermo Bello can purchase the electricity at the procurement price (Verschuur, 2010). This means that Thermo Bello can purchase relatively cheap electricity. Vitens also has a diesel generator to guarantee their electricity supply and to use it in times of high electricity prices. This also contributes to the security of supply of Thermo Bello. The supplier of (compensated) natural gas is Greenchoice since 2010.

The total CO_2 footprint has recently been calculated and compared to individual gas-fired boilers, the result being that the CO_2 footprint of both seems very similar. According to G. Verschuur (appendix 5 of the main report), the only option to reduce CO_2 emissions of P2H DH systems is to feed them with 'real green electricity' such as wind energy.

DH network

Thermo Bello has two (electric) distribution pumps which pump the water through the supply and return pipes to and from the production plant. In addition, each house has an individual pump to pump the water through the house. In 2009, these two electric pumps were responsible for 22% of the total electricity demand (Verschuur, 2010). The velocity depends on the heat demand. Thermo Bello calculated the distribution loss on 7%. However, an additional distribution loss of 9.5% was recorded in 2009. This distribution loss was caused by poorly insulated pipes in the crawl spaces of households. In response, a neighbourhood working group was founded to reduce the water level in crawl spaces to reduce the additional distribution loss. The average distribution loss was 13.3% in 2016 (Verschuur, 2018c).

2.2.2 Economic aspects

The total investment costs of Thermo Bello were around € 3,00,000 (Verschuur, 2018b). The investment capital is composed of various sources, such as: bank loans, private investors (Greenchoice and DEC), subsidy of the province and capital of three directors. The average annual turnover is € 250,000 and the profit was € 23,000 in 2016 (Verschuur, 2018c). However, private investors were mainly focused on profit rather than other benefits from Thermo Bello. Therefore, Thermo Bello issued depositary receipts with a fixed value of € 250 and a 4% dividend to local residents. According to G. Verschuur (appendix 5 of the main report) a major advantage was that benefits of Thermo Bello became circular, local profits remain local and can be invested locally. The current debt is € 42,500 of which is € 6,000 from the neighbourhood association.

The most recently published heat supply tariffs of Thermo Bello are from 2015. Table 2 shows a cost breakdown of the heat supply tariffs of Thermo Bello and a comparison with the maximum tariffs of ACM. The fixed and variable tariffs of heat supply are equal. Thermo Bello includes the measurement fee in the costs for the delivery device, in total € 102 per year.

Table 2. Cost breakdown heat supply Thermo Bello (based on Thermo Bello, 2015).

Category	Thermo Bello (2015)	ACM (2015)
Tariffs heat supply		
Fixed tariff heat supply (annually)	€ 281.78	€ 281.78
Variable tariff heat supply (per GJ)	€ 22.64	€ 22.64
Network operating costs		
Connection fee (one-time)	NA	€ 928.01
Additional fee (one-time per meter tube)	NA	€ 32.51
Fee service, maintenance and rent delivery device (annually)	€ 102.00	NA
Fee measurment device (annually)	NA	€ 24.78

2.2.3 Social aspects

To get public support, four aspects were investigated: (1) technical, (2) economic, (3) social and (4) cultural. The technical requirement was to guarantee the heat supply of consumers. Furthermore, a requirement was that it could be reasonably expected that the installations of Vitens would continue to function properly. In fact, Thermo Bello recorded zero errors and disruptions in 2016 (Verschuur 2018c). The financial requirement was to have a closed operating budget (in Dutch: *exploitatiebegroting*). The social requirement was that local residents could play an active role in the decision-making process and ultimately vote for the takeover. The cultural requirement was that it strongly contributes to the energy ambition of the neighbourhood, the profit is limited and the local residents have an influence on the development of the company (Verschuur, 2010).

As mentioned previously, four local residents started the initial exploration. However, the local community association did not fully trust the initiative which caused problems. In response, the team of four decided to expand and to involve more people from the neighbourhood to increase trust. The association VOEW was established and in a short period 68 people signed up voluntarily (Verschuur, 2010). After presenting the business case, the opinion of local residents was asked by a written survey. The survey concluded that a majority of local residents trusted the process which provided a solid starting point for voting on the takeover. In addition, the initiators have drawn up a program of requirements (in Dutch: *programma van eisen*) to make the idea understandable and accessible to everyone without getting bogged down in detail (Verschuur, 2010). In total ten starting points have been formulated.

The strength of the establishment of Thermo Bello was our open mindset (G. Verschuur, appendix 5 of the main report). We founded a business development association (VOEW) with the goal to explore and investigate if a takeover would be realistic and (economic) feasible). The primary goal was not a takeover.

2.2.4 Legal and organisational aspects

Thermo Bello is a private company with limited liability (in Dutch: *Besloten Vennootschap, BV*), founded in 2008. In 2010, a new association was established, the Stichting Administratiekantoor, which holds 100% of the shares (Verschuur, 2010). In 2013, the cooperative Thermo Bello UA was established and 100% of the shares were sold to this cooperative (Verschuur, 2018a). The association has issued certificates of shares, that are shares without voting rights. The voting rights are distributed among representatives of the various categories of the board of the association. Important to note is that the loans from private investors (Greenchoice and DEC) have been paid off, which also means that they no longer have voting rights. This approach enables decision-making in a smaller group which limits the risk of indecision and increases effectiveness. Figure 3 shows how the voting structure of Thermo Bello was organised.

Figure 3. Voting structure Thermo Bello (Verschuur 2010, p.10).

The total amount of voting rights was fifteen. The categories are: (1) private consumers and investors, (2) commercial consumers and investors, (3) neighbourhood association and investor BEL, (4) business partner and investor DEC, (5) business partner and investor Greenchoice and (6) the board. The majority of voting rights (eight) belong to consumers, which means that decisions are ultimately not taken by commercial parties, but by local residents.

The association has appointed a supervisory board to control and advice the executive board. The main reason for this was that there were too many tasks and too few staff members (Verschuur, 2010). In fact, the exploitation of a small DH system is financially not capable to hire sufficient staff members. A lack of time can lead to important mistakes. A supervisory board is a way to prevent this. Currently, Thermo Bello has three part-time staff members (0.6 FTE), including the director (Verschuur, 2018c). Table 3 shows the roles in the company Thermo Bello. It is an understatement that Thermo Bello is supported by the experience and willingness of volunteers, especially in the exploratory phase.

Table 3. Overview roles Thermo Bello (based on Verschuur 2018a).

Thermo Bello BV	**Cooperative Thermo Bello UA**
Director	Chairmain
Production station manager (2x)	Secretary
Data analyst (volunteer)	Treasurer
Reporter for energy balance reports (volunteer)	
Technical advisor (volunteer)	

Maintenance of the installations and pipelines is outsourced to specialised companies. A local administration office does the accounting. Greenchoice is responsible for the (financial) administration of private customers. The (financial) administration of commercial customers is done in-house (Verschuur, 2010).

Thermo Bello is not legally obliged to apply for a permit at ACM because it has an annual heat supply of 9,000 GJ which is below the required 10,000 GJ (Verschuur, 2018a).

2.3 Lessons

Below is an overview of lessons learned during the establishment and operation of Thermo Bello.

- There is a big gap between the design phase, the construction phase, and the operation phase of a DH system. Various contractors and consultancy companies design and construct different parts without having an overview of the total system, which can easily lead to mismatches between various parts of the DH system. This makes that the owner remains responsible for the integration of all aspects. To avoid this situation, it might be better to purchase a certain service instead of a certain product. Installations really need to be checked before completion and operation (G. Verschuur, appendix 5).
- The debate about the legal form has once again made clear local residents ultimately trust people, not structures (Verschuur 2010, p.15).
- It was very important that we (the initiators) did not request permission for acquisition in the early stages of the feasibility study. We only asked permission to carry out an in-depth feasibility study and acknowledged the option that it would not be realistic to take over (Verschuur 2010, p.34).
- Good communication is vital. Embrace resistance of local residents, because in most cases, resistance is based on knowledge and previous experiences. Residents want to see their problems and fears (risks) reflected and dealt with in the business plan (G. Verschuur, appendix 5 of the main report).
- The ratio between fixed and variable costs can be used as a financial incentive for consumers to save energy, ultimately contributing to (national) climate goals (Verschuur 2010, p.29).
- In the establishment of Thermo Bello, four phases can be distinguished (exploration, feasibility study, business development, and start-up). It is important to finish each phase with a milestone, thus keeping the focus on what has been done and what needs to be done. It also helps people who are less involved to keep track of the process (Verschuur 2010, p.38).

3 Mijnwater in Heerlen

Mijnwater BV is a DH company that extracts heat and cold from abandoned mining fields by means of large heat pumps. Mijnwater is active in Heerlen, a city near to Maastricht, the Netherlands. According to Verhoeven et al. (2014) Mijnwater is one of the most successful projects that developed abandoned mining areas into low-temperature sources of the European Union. Although Mijnwater uses mine water as primary source, it is not limited to mine water and able to apply the (P2H) DH system elsewhere (L. Hiddes, appendix 5 of the main report). In a nutshell, Mijnwater has five wells (sources): two hot sources in the Northern part of Heerlen, two cold sources in the Southern part of Heerlen and a fifth source in between to inject the cooled hot and warmed cold mine water. Figure 4 shows a geographical overview of the Mijnwater project.

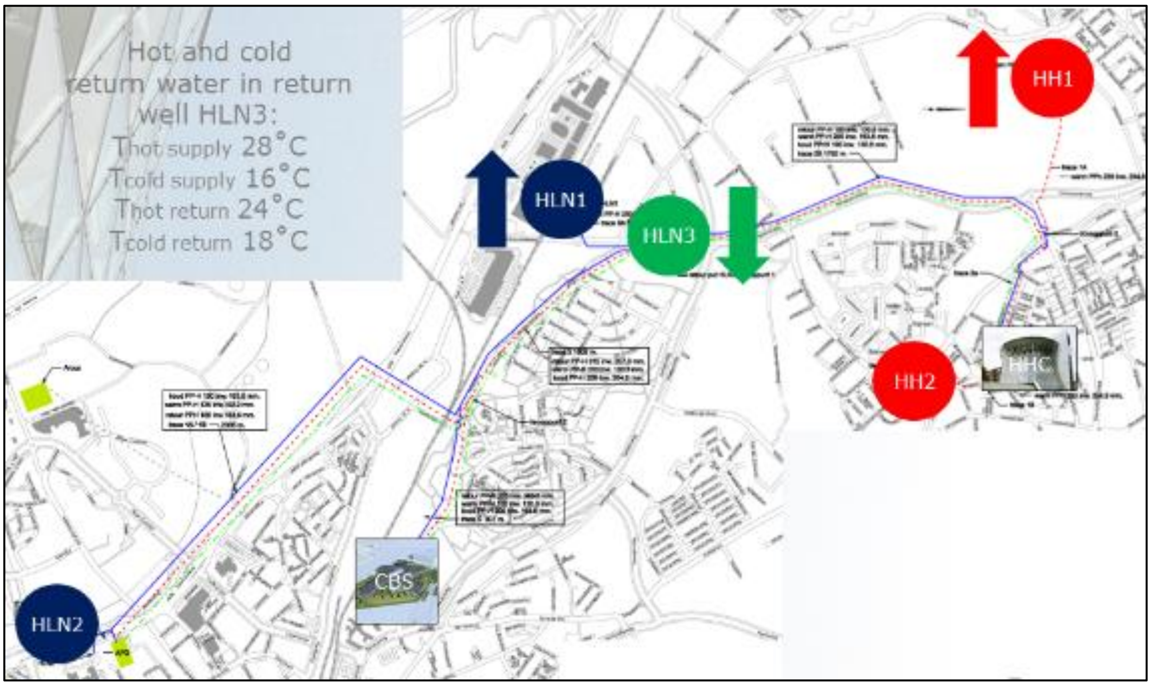

Figure 4. Geographical overview Mijnwater 1.0 (Mijnwater, 2018).

The heat and cold supply from abandoned mining fields started in 2008 as an initiative of the municipality Heerlen. In 2013, the independent company Mijnwater BV was established to let the initiative grow to a fully-fledged sustainable energy company. The company supplies heat to nine commercial buildings (several offices, (primary) school, day nursery, sports hall, supermarkets) and 270 households. Mijnwater currently supplies heat/cold to approximately 200,000 m^2 of floor area (Mijnwater, 2018b).

Paragraph 3.1 provides a brief introduction to the history and the motivations behind Mijnwater. Paragraph 3.2 analyses the technical and economic aspects of Mijnwater. Finally, paragraph 3.3 describes two important lessons learned from the establishment and operation of Mijnwater.

3.1 History and motivations

As mentioned in the introduction, the initiator of Mijnwater was the municipality Heerlen. In 2003, the municipality investigated the potential of extracting heat from abandoned mining fields. The heat/cold supply already started in 2008. Mijnwater has been developed in three stages: (1) Mijnwater 1.0, (2) Mijnwater 2.0 and (3) Mijnwater 3.0. Mijnwater 1.0 refers basically to the development of the five wells, the DH network and the first connections, for example the connection with the office of the Central Statistical Office of the Netherlands. In 2012, a new concept was developed (Mijnwater 2.0) which is based on energy exchange instead of energy supply and eenergy storage/buffering in mine water reservoirs instead of exhaustion. Mijnwater 3.0 refers to a further development to create a 'demand system' which recognises demand patterns over time. This means that the demand can be forecasted by customer patterns and the weather forecast, resulting in higher efficiency (Mijnwater, 2018b).

In the meantime, Mijnwater wants to grow into a large-scale supplier in the coming years. A new district of 309 households will be connected to the DH network. Subsequently, by the end of 2018, construction work will begin to connect another 2,000 households and another 9,000 households in the following years (Mijnwater, 2018a).

The initial motive of the municipality Heerlen was to reduce energy consumption and increase the generation of sustainable energy. In addition, the project contributes to the climate goals of the municipality: 20% CO_2 emissions reduction by 2020 and to become energy neutral by 2040 (gemeente Heerlen, 2018). The energy company Mijnwater has formulated several goals Mijnwater 2017a, p.4):

1. To use the infinite geothermal resources.
2. To provide a significant cost-effective contribution to the CO_2 emissions goals of the region.
3. To strengthen the image of a sustainable and innovative region.
4. To stimulate local employment and autonomy.
5. To create a feasible business case for Mijnwater BV.
6. To anchor knowledge in the region by cooperating with local educational and research institutions.
7. To strengthen social involvement and to increase environmental awareness of local residents.
8. To accelerate EU's energy transition through cross-border knowledge exchange and cooperation.

In addition, Mijnwater is aware of the national government's decision to quit natural gas consumption. An important motive is therefore to offer an alternative solution for natural gas consumption.

3.2 Analysis technical and economic aspects

This paragraph analyses the technical and economic aspects of the (P2H) DH system of Mijnwater. Paragraph 3.2.1 includes the technical aspects and paragraph 3.2.2 includes the economic aspects.

3.2.1 Technical aspects

The two Northern wells have a depth of 700 metres below surface and extract water with a temperature of 28 °C. The two Southern well have a depth of 250 metres below surface and extract water with a temperature of 16 °C. The fifth well in the middle of Heerlen has a depth of 350 metres and injects water with intermediate temperatures between 18 and 22 °C (Verhoeven et al., 2014). Fourteen industrial water-sourced heat pumps have been installed to withdraw heat from the mine water. In practise, most of the times only 3-4 heat pumps usually operate (L. Hiddes, appendix 5 of the main report). The heat is produced on a variable heating curve that is related to the weather forecasted. The average COP for (space) heating is 6 and the average COP for (space) cooling is 6.5.

The heat pumps are complemented with residual heat from local companies. For example, APG's data centre and Jumbo's refrigerators/freezers are used as a heat source. This interconnection with a variety of different (local) sources and the storage/buffering of heat in mine water is according to L. Hiddes (appendix 5 of the main report) enough back-up. The system can more or less be categorised as bivalent because it uses a different energy carrier (residual heat) to complement the heat pumps.

Households that are connected to the DH system no longer have natural gas connection. The households are heated and cooled with a low-temperature system. Individual booster heat pumps are used to generate hot tap water with a minimum temperature of 60 °C (Mijnwater, 2017b). The average COP of heat pump boosters is 5.5 (L. Hiddes, appendix 5 of the main report).

Mijnwater contributes to the reduction of CO_2 emission, the aim is to reduce CO_2 emission by at least 65% by 2030 compared to individual gas-fired boilers (Mijnwater, 2018b). This difference is realistic because on the one hand the DH system works at high COP values. On the other hand, Mijnwater currently installs solar PV on roofs to generate renewable electricity for feeding their heat pumps. This also contributes significantly to the reduction of their carbon footprint.

DH network

Mijnwater uses a three-pipe pipelines to distribute heat and cold from the wells to the place of consumption, the so-called mine water backbone. The firsts pipe delivers hot water (insulated), the second pipe delivers cold (non-insulated) and the third pipe returns the used mine water (non-insulated). The total length of the distribution system is around 7.8 kilometres (Verhoeven et al., 2014).

3.2.2 Economic aspects

Figure 5 shows a cost breakdown of all three business cases (1.0, 2.0 and 3.0) of Mijnwater compared to the conventional situation of an individual gas-fired boiler. First of all, it shows that the fuel costs significantly dropped over the years. Mijnwater is therefore able to spend € 14.90/GJ (62%) on Capex/Opex and € 9.10/GJ (38%) on fuel costs. It is estimated that the 'demand system' will lead to further fuel costs reduction, only € 5.00/GJ. In fact, this means that about 79% of the income can be used for Capex/Opex and only 21% is needed for fuel costs.

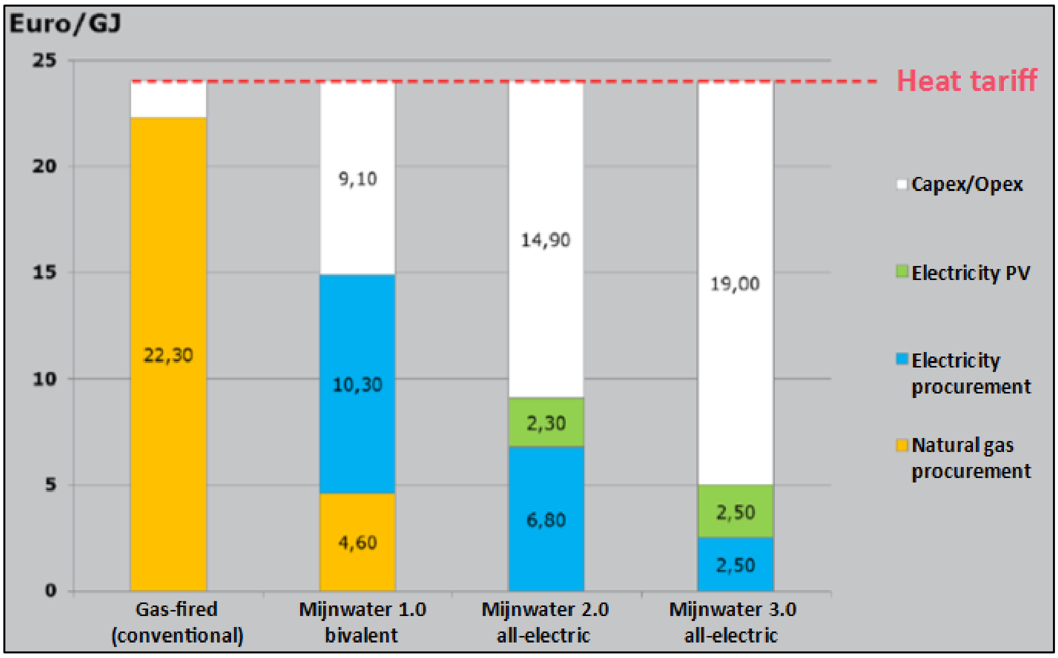

Figure 5. Cost breakdown heat supply costs Mijnwater (based on Mijnwater 2017a, p.7).

The tariffs of Mijnwater are aligned to the maximum supply tariffs of heat supply, set by ACM. Moreover, the amount that a household has to contribute to being connected (connection fee) depends on the energy demand of a household. According to L. Hiddes (appendix 5 of the main report) higher energy demand requires higher capacities, which in turn lead to higher investment costs. Mijnwater chooses to reflect these higher investment costs in the connection fee, which can be seen as an example of the well-known principle: 'the polluter pays'.

3.3 Lessons

Below is an overview of lessons learned during the establishment and operation of Mijnwater.

- Be very careful with the advice/advisory reports of installers/installation companies. Heating and cooling are very complex matters. Therefore, an understanding of the entire system and the entire process is required (L. Hiddes, appendix 5 of the main report).
- It is important to be aware that in the current situation (individual gas-fired boiler), efficiency losses (in Dutch: *rendementsverliezen*) of space heating and hot tap water occur behind the meter. In contrast, efficiency losses in a DH system occur before the meter (L. Hiddes, appendix 5 of the main report).

4 TexelEnergie on Texel

TexelEnergie is a local energy cooperative established by inhabitants of the island Texel, the Netherlands. According to J. Kuiken (appendix 5 of the main report) there is a certain sense of community and ownership on Texel. For example, the ferry is to Texel is called: Texel's own steamship company (in Dutch: *Texels Eigen Stoomboot Onderneming, TESO).* TexelEnergie is located in the village Oudeschild, but is active on the entire island. In fact, people throughout the Netherlands become customer. TexelEnergie procures and supplies sustainable energy. Moreover, TexelEnergie produces locally renewable energy with solar PV (TexelEnergie, 2018). TexelEnergie operated a small DH system between 2007 and 2017 in the district 'Wijk 99', part of the village Den Burg. The DH system was owned by TexelEnergie and supplied heat to 93 households (Schwencke, 2016). Figure 6 shows the geographical location of Wijk 99.

Figure 6. Location Wijk 99 (based on Google, 208b).

