RENEW

Energy Optimization & Integration in Westland

Niels Stikvoort
August 2013

Renewable Energy Network Westland (RENEW)

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General remarks:

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PREFACE

In front of you lies the graduation thesis written by a fourth year mechanical engineering student from Hague University Delft at Fluor B.V. This internship took place from May 6, 2013 to August 30, 2013.

In my third and fourth year my interest went to sustainability, development and innovation. At Fluor B.V. it was possible to further evolve my interests in this thesis.

This thesis is meant for everyone whom interests goes to sustainability, development and innovation and want to know more of what is going on at the areas Westland, Rotterdam and the Port of Rotterdam at this moment.

I would like to use this opportunity to express my gratitude to those who helped me during my internship. First of all I would like to thank my supervisor ir. ing. J.P. Berkhoff at Fluor B.V. for sharing his knowledge, time and various perspectives.

I also would like to thank ing. F.C.M. Zoller at HHS Delft with his good, reliable and prompt advice.

Furthermore, I would like to thank my colleagues at Fluor B.V. for their time and knowledge.

Niels Stikvoort
Haarlem, August 2013

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ABSTRACT

A lot of energy in the Port of Rotterdam is getting wasted by power plants or other petrochemical companies. This waste energy can be reused. The assignment of this feasibility study is how a technical design concept of an integrated district heating process is applicable in the Westland.

This thesis contains an inventory of the existing inventory of the areas Westland, Rotterdam and the port from in the past, nowadays, under construction and future visions, followed by the technical and economical aspects and at last an optimized business case.

This optimized business case exists out of two parts, namely:

- The primary network: this runs in the Port of Rotterdam and supplies a large amount of thermal energy with geothermal to the consumers in the Westland.
- Secondary network: this contains delivery areas with greenhouses and geothermal heat as suppliers and a city as a consumer;

The primary network can only be constructed, when the secondary network is profitable. The transition from the secondary network with the primary network is a difficult task. The greenhouses will convert from being only a supplier to being supplier as well as a consumer.

This business case has an estimate of 1.3 billion Euros with an accuracy of -20 to +40%. When the project is complete, then an estimated 300 million kg CO_2 per year could be saved. The payback time of one delivery area in Westland will be around 14 to 20 years. The payback time of the primary network depends highly on the gas price. The payback time of the primary network will be 18 to 28 years with a natural gas price of 0.25 eurocent per m^3 if everyone participates in this system.

SUMMARY

A lot of energy in the Port of Rotterdam is getting wasted by power plants or other petrochemical companies. This waste energy can be reused. The assignment of this feasibility study is how a technical design concept of an integrated district heating process is applicable in the Westland in the year 2023. This thesis focuses on the areas Westland and the Port of Rotterdam. Rotterdam is for the inventory of existing literature taken into account. The research, before the business, describes the technical and economical aspects.

LITERATURE

There are different kind of research developments of waste heat made by CE Delft[1] and DWA. These researches extend from existing heat networks to inventory for utilization of waste heat in North-Brabant.

A leader in sustainable initiatives is 'Sustainable Energy Systems in Advanced Cities' (SESAC). This European project tries to excel the sustainable program. They were busy in Delft with the 3E Climate-program and with a successful heat district in some areas in Delft ended in 2012.

Greenhouses gain their carbon dioxide (CO_2) from their 'Combined Heat & Power' (CHP). This CHP can produce CO_2, electricity and heat. External CO_2 delivery also has its uprising through the project 'Organic Carbon dioxide for Assimilation of Plants' (OCAP). A large area of Westland gets CO_2 delivery from OCAP, but another part of Westland still does not. However, a larger problem occurs, because the OCAP cannot cope with the ever rising external CO_2 delivery. Till now, there are no concrete plans for extending the OCAP pipelines in the Port of Rotterdam for more CO_2.

After a study in 2008 from the energy company Rotterdam extracting heat from Shell was not affordable. That is why steam and heat networks from waste processor AVR in Botlek through the Botlek to south and north Rotterdam are being constructed.

The first successful geothermal project that can extract heat in Westland is the Green Well Westland. This system can provide heat for a total of nine greenhouses with enough heat power of 11 MW_{th}. Other geothermal projects are on their way: Noordland-Kapittelland (30 MW_{th}), Geo Power Oudcamp (25 MW_{th}), Flora Holland (25 MW_{th}), Harting-Vollebregt (7MW_{th}), The Hague Leyenburg (7 MW_{th}) and Tomselect (7 MW_{th}). Furthermore, Westland has an estimated 45 underground thermal energy storages (UTES). These systems can contain around 25 MW of thermal power with enough depth and no external problems outside.

The most important sustainability decision in the Netherlands is the Green Deal. This deal is signed as a dedication for the government and the province Zuid-Holland to goal for a concrete sustainability percentage of 14% in the year 2020. And when in 2050, 50% of the energy must be sustainable. They want to achieve these results through visions, such as: the smart thermal grid and "kralen rijgen".

TECHNICAL & ECONOMICAL ASPECTS

An estimated 30 PJ of the total 39 PJ (951 MW of 1236 MW) heat power for the greenhouses in the Westland is needed this year. Momentarily, this is done by CHPs and hot water boilers. This costs a lot of natural gas. The remaining 9 PJ is used by local households and other utilities.

It will not be enough to provide the whole Westland with waste heat (995 MW) from the Port of Rotterdam. Therefore, transition from standard heat district heating systems to an optimized system asks for more effort and multiple suppliers. Next to the usual one way heat supply of the heat district brings the

[1] See glossary for more information.

RENEW project multiple heat suppliers. The suppliers are industries, greenhouses and geothermal. The energy storage is done by UTES and the consumers are greenhouses, cities and (non-)residential buildings.

Placing pipelines in the corridors of the Port of Rotterdam is no problem, but there will be a problem with the limited space in Westland. The shortest and agile route determines the overall costs. The benefits for external heat supply are better air quality, reduction of CO_2 emissions, better energy efficiency and saving fossil fuels. However, CHPs still have a purpose, when there are needs.

The consumers take the lowest price. Gas and electricity prices are the most important points. At the moment, these prices are affordable and that is why it provides the primary need for most of the greenhouses and households. There will only be change when the standard costs are rising.

Subsidy helps with this change. This financial contribution regularly determines if the project is successful or not. Important subsidies are: SDE+ for geothermal and subsidies for sustainable projects.

Without any steering by the government heat suppliers will not invest in long-term and costly projects. They have to invest in large systems, because it is not their core-business to deliver heat.

The Rabobank is a large investor for the greenhouses. They will benefit if more greenhouses come to and stay in Westland.

BUSINESS CASE

There are a few conditions and assumptions for the business made:

- The heat network contains at least two suppliers and consumers with at least one pipeline to the consumer and one pipeline to the supplier. The heat will be transported in liquid form. CO_2 delivery is for the greenhouses a necessity if they can or want to use the heat network. Thereby, ensuring continuous CO_2 delivery for the greenhouses is a must.
- Assuming every supplier and consumer participates in RENEW shall the estimated calculation of thermal power of waste heat and geothermal, and the required energy of the greenhouses and cities converge with evenly distributed heat. The remaining energy can be stored in the UTES that everyone has or could have available.
- High temperatures and pressures are needed.

The business case exists of two cases: the primary network runs in the Port of Rotterdam and the secondary network runs in the Westland. Meanwhile: the secondary network can operate without the primary network, but not the other way around.