The DH system initially operated by gas-fired boilers. In 2014, TexelEnergie replaced the gas-fired boilers with a biomass heating system (in Dutch: *biomassakachel*). The biomass heating system had a capacity of approximately 200 kWt and converted wood chips into heat. It supplied heat for space heating and hot tap water. Due to various circumstances which are explained in paragraph 4.1 the heat supply has been terminated.

Paragraph 4.1 provides a brief introduction to the history and motivations of TexelEnergie and the DH system in Wijk 99. Paragraph 4.2 analyses the social and legal/organisational aspects of the energy cooperative TexelEnergie. Finally, paragraph 4.3 mentions some lessons that have been drawn from the establishment and operation of the energy cooperative TexelEnergie.

4.1 History and motivations

In 2007, all five Wadden Sea Islands of the Netherlands jointly signed a covenant. Their ambition is: "*all Wadden Sea Islands will be completely self-sufficient in terms of a sustainable energy and water supply by 2020*" (Weerdhof 2011, p.4). In addition, the municipality of Texel is committed to: "*a clean, quiet and energy independent* island" (Elswijk 2010, p.2). The *Trias Energetica* concept is used to realise their ambitions. In the same year, a former politician made the statement: '*Once Texel has its own energy company, why should not we do it again?*' (TexelEnergie, 2018). This statement was the starting point for the establishment of the energy cooperative TexelEnergie. Twelve inhabitants have pursued this ambition and already on 7 November 2007, the energy cooperative TexelEnergie was officially established. As far as is known, TexelEnergie is the first energy cooperative of the Netherlands (TexelEnergie, 2018). After the establishment TexelEnergie, their first priority was to draw up the statutes and formulate their mission. The mission of TexelEnergie is formulated in four goals which are included in their statutes (Coöperatie TexelEnergie U.A. 2010, p.1):

1. Procurement and supply of sustainable energy.
2. Producing sustainable energy.
3. Promoting energy saving.
4. Collaborating with like-minded people.

The first activity of TexelEnergie was the procurement and supply of green electricity. The HVC waste treatment plant in Alkmaar converted domestic waste into (green) electricity. TexelEnergie then also started with the procurement and supply of compensated gas (green gas). In addition, TexelEnergie has carried out various projects with solar PV, smart grids and a biomass heating system. According to J. Kuiken (appendix 5 of the main report) TexelEnergie currently aims to produce sustainable energy itself and reduce/terminate the procurement.

In 2007, the housing corporation of rented houses in the district Wijk 99 let their residents choose whether they wanted heat from a DH system or an individual gas-fired boiler. The residents preferred a DH system and the housing corporation realised a DH system (gas-fired) in the district Wijk 99. As a result, the housing corporation had to act as an energy company and began to invoice heat (J. Kuiken, appendix 5 of the main report). The establishment of TexelEnergie was an excellent opportunity for the housing corporation to transfer their activities concerning energy to TexelEnergie.

TexelEnergie took over the invoicing of heat, but the DH system was obviously not sustainable. Therefore, TexelEnergie examined the possibility of replacing the gas-fired boilers with a biomass heating system. Finally, after a long process, the biomass heating was installed in 2014. In theory, the local forest management could provide enough wood chips from their waste, but in practice this was much more complex (J. Kuiken, appendix 5 of the main report).

In January 2014, the national government introduced the NMDA principle, the maximum supply tariff was set at € 24.03/GJ. In contrast, TexelEnergie used to invoice the actual costs, about € 38/GJ. This price gap led to a new investigation into the quality of the DH network. The DH network was found to have a large distribution loss of about 50%. First of all, it was too expensive to repair all leaks. Moreover, the introduction of the NMDA principle and the complexity with wood chips resulted in the termination of the exploitation of the biomass heating system in 2016 (J. Kuiken, appendix 5 of the main report). In consultation with the residents, the housing corporation has installed individual gas-fired boilers. The residents were particularly pleased with the fact that they could switch between energy suppliers.

4.2 Analysis social and legal/organisational aspects

This paragraph analyses the social and legal/organisational aspects of the energy cooperative TexelEnergie. Paragraph 4.2.1 includes the social aspects and paragraph 4.2.2 includes the legal/organisational aspects.

4.2.1 Social aspects

The local energy cooperative TexelEnergie fulfils two roles: supplier of (sustainable) energy and precursor by looking for ways and carrying out projects to transform the current energy system. Initially, TexelEnergie was, as energy supplier, clearly accepted by a certain part (early adapters) of the population of Texel. As an illustration, after the establishment of the cooperative was published, applications came in daily. Even so much that volunteers could barely process it (TexelEnergie, 2018). However, it is according to J. Kuiken (appendix 5 of the main report) much harder to recruit the majority of the population as an energy supplier that only wants to supply sustainable energy. The main motivation of the majority is economic, namely the supply tariff. In addition, many people prefer TexelEnergie because it has a 'front door'. Instead of calling to a call center, people can easily visit the local office, which much more personal and accessible (J. Kuiken, appendix 5 of the main report).

J. Kuiken (appendix 5 of the main report) pointed to a strong social aspect of a local energy cooperative compared to a major energy supplier. A local energy cooperative knows its customers more personally and knows when people face problems with paying their energy bills. It has already happened several times that TexelEnergie protects people against long debtors' trajectories and high fines by guiding them well. This way TexelEnergie avoided many problems. On the other hand, the default risk (in Dutch: *debiteurenrisico*) is a much larger challenge for small energy suppliers then large energy suppliers. Large energy suppliers have more customers, which means that the risk is more spread and the financial consequences/impact falls.

TexelEnergie, as a precursor, has an open and participatory process. Both social and economic benefits are returned to the community. TexelEnergie regularly organises information meetings to inform members and interested parties. People can become a member by buying a share with a fixed value of € 50, which gives people the right to vote. However, J. Kuiken (appendix 5 of the main report) states that the role as precursor also leads to resistance and tension. For example, people threaten to terminate their membership if they do not agree with certain (sustainable) alternatives. The strategy of TexelEnergie to increase acceptance and gain trust is time and time again organising information meetings. These meetings help to answer all questions satisfactorily and to remove any concerns.

4.2.2 Legal/organisational aspects

TexelEnergie is cooperatively organised with excluded liability (in Dutch: *uitgesloten aansprakelijkheid, UA*) which means that the members cannot be held liable. According to B. de Graaf (former director) TexelEnergie is cooperatively organised because of two reasons. On the one hand to involve the population as much as possible in the developments. On the other hand, to prevent the company from being taken over by a larger player in the future (TexelEnergie, 2018).

TexelEnergie is community owned. Citizens and businesses can support the mission of TexelEnergie (financially) by buying a share. TexelEnergie does not pay dividend. All members (eighteen years or older) have the right to vote. There are no exceptions, one vote per person (J. Kuiken, appendix 5 of the main report). TexelEnergie has a total of 2.5 FTE (including the director) who are responsible for all activities, except invoicing which is outsourced.

4.3 Lessons

Below is an overview of lessons learned during the establishment and operation of the DH system in Wijk 99.

- An energy cooperative has to be able to pay its bills (in Dutch: *de schoorsteen moet roken*). Projects must be economically viable or become economically viable within a reasonable period of time. Both the innovative and the commercial aspects are equally important (J. Kuiken, appendix 5 of the main report).
- Choose your partner organisations carefully. Because the primary organisation is always the contact of the customer and responsible, even if a partner organisation (secondary organisation) makes a mistake. In addition, cooperation with partners often decreases the recognisability of the primary organisation (J. Kuiken, appendix 5 of the main report).
- Document all agreements with third parties, because it can prevent disagreements later on in the project (J. Kuiken, appendix 5 of the main report).

5 The customer journey of EBO Consult

EBO Consult is a Danish independent administration company specialised in managing DH companies. Their focus is to secure cheap, sustainable and professional solutions in the management and operation of DH systems, while achieving a high level of security of supply and customer satisfaction (EBO Consult, 2018). EBO Consult uses the ‘customer journey’ to evaluate DH projects internally (Krabsen, 2016). According to Richardson (2010, p.2) a customer journey is: “*a diagram that illustrates the steps your customer(s) go through in engaging with your company, whether it be a product, an online experience, retail experience, or a service, or any combination*”.

5.1 The customer journey map

EBO Consult uses the customer journey as an internal evaluation tool to evaluate DH projects after completion. It is used on the one hand to understand the customer's point of view and on the other hand to optimise the customer journey. It identifies the so-called ‘meeting points’ between the cooperative and customers. As a result, meeting points can be optimised and excess meeting points can be removed (J. Krabsen, appendix 5 of the main report). Figure 7 shows the customer journey map of EBO Consult.

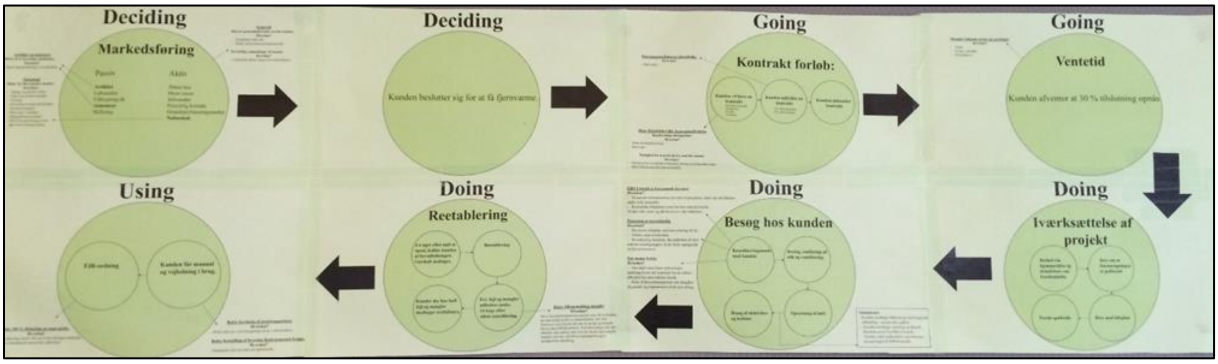

Figure 7. Customer journey map (Krabsen 2016, p.3).

A new customer of a DH system faces eight situations which can be categorised in four phases (Krabsen, 2016):

1) Deciding: the customer decides whether or not he wants to be connected to the DH system.
2) Going: the customer has decided to receive heat from the DH system.
3) Doing: installation of a DH connection (e.g. heat exchanger) in the customer’s house.
4) Using: the customer receives heat from the DH system).

The deciding phase consists of two situations. Firstly, the DH company organises a marketing campaign. Passive marketing strategies (e.g. articles, web pages or advertisements) and active marketing strategies (e.g. open house, information meetings or personal meetings) can be used (Krabsen, 2015). Secondly, the customer decides whether or not he wants to be connected to the DH system. The going phase consists of two situations. Firstly, the consumer signs a contract. Optionally, customers can opt for additional services such as an energy loan or technical support. Secondly, the customer needs to wait. A DH project only starts when 30% of the households accept (Krabsen, 2015). The doing phase consists of three situations. Firstly, the consumer receives a message to confirm the start of the DH project and a timetable for the executing/installation phase. Secondly, DH company installs the DH installation and pipelines. In addition, an installer personally visits the consumer to realise a DH connection behind the front door. Thirdly, the company removes the previous natural gas connection after 4-6 weeks. In addition, possible defects are detected and repaired. Finally, the consumer receives heat from the DH system.

The customer journey helps to systematically evaluate the customer experience, to investigate which situations could be improved and which situations work well. After the customer journey has been mapped, EBO Consult brainstorms with all involved parties to improve the problematic situations (EBO Consult, 2016). In this way, EBO Consult improves the customer journey and customer satisfaction for new DH projects.

5.2 Lessons

Below is an overview of lessons learned of the customer journey mapping of EBO Consult:

- Customers prefer personal contact and visibility. It is important to visit each customer individually in order to understand their situation and to adapt the installation process to their personal situations and preferences (EBO Consult 2016, p.3).
- Respect the private space of people and restore private spaces (e.g. garden) to their original state. If you carefully treat their private space, trust increases (R. Krabsen, appendix 5 of the main report).
- Communicate directly and honestly, even if something went wrong. Mistakes occur because often many contractors and subcontractors are involved during the execution of a DH project. People may not like it at first, but it builds trust in the long run. In addition, follow-up. Keep people informed and stay (in person) in contact with the customers (R. Krabsen, appendix 5 of the main report).

6 The marketing strategy of Reggefiber

Reggefiber is a Dutch company that lays fibre optic networks. The company is part of KPN, a Dutch landline and mobile telecommunications company. The vision of Reggefiber is: ‘to establish fibre optic connections in all districts of the Netherlands, one by one’ (Reggefiber, 2018). Compared to the conventional situation (mostly Asymmetric Digital Subscriber Line – ADSL), fibre optic networks offer several advantages. The biggest advantage is that the up- and download speeds are symmetrical, which means that they are equal (Consumentenbond, 2018a). Moreover, research by the Consumer Association showed that the percentage of interruptions of optical fibre networks is significantly lower compared to ADSL networks (Consumentenbond, 2018b). According to Stratix (2018), around 2.65 million Dutch households currently have an optical fibre connection, 80% of these connections has been realised by Reggefiber.

Reggefiber not only lays fibre optic networks, it also operates and maintains fibre optic networks. It is important to note that fibre networks of Reggefiber are accessible to every telecom provider, which means that consumers keep the freedom of choice. Telecom providers (indirect consumers) only pay service costs for the use of the fibre optic network. Thus, the transition from an ADSL network to a fibre optic network can be used as an example for the transition from an individual gas-fired boiler to a collective DH system. In addition, fibre optic networks require a different modem that must be installed 'behind the front door' (K. Mooibroek, appendix 5 of the main report).

6.1 The marketing campaign

The initiator of fibre optic networks is usually a municipality that in turn invites Reggefiber to realise their ambition to establish a fibre optic network in certain districts. K. Mooibroek (appendix 5 of the main report) emphasised that it is essential to have socio-political acceptance beforehand. Local authorities could play a key role in getting community acceptance and gaining trust. Moreover, local authorities could support a project by giving a lot of publicity.

When Reggefiber has socio-political acceptance, it starts with an environmental analysis which takes about two months. This includes the analysis of all physical characteristics (housing types, companies, associations etc.) and demographical characteristics (ages, incomes, influencers etc.). It is according to K. Mooibroek (appendix 5 of the main report) influencers and early adapters (in their case mostly computer nerds) important to ‘use’ these people. Reggefiber tries to contact them and visit them before the actual marketing begins. They organise personal meetings to explain their plans for setting up a fibre optic network. Moreover, they ask influencers and early adapters whether they want to play a (communicative) role. For example, they can write a blog or hold a short speech during one of the information meetings with local residents.

After the environmental analysis, the actual marketing campaign starts. This campaign consists of four consecutive phases: (1) creating awareness, (2) sowing, (3) harvesting one and (4) harvesting two. Each phase lasts about three weeks. The first phase is only about informing people about fibre optic networks, for example by organising walk-in events. It is according to K. Mooibroek (appendix 5 of the main report) very important that the marketing campaign creates commotion (in Dutch: *reuring*) in the neighbourhood. In addition, Reggefiber opens always a temporary store/office at a central place in the neighbourhood. This place enables locals to ask their questions at any time, which is an important measure to gain acceptance from the community and win trust (K. Mooibroek, appendix 5 of the main report).

The second phase is similar to the first phase but includes the announcement of the harvesting phases and the financial aspect begins to play a role. The third and the fourth phase are about signing contracts, people have to sign up for a (fibre optic) contract with a telecom provider. Because people often follow the example of someone else, associations can easily be used as a platform to recruit participants, possibly by offering an additional group discount (K. Mooibroek, appendix 5 of the main report). Close to the last deadline, Reggefiber visits each household individually, trying to convince them of all the benefits. In general, Reggefiber manages to connect about 80% of all households in a particular district with its strategy (F. Reinders, appendix 5 of the main report).

6.2 Lessons

Below is an overview of lessons learned during the campaigns of Reggefiber:

- A marketing campaign requires a flexible organisation and clear communication. Flexibility is important, because decisions have to be made quickly as time is limited. Clear communication with the community is important, and home visits in particular should be announced in advance (K. Mooibroek, appendix 5 of the main report).
- Being present is very important to gain acceptance and trust from the community. Setting up a temporary store or office at a central place where people can ask their questions and share their concerns is a good example of being physically present (K. Mooibroek, appendix 5 of the main report).
- People like to have a choice between two or three options. A lack of choice often leads to resistance (K. Mooibroek, appendix 5 of the main report).
- Visualisation often helps people to understand, for example a demonstration model illustrating the conventional connection and the new home connection (K. Mooibroek, appendix 5 of the main report).
- Empathise with people, try to understand their feelings and thoughts (e.g. suspiciousness), because then people are more inclined to participate (K. Mooibroek, appendix 5 of the main report).
- Create necessity because necessity makes people decide. A typical sales curve has the shape of a hockey stick. The majority of people sign up close to the deadline. Therefore, limit the timeframe of the campaign (e.g. three months) and announce a clear deadline (K. Mooibroek, appendix 5 of the main report).

7 Analysis aspects

In this chapter, the case studies are concluded with the analysis of the similarities and the differences between the five case studies. Moreover, the theoretical aspects derived from the literature are compared and verified by the empirical situation in the case studies. In addition, aspects are added that have not been found in the literature, but that are important for establishing 'a local P2H DH cooperative'. The analysis of the aspects of the case studies is classified according to the four overarching aspects: (1) technical aspects, (2) economic aspects, (3) social aspects and (4) legal/organisational aspects.

7.1 Technical aspects

Thermo Bello and Mijnwater can be regarded as small-scale P2H DH systems. In both cases the primary installation consists of brine-sourced heat pumps and a secondary installation has been installed, consisting of respectively a gas-fired boiler and the use of residual heat. Both DH systems can be considered bivalent. As mentioned by Schepers & Van Valkengoed (2009), the secondary installation not only complements the primary installation (during peak loads), but also functions as a back-up (during maintenance or breakdowns). Mijnwater illustrates how a local data centre or refrigerators and freezers in a supermarket can be used as a (secondary) heat source. Not only does this contribute to the sustainability, according to L. Hiddes (appendix 5 of the main report), it is also financially attractive for both parties (the supplier and the client).

Contrary to the theoretical requirement of an average effective temperature of minus 17 °C, Thermo Bello is dimensioned at an average effective temperature of minus 10 °C. According to G. Verschuur (appendix 5 of the main report) DH systems are usually dimensioned at minus 10 °C. Thermo Bello used a simultaneity factor of 0.53 and calculated their average distribution loss at 13.3% in 2016. Both values are similar to the values mentioned by Ecofys (2015). In addition, G. Verschuur (appendix 5 of the main report) mentioned the distribution pumps that are needed to pump the hot water through the pipelines. Similar to generation, a secondary (back-up) distribution pump is required.

It is very interesting to note that in both cases the heat used for space heating is generated collectively, while the heat used for hot tap water is generated individually. This results in a reduction of the total heat demand, because only hot tap water requires a supply temperature of 60 °C. In addition, both cases use a so-called variable heating curve which is related to the outside temperature. In case of Thermo Bello, the supply temperature varies between 20 °C and 50 °C. Various solutions are available to generate hot tap water at an individual level, for example the booster heat pump. The booster heat pump uses the low-temperature heat for space heating and increases the temperature to the required 60 °C, resulting in a (high) COP of around 5-5.5. The investment costs amount to approximately € 3,000 per household.

The average annual COP of Mijnwater for space heating is 6, which is very high compared to the theoretical COP values mentioned by Fischer & Madani (2017) and the COP values of Thermo Bello. Thermo Bello had an average annual COP of 3.64 in 2016 and their target is to achieve an average annual COP of 4.7. This difference can largely be attributed to the extraction temperature. Mijnwater extracts water that already has a temperature of 28 °C. However, the COP values confirm that the average COP values mentioned by Fischer & Madani (2017) are accurate.

Both G. Verschuur and L. Hiddes (appendix 5 of the main report) mentioned the importance of the input of renewable energy to reduce CO_2 emissions. A recent calculation revealed that the CO_2 emissions of Thermo Bello's P2H DH system is similar to the CO_2 emissions of individual gas-fired boilers. The only way to drastically reduce CO_2 emissions is by installing renewable energy devices (e.g. solar PV) or purchasing renewable energy (e.g. wind energy).

Interestingly, G. Verschuur and L. Hiddes (appendix 5 of the main report) learned the same lesson: a (P2H) DH system is very complex, which can easily lead to mistakes and mismatches between theory (advisory reports and design) and practise. L. Hiddes (appendix 5 of the main report) points to the importance of understanding the entire system. G. Verschuur (appendix 5 of the main report) mentions that it might be better to purchase a certain service instead of a certain product and stresses the importance of a final mechanical check before the P2H DH system starts operating.

7.2 Economic aspects

Thermo Bello and Mijnwater were not motivated by the price development on the wholesale markets (merit order effect) to establish a P2H DH system. In fact, in both cases the environmental and social motivations were leading. As derived from the literature review, P2H DH systems require high investment costs (Capex) that must be covered by loans and sufficient incomes. The DH cooperatives Thermo Bello and TexelEnergie have, in addition to bank loans and private investors, issued depositary receipts to raise sufficient investment capital. As a result, according to G. Verschuur (appendix 5 of the main report), the benefits become circular: local profits remain local and can be invested locally. Moreover, J. Kuiken (appendix 5 of the main report) mentions the importance of economic viability, because the lifetime of DH systems is generally very long. In addition, J. Kuiken (appendix 5 of the main report) adds the aspect of the default risk (in Dutch: *debiteurenrisico*), which can be a major burden, especially for small DH cooperatives.