The steps for RENEW begins with a heat network in one or more delivery areas in the Westland. The greenhouses start as suppliers for a small city. The principle is the same as RENEW, but without the waste heat. The following step begins when three or more delivery areas are operational. This ensures a steady income for the primary network to connect. When problems occur, then the delivery areas could retreat to their former network.

The business case has as estimate of 1.3 billion Euros with an accuracy of -20 to +40%. It could save 300 million kg CO_2 when it is finished. The payback time for the small delivery area is 14 to 20 years. The payback time for the primary network depends on the gas price. The payback time is 18 to 28 years with the current gas price of 0.25 eurocent and when everyone participates. How higher the gas price, how quicker the investments can be paid back. All with all, RENEW is a feasible and applicable and optimized district heating process for future Westland.

GLOSSARY

Atmosphere	A layer of gases surrounding the planet Earth.
Business case	The business case is a project management term which described the business assessment to start a project or task. In the business case, the costs are weighed against the benefits (Amerongen, 2013). The business case contains the proposed activities, climate results, future visions and recommendations.
CE Delft	An independent research and advice agency, which specializes in developing innovative sustainable solutions.
CHP	Combined Heat and Power.
CO2	Carbon dioxide.
Corridors	A passageway whose purpose is to provide access to other locations for the pipelines.
DCMR	A joint environmental protection agency of the province Zuid Holland and 16 municipalities.
District heating	System for distributing heat in a decentralized location for residential and commercial buildings.
DWA	An advice agency for a sustainable future.
Fossil fuels	Fuels formed by natural processes such as anaerobic decomposition of buried dead organism.
Geothermal	Thermal energy generated and stored in the Earth.
OCAP	Organic Carbon dioxide for Assimilation of Plants
Petrochemical	Chemical products derived from petroleum.
RENEW	Renewable Energy Network Westland; an optimized and integrated heat distribution system for Westland.
ROAD	"Rotterdam Opslag en Afvang Demonstratieproject"
SDE+	"Stimulering Duurzame Energieproductie" A subsidy from the government to accelerate the production of sustainable energy.
SESAC	Sustainable Energy Systems in Advanced Cities, whose goal is to accelerate innovation in renewable energy solutions.
Subsidy	Financial assistance given by one party for the support or development of another.
UTES	Underground Thermal Energy Storage.
Waste heat	Released/discharged heat when it has no value for the parcel.

SYMBOL LIST

A	Surface	[m^2]
c_p	Specific heat	[J / kg * K]
D	Diameter	[m]
e	Absolute roughness	[m]
f	Friction factor	[-]
L	Length	[m]
m	Mass	[kg]
P	Power	[W]
p	Pressure	[Pa]
Q	Heat	[J]
T	Temperature	[K]
U	Energy	[J]
v	Speed	[m/s]
Re	Reynolds number	[-]
Δ	Difference	[-]
ε	Relative roughness	[-]
η	Dynamic viscosity	[Pa * s]
η	Efficiency	[%]
λ	Coefficient of friction	[-]
ρ	Density	[kg / m^3]
Φ_m	Mass flow	[kg / s]
Φ_v	Volume flow	[m^3 / s]
th	Thermal	
e	Electricity	

Unit symbol	Unit name	Conversion
J	Joule	1 Ws
W	Watt	1 J/s

Prefix	Name	Factor	Factor
k	Kilo-	10^3	1,000
M	Mega-	10^6	1,000,000
G	Giga-	10^9	1,000,000,000
T	Tera-	10^{12}	1,000,000,000,000
P	Peta-	10^{15}	1,000,000,000,000,000

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1 INTRODUCTION

1.1 PROBLEM INDICATION

In energy intensive industries in the Port of Rotterdam a large amount of industrial waste heat is available. This heat disappears, nowadays, into the atmosphere or is discharged into the water from the Nieuwe Waterweg and further transported to the Noordzee (North Sea). Heat providers like the E.ON Coal plant (MPP3), under construction, at the Maasvlakte, where Fluor B.V. Haarlem also designed the ROAD CO_2 (E.ON Benelux, 2012) capture installation for the E.ON Coal Plant last year, and all other petro-chemical industries in the Port of Rotterdam towards the city of Rotterdam are discharging heat in the river. Most discharged heat can be reused for heating buildings and greenhouses. Advantages of reusing waste heat are using less fossil fuel, improving the air quality, reduction of CO_2 emissions and last but not least, it increases the energy efficiency ratio.

The International Energy Agency (IEA) is a department who gives annual reports about the global energy consumption generally. In their latest annual report (World Energy Outlook) they speak out their concern regarding the low investments in searching for possibilities in reducing energy consumption. Recently, the IEA (CE Delft, 2013) published a study stating that industrialized countries need to pay 90 Euros per ton CO_2 to avoid most of the damages to the climate in 2035, unless there is a reduction of fossil fuels consumption.

1.2 PROBLEM STATEMENT

There is a total waste heat potential of 100 PJ in the Netherlands each year (Lieshout & Schepers, 2011). Approximately 57 PJ of the total amount can be used. This is enough for 1.2 million residents and a reduction of 3.200 kton CO_2. The greenhouses in Westland (Zuiderwijk-Groenewegen, 2012) in the province of Zuid-Holland, surrounded by the cities The Hague, Delft and Rotterdam, are using 77% (30 PJ) of the total 39 PJ heat energy needed in that area. This is the largest continuous glass horticulture in Europe.

In the Green Deal (Province Zuid-Holland, 2011) there is an agreement that by 2050 more than 50% of the heat must be sustainable. At this moment only 1 or 2% is sustainable. The mid-term goal is achieving 14% in 2020. The government and the energy sector have the ambition to use approximately 25 PJ of waste heats in 2020. National legislation also heads that all new construction homes need to be climate-neutral in 2020.

The challenge is to get the waste heat from the Port of Rotterdam to the greenhouses in the Westland with minimal costs for a more sustainable future. But this will only work; when the energy user feels the urgency to save money, when it is financial attractive, or when it is social self-evident.

1.3 OBJECTIVE

The objective of this research thesis is to contribute the transition to sustainable energy, from central to decentralized energy, for the greenhouses and to reduce the fossil fuels consumption and CO_2-emissions in the year 2023. The first step will be the determination of the heat suppliers and consumers to regulate the behavior of the in- and outflow of the heat network. This is followed by the business case, which includes: integration and optimization of the suppliers and consumers in heat network.

This thesis will be returned to Fluor B.V. within the available time and with the following content:

- An inventory about existing initiatives, current links and visions of the future;
- An overview of heat demand and –supply using geographic location;
- An estimate;
- A feasibility study about the main question;
- An appendix.

1.4 SCOPE

This research thesis concentrates on the areas Westland and the Port of Rotterdam (figure 1.1). Westland consists mostly out of greenhouses. The Port of Rotterdam is divided in four areas: Maasvlakte, Europoort, Botlek and Pernis. Rotterdam and the surrounding areas will also be taken into account for inventory of the existing initiatives.

Figure 1.1 Overview areas (Westland, Rotterdam & Port of Rotterdam)

Greenhouses in Westland, unless they can provide heat with their CHP, are the main consumers in this thesis. Power plants and other petro-chemical companies are the suppliers of waste heat. CHPs or other heat suppliers will be secondary heat suppliers in the thermal grid. (A more detailed description about the target groups can be read in chapter three)

This research is divided in two areas. As mentioned earlier the two areas Westland and Port of Rotterdam are further defined in the sub-paragraphs below.

1.4.1 WESTLAND

The Westland is a region of Zuid-Holland as shown in figure 1.2. It stretches from north of the Nieuwe Waterweg, South of The Hague, northwest of Maassluis and West of Delft. This area is best known for the presence of many greenhouses. About 50% of the Dutch greenhouse complex is located in Zuid-Holland and almost a third of the total consumption is related to the greenhouse; a total of 4281 hectare is in the glass horticulture (LEI Wageningen UR, CBS, 2012). The CHPs from greenhouses are not only used for heat, but also for the supply of electricity (especially illumination growers) and CO_2 supply. In the upcoming years switching to biogas or external heat delivery should be done to achieve greater sustainability for the greenhouse.

The following towns are in and around this area:

- Monster
- Den Haag
- Wateringen
- Naaldwijk
- Mariendijk
- Westerlee
- De Lier
- Schipluiden
- Poeldijk
- Wateringen
- ’s Gravenzande
- Poeldijk
- Honselersdjk
- Maasdijk
- Delft
- Hoek van Holland

Figure 1.2 Area Westland

1.4.2 PORT OF ROTTERDAM

The Port of Rotterdam (figure 1.3) is the largest port and industrial complex in Europe with a total cargo output of 430 million ton. There is a lot of industry at the port, but there are no plans to use waste heat for the Westland at the moment.

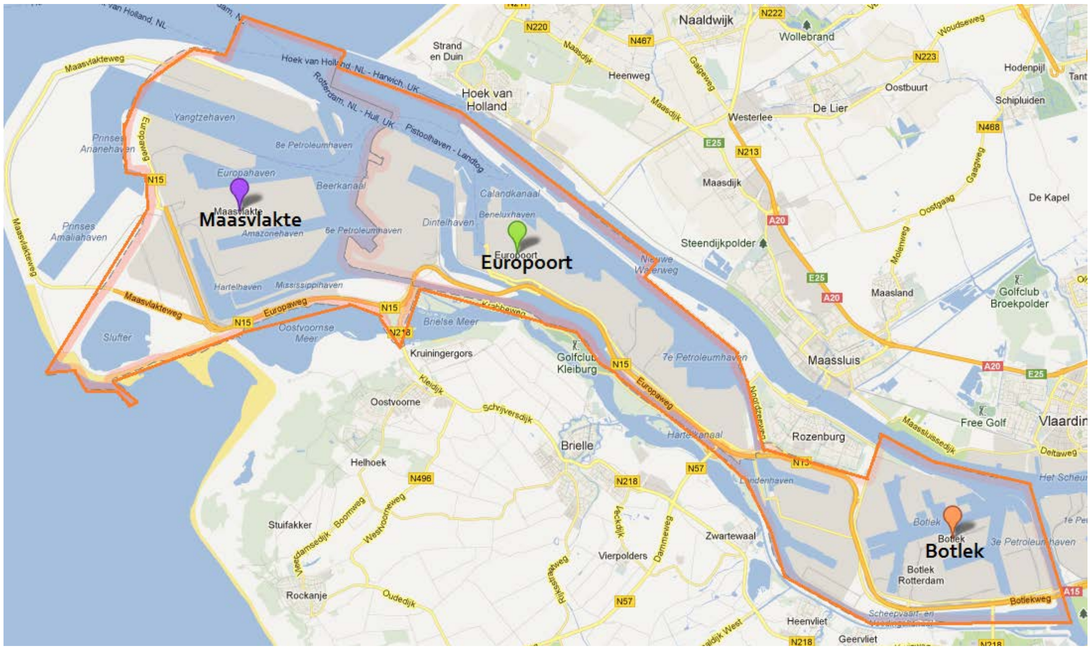

Figure 1.3 Area Port of Rotterdam (Maasvlakte, Europoort & Botlek)

1.5 ASSIGNMENT

This assignment is commissioned by Fluor B.V. and is divided in three parts. The first part describes the research of all existing initiatives, current links and visions of the future in the area Westland, and the city and Port of Rotterdam. The second part contains the business case for the areas. The last part exists out of integration and optimization of the applicability of this assignment. The second and third parts are always colliding to make a better result.

The main question is: how is a technical design concept of an integrated district heating process applicable in the Westland?

Sub-studies are:

- Which companies can deliver waste heat and what mount is available in the Port of Rotterdam?
- How many hectares of greenhouses in the Westland can utilize waste heat from the Port of Rotterdam?
- How does a district heating network look like and work?
- How does a modular heat distribution exits in a greenhouse society? How will the contracts complement with each other? Which price rates are set for the consumers?
- What are the costs for the realization of this technical design concept? What is the pay-back-time for the investments?

1.6 Methodology

This section gives a brief summary of the project methodology. This summary will explain the method of inventory, communication and information and the research design of this thesis.

1.6.1 Method of inventory

The inventory gives a short overview of the existing initiatives, current links and visions of the future. This chapter is divided in three stages: history, current and under construction, and future visions.

Each stage is accurately examined for the most reliable source and information. Each source can be looked up at the bibliography if required.

1.6.2 Communication and information

The contact list with name, company, address, telephone and mobile number, e-mail and website are shown in appendix A. Below is an overview of the contacts. This shows the company name, whom the contact is, how the contact is made and if there was a business meeting.

Table 1.1 Project contacts

Company, community, province	Whom?	How?	Business meeting?
Westland Infra	Arie Vellekoop	E-mail	No
Community Westland	Frans Pijls	Email/phone	No
AgentschapNL Ministry of Economic affairs.	Lydia Dijkshoorn	E-mail/phone	No
Visser & Smit Hanab Rotterdam	Dennis in t Groen/Peter Leijs	Email/phone	Yes
LTO Glaskracht	Gaby Duijndam	Phone	Yes
Stedin Rotterdam	Guy Konings	Phone	Yes
Weijers Waalwijk	Maurice Verhulst	E-mail/phone	No
Province Zuid-Holland	Arend Bosma/Lotte Visser	Phone	Yes
OCAP Rotterdam	Jacob Limbeek	E-mail/phone	Yes
Warmtebedrijf Rotterdam	Wouter Verhoeven/Co Hamers	E-mail	No
Havenbedrijf Rotterdam	Joris Hurenkamp	Phone	No
Community Westland	Jeroen Straver	E-mail	Yes

1.6.3 Research Design

Figure 1.4 shows the research design of the project. This design is a tool to remember the main steps throughout this thesis. The first phase shows the technical heat aspects for this project. Heat consumers and suppliers will be characterized and organized in a geographical map. With the geographical reference, an energy network can be designed to link the consumers and suppliers together.

Phase 2 described the economical aspects of this project. Costs and benefits will be determined throughout the costs of infrastructure, production of the pipelines and most important the profitability for both parties. The transitions from centralized production of heat, CO_2 and electricity to decentralized heat production are the costs of alternative source. These costs are determined by the prices of natural gas and electricity and will eventually determine the maximum purchases.

These two phases, combined, form a part of the business case.