Heat tariffs are obviously used to invoice the services that heat supplier provides to its customer. However, heat tariffs can also be used as a financial incentive. The ratio between fixed and variable tariffs can be used as a financial incentive for consumers to save energy, ultimately contributing to (national) climate goals (Verschuur 2010, p.29). Mijnwater uses the connection fee as a financial incentive to stimulate consumers to insulate their houses. This is a win-win situation for both parties, because a higher degree of insulation decreases the required production capacity and lowers the consumers' energy bills (L. Hiddes, appendix 5 of the main report).

7.3 Social aspects

The DH cooperatives Thermo Bello and TexelEnergie, as well as the customer journey of EBO Consult and the marketing strategy of Reggefiber show the importance of the social aspects. After all, without consumers it is impossible to establish a local P2H DH cooperative. The six values and seven principles adopted by the International Co-operative Alliance are not directly found by Thermo Bello and TexelEnergie. However, indirectly (underlying) each of these values and principles were found, which is in line with Viadot (2013).

In both cases (Thermo Bello and TexelEnergie), the two dimensions of participation (process and outcome) mentioned by Walker & Devine-Wright (2008) were to a large extent distributed to the local community. The DH projects were driven and carried out by local people (process). The economic and social benefits were partially distributed among the community (outcome). Thermo Bello, for example, started with the distribution of economic benefits when they were able to repay their loans by issuing certificates and being financially stable. In view of the ladder of citizen participation developed by Arnstein (1969), the citizens participate on the highest rung because they have the power to influence the outcome and make decisions.

Various scholars (e.g. Walker & Devine-Wright, 2008 and Yildiz et al., 2015) warned for the possibility of conflicts within an energy cooperative. Such conflicts have indeed been found in the investigated cases. However, G. Verschuur (appendix 5 of the main report) proposes to embrace local resistance because it is in most cases based on knowledge and previous experiences. K. Mooibroek (appendix 5 of the main report) emphasises the importance of showing empathy, trying to understand the community's feelings and thoughts (e.g. suspiciousness). People tend to participate more in a DH cooperative when their fears, feelings, and thoughts are taken seriously and discussed in for example the business plan. Moreover, K. Mooibroek (appendix 5 of the main report) states that a lack of choice often leads to resistance. That is why it is important to let people (potential customers) choose between two or three options.

A large body of literature (e.g. Walker et al., 2010; Wüstenhagen et al., 2007 and Yildiz et al., 2015) mentions that social acceptance and trust are essential for establishing a community energy project. All the investigated cases underline this statement, and reciprocal trust in particular is an aspect mentioned often. Different strategies can be used to gain social acceptance and trust. K. Mooibroek and R. Krabsen (appendix 5 of the main report) both pointed to the importance of being visible and physically present. Setting up a temporary store or office at a central place where people can ask their questions is a good example of being physically present. Both respondents also mentioned that visualisation (e.g. videos or demonstration models) and creating necessity are key strategies to gain acceptance and recruit participants. R. Krabsen (appendix 5 of the main report) stresses the importance of direct and honest communication. People may not like it at first, but it builds trust in the long run. Finally, K. Mooibroek and R. Krabsen (appendix 5 of the main report) mentioned that so-called local influencers or local ambassadors as a key strategy to convince the local community.

R. Krabsen (appendix 5 of the main report) states that P2H DH not only goes 'behind the front door' but also 'behind the garden gate'. First of all, it is important to visit people's houses individually in order to understand their situation and to adapt the installation process to their personal situation and preferences. Secondly, it is important to restore for example the garden to its original state after construction work is done. Careful handling of people's private property increases trust.

J. Kuiken (appendix 5 of the main report) pointed to a strong social benefit of a local energy cooperative compared to a major energy supplier. A local DH cooperative can protect and assist vulnerable people because it knows its customers more personally and knows when people face problems with paying their energy bills.

7.4 Legal/organisational aspects

Thermo Bello and TexelEnergie are both DH cooperatives that are owned by the community. Thermo Bello illustrates the possibility of a hybrid between a limited partnership and a civil partnership. The management consists of project-initiating investors, but decisions are taken by a democratic process. Both DH cooperatives evolved from the bottom-up with informal meetings, as was mentioned by Schoor & Scholtens (2015). Both DH cooperatives have a paid board of directors and staff members. G. Verschuur (appendix 5 of the main report) emphasises the importance of a supervisory board. A small-scale DH cooperative is financially not capable of hiring sufficient staff members and a lack of time can lead to big mistakes. A supervisory board consisting of volunteers is a way to prevent this.

Schwenke (2016) mentioned that small initiatives align themselves with larger energy companies with a strong focus on sustainability. This is more or less also the case with Thermo Bello and TexelEnergie. In both cases the invoicing of heat is outsourced. According to J. Kuiken (appendix 5 of the main report), this is because many rules and legislation apply, making it too complicated for a small energy supplier. Also, maintenance of the installations and pipelines is outsourced to specialised companies. J. Kuiken (appendix 5 of the main report) emphasises the importance of documenting all agreements with third parties, even if it seems unnecessary. This can prevent many problems.

Both cases are cooperatively organised with excluded liability (UA), which means that the members cannot be held liable. People can join the cooperative by buying at least one share. All members (above the age of eighteen) have the right to vote. There are no exceptions: one vote per person in accordance with the values and principles adopted by the International Co-operative Alliance. It is important to keep in mind that a cooperative structure requires statutes that include at least the name, purpose, and obligations of the cooperative.

Thermo Bello, Mijnwater, and TexelEnergie all use the maximum heat tariffs set by ACM. The Heat Act does not prescribe a maximum tariff for a delivery device (e.g. heat exchanger), but it has to be a 'reasonable amount'. Thermo Bello invoiced € 77.22/household for renting the delivery device in 2015, which apparently meets the criteria 'reasonable amount'.

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Appendix 4

Calculations and figures business case EcoGenie 2.0 in Paddepoel-Noord

Contents

1 Current (reference) situation in Paddepoel-Noord

Households in Paddepoel-Noord currently use natural gas for space heating, hot tap water and cooking. Each household has an individual gas-fired boiler installed. According to ACM (2018b) it can be assumed that this is an HR107 boiler. Paragraph 1.1 contains a calculation of the current energy costs and the current CO_2 emissions per household in Paddepoel-Noord. Paragraph 1.2 contains a calculation of the future heat tariff for EcoGenie 2.0 per household in Paddepoel-Noord.

1.1 Calculation current energy costs and CO_2 emissions in Paddepoel-Noord

Table 1 shows the historical electricity and natural gas consumption of Paddepoel-Noord between 2014-2016. The numbers are based on the database Klimaatmonitor. It is important to keep in mind that Klimaatmonitor aggregates and allocates data meaning that this database shows an indication of the local situation, but only real-time measurements can provide the exact data. Only the energy consumption of intermediate and corner houses is included in the table because this housing type is the target group.

Table 1. Historical electricity and natural gas consumption in Paddepoel-Noord 2014-2016 (based on numbers Klimaatmonitor, 2018).

Historical electricity and natural gas consumption in Paddepoel-Noord 2014-2016				
Year	**Intermediate houses (kWh)**	**Corner houses (kWh)**	**Intermediate houses (Nm^3)**	**Corner houses (Nm^3)**
2014	2,950	3,050	1,500	1,700
2015	2,840	2,960	1,640	1,850
2016	2,760	3,010	1,710	1,960
Average	2,850	3,007	1,617	1,837

Table 2 shows the average electricity and natural gas consumption in Paddepoel-Noord. The average consumption is based on a ratio of one corner house on two intermediate houses.

Table 2. Average electricity and natural gas consumption households in Paddepoel-Noord.

Average electricity and natural gas consumption in Paddepoel-Noord		
Description	**Electricity (kWh)**	**Gas (Nm^3)**
Intermediate houses	2,850	1,617
Corner houses	3,007	1,837
Average consumption	2,902	1,690

Table 3 shows the conversion of natural gas from Nm^3 to kWh, which is necessary to make comparisons. The shares of space heating, share of hot tap water and share of cooking are based on Menkveld et al. (2017). The energy content of L-gas is based on ECN (2016). The conversion factor is calculated at 34.30, which results in a natural gas consumption of 16,102 kWh/year and 58 GJ/year.

Table 3. Conversion of natural gas (Nm^3) to kWh.

Conversion of natural gas (Nm^3) to kWh			
Description	**Gas (%)**	**Category**	**MJ/Nm^3**
Share space heating	76.84%	L-gas upper value	35.096
Share hot tap water	21.05%	L-gas under value	31.669
Share cooking	2.11%	L-gas under value	31.669
Natural gas consumption kWh/year	16,103	Conversion factor	34.30
Natural gas consumption in GJ/year	58		

Table 4 shows the carbon intensity of electricity and natural gas. The aggregate carbon intensity (ACI) is based on Ang & Su (2016) and the carbon intensity of natural gas is based on Klimaatplein (2018). A gas-fired boiler uses around 0.28 kWh/Nm^3, which means an additional 0.124 kg/Nm^3 CO_2 emissions (Schepers & Scholten, 2016). Appendix 1 of the main report explains these numbers in more detail.

Table 4. Carbon intensity electricity and natural gas.

Carbon intensity electricity and natural gas	
Description	**kg**
Aggregate carbon intensity (ACI) per kWh	0.44
Carbon intensity natural gas per Nm^3	1.89
Additional CO_2 emissions per Nm^3	0.124

Table 5 shows the electricity and natural gas tariffs of 2018 (excl. VAT). The variable and fixed supply costs are based on numbers of Essent (2018). The Energy Tax and Tax on sustainable energy as well as the tax discount are based on numbers of the Dutch tax authority (Belastingdienst, 2018). The network operation costs are based on tariffs of Enexis (2018a) and Enexis (2018b). The investment and maintenance costs of a HR107 boiler are based on ACM (2018a). Appendix 1 of the main report explains these tariffs in more detail.

Table 5. Electricity and natural gas tariffs in 2018 (excl. VAT).

Electricity and natural gas tariffs in 2018 (excl. VAT)			
Description		**Electricity**	**Natural gas**
Energy supplier	Variable supply costs (single tariff per kWh/Nm^3)	€ 0.0527	€ 0.2576
	Fixed supply costs (per day)	€ 0.1138	€ 0.1138
	Energy Tax (per kWh/Nm^3)	€ 0.1046	€ 0.2600
	Tax on sustainable energy (per kWh/Nm^3)	€ 0.0132	€ 0.0285
Network operation costs	Connection services (per day)	€ 0.0486	€ 0.0761
	Fixed charge transport services (per day)	€ 0.0493	€ 0.0493
	Transport services (per day)	€ 0.3314	€ 0.1988
	Metering services (per day)	€ 0.0785	€ 0.0574
Tax discount	Tax credit Energy Tax (annually)	-€ 308.54	NA
	Tax credit VAT (21%) (annually)	-€ 64.79	NA
HR107 boiler	Investment cost (one-time)	NA	€ 1,952.96
	Maintenance costs (annually)	NA	€ 118.83
	Lifetime (years)	NA	15
	Remaining lifetime (years)	NA	7.5

Table 6 shows the calculation of a typical electricity and natural gas bill in Paddepoel-Noord. The energy bill is based on the average electricity and natural gas consumption in Paddepoel-Noord (table 2) and the key numbers (table 5). The total energy costs of a household in Paddepoel-Noord is € 1,817.95/year, which is € 151.50/month (incl. VAT). The total costs of natural gas incl. boiler of a household in Paddepoel-Noord is € 1,532.44/year, which is € 127.70/month (incl. VAT).

Table 6. Calculation electricity and natural gas bill in Paddepoel-Noord.

Caluculation electricity and natural gas bill in Paddepoel-Noord in 2018					
Description		**Electricity (kWh) (incl. VAT)**	**Natural gas (Nm^3) (incl. VAT)**	**Natural gas (kWh) (incl. VAT)**	**Natural gas (kWh) (excl. VAT)**
Energy supplier	Variable supply costs (single tariff)	€ 152.95	€ 435.35	€ 435.35	€ 435.35
	Fixed supply costs	€ 41.52	€ 41.52	€ 41.52	€ 41.52
	Energy Tax	€ 303.51	€ 439.42	€ 439.42	€ 439.42
	Tax on Sustainable Energy	€ 38.31	€ 48.17	€ 48.17	€ 48.17
	VAT (21%)	€ 103.90	€ 193.82	€ 193.82	NA
Network operation costs	Connection services	€ 17.73	€ 27.78	€ 27.78	€ 27.78
	Fixed charge transport services	€ 18.00	€ 18.00	€ 18.00	€ 18.00
	Transport services	€ 120.96	€ 72.56	€ 72.56	€ 72.56
	Metering services	€ 28.67	€ 20.96	€ 20.96	€ 20.96
	VAT (21%)	€ 38.92	€ 29.25	€ 29.25	NA
Tax discount	Tax credit Energy Tax	-€ 308.54	NA	NA	NA
	Tax credit VAT (21%)	-64.79	NA	NA	NA
Total energy costs excl. boiler	Annual energy costs	€ 491.14	€ 1,326.81	€ 1,326.81	€ 1,103.74
	Total annual energy costs	€ 1,817.95			
	Monthly energy costs	€ 40.93	€ 110.57	€ 110.57	€ 91.98
	Total monthly energy costs	€ 151.50			
	Costs per unit	€ 0.1692	€ 0.7851	€ 0.0824	€ 0.0685
Total costs incl. boiler	Annual energy costs	€ 491.14	€ 1,532.44	€ 1,532.44	€ 1,309.37
	Total annual energy costs	€ 2,023.58			
	Monthly energy costs	€ 40.93	€ 127.70	€ 127.70	€ 109.11
	Total monthly energy costs	€ 168.63			
	Costs per unit	€ 0.1692	€ 0.9068	€ 0.0952	€ 0.0813

Table 7 provides an overview of the current energy consumption and associated CO_2 emissions per household in Paddepoel-Noord. The CO_2 emissions is based on the carbon intensities (table 4) and the average electricity and natural gas consumption in Paddepoel-Noord (table 2). The annual energy costs are taken from table 6.

Table 7. Current energy consumption and CO_2 emissions in Paddepoel-Noord.

Current energy consumption and CO_2 emissions in Paddepoel-Noord					
Description	**Electricity**	**Heat**	**Total**	**Electricity (%)**	**Heat (%)**
CO_2 emissions (incl. additional electricity gas-fired boiler)	1,072	3,399	4,471	24.0%	76.0%
Annual energy costs incl. boiler (incl. VAT)	€ 411.06	€ 1,612.52	€ 2,023.58	20.3%	79.7%
Annual energy costs excl. boiler (incl. VAT)	€ 411.06	€ 1,406.89	€ 1,817.95	22.6%	77.4%

Figure 1 shows the ratio of energy costs and CO_2 emissions between electricity and natural gas per household in Paddepoel-Noord in percentages. Figure 1 is a visualisation of the numbers in table 7.

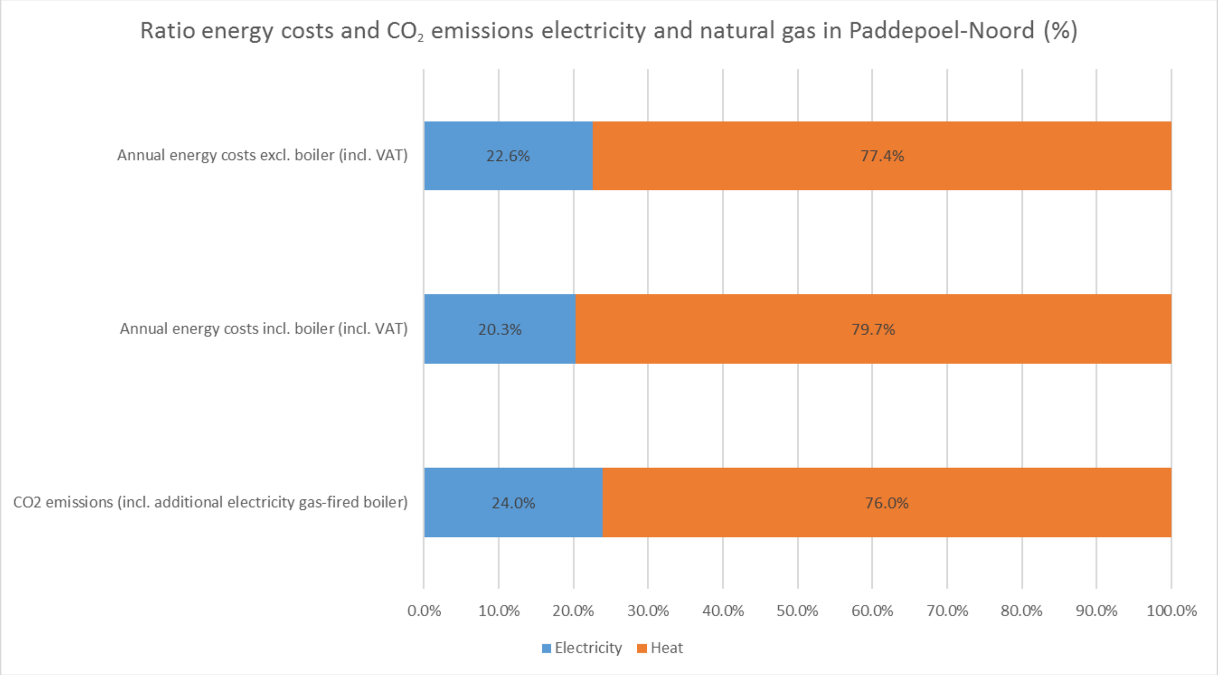

Figure 1. Ratio energy costs and CO_2 emissions electricity and natural costs in Paddepoel-Noord.

1.2 Calculation reference heat tariff in Paddepoel-Noord

In case of an individual gas-fired boiler, the efficiency loss (in Dutch: *rendementsverlies*) of space heating/hot tap water takes place behind the meter. In contrast, the efficiency loss of space heating/hot tap of DH systems takes place before the meter (L. Hiddes, appendix 5 of the main report). This difference is in favour of the customer. That is why the heat tariff must be adjusted to the efficiency loss. Table 8 shows the calculation of additional costs from the efficiency loss per household in Paddepoel-Noord. The additional costs of the efficiency loss are calculated at € 147.85/year.

Table 8. Calculation additional costs efficiency loss per household in Paddepoel-Noord.

Calculation additional costs efficiency loss per household in Paddepoel-Noord			
Description	**Amount**	**Unit**	**Source**
Average natural gas consumption	1,690	Nm^3	Calculated
Aggregated efficiency loss	16.02	%	Calculated
Additional natural gas consumption	271	Nm^3	Calculated
Additional costs efficiency loss	€ 147.85	Year/houdehold	Calculated

It is assumed that inhabitants of Paddepoel-Noord will switch to an electric stove because it eliminates the fixed supply costs and the fixed network operation costs. Table 9 shows the calculation of the additional costs for cooking per household.

Table 9. Calculation additional cost cooking.

Calculation additional costs cooking			
Average electicity demand cooking	211	kWh/year household	ECN (2014)
Additional costs cooking on electricity	€ 35.97	Year/houdehold	Calculated

Table 10 shows the calculation of the heat tariff for EcoGenie 2.0 In Paddepoel-Noord. The heat tariff (incl. boiler) is calculated at € 25.90/GJ (excl. VAT). Because EcoGenie aims to supply heat 10-20% cheaper, the heat tariff is reduced by 10%. Therefore, the maximum heat tariff is € 22.06/GJ (excl. VAT).

Table 10. Calculation heat tariff for EcoGenie 2.0 in Paddepoel-Noord.

Calculation heat tariff for EcoGenie 2.0 in Paddepoel-Noord			
Description	**Amount**	**Unit**	**Source**
Total heat costs (incl. boiler) per househol	€ 1,389.45	Per year	Calculated
Total heat costs (incl. boiler) with additional cooking/efficiency loss)	€ 1,501.33	Year/houdehold	Calculated
Heat tariff (incl. boiler) with additional cooking/efficiency loss)	€ 25.90	Per GJ	Calculated
Heat tariff (incl. boiler) with additional cooking/efficiency loss) -10%	**€ 23.31**	Per GJ	Calculated

2 Calculation maximum tariff according to the Heat Act

Table 11 shows the average natural gas consumption without cooking in Paddepoel-Noord.

Table 11. Average natural gas consumption without cooking in Paddepoel-Noord.

Average natural gas consumption without cooking Paddepoel-Noord			
Description	**Natural gas (%)**	**Natural gas (Nm^3)**	**Natural gas (%)**
Share space heating	76.84%	1,299	78.49%
Share hot tap water	21.05%	356	21.51%
Total natural gas consumption	97.89%	1,654	100.00%

Table 12 shows the conversion of natural gas from Nm^3 to GJ, the unit used to measure heat. The shares of space heating, share of hot tap water are based on Menkveld et al. (2017). The energy content of L-gas is based on ECN (2016). The conversion factor is calculated at 34.36, which results in a natural gas consumption of 15.790 kWh/year and 56.8 GJ/year.

Table 12. Conversion of natural gas (Nm^3) to GJ.

Conversion of natural gas (Nm^3) to GJ			
Description	**Natural gas (%)**	**Description**	**MJ/Nm^3**
Share space heating	78.49%	L-gas upper value	35.096
Share hot tap water	21.51%	L-gas under value	31.669
Gas consumption kWh/year	15,790	Conversion factor	34.36
Gas consumption GJ/year	56.8		

Table 13 shows the maximum heat tariffs for 2018 (excl. VAT). The tariffs are based on the principle ‘not more than usual’. The fee for the delivery device has not been determined, but a supplier may only charge a 'reasonable fee' that is comparable to other heat suppliers. Appendix 2 of the main report explains these maximum tariffs in more detail.

Table 13. Maximum heat tariffs 2018 (excl. VAT) (based on ACM 2018b).

Maximum heat tariffs 2018 (excl. VAT)		
Description		**Heat**
Heat supplier	Fixed tariff supply heat (annually)	€ 255.80
	Variable tariff supply heat (per GJ)	€ 19.88
Heat supplier (network operating costs	Connection fee (one-time)	€ 857.67
	Lifetime (years)	22.5
	Additional fee (one-time per meter tube)	€ 27.91
	Fee delivery device (e.g. heat exchanger)	NA
	Fee measurment device (annually)	€ 20.96

Table 14 shows the calculation of the maximum heat costs in Paddepoel-Noord in 2018. These costs are based on the maximum heat tariffs 2018 set by ACM (table 13). An additional fee for pipelines is not included in this calculation because Paddepoel-Noord consists mainly consists of terraced houses, which means short distances. The fee for the delivery device is not included in this calculation because this fee is not determined by ACM. The maximum heat tariff is calculated at € 29.81/GJ (incl. VAT) and € 25.05/GJ (excl. VAT). The maximum heat tariff is € 29.81/GJ (incl. VAT) and € 25.05/GJ (excl. VAT). The maximum tariff of € 25.05/GJ (excl. VAT) is more than the calculated heat tariff of €23.31 €/GJ, based on the current situation (paragraph 1.2). This means that it is legally permitted to charge € 23.31/GJ.

Table 14. Calculation maximum heat costs in Paddepoel-Noord in 2018.

Calculation maximum heat costs in Paddepoel-Noord in 2018			
Description		**Heat (incl. VAT)**	**Heat (excl. VAT)**
Heat supplier	Fixed tariff supply heat	€ 255.80	€ 255.80
	Variable tariff supply heat	€ 1,129.84	€ 1,129.84
	VAT (21%)	€ 237.27	NA
Heat supplier (network operating costs	Connection fee	€ 38.12	€ 38.12
	Additional fee	NA	NA
	Fee delivery device	NA	NA
	Measurment fee	€ 20.96	€ 20.96
	VAT (21%)	€ 12.41	NA
Total heat costs excl. connection costs	Total anual heat costs	€ 1,656.27	€ 1,406.60
	Monthly energy costs	€ 138.02	€ 117.22
	Costs per GJ	€ 29.14	€ 24.74
Total heat costs incl. connection costs	Total anual heat costs	€ 1,694.39	€ 1,423.76
	Monthly energy costs	€ 141.20	€ 118.65
	Total costs per GJ	€ 29.81	€ 25.05

3 Business case EcoGenie 2.0 in Paddepoel-Noord

Basically, EcoGenie 2.0 will consist of an industrial GSHP, an industrial electric boiler and an oil-fired boiler (as hybrid back-up). The heat will be distributed by distribution pumps and so-called twin-pipes. EcoGenie 2.0 will supply heat to approximately 100-200 households. The following calculations are based on a number of 200 households, because logically it can be assumed that this will lead to a more positive business case.

Paragraph 3.1 contains the key numbers and the basic engineering of the P2H DH system EcoGenie 2.0. In addition, this chapter contains the calculation of CO_2 emissions and compares this with the current situation. Paragraph 3.2 includes the operating budget based on the current heat tariff in Paddepoel-Noord (-10%), calculated in chapter 1. Paragraph 3.3 includes the operating budget based on the maximum heat tariff in Paddepoel-Noord, calculated in chapter 2. Finally, paragraph 3.4 contains the operating budget based on subsidy in Paddepoel-Noord.

3.1 Key numbers and basic engineering

Table 15 shows general key numbers of Paddepoel-Noord. The average heat demand is based on previous calculations (see table 12). The heat tariff is based on the current situation (see table 10). The required loan is based on the total capital expenditures (Capex) of the P2H DH system.

Table 15. General key numbers of Paddepoel-Noord.

General key numbers of Paddepoel-Noord			
Description	**Amount**	**Unit**	**Source**
Average electricity demand	2,902	kWh/year household	Klimaatmonitor (2018)
Average heat demand (excl. cooking)	15,790	kWt/year/household	Calculated
Average heat demand (excl. cooking)	57	GJ/year household	Calculated
Heat tariff -10% (excl. VAT)	23.31	€/GJ	Calculated
Participants	200	households	Assumed
Project term	40	year	P. Breithaupt (personal communication, 17 July 2018)
Loan	€ 2,750,000.00	euro	Calculated
Interest rate	4.00%	%	P. Breithaupt (personal communication, 17 July 2018)

Table 16 shows the key numbers of the fuel costs and the energy tax.

Table 16. Key numbers fuel cost and energy tax.

Key numbers fuel costs and energy tax			
Description	**Amount**	**Unit**	**Source**
Fuel costs electricity	0.045	kWh	EPEX Spot
Fuel costs bio Diesel	2.0625	MJ/output	EBO Consult (2018)
Energy tax electricity 50,001 t/m 10 million kWh	0.01404	€/kWh	Belastingdienst (2018)
Tax on Sustainable Energy 50,001 t/m 10 million kWh	0.00480	€/kWh	Belastingdienst (2018)
VAT	21.00%	%	Belastingdienst (2018)

Table 17 shows the key numbers of the DH engineering. Paragraph 3.1.3 of the main report explains more about these numbers. Due to the risk of legionella contamination, the minimum supply temperature (hot tap water) is set at 60 °C (Van Vliet et al., 2016).

Table 17. Key numbers of the DH engineering.

Key numbers DH engineering			
Description	**Amount**	**Unit**	**Source**
Theoretical peak load space heating	14.30	kWt/household	Ecofys (2015)
Theoretical peak load hot tap water	0.75	kWt/household	Ecofys (2015)
Total theoretical peak load	15.05	kWt/household	Calculated
Total operational peak load	9.25	kWt/household	Calculated
Simultaneity factor	0.53	NA	Ecofys (2015)
Distribution loss space heating (efficiency)	90	%	Ecofys (2015)
Distribution loss hot tap water (efficiency)	62	%	Ecofys (2015)
Aggregated distribution loss	16.02%	%	Calculated
Delivery temperature	60	°C	Van Vliet et al. (2018)
Return temperature	30	°C	Calculated
Water heat capacity	4.187	kJ/kgK	Toppr (2018)

Table 18 shows the key numbers of the Ground-Sourced Heat Pump (GSHP), which is part of the primary installation. The GSHP increases the water temperature from 30 to 55 °C with an average coefficient of performance (COP) of 5.

Table 18. Key numbers GSHP.

Key numbers GSHP			
Description	**Amount**	**Unit**	**Source**
Installation GSHP	700	€/kWt	EBO Consult (2018)
Fixed O&M GSHP	2.14	€/kW/year	EBO Consult (2018)
Variable O/M GSHP	0.0018	€/kWh fuel	EBO Consult (2018)
Technical lifetime GSHP	25	years	EBO Consult (2018)
Coefficient of performance (COP)	5	NA	Thermo Bello (2018c)
Installed capacity (to 55 °C)	1,521	kW	Calculated
Total electricity input	3,011	kWh/year	Calculated
Total heat output	54.2	GJ/year	Calculated

Table 19 shows the key numbers of the electric boiler, which is part of the primary installation. The electric boiler increases the water temperature from 55 to 60 °C.

Table 19. Key numbers electric boiler.

Key numbers electric boiler			
Description	**Amount**	**Unit**	**Source**
Installation electric boiler	100	€/kWt	EBO Consult (2018)
Fixed O&M electric boiler	1.177	€/kW/year	EBO Consult (2018)
Variable O/M electric boiler	0.0005	€/kWh fuel	EBO Consult (2018)
Technical lifetime electric boiler	20	years	EBO Consult (2018)
Coefficient of performance (COP)	1	NA	EBO Consult (2018)
Installed capacity (55 to 60 °C)	304	kW	Calculated
Total electricity input	3,011	kWh/year	Calculated
Total heat output	10.8	GJ/year	Calculated

Table 20 shows the key numbers of the oil-fired boiler, which is the secondary/back-up installation. The oil-fired boiler increases the water temperature from 30 to 60 °C.

Table 20. Key numbers oil-fired boiler.

Key numbers oil-fired boiler			
Description	**Amount**	**Unit**	**Source**
Installation oil-fired boiler	100	€/kWt	EBO Consult (2018)
Fixed O&M oil-fired boiler	2.14	€/kW/year	EBO Consult (2018)
Variable O/M oil-fired boiler	0.0016	€/kWh	EBO Consult (2018)
Technical lifetime oil-fired boiler	25	years	EBO Consult (2018)
Installed capacity	1,851	kW	Calculated
Total fuel input	251	kWh/year	Calculated
Total heat output	0.9	GJ/year	Calculated

Table 21 shows the key numbers of the distribution pumps and pipelines.

Table 21. Key numbers distribution pumps and pipelines.

Key numbers distribution pumps and pipelines			
Description	**Amount**	**Unit**	**Source**
Installation twin pipes	200.00	€/m pipeline	G. Verschuur (appendix 5 of the main report)
Fixed O/M twin pipes	0.13	m/year	Assumed
Technical lifetime twin pipes	40	years	G. Verschuur (appendix 5 of the main report)
Needed twin pipes	15	m/household	P. Breithaupt (personal communication, 17 July 2018)
Installation distribution pump	10,000	per unit	G.Verschuur ((appendix 5 of the main report)
Fixed O/M distribution pump	200	year	Assumed
Technical lifetime distribution pump	15	years	G. Verschuur (appendix 5 of the main report)
Heat heat exchanger and meter	84.30	€/year/household	Thermo Bello (2015)

Table 22 shows the network operating costs medium-voltage grid, based on a calculation by Enexis. The displayed network operating costs include a one-time connection costs and operation costs per electrical current. Appendix 1 includes a map with the location of the medium-voltage grid in Paddepoel-Noord.

Table 22. Key numbers network operating costs medium-voltage grid.

Network operating costs medium-voltage grid			
Description	**Amount**	**Unit**	**Source**
Total operating costs 173 kVA t/m 1750 kVA	269.13	€/year/household	Calculation Enexis (2018)

Table 23 shows the key numbers of the miscellaneous costs. Appendix 3 of the main report explains these costs in more detail. Inhabitants must first of all replace their gas-fired stove with an induction stove. Secondly, most likely they require a conversion to a three-phase power connection (P. Breithaupt, personal communication, 17 July 2018). A total of € 2,000/household is reserved for the replacement of the gas stove and the conversion to a three-phase power connection.

Table 23. Key numbers miscellaneous costs.

Description	Amount	Unit	Source
Development and engineering costs	10%	%/investment costs	P. Breithaupt (personal communication, 17 July 2018)
Construction production facility	50,000	€/one-time	Assumed
Staff	47,500	€/year	Thermo Bello (2018c)
Incasso administration	4,000	€/year	Thermo Bello (2018c)
Housing	5,000	€/year	Thermo Bello (2018c)
Overheads	14,000	€/year	Thermo Bello (2018c)
Replacement gas-fired stove	1,000	€/household	P. Breithaupt (personal communication, 17 July 2018)
Conversion to three-phase power	1,000	€/household	P. Breithaupt (personal communication, 17 July 2018)
Removal tariff connection natural gas	289.89	€/household	Enexis (n.d.)
Compensation fine	100.00	€/household	Richtsnoeren Redelijke Opzegvergoeding Vergunninghouders article 4.1

Table 24 shows the calculation of the average distribution loss in percentage. The average distribution loss is calculated at 16.02%.

Table 24. Calculation average distribution loss (%).

Calculation average distribution loss (%)			
Share space heating	78.49%	Distribution loss	10.00%
Share hot tap water	21.51%	Distribution loss	38.00%
Average distribution loss	16.02%		

Table 25 shows the calculation of the peak load in Paddepoel-Noord. The aggregated distribution loss is added to the total theoretical peak load and the simultaneity factor is subtracted from the total theoretical peak load. The total operational peak load is calculated at 9.25 kWth/household.

Table 25. Calculation peak load in Paddepoel-Noord.

Calculation peak load in Paddepoel-Noord		
Theoretical peak load space heating	14.30	kWth/household
Theoretical peak load hot tap water	0.75	kWth/household
Total theoretical peak load	15.05	kWth/household
Aggregated distribution loss	16.02%	%
Simultaneity factor	0.53	NA
Total operational peak load	9.25	kWth/household

Table 26 shows the calculation of the electricity input and the heat output of the GSHP. The GSHP requires 3,011 kWh electricity to produce 54.2 GJ heat per year/household. It is assumed that the GSHP operates 360 days a year.

Table 26. Calculation input and output GSHP in Paddepoel-Noord.

Calculation input and output GSHP in Paddepoel-Noord		
Average heat demand (excl. cooking, incl. distribution loss)	18,320	kWt/year household
Total operational peak load	9.25	kWth/household
Delivery temperature	55	°C
Feed temperature	30	°C
Mass flow	0.0166	kg/s
Electricity input (to 55 °C) (360 days)	3,011	kWh/year household
Heat output	54.2	GJ/year household
Ratio of total capacity	82.19	%

Table 27 shows the calculation of the electricity input and the heat output of the electric boiler in Paddepoel-Noord. The electric boiler requires 3,011 kWh electricity to produce 10.8 GJ heat per year/household. It is assumed that the electric boiler operates 360 days a year.

Table 27. Calculation input and output electric boiler in Paddepoel-Noord.

Calculation input and output electric boiler in Paddepoel-Noord		
Average heat demand (excl. cooking, incl. distribution loss)	18.320	KWth/year household
Total operational peak load	9,25	KWth/household
Delivery temperature	60	deg. Celsius
Feed temperature	55	deg. Celsius
Mass flow	0,0166	kg/s
Electric input (55 to 60 deg Celsius) (360 days)	3.011	KWth/ year household
Heat output	10,8	GJ/year household
Ratio of total capacity	16,44	%

Table 28 shows the calculation of the (bio) diesel input and the heat output of the oil-fired boiler in Paddepoel-Noord. The oil-fired boiler requires 251 kWh diesel to produce 0.9 GJ heat per year/household. It is assumed that the oil-fired boiler operates 5 days a year.

Table 28. Calculation input and output oil-fired boiler in Paddepoel-Noord.

Calculation input and output oil-fired boiler in Paddepoel-Noord		
Average heat demand (excl. cooking, incl. distribution loss)	18,320	kWt/year household
Total operational peak load	9.25	kWth/household
Delivery temperature	60	°C
Feed temperature	30	°C
Mass flow	0.0166	kg/s
Diesel input (30 to 60 °C) (5 days)	251	kWh/year household
Heat output	0.9	GJ/year household
Ratio of total capacity	100.0	%

Table 29 shows the (direct) CO_2 emissions per household in Paddepoel-Noord. The CO_2 emissions are calculated on the basis of the carbon intensity of the current energy mix (table 4). In addition, the CO_2 emissions of the oil-fired boiler and the additional CO_2 emissions of cooking were added. The total annual (direct) CO_2 emissions of the P2H DH system is 3,405 kg per household, which is 100.2% compared to the current situation (paragraph 1.1).

Table 29. Calculation CO_2 emissions per household in Paddepoel-Noord.

Calculation CO_2 emissions per household in Paddepoel-Noord		
Description	**Amount (kg)**	**Amount (%)**
CO_2 emissions GSHP	1,325	39.0%
CO_2 emissions electric boiler	1,325	39.0%
CO_2 emissions oil-fired boiler	663	19.5%
CO_2 emissions additional electricity cooking	93	2.7%
Total CO_2 emissions	3,405	100.2%

Table 30 shows a comparison of the (direct) CO_2 emissions per household in Paddepoel-Noord. The current situation is calculated in table 4 and the P2H DH system powered on fossil electricity is calculated in table 29. The total annual (direct) CO_2 emissions of the P2H DH system powered by offshore wind energy is 755 kg per household, which is 22.2% compared to the current situation.

Table 30. Comparison CO_2 emissions per household in Paddepoel-Noord.

Comparison CO_2 emissions per household in Paddepoel-Noord		
Description	**Amount (kg)**	**Amount (%)**
Current situation	3,399	100.0%
P2H DH system on fossil electricity	3,405	100.2%
P2H DH system on offshore wind energy	755	22.2%

Figure 2 shows the CO_2 emissions of EcoGenie 2.0 in Paddepoel-Noord in percentage. Figure 2 is a visualisation of the numbers in table 30.

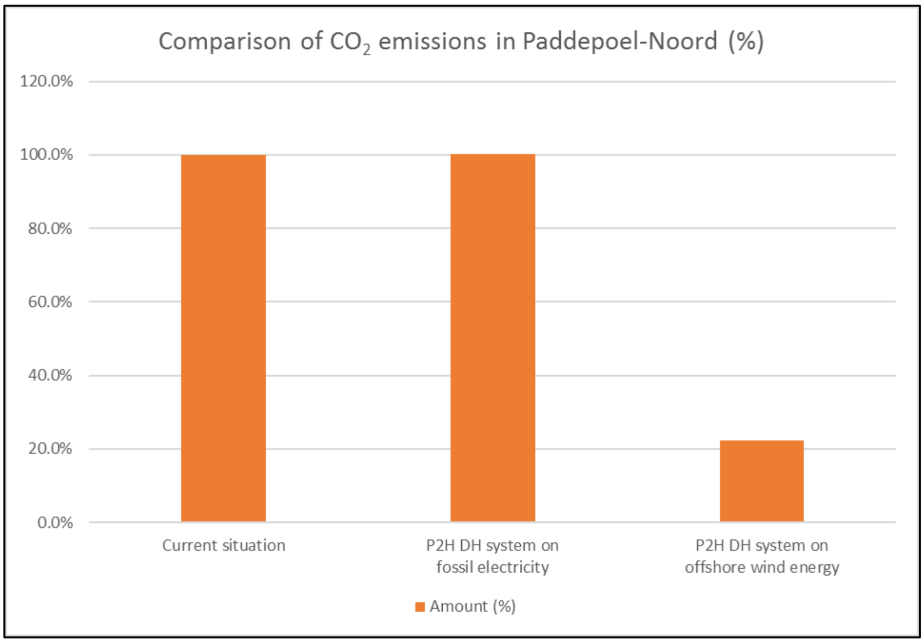

Figure 2. CO_2 emissions EcoGenie 2.0 in Paddepoel-Noord.

3.2 Operating budget based on current heat tariff in Paddepoel-Noord

The operating budget based on the current heat tariff (-10%) in Paddepoel-Noord is attached as appendix 2. Figure 3 shows the cash flow that becomes positive after 12 years. The Return on Invested Capital (ROIC) is calculated at 1.85%.

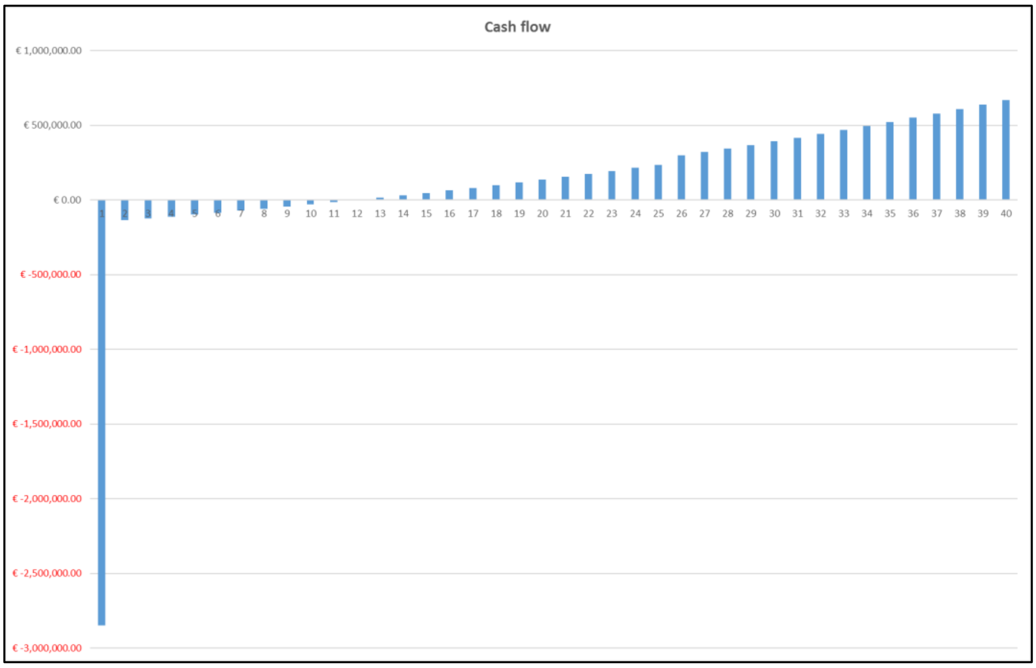

Figure 3. Cash flow

Figure 4 shows the Net Present Value (NPV) which also becomes positive after 13 years. The ROIC is calculated at -0.64%.

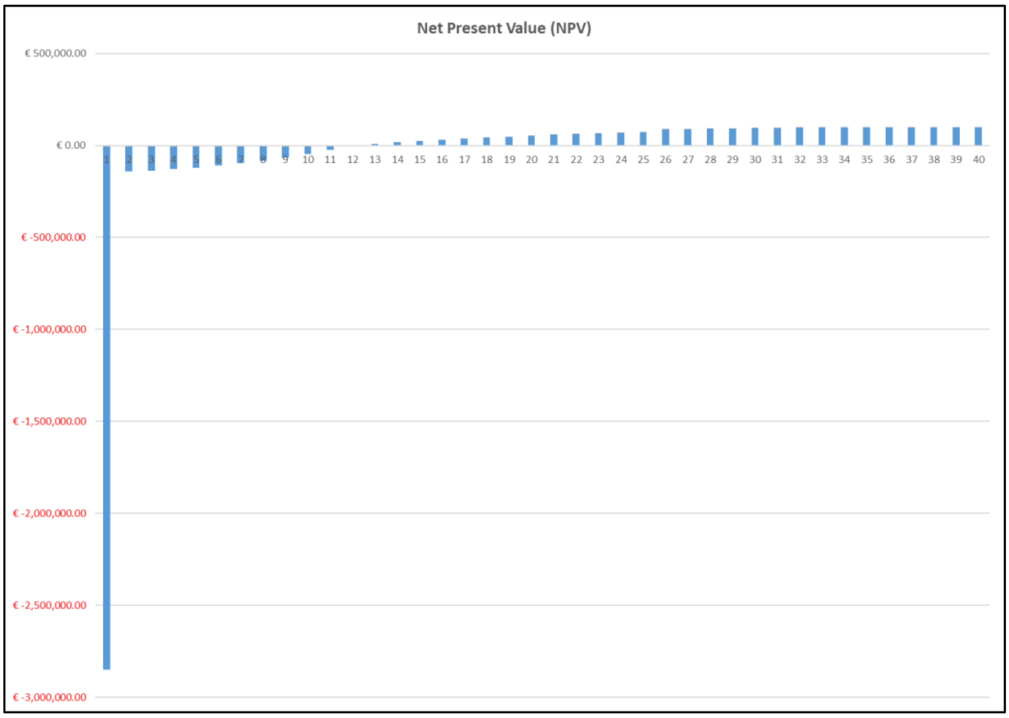

Figure 4. Net Present Value (NPV).