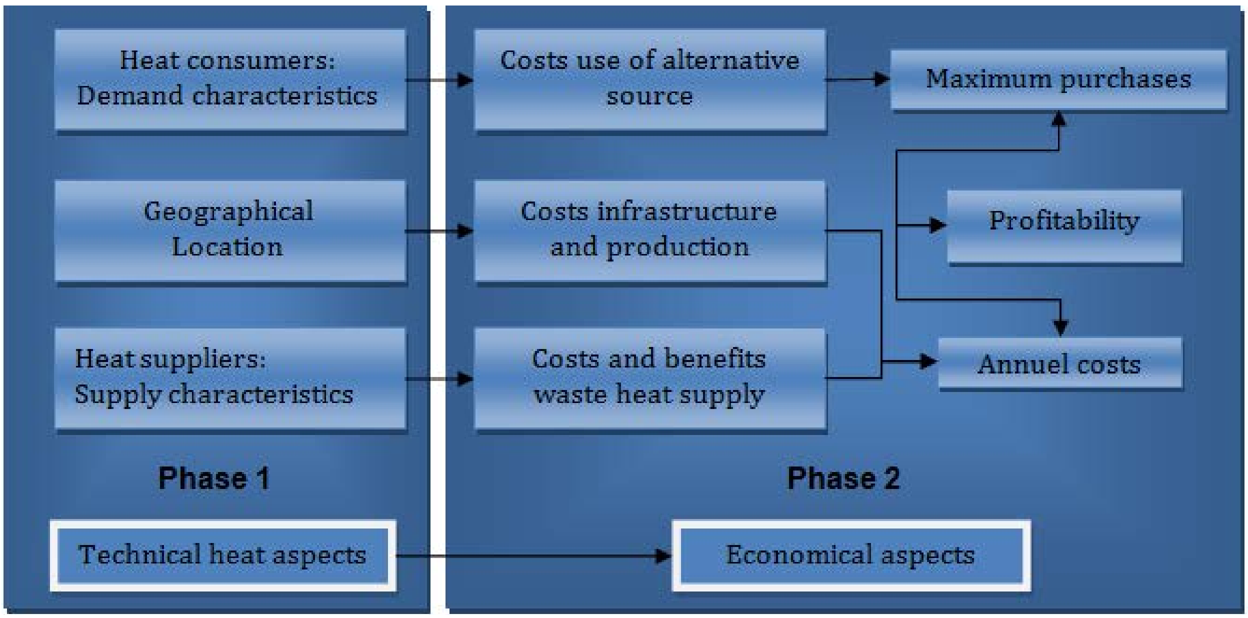

Figure 1.4 Research Design

1.7 Thesis Outline

This thesis starts with an inventory of all existing initiatives, current links and visions of the future in the area Westland, the city and Port of Rotterdam. Followed are the energy data, the largest current links and a conclusion.

The chapter 'Technical aspects' will give the technical heat demand and –supply and infrastructure aspects. The economical aspects are defined in chapter four. This information can be used to set a definition for a business case.

The business case will be further elaborated in chapter five.

Conclusions and recommendations will form the end of this thesis.

2 INVENTORY OF EXISTING LITERATURE

This inventory describes the total existing (waste) heat initiatives of the three areas and surroundings in three sections: history, current links and under construction, and visions of the future. Articles and reports are summed and at the end there will be a conclusion.

Short summaries explain the method of existing literature dividing the suppliers and consumers. There are usually four suppliers of waste heat (Wetzels, 2010): chemical industry and the refining sector, producers of electricity, the flow gases from CHP plants and district heating. The suppliers give the waste heat to the consumers. The consumers are: households, services and government, industries and greenhouses. UTES, geothermal and CHP will also be discussed. All of these consumers and suppliers are combined below.

2.1 HISTORY

Energy and waste heat are big topics nowadays. If you are looking through achieves or on the internet, then you will find lots of articles, reports and projects regards to those topics. This paragraph enumerates the existing initiatives from the past.

In the year 1975 (Fortuin, 1970) the topic energy exchange was examined. This report gives an estimation of the importance of energy exchange in Rijnmond and Westland. This shows old energy balances that can be used for future projects. At the time, an energy balance shows that energy exchange was around 1.1 million tons of oil equivalent yields per year.

In 1992 (Gemeente Westland, 2007) the climate treaty of Rio de Janeiro (Rio+20) is established. This treaty aims on irreversible and dangerous influence on the climate. The EU has the objective to prevent a rising of 2 degrees Celsius relative to the pre-industrial level (temperature before the existing industries in 1850, around 16.4 degrees Celsius globally (Revkin, 2009)). An increase of 0.8 degrees Celsius has already been measured. Global emissions need to be halved by 2050 compared to 1990 to achieve this objective. In the Kyoto-protocol, the successor to the treaty of Rio de Janeiro, has determined that gas emissions have been reduced by 6% in the Netherlands compared to 1990 to 2010. The Kyoto-protocol has also determined a CO_2 ceiling of 6.5 Mt in 2010 to 7.2 Mt CO_2 in the nearby future.

A decade further, on October 2002, CE Delft (Rooijers, 2002) has shown an interesting essay for ‘Energy Rijnmond’ about waste heat utilization. Study has shown that there are many waste heat opportunities, but the companies do not take enough initiative to offer waste heat to others.

On December 22 2008 DWA (DWA Installation and energy advice, 2008) introduces inventory residues West-Brabant. This report presents the results on utilization of residues in West-Brabant. This study was commissioned by the Province of North-Brabant, Brabantse Ontwikkelings Maatschappij (BOM) (Brabant Development Agency) and REWIN.

CE Delft (Schepers & Valkengoed, 2009) has also made an overview of large-scale and small-scale heating networks in the Netherlands on October 2009. Although this is already outdated, the heating networks still exists in the area of Rotterdam and The Hague. This also shows that Zuid-Holland has the largest district heating in the Netherlands.

Heat supply and the greenhouse combined with a modified insert (part replacement) of existing CHP capacity in horticulture is expected as one of the great contribution (Province Zuid-Holland, 2011). In addition, an increase in the acceptance of heat obligation to connect to heat networks also plays a role in the discussion. A heat obligation guarantees demand, but a possible introduction of this must be done with care and security. The Building Act 2012 has the obligation to connect buildings to heat network.

However, the Building Act also has another similar principle. That stated: “Instead of connecting to a heat network, you may also use an equivalent solution”, and thus the obligation does not apply.

2.2 EXISTING INITIATIVES, CURRENT LINKS & UNDER CONSTRUCTION

This paragraph shows existing initiatives and heat networks or under construction in Zuid-Holland.

2.2.1 EXISTING INITIATIVES

SESAC is one of the initiatives. SESAC (Sustainable Energy Systems in Advanced Cities, 2012) is a European project that aims at accelerating innovation in renewable energy solutions. This project has proven successful in Delft. Delft has started an ambitious program with the 3E Climate-program in the year 2003. This promotes efficiency and effective use of energy. This project uses industrial waste heat near Delft for households in Delft and reduces CO_2 emissions. This project ended in the year 2012.

Led by Deltalinqs and the province Zuid-Holland (Province Zuid-Holland, 2011) and in consultation with DCMR and Rotterdam the heat supply is mapped. A focus point is the confidentiality of the information. Availability of waste heat will be influenced by the Emissions Trading System (ETS) and the possible foreseeable Energy Efficiency Directive (EED).

2.2.2 CO_2

CO_2 is often produced in-house by the CHPs with gas cleaning and is used for the assimilation of plants in the greenhouses, but external CO_2 delivery has his uprising. This already takes place at a number of greenhouses by OCAP or with supply of liquid CO_2. In the year 2005 OCAP (OCAP) (Organic Carbon dioxide for Assimilation of Plants) was created. This project was created by building company VolkerWessels and gas company Linde Gas whom they supply 400 kton CO_2 per year or 2.2 kton per day to 580 greenhouses in Westland at the moment. An 85 kilometer (figure 2.1) long pipeline, mostly an old oil pipeline with a diameter of 660 mm, is placed and extended by Visser & Smit Hanab in Westland, B-triangle and Zuidplaspolder to distribute CO_2 with an equivalent production of 115 million m^3 natural gas.