Figure 5 shows the cumulative cash flow that becomes positive after about 31 years.

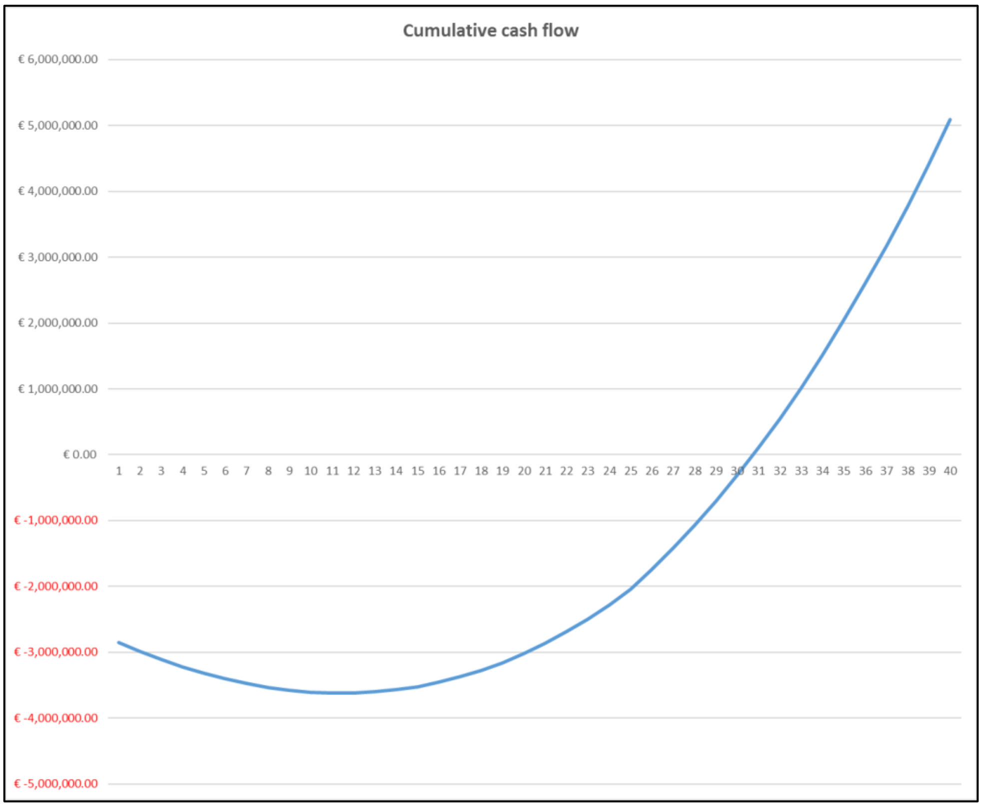

Figure 5. Cumulative cash flow.

3.3 Operating budget based on maximum heat tariff in Paddepoel-Noord

The operating budget based on the maximum heat tariff in Paddepoel-Noord is attached as appendix 3. Figure 6 shows the cash flow that becomes positive after 12 years. The ROIC is calculated at 2.00%.

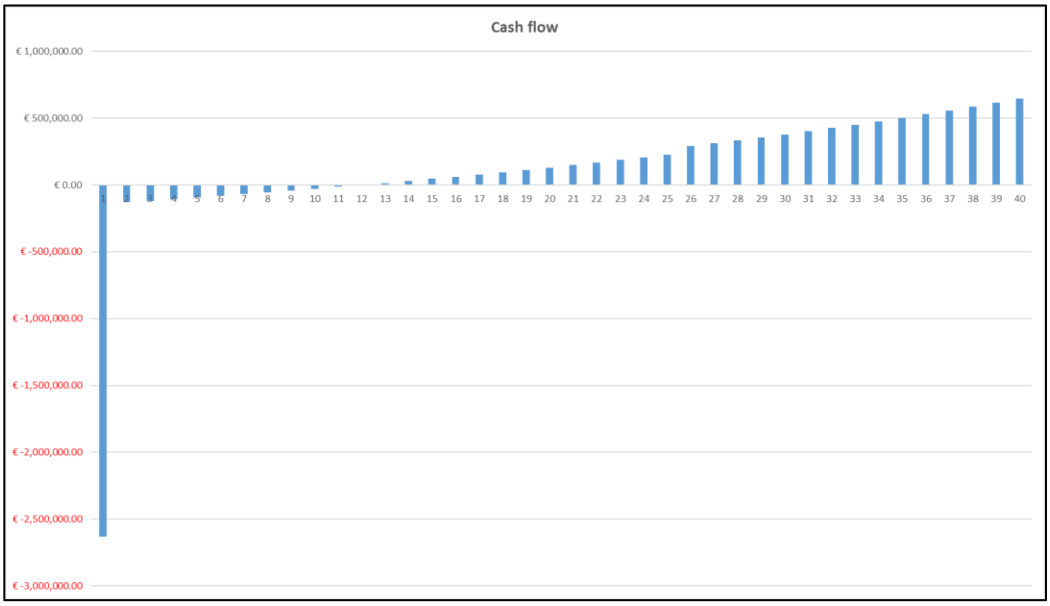

Figure 6. Cash flow.

Figure 7 shows the Net Present Value (NPV) which also becomes positive after 12 years. The ROIC is calculated at -0.57%.

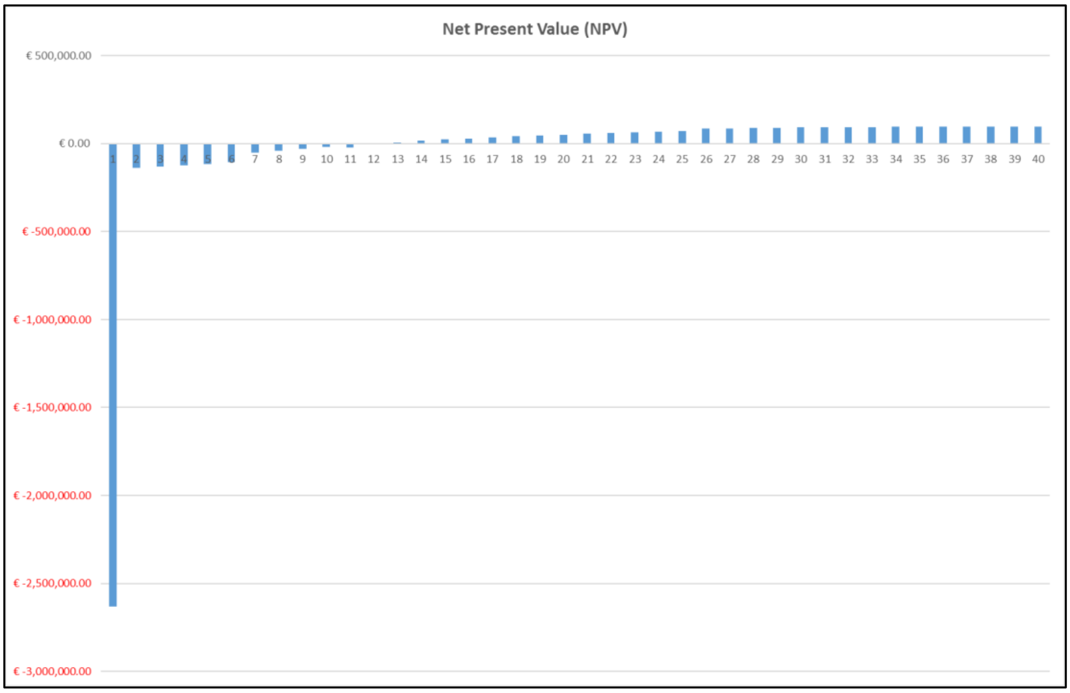

Figure 7. Net Present Value (NPV).

Figure 8 shows the cumulative cash flow that becomes positive after about 31 years.

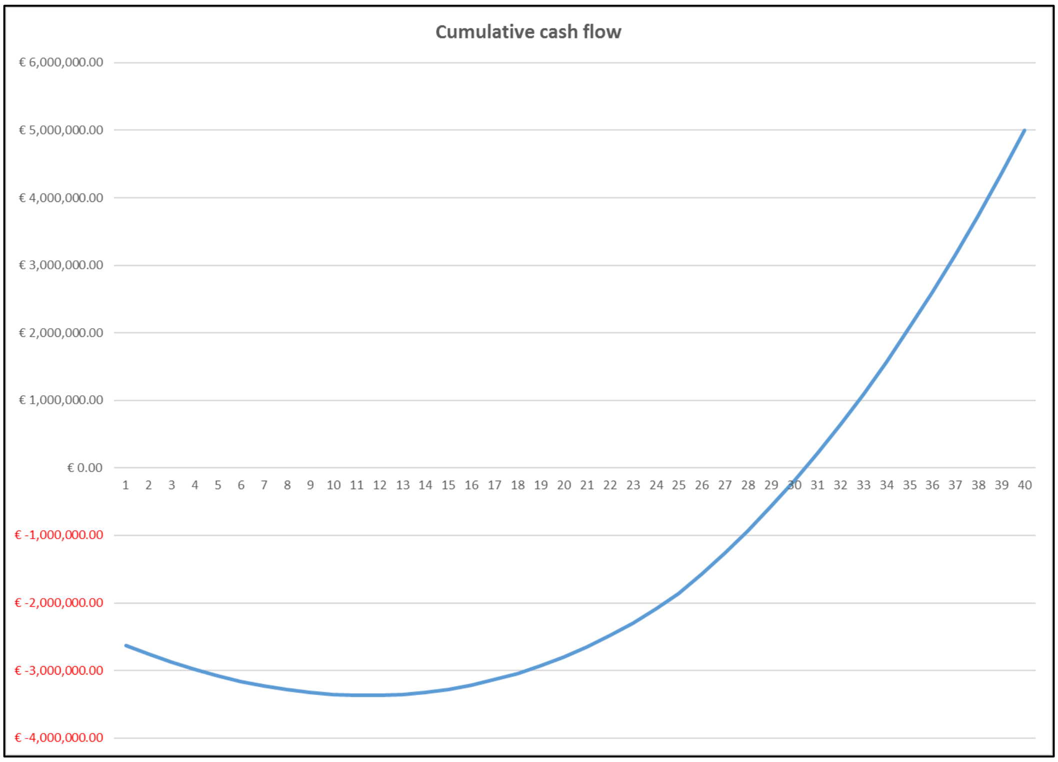

Figure 8. Cumulative cash flow.

3.4 Operating budget based on subsidy in Paddepoel-Noord

The operating budget based on € 5,000 subsidy in Paddepoel-Noord is attached as appendix 4. Figure 9 shows the cash flow that becomes positive after 8 years. The ROIC is calculated at 4.58%.

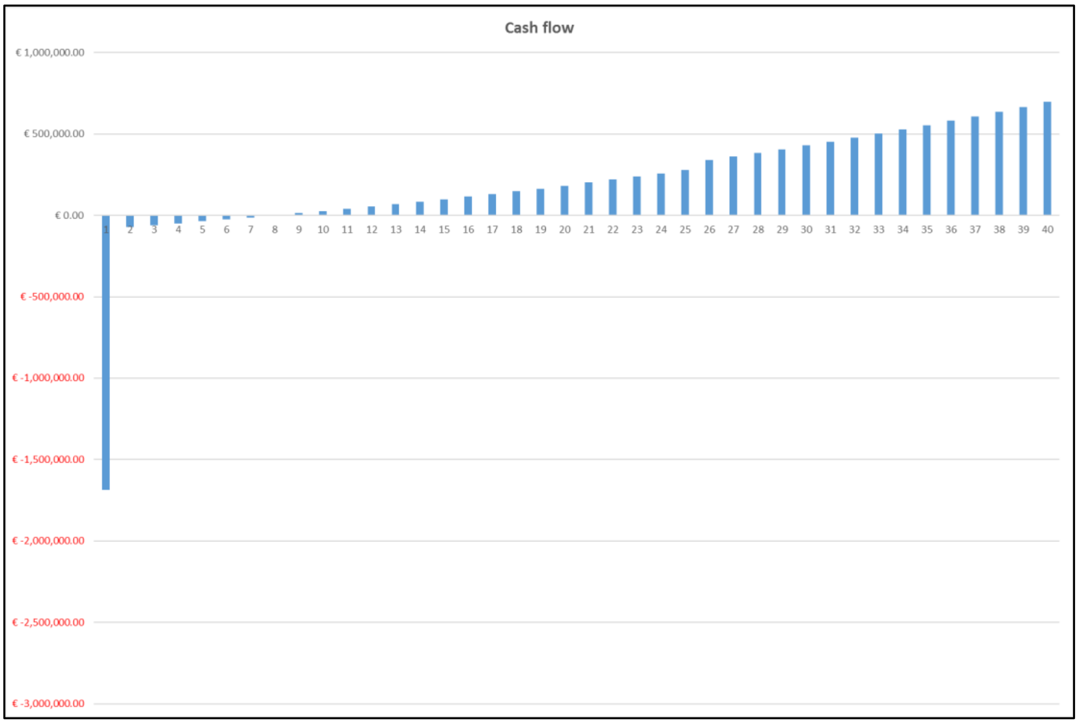

Figure 9. Cash flow.

Figure 10 shows the Net Present Value (NPV) which becomes positive after 9 years. The ROIC is calculated at 0.30%.

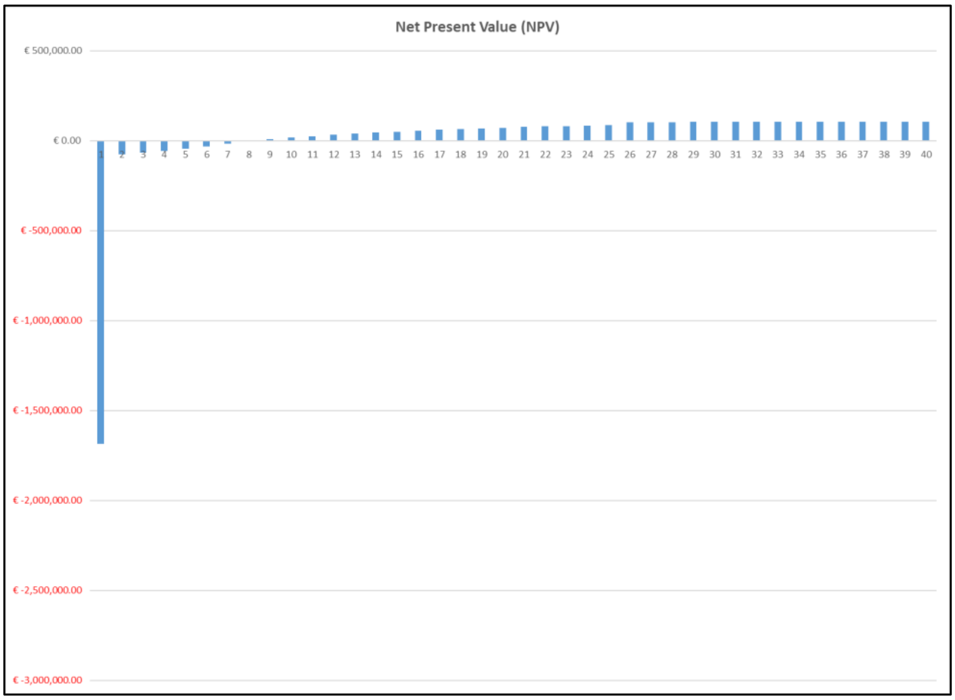

Figure 1028. Net Present Value (NPV).

Figure 11 shows the cumulative cash flow that becomes positive after about 24 years.

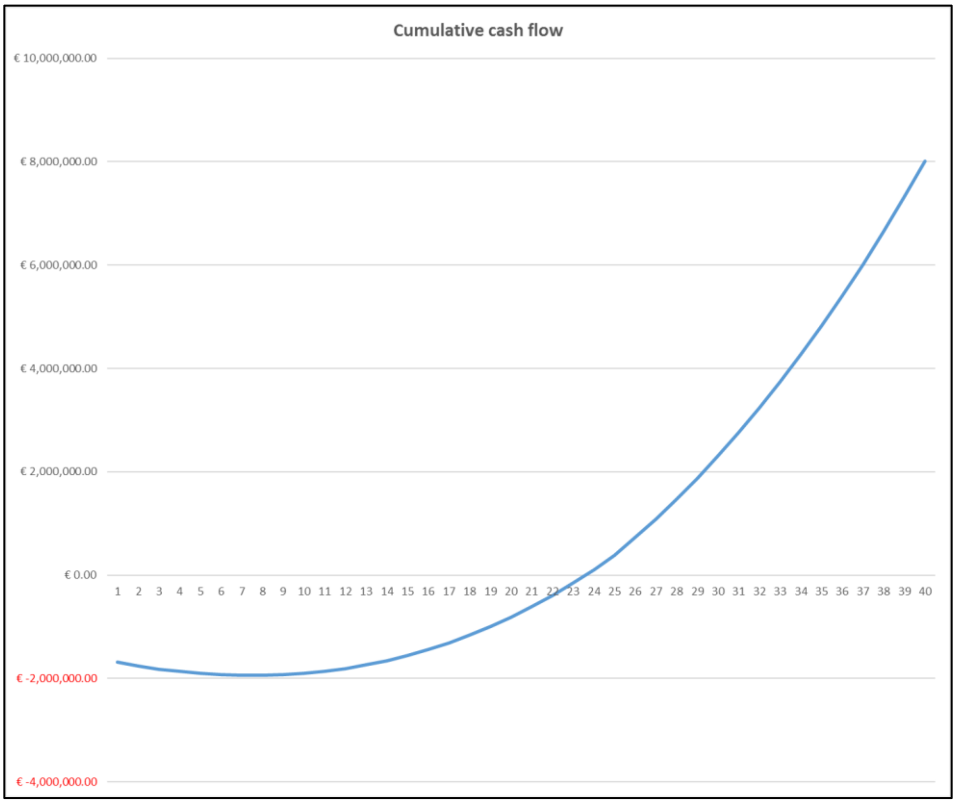

Figure 11. Cumulative cash flow.

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Appendix 1: Location medium-voltage grid in Paddepoel-Noord

Figure 1 shows the location of the medium-voltage grid in Paddepoel-Noord. The red lines represent the (underground) cables and the red squares represent distribution stations.

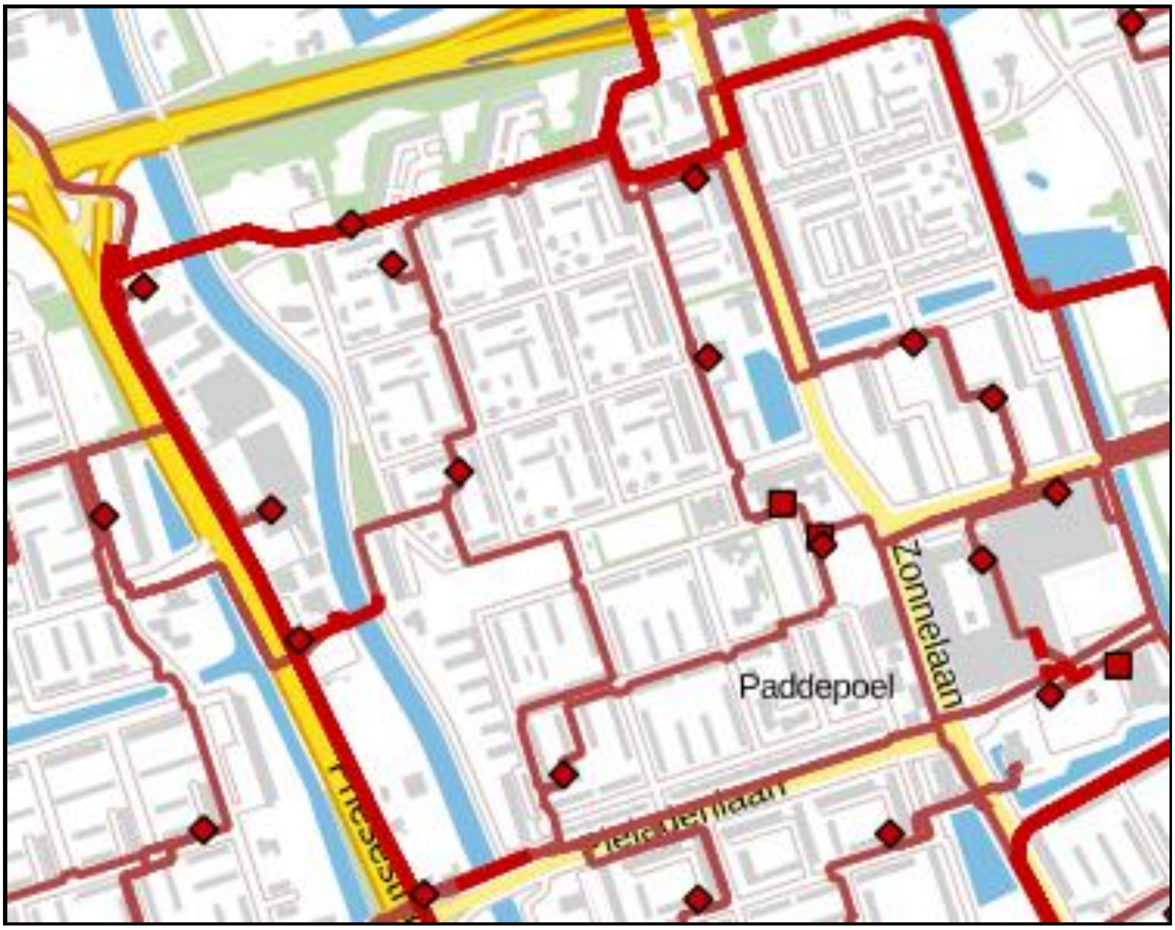

Figure 1. Location medium-voltage grid in Paddepoel-Noord (Enexis, 2018c).