Figure 2.1 OCAP Project

There are no concrete plans for extension in the Port of Rotterdam in the near future. The project ROAD (E.ON Benelux, 2012) for the E.ON power plant was a well known CO_2 source, because of its high quality CO_2. However, the extra CO_2 delivery will only be a vision, unless the costs are subsidized by the government.

Such a case also happened at Air Liquide, Botlek. This company did not have enough subsidies and could not be connected to the OCAP grid through the high investments.

A more detailed CO_2 delivery in Westland is shown in figure 2.2 (Limbeek, 2013). The bold blue line represents the existing CO_2 pipeline. The blue area shows the CO_2 delivery area. The orange area presents a possible delivery area in the future. There is a new pipeline needed to give the orange area CO_2. A second option is extending the blue line with boosters. Above all, there will be more CO_2 needed to comprehend the overall demanding quantity of CO_2.

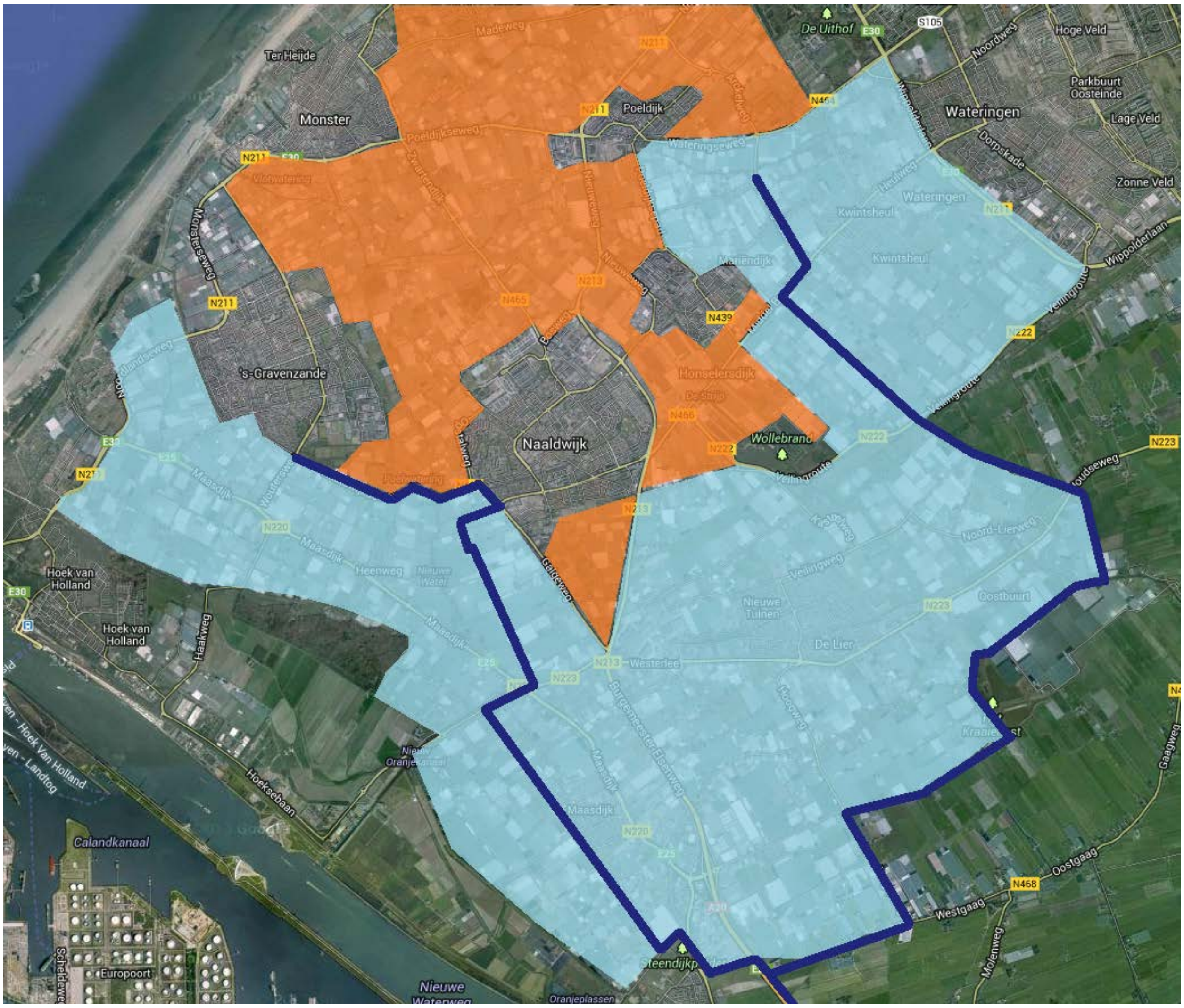

Figure 2.2 OCAP CO_2 delivery and future expansion

2.2.3 CURRENT LINKS & UNDER CONSTRUCTION

Another innovative way for zero CO_2 emissions is using greenhouses as an energy source. Vestia Westland (Vestia Westland, 2013) has develops in Naaldwijk the innovative Hoogeland district. This district gets their heat energy from greenhouses. This innovative way makes Hoogeland one of the first areas to be CO_2-emission free.

On the end of the year 2012, CE Delft (Buck, Lieshout, Afman, Vliet, & Jordan, 2012) began a research commissioned by the Company Rotterdam (Warmtebedrijf Rotterdam, 2013) to explore heat opportunities for connecting eight companies in area Botlek and Pernis. A study (Groot & Rooijers, 2008) by the Energy Company Rotterdam has discovered that the cost of heat demodulation at Shell were too high. Therefore, a new pipeline from AVR to Rotterdam South is being built. Visser & Smit Hanab and BIG (Buisleiding Industrie Gilde) are taking the lead to making this link complete (figure 2.3). At the end of 2013, completion of the new heating network will give 25.000 home equivalents waste heat. This will save 34 to 40 tons CO_2-emissions. Also, another pipeline (figure 2.4) from AVR to North of Rotterdam is in process to being build. This is also for 25.000 home equivalents.