Appendix 2: Operating budget based on current heat tariff in Paddepoel-Noord.

Table 1 shows the operating budget of year 1-18 based on the current heat tariff (-10%) in Paddepoel-Noord.

Table 1. Operating budget year 1-18.

	Period:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Year:	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	Description																		
Capital Expenditures (Capex)																			
Primary installation	Installation GSHP	€ 1,064,882.42																	
	Depreciation GSHP	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30
	Fixed O&M GSHP	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50
	Installation electric boiler	€ 30,425.21																	
	Depreciation electric boiler	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26
	Fixed O&M electric boiler	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10
Secondary installation	Installation oil-fired boiler	€ 185,086.71																	
	Fixed O&M oil-fired boiler	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09
DH pipelines and distribution pumps	Installation twin pipes	€ 600,000.00																	
	Fixed O/M twin pipes	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00
	Installation distribution pump	€ 21,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33
	Fixed O/M distribution pump	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00
	Construction production facility	€ 50,000.00																	
Miscellaneous	Development and engineering costs	€ 275,000.00																	
	Replacement gas-fired stove	€ 200,000.00																	
	Conversion to three-phase power	€ 200,000.00																	
	Removal tariff connection natural gas	€ 57,978.00																	
	Compensation fine	€ 20,000.00																	
	Subtotal Capex:	€ 2,753,606.91	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58
Operating Expenses (Opex)																			
Primary installation	Variable O/M GSHP	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12
	Fuel GSHP	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
	Variable O/M electric boiler	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14
	Fuel electric boiler	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
Secondary installation	Variable O/M oil-fired boiler	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31
	Fuel oil-fired boiler	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76
DH pipelines and distribution pumps	Total network operating costs (Enexis)	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00
Miscellaneous	Heat exchanger and meter	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00
	Staff	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00
	Incasso administration	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00
	Housing	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00
	Overheads	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00
	Subtotal Opex:	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40
	Total Capex & Opex:	€ 2,951,337.32	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98
Incomes																			
	Heat supply to customers (inrease of 3% year)	€ 306,755.83	€ 315,958.51	€ 325,437.26	€ 335,200.38	€ 345,256.39	€ 355,614.09	€ 366,282.51	€ 377,270.98	€ 388,589.11	€ 400,246.79	€ 412,254.19	€ 424,621.81	€ 437,360.47	€ 450,481.28	€ 463,995.72	€ 477,915.59	€ 492,253.06	€ 507,020.65
	VAT sales (21%)	€ 64,418.73	€ 66,351.29	€ 68,341.83	€ 70,392.08	€ 72,503.84	€ 74,678.96	€ 76,919.33	€ 79,226.91	€ 81,603.71	€ 84,051.82	€ 86,573.38	€ 89,170.58	€ 91,845.70	€ 94,601.07	€ 97,439.10	€ 100,362.27	€ 103,373.14	€ 106,474.34
	Earnings Before interest and tax (EBIT):	€ -2,580,162.76	€ 134,344.82	€ 145,814.11	€ 157,627.48	€ 169,795.26	€ 182,328.06	€ 195,236.85	€ 208,532.91	€ 222,227.85	€ 236,333.63	€ 250,862.59	€ 265,827.42	€ 281,241.19	€ 297,117.37	€ 313,469.84	€ 330,312.89	€ 347,661.22	€ 365,530.01
Energy tax	Energy tax electricity	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29
	Tax on Sustainable Energy	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98
	Interest (4%) and repayment	€ 178,750.00	€ 176,000.00	€ 173,250.00	€ 170,500.00	€ 167,750.00	€ 165,000.00	€ 162,250.00	€ 159,500.00	€ 156,750.00	€ 154,000.00	€ 151,250.00	€ 148,500.00	€ 145,750.00	€ 143,000.00	€ 140,250.00	€ 137,500.00	€ 134,750.00	€ 132,000.00
	VAT sales (21%)	64,418.73	66,351.29	68,341.83	70,392.08	72,503.84	74,678.96	76,919.33	79,226.91	81,603.71	84,051.82	86,573.38	89,170.58	91,845.70	94,601.07	97,439.10	100,362.27	103,373.14	106,474.34
	VAT procurement (21%)	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80
	Earnings After Taxes (EAT):	€ -2,850,791.56	€ -135,466.55	€ -123,237.79	€ -110,724.67	€ -97,918.66	€ -84,810.97	€ -71,392.55	€ -57,654.07	€ -43,585.94	€ -29,178.27	€ -14,420.86	€ 696.76	€ 16,185.42	€ 32,056.23	€ 48,320.67	€ 64,990.54	€ 82,078.01	€ 99,595.60

Table 2 shows the operating budget of year 19-40 based on the current heat tariff (-10%) in Paddepoel-Noord.

Table 2. Operating budget year 19-40.

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060
€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30															
€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50
€ 1,521.26	€ 1,521.26																				
€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10
€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09
€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00
€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33										
€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00
€ 50,234.58	€ 50,234.58	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69
€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12
€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14
€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31
€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76
€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00
€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00
€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00
€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00
€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00
€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00
€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40
€ 247,964.98	€ 247,964.98	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09
€ 522,231.27	€ 537,898.21	€ 554,035.16	€ 570,656.21	€ 587,775.90	€ 605,409.18	€ 623,571.45	€ 642,278.59	€ 661,546.95	€ 681,393.36	€ 701,835.16	€ 722,890.22	€ 744,576.92	€ 766,914.23	€ 789,921.66	€ 813,619.31	€ 838,027.89	€ 863,168.72	€ 889,063.78	€ 915,735.70	€ 943,207.77	€ 971,504.00
€ 109,668.57	€ 112,958.62	€ 116,347.38	€ 119,837.80	€ 123,432.94	€ 127,135.93	€ 130,950.00	€ 134,878.50	€ 138,924.86	€ 143,092.61	€ 147,385.38	€ 151,806.95	€ 156,361.15	€ 161,051.99	€ 165,883.55	€ 170,860.05	€ 175,985.86	€ 181,265.43	€ 186,703.39	€ 192,304.50	€ 198,073.63	€ 204,015.84
€ 383,934.86	€ 402,891.86	€ 423,938.82	€ 444,050.30	€ 464,765.12	€ 486,101.38	€ 508,077.74	€ 573,308.68	€ 596,623.39	€ 620,637.54	€ 645,372.12	€ 670,848.74	€ 698,422.99	€ 725,451.13	€ 753,290.12	€ 781,964.27	€ 811,498.65	€ 841,919.07	€ 873,252.09	€ 905,525.11	€ 938,766.31	€ 973,004.75
€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29
€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98
€ 129,250.00	€ 126,500.00	€ 123,750.00	€ 121,000.00	€ 118,250.00	€ 115,500.00	€ 112,750.00	€ 110,000.00	€ 107,250.00	€ 104,500.00	€ 101,750.00	€ 99,000.00	€ 96,250.00	€ 93,500.00	€ 90,750.00	€ 88,000.00	€ 85,250.00	€ 82,500.00	€ 79,750.00	€ 77,000.00	€ 74,250.00	€ 71,500.00
109,668.57	112,958.62	116,347.38	119,837.80	123,432.94	127,135.93	130,950.00	134,878.50	138,924.86	143,092.61	147,385.38	151,806.95	156,361.15	161,051.99	165,883.55	170,860.05	175,985.86	181,265.43	186,703.39	192,304.50	198,073.63	204,015.84
4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80
€ 117,556.22	€ 135,973.16	€ 156,381.36	€ 175,752.42	€ 195,622.11	€ 216,005.38	€ 236,917.66	€ 300,970.10	€ 322,988.46	€ 345,584.86	€ 368,776.66	€ 392,581.72	€ 418,351.76	€ 443,439.07	€ 469,196.49	€ 495,644.14	€ 522,802.72	€ 550,693.56	€ 579,338.62	€ 608,760.53	€ 638,982.61	€ 670,028.84

Appendix 3: Operating budget based on maximum heat tariff in Paddepoel-Noord

Table 1 shows the operating budget of year 1-18 based on the maximum heat tariff (ACM) in Paddepoel-Noord.

Table 1. Operating budget year 1-18.

	Period:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Year:	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	Description																		
Capital Expenditures (Capex)																			
Primary installation	Installation GSHP	€ 1,064,882.42																	
	Depreciation GSHP	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30
	Fixed O&M GSHP	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50
	Installation electric boiler	€ 30,425.21																	
	Depreciation electric boiler	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26
	Fixed O&M electric boiler	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10
Secondary installation	Installation oil-fired boiler	€ 185,086.71																	
	Fixed O&M oil-fired boiler	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09
DH pipelines and distribution pumps	Installation twin pipes	€ 600,000.00																	
	Fixed O/M twin pipes	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00
	Installation distribution pump	€ 21,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33
	Fixed O/M distribution pump	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00
	Construction production facility	€ 50,000.00																	
Miscellaneous	Development and engineering costs	€ 250,000.00																	
	Replacement gas-fired stove	€ 200,000.00																	
	Conversion to three-phase power	€ 200,000.00																	
	Removal tariff connection natural gas	€ 57,978.00																	
	Compensation fine	€ 20,000.00																	
	Subtotal Capex:	€ 2,728,606.91	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58
Operating Expenses (Opex)																			
Primary installation	Variable O/M GSHP	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12
	Fuel GSHP	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
	Variable O/M electric boiler	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14
	Fuel electric boiler	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
Secondary installation	Variable O/M oil-fired boiler	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31
	Fuel oil-fired boiler	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76
DH pipelines and distribution pumps	Total network operating costs (Enexis)	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00
Miscellaneous	Heat exchanger and meter	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00
	Staff	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00
	Incasso administration	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00
	Housing	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00
	Overheads	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00
	Subtotal Opex:	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40
	Total Capex & Opex:	€ 2,926,337.32	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98
Incomes																			
Network operating costs	Connection fee (one-time) (increase 3%/year)	€ 187,439.71																	
	Fee delivery device (increase 3%/year)	€ 15,444.00	€ 15,907.32	€ 16,384.54	€ 16,876.08	€ 17,382.36	€ 17,903.83	€ 18,440.94	€ 18,994.17	€ 19,564.00	€ 20,150.92	€ 20,755.44	€ 21,378.11	€ 22,019.45	€ 22,680.03	€ 23,360.44	€ 24,061.25	€ 24,783.09	€ 25,526.58
	Fee measurement device (increase 3%/year)	€ 4,191.74	€ 4,317.49	€ 4,447.01	€ 4,580.42	€ 4,717.84	€ 4,859.37	€ 5,005.15	€ 5,155.31	€ 5,309.97	€ 5,469.26	€ 5,633.34	€ 5,802.34	€ 5,976.41	€ 6,155.70	€ 6,340.38	€ 6,530.59	€ 6,726.51	€ 6,928.30
Tariffs heat supply	Fixed tariff heat supply (increase 3%/year)	€ 51,160.33	€ 52,695.14	€ 54,275.99	€ 55,904.27	€ 57,581.40	€ 59,308.84	€ 61,088.11	€ 62,920.75	€ 64,808.38	€ 66,752.63	€ 68,755.21	€ 70,817.86	€ 72,942.40	€ 75,130.67	€ 77,384.59	€ 79,706.13	€ 82,097.31	€ 84,560.23
	Variable tariff heat supply (inrease of 3%/year)	€ 225,967.72	€ 232,746.75	€ 239,729.16	€ 246,921.03	€ 254,328.66	€ 261,958.52	€ 269,817.28	€ 277,911.79	€ 286,249.15	€ 294,836.62	€ 303,681.72	€ 312,792.17	€ 322,175.94	€ 331,841.22	€ 341,796.45	€ 352,050.35	€ 362,611.86	€ 373,490.21
	VAT sales (21%)	€ 101,682.73	€ 64,190.01	€ 66,115.71	€ 68,099.18	€ 70,142.15	€ 72,246.42	€ 74,413.81	€ 76,646.23	€ 78,945.61	€ 81,313.98	€ 83,753.40	€ 86,266.00	€ 88,853.98	€ 91,519.60	€ 94,265.19	€ 97,093.15	€ 100,005.94	€ 103,006.12
	Earnings Before interest and tax (EBIT):	€ -2,340,451.09	€ 121,891.73	€ 132,987.43	€ 144,416.00	€ 156,187.43	€ 168,312.00	€ 180,800.31	€ 193,663.27	€ 206,912.12	€ 220,558.43	€ 234,614.13	€ 249,091.51	€ 264,003.20	€ 279,362.25	€ 295,182.06	€ 311,476.48	€ 328,259.72	€ 345,546.46
Energy tax	Energy tax electricity	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29
	Tax on Sustainable Energy	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98
	Interest (4%) and repayment	€ 162,500.00	€ 160,000.00	€ 157,500.00	€ 155,000.00	€ 152,500.00	€ 150,000.00	€ 147,500.00	€ 145,000.00	€ 142,500.00	€ 140,000.00	€ 137,500.00	€ 135,000.00	€ 132,500.00	€ 130,000.00	€ 127,500.00	€ 125,000.00	€ 122,500.00	€ 120,000.00
	VAT sales (21%)	101,682.73	64,190.01	66,115.71	68,099.18	70,142.15	72,246.42	74,413.81	76,646.23	78,945.61	81,313.98	83,753.40	86,266.00	88,853.98	91,519.60	94,265.19	97,093.15	100,005.94	103,006.12
	VAT procurement (21%)	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80
	Earnings After Taxes (EAT):	€ -2,632,093.90	€ -129,758.35	€ -118,088.35	€ -106,143.25	€ -93,914.80	€ -81,394.49	€ -68,573.57	€ -55,443.03	€ -41,993.57	€ -28,215.62	€ -14,099.34	€ 365.43	€ 15,189.15	€ 30,382.57	€ 45,956.80	€ 61,923.26	€ 78,293.71	€ 95,080.27

Table 2 shows the operating budget of year 19-40 based on the maximum heat tariff (ACM) in Paddepoel-Noord.

Table 2. Operating budget year 19-40.

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060
€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30															
€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50
€ 1,521.26	€ 1,521.26																				
€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10
€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09
€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00
€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33										
€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00
€ 50,234.58	€ 50,234.58	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69
€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12
€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14
€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31
€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76
€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00
€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00
€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00
€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00
€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00
€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00
€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40
€ 247,964.98	€ 247,964.98	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09
€ 26,292.38	€ 27,081.15	€ 27,893.58	€ 28,730.39	€ 29,592.30	€ 30,480.07	€ 31,394.47	€ 32,336.31	€ 33,306.40	€ 34,305.59	€ 35,334.76	€ 36,394.80	€ 37,486.64	€ 38,611.24	€ 39,769.58	€ 40,962.67	€ 42,191.55	€ 43,457.29	€ 44,761.01	€ 46,103.84	€ 47,486.96	€ 48,911.56
€ 7,136.15	€ 7,350.23	€ 7,570.74	€ 7,797.86	€ 8,031.80	€ 8,272.75	€ 8,520.94	€ 8,776.56	€ 9,039.86	€ 9,311.06	€ 9,590.39	€ 9,878.10	€ 10,174.44	€ 10,479.68	€ 10,794.07	€ 11,117.89	€ 11,451.42	€ 11,794.97	€ 12,148.82	€ 12,513.28	€ 12,888.68	€ 13,275.34
€ 87,097.04	€ 89,709.95	€ 92,401.25	€ 95,173.29	€ 98,028.48	€ 100,969.34	€ 103,998.42	€ 107,118.37	€ 110,331.92	€ 113,641.88	€ 117,051.14	€ 120,562.67	€ 124,179.55	€ 127,904.94	€ 131,742.09	€ 135,694.35	€ 139,765.18	€ 143,958.13	€ 148,276.88	€ 152,725.18	€ 157,306.94	€ 162,026.15
€ 384,694.92	€ 396,235.77	€ 408,122.84	€ 420,366.52	€ 432,977.52	€ 445,966.85	€ 459,345.85	€ 473,126.23	€ 487,320.01	€ 501,939.61	€ 516,997.80	€ 532,507.74	€ 548,482.97	€ 564,937.46	€ 581,885.58	€ 599,342.15	€ 617,322.41	€ 635,842.09	€ 654,917.35	€ 674,564.87	€ 694,801.81	€ 715,645.87
€ 106,096.30	€ 109,279.19	€ 112,557.57	€ 115,934.29	€ 119,412.32	€ 122,994.69	€ 126,684.53	€ 130,485.07	€ 134,399.62	€ 138,431.61	€ 142,584.56	€ 146,862.09	€ 151,267.96	€ 155,806.00	€ 160,480.18	€ 165,294.58	€ 170,253.42	€ 175,361.02	€ 180,621.85	€ 186,040.51	€ 191,621.72	€ 197,370.37
€ 363,351.80	€ 381,691.31	€ 402,102.26	€ 421,558.64	€ 441,598.71	€ 462,239.98	€ 483,500.49	€ 547,994.11	€ 570,549.39	€ 593,781.32	€ 617,710.22	€ 642,356.98	€ 669,076.47	€ 695,224.22	€ 722,156.40	€ 749,896.54	€ 778,468.89	€ 807,898.41	€ 838,210.81	€ 869,432.59	€ 901,591.02	€ 934,714.21
€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29
€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98
€ 117,500.00	€ 115,000.00	€ 112,500.00	€ 110,000.00	€ 107,500.00	€ 105,000.00	€ 102,500.00	€ 100,000.00	€ 97,500.00	€ 95,000.00	€ 92,500.00	€ 90,000.00	€ 87,500.00	€ 85,000.00	€ 82,500.00	€ 80,000.00	€ 77,500.00	€ 75,000.00	€ 72,500.00	€ 70,000.00	€ 67,500.00	€ 65,000.00
106,096.30	109,279.19	112,557.57	115,934.29	119,412.32	122,994.69	126,684.53	130,485.07	134,399.62	138,431.61	142,584.56	146,862.09	151,267.96	155,806.00	160,480.18	165,294.58	170,253.42	175,361.02	180,621.85	186,040.51	191,621.72	197,370.37
4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80
€ 112,295.43	€ 129,952.04	€ 149,584.62	€ 168,164.27	€ 187,226.31	€ 206,785.21	€ 226,855.88	€ 290,048.97	€ 311,189.69	€ 332,889.64	€ 355,165.58	€ 378,034.81	€ 402,848.44	€ 426,958.15	€ 451,716.15	€ 477,141.89	€ 503,255.40	€ 530,077.31	€ 557,628.89	€ 585,932.01	€ 615,009.23	€ 644,883.76

Appendix 4: Operating budget based on subsidy in Paddepoel-Noord

Table 1 shows the operating budget of year 1-18 based on subsidy (€ 5,000/household) in Paddepoel-Noord.

Table 1. Operating budget year 1-18.