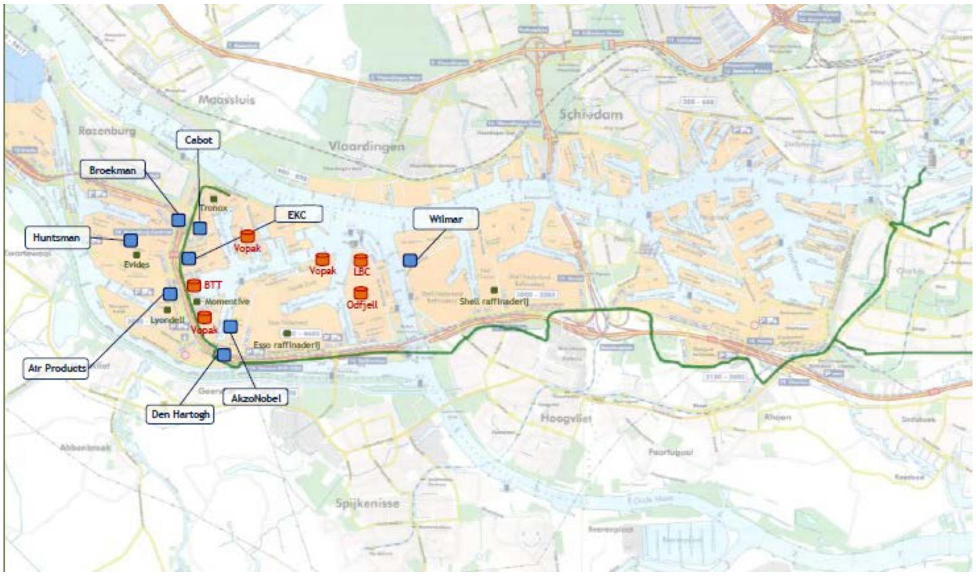

Figure 2.3 Waste heat Botlek/Pernis to South of Rotterdam

Figure 2.4 Waste heat Botlek to North of Rotterdam

Furthermore, the new heating pipeline is not the only pipeline being built by Visser & Smit Hanab (VSHanab, 2013). A steam network from AVR to chemical company Emerald Kalama Chemical has been build and operational on Wednesday May 1, 2013. A quote from Stedin stated: “The next step will be to expand this steam network from EKC to AkzoNobel. In the near future this network will be stretched to Vopak as seen in figure 2.5 (Stedin)”.

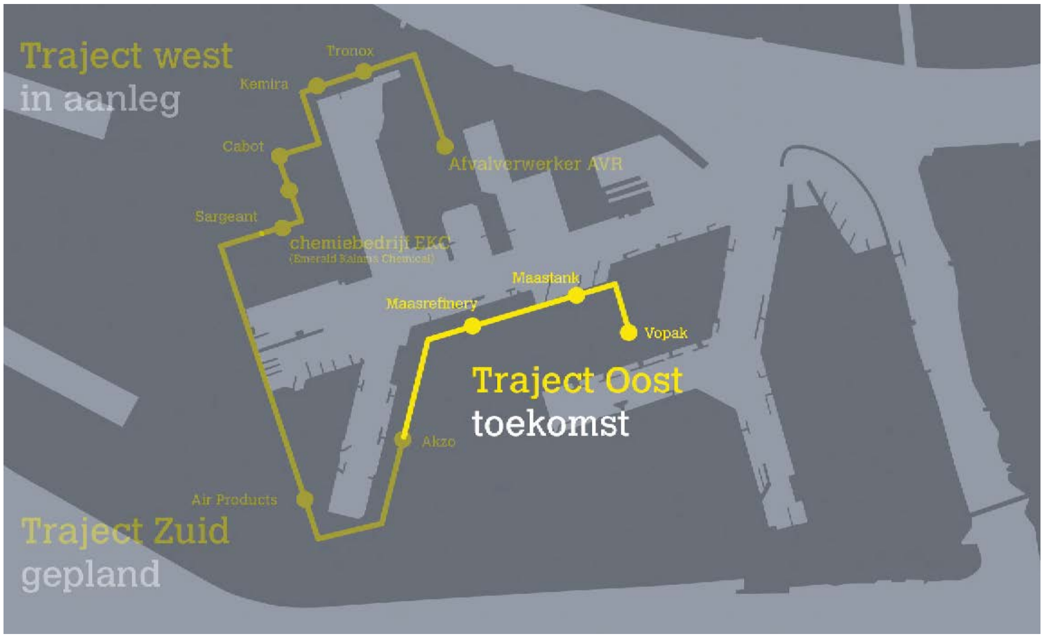

Figure 2.5 Stedin steam network Botlek

At May 16, 2013 a heat manifestation (Warmtenetwerk, 2013) was organized by the Energy Company Rotterdam. Stakeholders and critics had presented their visions and future plans for some 250 men. The following people shared their visions on stage: Gert Dijkra from 'BIG', Mystery Guest Jules Deelder, Co Hamer from 'Warmtebedrijf Rotterdam', Frank Kersloot from 'Eneco Warmte en koude', Marnix van Alphen from 'NUON', Carl Berg from 'community Rotterdam', Carl Konings from 'Stedin' and as last Peter Anderburg from 'Springnet/the climate bridge' from Sweden.

2.2.4 GEOTHERMAL

Green Well project in Westland (figure 2.6) made an attempt to make greenhouses more sustainable. Five companies in Honselersdijk, as seen below, have 22.5 ha together with a heat demand of 62.000 MWh_{th}. 40.000 MWh_{th} is gained by means of geothermal heat exchange (Green Well Westland, 2011).

Figure 2.6 Project Green Well Westland

A few other geothermal projects are in progress or operational. Flora Holland (FloraHolland, 2009) at Naaldwijk has a possibility to gain 25 MW of geothermal heat. Through 2600 meter deep boreholes hot water is pumped to the surface.

Above Hoek van Holland and under s-Gravenzande there is a geothermal project called Noordland & Kapittelland (Aardwarmteproject Noordland / Kapittelland, 2012). They are busy to find suitable consumers for their geothermal that could deliver 30 to 32 MW_{th}.

Geo Power Oudcamp (Geo Power Outcamp) is an association with seven greenhouses. Geo Power wants to use a 4,000 meter deep water source to bring enough heat for the greenhouses in that area.

The greenhouse Harting-Vollebregt (Harting-Vollebregt) wants to collect his own energy by geothermal. He wants to bring 7 MW of heat power with a possible temperature of 78 degrees Celsius.

Also Greenhouse Ammerlaan (AgentschapNL, 2010) ‘Soil & hydroponics’ in Pijnacker, Stanislas College and leisure center ‘De Viergang’ are working together to use geothermal for their energy source instead of natural gas. Joint agreements are made for marketing and distribution. Furthermore, a joint agreement is made by Ammerlaan and Dick Oosthoek to provide geothermal heat for horticulture area ‘FES Oostland’ and surrounding cities in July 2013 (Community Pijnacker-Nootdorp, 2013).

An exploration license is given to Tomselect (Ekwadraat, 2013) to search for the feasibility of geothermal. They hope to start drilling and gain 7 to 8 MW of geothermal heat in the year 2014.

Geothermal heat exchange takes place below Rotterdam at Voorne/Putten. About 8 to 15 greenhouses in Vierpolders area are available to use heat and CO_2 from Botlek, Rotterdam. Also, some CHPs are connected to this system. An estimated 15 to 30 kton per year CO_2 emission is saved.

A summary of the geothermal projects in the Westland is given in the table below. A total of 111 MW of geothermal heat will be available in the near future.

Table 2.1 Summary geothermal projects Westland

Geothermal	Thermal power (potential) [MW]	Depth [m]	Temperature [^oC]	Flow rate (m^3/h)	Realized?
Noordland-Kapittelland	30	3700	143	-	In process
Geo Power Oudcamp	25<	2600/4000	95/140	-	In process
Flora Holland*	25/39[2]	2500/3500 – 4000	95/140	-	In process/ No
Green Well Westland	9.7	3000	85	180	Finished
Harting-Vollebregt	7	2300	78	152	In process
Leyenburg	7	2200	75	150	Finished
Tomselect	7-8	2400	80	-	In process

[2] There is not sufficient prove that 39 MW_{th} is feasible. The permit to drill 3500-4000 meters is denied.