	Period:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Year:	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	Description																		
Capital Expenditures (Capex)																			
Primary installation	Installation GSHP	€ 1,064,882.42																	
	Depreciation GSHP	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30
	Fixed O&M GSHP	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50
	Installation electric boiler	€ 30,425.21																	
	Depreciation electric boiler	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26	€ 1,521.26
	Fixed O&M electric boiler	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10
Secondary installation	Installation oil-fired boiler	€ 185,086.71																	
	Fixed O&M oil-fired boiler	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09
DH pipelines and distribution pumps	Installation twin pipes	€ 600,000.00																	
	Fixed O/M twin pipes	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00
	Installation distribution pump	€ 21,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33
	Fixed O/M distribution pump	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00
	Construction production facility	€ 50,000.00																	
Miscellaneous	Development and engineering costs	€ 175,000.00																	
	Replacement gas-fired stove	€ 200,000.00																	
	Conversion to three-phase power	€ 200,000.00																	
	Removal tariff connection natural gas	€ 57,978.00																	
	Compensation fine	€ 20,000.00																	
	Subtotal Capex:	€ 2,653,606.91	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58	€ 50,234.58
Operating Expenses (Opex)																			
Primary installation	Variable O/M GSHP	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12
	Fuel GSHP	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
	Variable O/M electric boiler	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14
	Fuel electric boiler	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
Secondary installation	Variable O/M oil-fired boiler	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31
	Fuel oil-fired boiler	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76
DH pipelines and distribution pumps	Total network operating costs (Enexis)	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00
Miscellaneous	Heat exchanger and meter	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00
	Staff	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00
	Incasso administration	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00
	Housing	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00
	Overheads	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00
	Subtotal Opex:	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40
	Total Capex & Opex:	€ 2,851,337.32	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98	€ 247,964.98
Incomes																			
	Subsidy (€5,000 household)	€ 1,000,000.00																	
	Heat supply to customers (inrease of 3% year)	€ 306,755.83	€ 315,958.51	€ 325,437.26	€ 335,200.38	€ 345,256.39	€ 355,614.09	€ 366,282.51	€ 377,270.98	€ 388,589.11	€ 400,246.79	€ 412,254.19	€ 424,621.81	€ 437,360.47	€ 450,481.28	€ 463,995.72	€ 477,915.59	€ 492,253.06	€ 507,020.65
	VAT sales (21%)	€ 64,418.73	€ 66,351.29	€ 68,341.83	€ 70,392.08	€ 72,503.84	€ 74,678.96	€ 76,919.33	€ 79,226.91	€ 81,603.71	€ 84,051.82	€ 86,573.38	€ 89,170.58	€ 91,845.70	€ 94,601.07	€ 97,439.10	€ 100,362.27	€ 103,373.14	€ 106,474.34
	Earnings Before interest and tax (EBIT):	€ -1,480,162.76	€ 134,344.82	€ 145,814.11	€ 157,627.48	€ 169,795.26	€ 182,328.06	€ 195,236.85	€ 208,532.91	€ 222,227.85	€ 236,333.63	€ 250,862.59	€ 265,827.42	€ 281,241.19	€ 297,117.37	€ 313,469.84	€ 330,312.89	€ 347,661.22	€ 365,530.01
Energy tax	Energy tax electricity	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29
	Tax on Sustainable Energy	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98
	Interest (4%) and repayment	€ 113,750.00	€ 112,000.00	€ 110,250.00	€ 108,500.00	€ 106,750.00	€ 105,000.00	€ 103,250.00	€ 101,500.00	€ 99,750.00	€ 98,000.00	€ 96,250.00	€ 94,500.00	€ 92,750.00	€ 91,000.00	€ 89,250.00	€ 87,500.00	€ 85,750.00	€ 84,000.00
	VAT sales (21%)	64,418.73	66,351.29	68,341.83	70,392.08	72,503.84	74,678.96	76,919.33	79,226.91	81,603.71	84,051.82	86,573.38	89,170.58	91,845.70	94,601.07	97,439.10	100,362.27	103,373.14	106,474.34
	VAT procurement (21%)	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80
	Earnings After Taxes (EAT):	€ -1,685,791.56	€ -71,466.55	€ -60,237.79	€ -48,724.67	€ -36,918.66	€ -24,810.97	€ -12,392.55	€ 345.93	€ 13,414.06	€ 26,821.73	€ 40,579.14	€ 54,696.76	€ 69,185.42	€ 84,056.23	€ 99,320.67	€ 114,990.54	€ 131,078.01	€ 147,595.60

Table 2 shows the operating budget of year 19-40 based on subsidy (€ 5,000/household) in Paddepoel-Noord.

Table 2. Operating budget year 19-40.

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
2039	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**	**2051**	**2052**	**2053**	**2054**	**2055**	**2056**	**2057**	**2058**	**2059**	**2060**
€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30	€ 42,595.30															
€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50	€ 3,255.50
€ 1,521.26	€ 1,521.26																				
€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10	€ 358.10
€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09	€ 396.09
€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00	€ 375.00
€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33	€ 1,333.33										
€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00	€ 400.00
€ 50,234.58	€ 50,234.58	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 48,713.32	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 6,118.02	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69	€ 4,784.69
€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12	€ 1,084.12
€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14	€ 301.14
€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04	€ 27,103.04
€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31	€ 80.31
€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76	€ 872.76
€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00	€ 53,826.00
€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00	€ 16,860.00
€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00	€ 47,500.00
€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00	€ 4,000.00
€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00	€ 5,000.00
€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00	€ 14,000.00
€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40	€ 197,730.40
€ 247,964.98	€ 247,964.98	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 246,443.72	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 203,848.42	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09	€ 202,515.09
€ 522,231.27	€ 537,898.21	€ 554,035.16	€ 570,656.21	€ 587,775.90	€ 605,409.18	€ 623,571.45	€ 642,278.59	€ 661,546.95	€ 681,393.36	€ 701,835.16	€ 722,890.22	€ 744,576.92	€ 766,914.23	€ 789,921.66	€ 813,619.31	€ 838,027.89	€ 863,168.72	€ 889,063.78	€ 915,735.70	€ 943,207.77	€ 971,504.00
€ 109,668.57	€ 112,958.62	€ 116,347.38	€ 119,837.80	€ 123,432.94	€ 127,135.93	€ 130,950.00	€ 134,878.50	€ 138,924.86	€ 143,092.61	€ 147,385.38	€ 151,806.95	€ 156,361.15	€ 161,051.99	€ 165,883.55	€ 170,860.05	€ 175,985.86	€ 181,265.43	€ 186,703.39	€ 192,304.50	€ 198,073.63	€ 204,015.84
€ 383,934.86	€ 402,891.86	€ 423,938.82	€ 444,050.30	€ 464,765.12	€ 486,101.38	€ 508,077.74	€ 573,308.68	€ 596,623.39	€ 620,637.54	€ 645,372.12	€ 670,848.74	€ 698,422.99	€ 725,451.13	€ 753,290.12	€ 781,964.27	€ 811,498.65	€ 841,919.07	€ 873,252.09	€ 905,525.11	€ 938,766.31	€ 973,004.75
€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29	€ 16,912.29
€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98	€ 5,781.98
€ 82,250.00	€ 80,500.00	€ 78,750.00	€ 77,000.00	€ 75,250.00	€ 73,500.00	€ 71,750.00	€ 70,000.00	€ 68,250.00	€ 66,500.00	€ 64,750.00	€ 63,000.00	€ 61,250.00	€ 59,500.00	€ 57,750.00	€ 56,000.00	€ 54,250.00	€ 52,500.00	€ 50,750.00	€ 49,000.00	€ 47,250.00	€ 45,500.00
109,668.57	112,958.62	116,347.38	119,837.80	123,432.94	127,135.93	130,950.00	134,878.50	138,924.86	143,092.61	147,385.38	151,806.95	156,361.15	161,051.99	165,883.55	170,860.05	175,985.86	181,265.43	186,703.39	192,304.50	198,073.63	204,015.84
4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80	4,765.80
€ 164,556.22	€ 181,973.16	€ 201,381.36	€ 219,752.42	€ 238,622.11	€ 258,005.38	€ 277,917.66	€ 340,970.10	€ 361,988.46	€ 383,584.86	€ 405,776.66	€ 428,581.72	€ 453,351.76	€ 477,439.07	€ 502,196.49	€ 527,644.14	€ 553,802.72	€ 580,693.56	€ 608,338.62	€ 636,760.53	€ 665,982.61	€ 696,028.84

Appendix 5

Summaries interviews

Contents

1 Fokko Reinders (Relation Manager and advisor sustainability at Enexis) and Kees van Dalen (Strategic Advisor at Enexis)

Date: 17 May 2018.

Fokko: Last year I did research on Paddepoel-Noord to investigate for example the housing types and the population characteristics. We also thought about solutions and possibilities to make Paddepoel-Noord more sustainable. The result was a covenant with different stakeholders. I can share this covenant with you.

Fokko: Be aware of the installations behind the meter (e.g. radiators, boiler). The installations must be reconnected and maybe even replaced (radiators).

Fokko: It is possible to connect a P2H system to the medium-voltage grid in Paddepoel-Noord. The following link provides an overview of the location of the medium-voltage grid in Groningen: http://129.125.49.13/Viewer.aspx?map=Energiekansenkaart.

Kees: An interesting project in the energy transition is Traais Energie Collectief. It is a citizens' initiative in Terheiden, a village near Breda. They want to become energy neutral by 2030. The village has a total of 2,000 households and 6,000 inhabitants. They apply a citizens-owned windmill and solar-project for their electricity-consumption and they want to apply geothermal (shallow) to provide the baseload and elephant grass to provide the peak load for their heat-demand. They have calculated the business case, in combination with an SDE subsidy and a bank loan, the investment per citizen is an acceptable amount.

Fokko: Enexis is a public company and we have a public task. We want to serve the common good and therefore support DH initiatives. We recognise that our role as DSO will change in the future.

Kees: They plan to revise the Heat Acts next year. If we want to realise that ambition, we need to set the pickets as soon as possible otherwise we will not reach the ambition.

Kees: Recently a graduate student of the RUG investigated the institutional design for DH systems. We can send the thesis to you as well.

Fokko: The province of Zeeland has experienced a major disaster, namely the flood of 1953. In response, they built the Delta Works to protect their province. As a result, the province of Zeeland is known nationally and internationally because of its Delta Works. The province of Groningen is currently experiencing the earthquakes and that is terrible of course. However, it makes Groningen a very good testing ground (in Dutch: *proeftuin*) for sustainable energy solutions. Wouldn't it be great when Groningen, similar to the province of Zeeland, will be known nationally and internationally because of the sustainable energy and sustainable heat solutions?

Kees: What I find interesting about P2H is that it integrates the power and heat sector. In general, we have lived on separate 'islands' for a long time, but the time for integration has arrived.

Kees: Do you know Aris de Groot, managing director of EcoVat? EcoVat works on seasonal thermal energy storage.

Fokko: Kevin Mooibroek, former sales manager at Reggefiber, has an interesting story about how to recruit participants. Reggefiber is a company that lays fibre optic networks. In order to get started, they needed at least 30% of the citizens to participate. Their strategy to recruit participants was to be present in the neighbourhood. For example, to open a small store in a shipping container where local residents can ask all their questions and to approach all people multiple times. As a result, eventually 80% of the citizens participated and invested in a fibre optic connection. It was important that people could see that something was happening in their neighbourhood and that because people like to become part of it.

Kees: The previous urban renewal in Groningen is another good example of citizens participation. Also, in this case an office was placed in the neighbourhood to create a place where residents could ask all their questions. In addition, residents were visited from door to door to explain everything to them. Then, one contractor started to renew the houses, one by one. It is interesting to note that these neighbourhoods are still among the best neighbourhoods in the city, e.g. the Noorderplantsoenbuurt.

2 Gerwin Verschuur (Managing Director of Thermo Bello)

Date: 20 June 2018.

How is the DH system of Thermo Bello dimensioned (peak load, simultaneity factor)?
The production installations of Thermo Bello are dimensioned on -10 °C which is common for DH systems. Theoretically we supply water of maximum 50 °C, however, in practice we supply water of 52 °C. In 2012, we had ten days of -20 °C. Thermo Bello could supply enough heat, only a few houses got in trouble due to poor insulation. Our simultaneity factor is around 0.50. A factor of 0.53 is good.

Does Thermo Bello also supplies cold?
No, we do not, but we allow commercial parties to use our DH network to release heat during hot weather. A total of eight fans have been installed to cool commercial buildings. The released heat can be partly reused. For example, some commercial building release heat during the day to the DH system while the DH system is used for space heating in households during the evening. Perhaps this heat can be used in the future for hot tap water. When commercial parties use our DH network, we have to switch off and restart our pumps. This is a difficult process for us, especially to guarantee the heat supply. I would never do this again.

Why does Thermo Bello not supply hot tap water?
At the moment there are high-temperature heat pumps available on the market, but by the time Thermo Bello started, only low-temperature heat pumps existed. The neighbourhood uses different systems for hot tap water. We are currently experimenting with ten so-called booster heat pumps, supplied by a company called Itho Daalderop. These heat pumps are used as an individual solution. The investment costs amount to approximately € 3,000. The COP is around 5 because the water temperature just needs to be raised from 50 to 60 °C.

Do you have detailed prices of installations (heat pump, distribution pumps) and the construction of the pipelines available for our business case?

- The total contract sum of the construction of 1 km pipeline was € 300,000. However, this also included a directional drilling. € 200 per meter pipeline is a realistic price. Most costs are made with digging (a lock of 1-1.20 m is required) and repaving the streets.
- The costs of distribution pumps depend on size, pressure, variable controlled speed etc. € 10,000 per pump is a realistic price. You always need two pumps, one as back-up. The lifetime is around 15 years. The maintenance costs are really low.
- Our (electric) heat pump costed € 70,000 including installation. The capacity is 780 kWt (output) and 220 kW (input).
- The heat pump including heat exchanger (TSA) and additional pump to pump brine water costed € 150,000 including installation.

Does Thermo Bello have lower CO_2 emissions compared to individual gas-fired boilers, if so, how much?
Not much. Currently we buy our electricity from Vitens which is 'grey with a bit of green'. We are trying to purchase real green electricity, e.g. wind energy. In that case, our system will become more sustainable. Recently, a student from the University of Twente calculated our CO_2 footprint.

Did Thermo Bello receive any subsidies and if so, which?
In the beginning, the municipality guaranteed our bank loan. We got a subsidy to write a brochure and we got a subsidy to write the report '*Thermo Bello: energie voor de wijk; nieuwe nuts in de praktijk*' to cover partly the starting up costs. Later we received € 100,000 to expand the DH network and we charged € 75,000 to connect a local school building.

In the beginning we had a loan from Greenchoice (€ 50,000) and a loan from DEC (€ 50,000) which is a division of VolkerWessels. Later we saw that both parties were mainly focused on profits and raised the interest and dividend to (for us) unacceptable amounts. In response, we have issued depositary receipts with a fixed value of € 250 and a 4% dividend to local residents. With that money we were able to pay off all of our loans which made us independent of commercial investors. In addition, the profit is circular (it stays in the neighbourhood). Currently we have a total debt of € 42,500, of which € 6,000 was from the neighbourhood association.

Is the voting structure as described in the report 'Nieuwe nuts in de praktijk' still the same, or has it changed because it is a cooperatively organised?
The voting rights are divided among two parties A and B because we do not have commercial investors anymore. The commercial consumers do not want to have a vote. We have to change the statutes which we are going to do this year.

How does Thermo Bello relate to the Heat Act?
The Heat Act differentiates two categories: obliged or not obliged. When you are obliged (>10,000 GJ) you have to stick to 18 legal requirements. When you are not legally obliged (<10,000) only 8 legal requirements apply.

What was the perception of the residents and the municipality during the exploratory phase?
Basically, two responses: (1) nice to explore, we will see how it will turn out and (2) fearful, too much responsibility etc.

'The municipality' does not really exist because a municipality consists of people as well.

Our strength was that we had an open mind-set. We founded a business development association (VOEW) with the goal to explore and investigate if a takeover would be realistic and (economic) feasible). The primary goal was not a takeover.

What is/are your recommendation(s) for establishing a DH system and requiting participants?
Communicate. Seek for resistance and embrace it. People have to adjust their mind-set. People have to become a participant instead of just being a consumer. Sometimes called a prosumer or in Dutch 'consumens'. You need to take all the fears and problems that people might have very seriously. Their point of view is often based on knowledge or previous experience which is useful. The problems and fears (risks) must be reflected in the business plan. In addition, you need capable people, a solid business plan and perhaps a few guarantees.

What are the most important lessons you have learned of establishing and operating the energy company Thermo Bello?
I have learned that there is a big gap between design, construction and operation of a DH system. Companies hire different engineering companies, with the risk that the overview of the total system gets lost. The responsibility of the integration of all different elements is for the client itself at the moment. We discovered, for example, still after a few years a couple of issues in our DH system. We have checked our DH system by disconnecting sensors and seeing what is happening. I think it is better to purchase a certain service instead of a certain product. Installations really need to be checked before completion and operation. 5-10% of the costs need to be paid to test and report the operation of the installations before completion and operation.

Do you have any recommendations for EcoGenie Paddepoel-Noord?

- I like the three C's of Paddepoel-Noord (cost reduction, CO_2 emissions reduction and an increase of comfort) however I would suggest to highlight the aspect of ownership as well. This will be a big change for the people. If you treat residents as consumers, they will remain consumers, but that is not what you want. Emphasise that you want to do something special, want something unique and want to be an example for the rest of the Netherlands.
- I would suggest to emphasise the urgency of the problem of natural gas. Make people aware and emphasise that, when they invest in a small-scale DH project instead of a large-scale DH project, the profit will circulate in the neighbourhood itself. By way of comparison, investors of large-scale DH projects want to have an IRR of 15%. A small-scale DH project can be satisfied with for example an IRR of 6%.

Do you know similar projects in or outside the Netherlands and do you know people who are interesting to interview about this topic?
No, I don't know other projects. In Denmark, members of DH cooperatives are only network operator. In Italy, DH systems are often powered by a biomass plant.

You can talk to Maya van der Steenhoven. She is director of the program for (large-scale) heat and cold projects in the province of Zuid Holland. However, she also has affinity with cooperatives. You can use my name as a reference.

Do you have any additional questions and/or remarks about this research or this interview?
I would like to receive the thesis as well. On 15 August we will have a meeting about cooperative DH systems. If possible, we would like to receiver your thesis in advance. 10 August will be a good date to receive a draft version.

3 Jord Kuiken (Project Manager at TexelEnergie)

Date: 10 July 2018.

What is your current position at TexelEnergie and what is your background (education, jobs etc.)?
I have a background in the automotive sector. I moved to Texel for private reasons in 2010 and applied for a job at TexelEnergie. TexelEnergie is a small cooperative, we do everything together with a small team (2.5 FTE). My activities range from helping customers to start-up new energy projects.

TexelEnergie is an energy cooperative that produces and supplies sustainable energy. It was established in response to the ambition of the municipality to be self-sufficient by 2020. The municipality wanted to use the market to achieve this ambition, which is why residents of Texel started TexelEnergie in 2007. People can become customers and/or become a member of TexelEnergie. TexelEnergie is not exclusively for residents of Texel, people throughout the Netherlands can become customers.

There is a certain sense of community and ownership on Texel. For example, the ferry is to Texel is called: Texel's own steamship company (in Dutch: *Texels Eigen Stoomboot Onderneming, TESO).* As a result, the step towards the establishment of an energy cooperative is much smaller.

What does TexelEnergie do to make the heat supply more sustainable?
We purchase (exclusively Dutch energy) and supply green electricity and green gas. As soon as we can produce sustainable energy ourselves, we want to reduce the purchase of energy. We investigate every possibility. In my opinion, wind energy is an interesting alternative, but it is not permitted from the province of Noord-Holland. We have carried out projects with solar PV, smart grids and a biomass heating system (in Dutch: *biomassakachel*).

Can you explain the process of establishing and realising the DH system?
A housing corporation had 93 households in the district 'Wijk 99' which were connected to a DH system powered by gas-fired boilers. It concerns three streets with terraced houses. The DH system is established in 2007. Residents could choose whether they wanted heat from a DH system or an individual gas-fired boiler. The residents chose to be connected to a local DH system with the result that the housing corporation had to act as an energy company and began to invoice heat.

The establishment of TexelEnergie was an excellent opportunity for the housing corporation to transfer their activities concerning energy to TexelEnergie. TexelEnergie then investigated the possibility of replacing the gas-fired boilers with a biomass heating system. Not the residents but the local residents protested against the biomass heating system. However, the municipality has granted a permit to TexelEnergie to carry out the project. In response, local residents started a lawsuit, but the municipality won. Meanwhile, we discovered that the quality of the DH pipes was really poor. In response, the housing corporation promised to repair all the leaks. Finally, the biomass heating system was installed in 2014, but under close supervision of several environmental services. The emissions had to be regularly measured by certified companies.

In January 2014, the national government introduced the NMDA principle. At that time, our costs were about € 38/GJ, the current maximum tariff is about € 22/GJ. It is clear that our costs were far too high, and we were no longer allowed to invoice our costs. That was the reason to examine our DH network and we discovered large distribution losses. Moreover, we faced many difficulties with wood chips. All this together was the reason to stop the exploitation because it was not economically justified anymore to continue.

We conducted a survey among the residents. The residents thought it was fine to switch to an individual gas-fired boiler. It gave them the opportunity to choose between different suppliers. Between 2016 and 2017, the residents switched to individual gas-fired boilers and the biomass heating system was sold.

How was the DH system of TexelEnergie dimensioned (peak load, simultaneity factor, distribution loss)?
The biomass heating system had a capacity of approximately 200 kW. We concluded (far too late) that the distribution loss was around 50%.

Did TexelEnergie supply heat for both space heating and hot tap water?
Yes, we did both.

Was the DH network constructed by TexelEnergie or was it taken over from another party?
The DH network was constructed by the housing corporation.

How was the DH system financed (subsidy, shares)?
No subsidies or shares. We have charged the actual costs to our customers, including a contribution for the administration.

How did inhabitants of Texel respond to TexelEnergie as a local energy cooperative, what was their perception and motivation?
Two responses:

- Awesome. As a local energy cooperative, you have a ‘front door’. The energy supplier will become much more accessible, in our case this is especially important for foreigners with a cottage. Instead of calling a call centre, you can get easily support from local people.
- On the other hand, our ideas can lead to tension as well. If we investigate the possibilities of wind energy, for example, this could lead people to say that they will cancel their membership in we continue.

How can residents/members participate (decision making and sharing of the benefits)?
People can become a member by buying shares. TexelEnergie has a total number of 13,500 shares with a fixed value of € 50/share. Approximately 50% has been issued so far. TexelEnergie does not pay dividend because in our opinion it does not match with our ambitions.

How are decisions taken, who has the right to vote?
All members (above eighteen) have the right to vote. There are no exceptions, one vote per person.

How does TexelEnergie recruit participants?
It is difficult because there is a lot of competition on the energy market. The first group (early adapters) was relatively simple, they do not care much about a higher energy tariff. The second group (majority) is much more difficult because they are more concerned with their energy tariff.

In general, an energy company earns approximately € 100/customer. That is why an energy company must have around 15,000 customers. Jan Rotmans (professor at the Erasmus University) predicted that many energy cooperatives will be established in the coming years, but many cooperatives will also disappear. Without volume, it is not economically feasible. In addition, you have the default risk (in Dutch: *debiteurenrisico*). The default risk is slightly lower with owner-occupied housing than rented housing.

How do you create public support and win trust from the residents, the market and the local government?
In retrospect, we could have organised more meetings with local residents. But the atmosphere at meeting with local residents about the biomass heating systems was completely different from other meetings TexelEnergie organises (e.g. about solar PV or energy saving).