2.2.5 UNDERGROUND THERMAL ENERGY STORAGE (UTES)

The UTES (Sanner & Knoblich, 1999) is a storage medium which has a geological range from earth or sand to solid bedrock, or aquifers. The temperatures can vary between 10 to 40 degrees Celsius. The following technology is widely used in the Netherlands:

- ATES (Aquifer Thermal Energy Storage). This exists of two of more wells into a deep aquifer that is contained between impermeable geological layers above and below. One half of the doublet is for water extraction and the other half for reinjection, so the aquifer is kept in hydrological balance with no net extraction. The heat (or cold) storage medium is the water and the substrate occupies. The maxed depth of this system is 1000 meters. Usually, it goes down to 200 meters. The cooling power and the heating power are determined by the scale of the project.
- BTES (Borehole Thermal Energy Storage). BTES stores can be constructed wherever boreholes can be drilled and are composed of one to hundreds of vertical boreholes, typically 155 mm in diameter. This type of installation does not go very deep, around 100 meters, and the overall coefficient of performance (COP) is 4-8.

Figure 2.7 shows all the underground thermal energy storages (around 45 systems, mostly ATES units) and brine discharges[3] in the Westland (Sanchez, Raat, Klein, Paalman, & Essink, 2012). The presence of brine discharges near the UTES units determines the efficiency of the UTES. Therefore, recommended when placing an UTES system is to take the possible influences of groundwater by the brine injection into account. An equivalent system can produce a thermal power of 25 MW (Deltares, 2008).

Figure 2.7 UTES Westland (2010)

[3] Greenhouses often use groundwater as an additional irrigation water source. This groundwater is extracted from the first aquifer layer under the ground. This water is broke and should therefore be desalinated; this is done by means of reversed osmosis. The groundwater is passed through a membrane under pressure. After the membrane passage, there is practically no salt in the (irrigation) water. On the other side of the membrane salt accumulates. This salt solution is referred to as brine and is injected at a greater depth in the second aquifer layer.

2.2.6 COMBINED HEAT & POWER (CHP)

One of the most versatile systems for the horticulture is the combined heat and power (Figure 2.8), for short: CHP. This system consists of a gas driven combustion engine with a generator.

This generator produces electricity which can be used for themselves or can be returned to the electricity network.

This liquid cooled combustion engine also produces heat. The temperature of the cooling liquid lies around 80 degrees Celsius. This heat energy can directly be used for the greenhouses, stored in buffer tanks or transported to other locations.

After burning gas, the residue CO_2 remains. First the CO_2 is cleaned and then is used for the plants in the greenhouse.

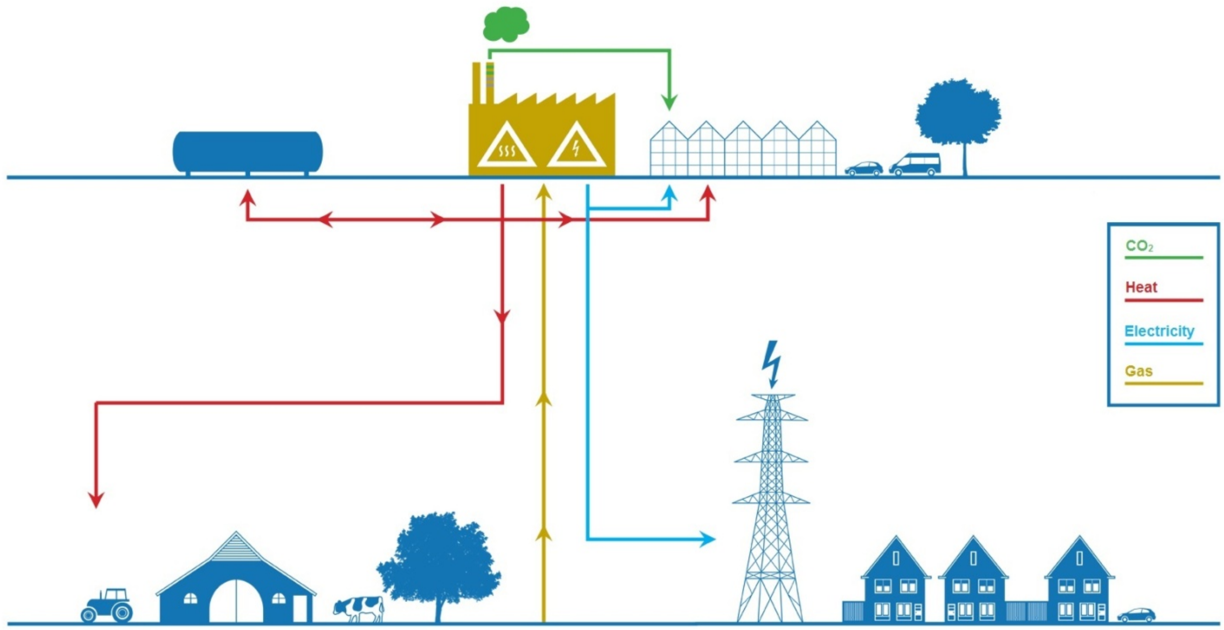

Figure 2.8 Schematic of a CHP (Powerhouse, 2013)

2.2.7 EXISTING LINKS

The largest links of the Port of Rotterdam are:

- A steam network between AVR and EKC in the Botlek area. In the future, it will be expanded to AkzoNobel.
- In the end of 2013 there will be an operational hot water network for 25.000 equivalent households between AVR and South Rotterdam. In the near future, there will be a hot water network for 25.000 equivalent households between AVR and North Rotterdam.
- An 85 kilometer long pipeline for CO_2 with a diameter of 500 mm exists from Botlek to Westland, B-triangle and ends in the Zuidplaspolder.

2.3 Visions of the Future

It is not a new vision of Westland to use waste heat for greenhouses or buildings. In the Sustainability agenda 2012-2020 (Duurzaamheidsagenda) (Zuiderwijk-Groenewegen, 2012) you can read the vision of the Westland regarding present and future activities. A short summarize is given in the following paragraphs.

2.3.1 Green Deal

The province Zuid-Holland has a contract with the government about the Green Deal (Province Zuid-Holland, 2011). This deal was signed by the government and the province on October 3, 2011. This results in a set of concrete agreements that together can be understood as a strategy for 2020. The province has formed a project team with input from DCMR and AgentschapNL. The management, supervision and the support of the agreements require a certain level of central organization, which is shaped in an independent Program Office Renewable Heat. This office includes as expected three full time equivalents, spread over competencies as follows: coordinator, business developer, facilitator and content expert with support of a secretariat. In addition, external specialists are deployed to address specific questions. The main tasks of the Program Office are: facilitating research, sharing knowledge, connect with notarized financial institution for financiering and fundraising and substantive support of heat projects. The vision is shown in figure 2.9.