People can always ask their questions and discuss their problems about, for example, energy bills that they have received. Moreover, our cooperative has a strong social aspect. We help people who have difficulty with paying their energy bills. This is possible because we know them and their situation. By way of comparison: at large energy companies these people end up in formal debtors' trajectories. People receive high fines in a short time. As TexelEnergie we try to avoid these processes by guiding these people well in advance. This way we avoid many problems.

What are the most important lessons you have learned from your position as project manager at TexelEnergie?

1. As an energy cooperative you must be able to pay your bills (in Dutch: *de schoorsteen moet roken*). Projects must be economically viable or become economically viable in time. That is why you need both: being commercial and being innovative. In addition, you need to have knowledge about the energy market.
2. Be careful when choosing partners. On the one hand, customers go to the cooperative with all their problems. It does not matter who is responsible (you or one of your (administrative) partners) but the cooperative is in charge to solve the problems. Even if the solution is out of reach. On the other hand, cooperation with partners often leads to loss of recognisability.
3. It is important to document all the agreements you make with third parties.

Do you have any recommendations for EcoGenie Paddepoel-Noord?
It is very important to know whether it is economically viable and to know the quality of the DH network. Measurements in the DH network are very important, know the input ant the output.

Realising/purchasing of a biomass heating system was not very difficult but operating was much more difficult. Exploitation means 24 hours and 365 days per year.

In retrospect, we needed a ‘concierge’ who went daily to the biomass heating system and inspects the installation quickly.

Do you have any additional questions and/or remarks about this research or this interview?
I would like to receive a newsletter and stay informed of this project.

4 Kevin Mooibroek (Former Sales Manager at Reggefiber and entrepreneur)

Date: 05 June 2018.

What is your current position and what is your background (education, jobs etc.)?

I studied Commercial Economy. At the moment I have my own enterprise named Amsterdam Good Cookies and sell the best Dutch cookies, namely: ‘stroopwafels’. This idea emerged in Costa Rica where I worked. One day, I met a Dutch woman that baked stroopwafels and I decided to give some stroopwafels to my employee. He loved them so much that I, as sales manager, decided to use stroopwafels as promotional gift. It resulted in many contacts because people liked stroopwafels so much. Now it is my dream to share the feeling of a freshly baked stroopwafel with everyone around the world. I think everyone should have the right to eat a freshly baked stroopwafel. In addition, I like to make people happy and to let people smile. Before I started my own enterprise, I worked at Reggefiber for three years.

What was your job and what were your tasks at Reggefiber?
I worked as a sales manager between 2011 and 2014. Reggefiber is a company that lays fibre optic networks and connects households to it. To do this, it was necessary to recruit participants. Especially because fibre optic goes ‘behind the front door’. More participants naturally leads to a better business case. The goal of Reggefiber was to develop a fibre optic networks in various neighbourhoods of Emmen. It was my job to recruit as many participants as possible.

What was the perception of fibreoptic in that time?
Many people did not know what it was and why they needed it. Only a few early adopters knew the advantages of fibre optic, in our case mostly the computer nerds.

What was the strategy of Reggefiber to recruit participants?
After we got support from local authorities we started with an environmental analysis. We spend two months to gather as much information as possible about a particular neighbourhood. Think about:

- Do people live in owner-occupied houses or rented houses?
- Demographical characteristics?
- Are there any associations in the neighbourhood?
- Who are the key persons or influencers in the neighbourhood?
- Are there other plans (e.g. construction plans)?
- What kind of people live there and what would be their motivation to join?
- Are there already people that do something with fibre optic of sustainable energy?

We used the so-called mosaic score test to analyse the kind of people that live in a particular neighbourhood. We used CRM software. It multiplies certain ‘types’ (e.g. computer nerds or prosperous middle class) with the number of people who belong to that particular group. On this basis, we made predictions of the number of people who would be willing to sign-up for a fibre optic connection (expected penetration rate). In theory we needed at least 30%, but even if we have less than 30%, we started our campaigns. Moreover, it showed us which type of people we should concentrate on, that helped us to determine our strategy and to focus our campaigns. In addition, we made a SWOT analysis of the neighbourhood.

If we found influencers, we visited them before the campaign started. We asked if they wanted to become part of our campaign. For example, they can write an article in a local newspaper or give a speech to local citizens about why fibre optic is so important. On the other hand, the threat is that these people may find themselves too important which can become a frustration. It is important to keep the control in your own hands.

Our campaigns consisted of four phases: creating awareness > sowing > harvesting 1 > harvesting 2. Each phase lasted three weeks. Our budget was € 12.31 per household.

The awareness phase was just to inform people. We organised, for example, walk-in events with free coffee, cookies and a drink. As an invitation we send a letter to each household. In case people were convinced, they could already sign-up. If people were not convinced, we simply encouraged them to think about it. Use local associations, for example a special discount for all members of a local football club. Be creative. Most important is to create commotion (in Dutch: *reuring*). We opened a store of a bus in the neighbourhood for three or four days a week. A place to be present and to explain to people what you do. Essential to win trust of people.

The sowing phase is similar to the awareness phase but gives a little more information to people. Also, the next phase (harvesting) will be announced.

Harvesting 1 and harvesting 2 phases are about signing contracts. Make people aware that it is their only chance and that the time is limited. If they do not sign up, we said that we go to another neighbourhood were people are willing to join.

Did you have to create public support from local authorities? If yes: what was their perception and how did you get this support?
Public support of local authorities is essential. Before we started planning, we had already spoken with local authorities. If they are not convinced, you cannot start. Moreover, local authorities can give you a lot of publicity and help you to win trust of people.

Would you use the same strategy as before with today's knowledge?
Yes, definitely. This strategy has proven itself, so why should I change it?

What is/are your recommendation(s) for recruiting participants for a DH cooperative?

- It is very important to be present in the neighbourhood. Find a central place in the neighbourhood so people can see that something is happening and to answer people's questions. This is a way to gain trust of citizens.
- Give people a choice between two or three options. That was really helpful for us. Give people the feeling that they have a choice, otherwise it only leads to resistance.
- Visualise it for people. Build, for example, a demonstration model so people can see with their own eyes what the differences will be.
- Empathise with people, for example, try to understand their suspicious feeling, but use it to convince them to switch to a DH system. Does a DH system increase the value of people's homes?
- When you run campaigns, especially when you go up to people's houses, always announce it so people are prepared.
- Large companies often respond slowly because decision-making is very time consuming. However, in campaigns to recruit participants, decisions need to be made quickly. If there is an opportunity for publicity but is costs money, you cannot take eight weeks to take a decision. Therefore, a flexible organisation is very important.

- Create necessity. Necessity makes people choose. The typical sales curve has the shape of a hockey stick. The majority of people sign-up close to the deadline. Therefore, limit the timeframe of the campaign (e.g. three months) and announce a clear deadline, otherwise it is just a waste of money and effort.

Do you have any additional questions and/or remarks about this research or this interview?
No.

5 Louis Hiddes (Director of Mijnwater)

Date: 29 June 2018.

How is the DH system of Mijnwater dimensioned (peak load, simultaneity factor, distribution loss)?
Our distribution loss is almost zero because we distribute only very low temperatures. Our maximum capacity to deliver the peak load is sufficient because we use time (buffering) to meet the peak demand if necessary. Our heat pumps can operate during nights and store the energy (heat) in buffer vessels. In this way, the required capacity can be reduced, saving investment costs.

Does Mijnwater have a secondary (backup installation), if yes: what kind?
We do not have a specific backup installation because our system uses, next to heat/cold from wells, also exchanges heat/cold from local enterprises. We exchange for example residual heat/cold with the data centre of APG exchange heat/cold with the refrigerators and freezers of Jumbo. Because our DH system is an interconnected system, we do not need a backup installation. We try to understand the needs of local enterprises. For example, Jumbo spent € 65,000 per year on cooling in the past, but currently spends € 50,000 per year. We use the residual heat/cold to serve other parties. This means that we create added value for both parties.

What is the average Coefficient of Performance (COP) of the DH system?
The average COP for (space) heating is 6, the average COP for (space) cooling is 6.5 and the COP of heat pump boosters (hot tap water) is 5.5. We have a variable heating curve which is connected to the weather forecast.

The webpage of Mijnwater mentions a CO_2 emissions reduction of 65%, how is this calculated?
Especially because of high COP values. In addition, our electricity is partly fossil and partly renewable. At the moment we are installing solar PV on roofs of houses connected to our DH system. Some households also have solar collectors installed on their roofs to generate hot tap water.

How did you create (public) support and trust from commercial parties, local government and households?
Commercial parties only think on the short-term. Mijnwater is attractive for households because it supplies heat cheaper and offers more comfort than a conventional system. We use the maximum tariffs of the Heat Act. Very important to realise, however, is that in case of a gas-fired boiler, the efficiency loss (in Dutch: *rendementsverlies*) of space heating/hot tap water takes place behind the meter. In contrast, the efficiency loss of space heating/hot tap of DH systems takes place before the meter. This means that energy consumption on the energy bill of an average household is reduced by 10-12 GJ per year.

You said earlier that you do not foresee a role for local DH cooperative, could you explain that?
Exploitation means managing and securing the heat supply of consumer for a period of at least 30-50 years. Energy is one of the basic needs. Therefore, only professionals should be used for this task. There is a lot of knowledge needed about, for example tendering, contracts, maintenance etc.

What are the most important lessons you have learned of establishing and operating the energy company Mijnwater?

- Never listen to installers/installation companies because they do not know what happens within a building or house. Once, for example, we listened to an advice to install a certain heat pump, but it turned out to have an overcapacity of 70%. To prevent this, we do 75-85% of our engineering in-house.
- Try to mirror your own thoughts and ideas with others. Try to seek for the substantiation together. I find the process more important than the outcome, usually a report. I often read in the last sentence of a report: 'more research is necessary'. To avoid this, you need to gather knowledgeable and experienced people to compare your own thoughts and ideas so that they become solid.

Do you have any recommendations for EcoGenie Paddepoel-Noord?

- Think carefully about the installation of industrial heat pumps. Our experience is that we have a lot of overcapacity. For example, we installed fourteen industrial heat pumps, but we normally only use 3-4 heat pumps. The investment costs and maintenance costs are very high.
- In my opinion, the consumer with the poorest insulated house needs to pay the highest connection fee. Three consecutive measures are needed: (1) good ventilation, (2) filling cracks (to avoid cold air flows) and (3) insulating walls, roof, windows etc. Use balanced ventilation instead of mechanical ventilation. Balanced ventilation means that the supply and discharge of air is equal, which is more energy efficient.

Do you have any additional questions and/or remarks about this research or this interview?

Do not hesitate to visit our company, because there is much more to tell and to show about our company.

6 Rie Krabsen (Marketing Officer at EBO Consult)

Date: 23 July 2018.

What is your current position and what is your background (education, jobs etc.)?
I work as a marketing officer at EBO Consult in Hvidovre, near Copenhagen. I have a bachelor's degree in social science and a master's degree in cross cultural communication. At EBO Consult we currently manage five DH cooperatives. We mainly work on expanding existing DH systems instead of setting up new DH systems. This is because the penetration rate of DH systems in Denmark is very high, especially in cities.

Can you explain more about customer journey mapping of EBO Consult (what, why, how)?
We use the customer journey as an internal evaluation tool to evaluate our DH projects after completion. The customer journey is first of all used to understand the customer's point of view. The customer journey is used in the second place to identify so-called 'meeting points' between the cooperative and customers. This is done to optimise meeting points and to remove excess meeting points.

Has EBO Consult applied the customer journey once or more?
We only applied it once since we developed the customer journey. DH projects are often long-term projects, which means that completion and evaluation do not often occur.

Do citizens participate in the customer journey evaluation process, if yes: how?
We do not involve citizens directly but they are indirectly involved. It was an internal evaluation with our own employees. Many of our own employees, however, had talked to the customers and knew very well what they liked and did not like about their customer journey.

A district heating project only starts when 30% of the households accept it, if not: what happens to the contracts/commitments you have made with the minority of households?
We do not have a business case below 30%, which means that the project cannot continue. We include a clause in the consumer contract that, in case the 30% is not reached, the contract is terminated.

The majority of the residents sign up during the marketing campaign. However, there is always a small group that only sign-up when their neighbour does it or if they see that something is happening.

What are the most important lessons you have learned from Customer Journey mapping?

- Respect the private space of people. To establish a DH connection, you need to enter people's garden and dig in the ground. It is very important, at least in Denmark, to be very careful with their gardens and to restore everything as it was before you started. If you carefully threat their private space, trust increases.
- Communicate directly and honestly, even if something went wrong. Mistakes always occur because usually many contractors and subcontractors are involved during the execution of a DH project. People may not like it on the short-term but it builds trust on the long-term. In addition, follow-up. Keep people informed and stay (in person) in contact with the customers.

What are your recommendations for recruiting participants for district heating?

- Be very structured and clear in your communication to residents. Avoid confusion.
- Use local 'ambassadors', people who have experience with DH and can convince others of the benefits.
- Commitment is very important, even if people are only interested. For example, try to get their contact information so that you can keep in touch.

What are your recommendations for getting the support and building trust among residents?
See my answer to other questions. In addition, I think that people find the cooperative structure attractive because it is not about profit making. It is very important to communicate in person.

Do you have any recommendations for the EcoGenie 2.0 project in Paddepoel-Noord?

- Start with image building which is in fact a continuous process, especially if you want to expand. That is why it is very important to communicate personally that your organisation has a face.
- It is very important to know your target group. Start with a data collection to examine and identify the residents that live in a particular neighbourhood. The challenge in Denmark is how we can reach the majority of the people, because often only a minority of people are interested. That is why it is important to make DH interesting for 'normal people'. People who say: 'everything works well, why should I switch'? Therefore, you must create a need, you could use for instance the earthquakes that occur in Netherlands.
- Do not communicate in a technical way, especially not in the beginning of a DH project because residents may not even know what DH is. In addition, be creative in your communication and not boring, use for example videos.

Do you have any additional questions and/or remarks about this research or this interview?
I would like to receive a copy of the final thesis if possible.

7 Wouter van Bolhuis (Programme Manager energy transition at the municipality of Groningen)

Date: 11 July 2018.

What is your current position and what is your background (education, jobs etc.)?

I studied social planning at the University of Groningen. I currently work at the department of Spatial Planning and Economic Affairs of the municipality of Groningen. This department has a number of programmes, such as living, accessibility, living quality and energy transition. I work as programme manager energy transition. I have a connecting role between different parties, I try to connect people and ideas.

In 2010, the municipality of Groningen started with a master plan. The (political) ambition was to become energy-neutral by 2035. In the following years, the municipality has made a budget available and developed a strategy to reach this ambition. The energy transition has accelerated rapidly in the last three years. The energy transition is a symbol for other areas of sustainable, e.g. sustainable constructions. Actually, we have two main goals:

1. An environmental goal: to become carbon-neutral by 2035, which is a step further than energy-neutral.
2. An economic goal: to make a profit with the energy transition in twenty years' time. This is only possible if we become really good at what we do. Therefore, we want to be a forerunner in the energy transition, so that our knowledge and experience can also be used in other parts of the Netherlands. For example, we cooperate with the province of Groningen and have developed the PR campaign 'Gronings Bod'. We want to become a forerunner in the hydrogen sector. The 'joke' was: hydrogen costs € 35 billion, but we (province of Groningen) do it for half.

In addition, the energy transition can create employment. An interesting example is the Holthausen Groep. They build/transform special vehicles (for example a road sweeper from the municipality of Groningen) into hydrogen vehicles. This is a nice market. They are currently scaling up from 50 vehicles to 500 vehicles per year.

We started two initiatives: WarmteStad BV and Gresco. WarmteStad is an energy company that supplier of sustainable heat. Gresco is mainly concerned with the sustainability of our buildings, the municipality of Groningen holds namely 250 buildings.

What are the most promising alternatives for the transition to a sustainable heat supply in the Netherlands?

Basically, there are three alternatives: (1) DH systems, (2) all-electric and (3) hybrid system with green gas. Green gas is not sufficiently available, so we have to think carefully about how to use it. Maybe for high-temperature heat in industries. Maybe we can combine it with hydrogen. We think about the option to use green gas in the old town because it has many monumental buildings. In this way, the characteristics of these buildings will not be destroyed by impactful measures. All-electric must be used for new buildings and houses.

However, the existing building environment is the biggest challenge. We think that large DH systems are the way forward in the existing built environment. We planned to construct a geothermal source to supply heat to 10,000 households in the northwest of the city. Unfortunately, this plan did not succeed. Because the DH network has been installed, we are going to install a CHP. Biomass is not very sustainable, think about forests in America. In my opinion, biomass should only be used as back-up or to cover the peak demand.

We must be careful with heat sources that are not in our sphere of influence. For example, the power plant and the data center in the Eemshaven could be used. They have residual heat of approximately 40 °C. We could transport the heat to a place of consumption, but what will happen if a company stops working? Energy is essential and we must guarantee the security of supply. Important to note, the future heat supply will not consist of one solution but of many solutions that complement each other.

Do you think that we should currently pursue large-scale alternatives or small-scale alternatives?
It is important that the energy transition goes fast enough. Many small projects can also make a big contribution. In addition, large-scale solutions are more robust. This contributes to matching the supply and demand. In the case of many small-scale solutions, they must be connected to a certain backbone.

To what extent is the municipality of Groningen on track to become energy-neutral by 2035?
We are not on track. Approximately 6% of the total energy consumption is currently renewable. The plans for a geothermal energy source (which unfortunately did not succeed) could contribute 2%. It will take time to realise a sustainable alternative. In addition, we really depend on national policies and regulations. They have to develop policies and regulations for the mobility and the built environment and can speed up the transition. The most important thing is to be ready when national policies and regulations change.

The municipality of Groningen uses an area-oriented approach to determine promising heat alternatives, please explain what this means for Paddepoel-Noord?
We use the Energy Transition Model (ETM) of Quintel Intelligence. This model can be applied on different levels (national, regional and local). We applied it to the region with the IABR project and to all the neighbourhoods of the city. The model shows what is the most optimal sustainable alternative for a specific situation, based on many characteristics (technical and social). Is has a total of 400 parameters. The model is based on reliable information and the outcomes are really useful. However, this model is top-down. Therefore, we developed the ET Moses model which is bottom-up.

P2H DH systems is not (emphatically) mentioned in the heat policy of the municipality of Groningen, why not?
P2H is just a term, but we are looking for alternatives to use ambient heat. The heat policy of 2012 is not a technical document, but a political document. The three criteria: (1) open, (2) social and (3) sustainable are most important.

The heat policy of the municipality of Groningen describes three criteria (open, social and sustainable) for DH systems. Do these three criteria apply to small-scale DH systems (100-200 households)?
The national government is currently working on the market organisation and The Unbundling Act (in Dutch: *Splitsingswet*) because it is forecasted that heat will be provided by local solutions. That is why the distinction between producer, network operator and supplier is not that relevant.

The heat market is an integrated system. In my opinion it is not wise to stimulate competition in the beginning. Therefore, the P2H DH system must be protected to become mature. Later, when it is mature and functioning well, market forces can stimulate potential innovations.

What role do you think DH cooperatives can play in the future heat supply, do you also see threats/objections?
A DH cooperative serves the public interest. In fact, a municipality can also be regarded as a cooperative because it serves the public interest. In our case, residents are not member but can vote. We have the responsibility to maintain an overview. On the other hand, a cooperative is usually focused on the interests of a specific group of people. This leads to several dilemmas. It is our task as a municipality to represent the interests of all residents. For example, we think that sustainable energy should be available to everyone, not just for the people who can afford it. We have socialised the energy costs, which means that a household on Texel pays the same connection tariff as a household in Groningen. What would your answer be if people who live in the same street pay a different connection price and come to you for an explanation? How are you going to explain that? These are important questions and challenges.

Moreover, we must accelerate the energy transition. Grunneger Power is one of the largest energy cooperatives of the Netherlands, it has around 1,000 customers. This is only 1% of the total number of households in the city of Groningen.

I recently visited the island Samsø, a Danish island which is carbon neutral. I did not hear the word 'municipality' a single time. The residents organised themselves. It was successful because of two reasons: high energy prices and the bankruptcy of a slaughterhouse (unemployment).

How can the municipality of Groningen support a sustainable DH cooperative (e.g. subsidies)?
We support Stichting Paddepoel Energiek financially. However, the energy transition is too big to use subsidies as measure. Projects must be economic feasible. We might support the EcoGenie 2.0 initiative by covering the start-up costs or by removing the non-profitable top (in Dutch: *onrendabele top)*. However, this depends on the business case that is currently being calculated.

What are your recommendations for getting the support and building trust among residents?
Discover the sustainable alternatives together with the neighbourhood/community and find the solution together. Think about the ETM model. We visit a neighbourhood and invite the neighbourhood to talk about the energy challenge and different solutions. Based on my experience, this process automatically leads to the most desirable solution. This is a totally different approach than just offering one alternative, whether people like it or not. If you make people part of the process, people are more acceptable to the solution. Involve people and come together to a conclusion.

What are the most important lessons you have learned from your position as program manager energy transition at the municipality of Groningen?

- To change something, you need a problem. If people do not feel the urgency, they do not rush. Nowadays, energy and its availability are too normal and too cheap. People even lack knowledge. The positive side effect of the earthquakes in the province of Groningen is that it has increased the urgency and the knowledge.
- You have to be aware that people have different motives and take this into account during projects. Linda Steg (behavioural psychology) analysed different motives. In general, people can be motivated by: (1) money, (2) the environment, (3) the local/cooperative aspect or (4) to guarantee the future for their grandchildren. It is important to look after all these motives, otherwise you will lose people during the process.

Do you have any recommendations for the EcoGenie 2.0 project in Paddepoel-Noord?
No, I have said everything wat is relevant to you.

Do you have any additional questions and/or remarks about this research or this interview?
No.