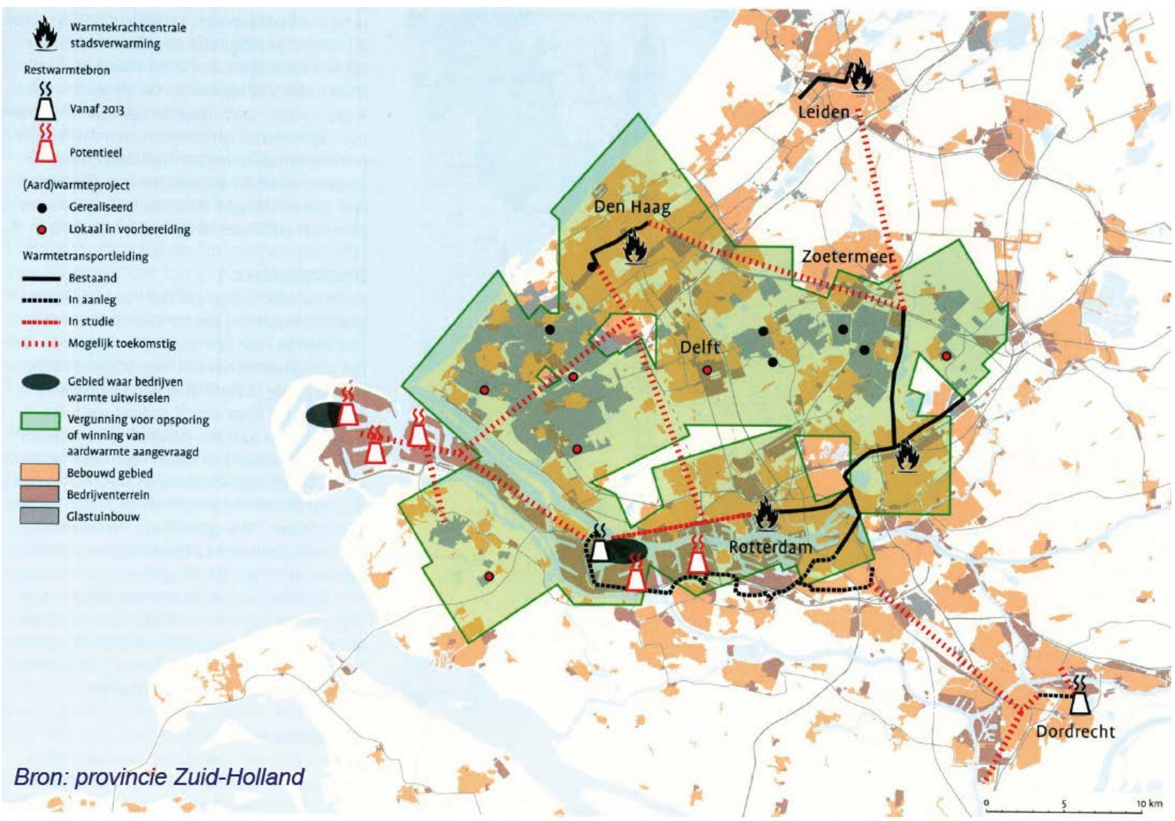

Figure 2.9 Green Deal

The Energy Research Grant program (Ministry of Economic Affairs, 2008) gives research, in the field of heat and cold, a prominent place with explicit support of relevant heating and cooling techniques. A subsidy scheme for energy networks, which is part of the greenhouse, is developed and has a budget of 22.5 million Euros.

2.3.2 SMART THERMAL GRID

A Smart Thermal Grid or STG is a heating grid with providers and consumers. This grid can consist of geothermal heat, power plant, CHPs and more. The main difference between a smart grid and a conventional grid is providing heat from central points to decentralize points. The heat network contains more than one heat provider. Those providers can also be consumers. Demand and supply are adjusted to the heat market.

In figure 2.10, below, shows a concept "kralen rijgen" (Province Zuid-Holland, 2011). This means connecting heat suppliers and consumers with each other to make a large grid that everyone can use in Zuid-Holland. Further expansion of this grid will supply heat to everyone in Zuid-Holland.

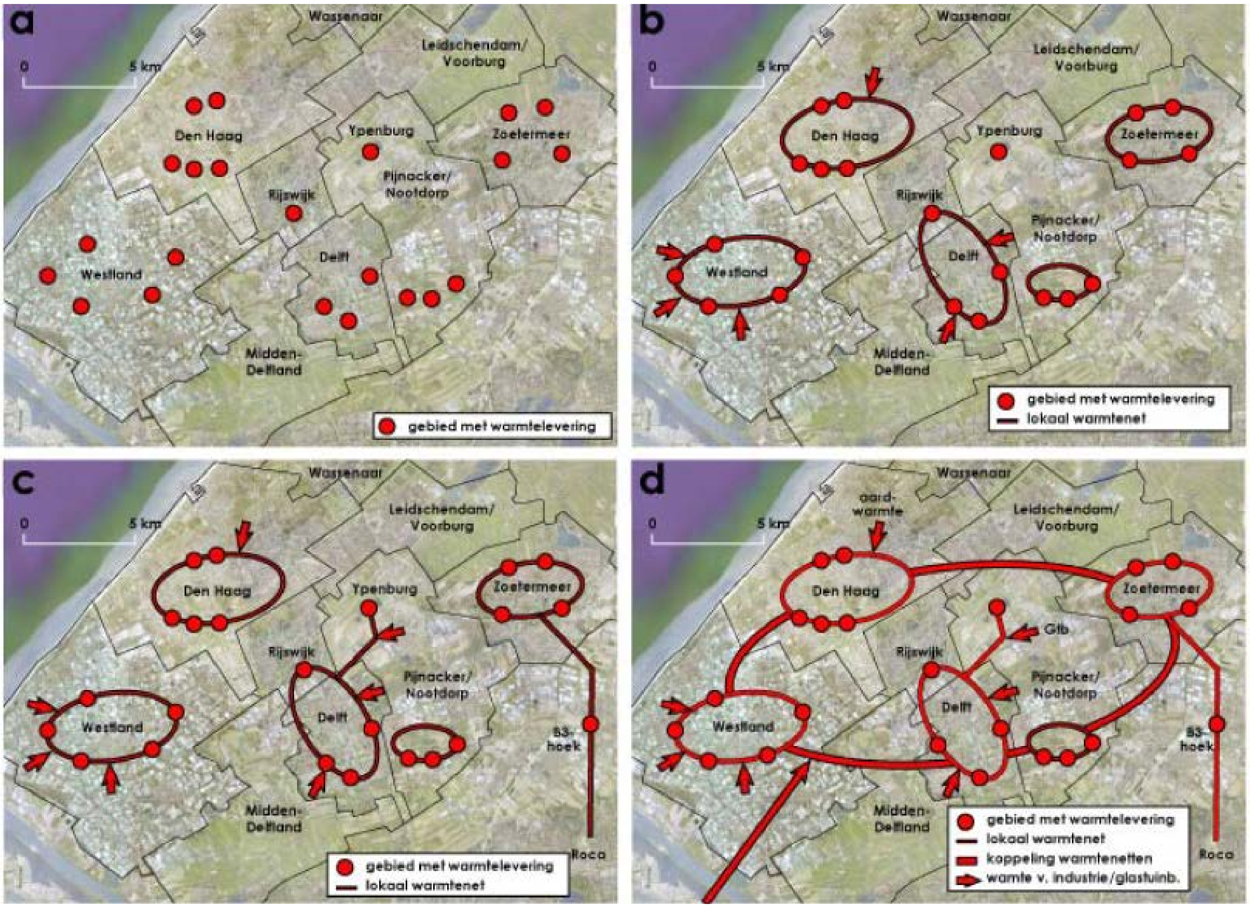

Figure 2.10 "Kralen rijgen"

2.4 ENERGY DATA

An estimated 30 PJ per year or 951.3 MW_{th} is needed for the greenhouses. Most of them got a CHP-installation that provides heat, electricity and CO_2. Also (non-)residential buildings are using 285 MW_{th} or 9 PJ of heat energy every year. With a total of 39 PJ per year (1.1 GW_{th}) has Westland one of the largest heat demands in the Netherlands.

In the figure 2.11, below, the heat use of the greenhouses (AgentschapNL & Dijkshoorn) can be seen. This shows a good overview of the heat use of the greenhouses.

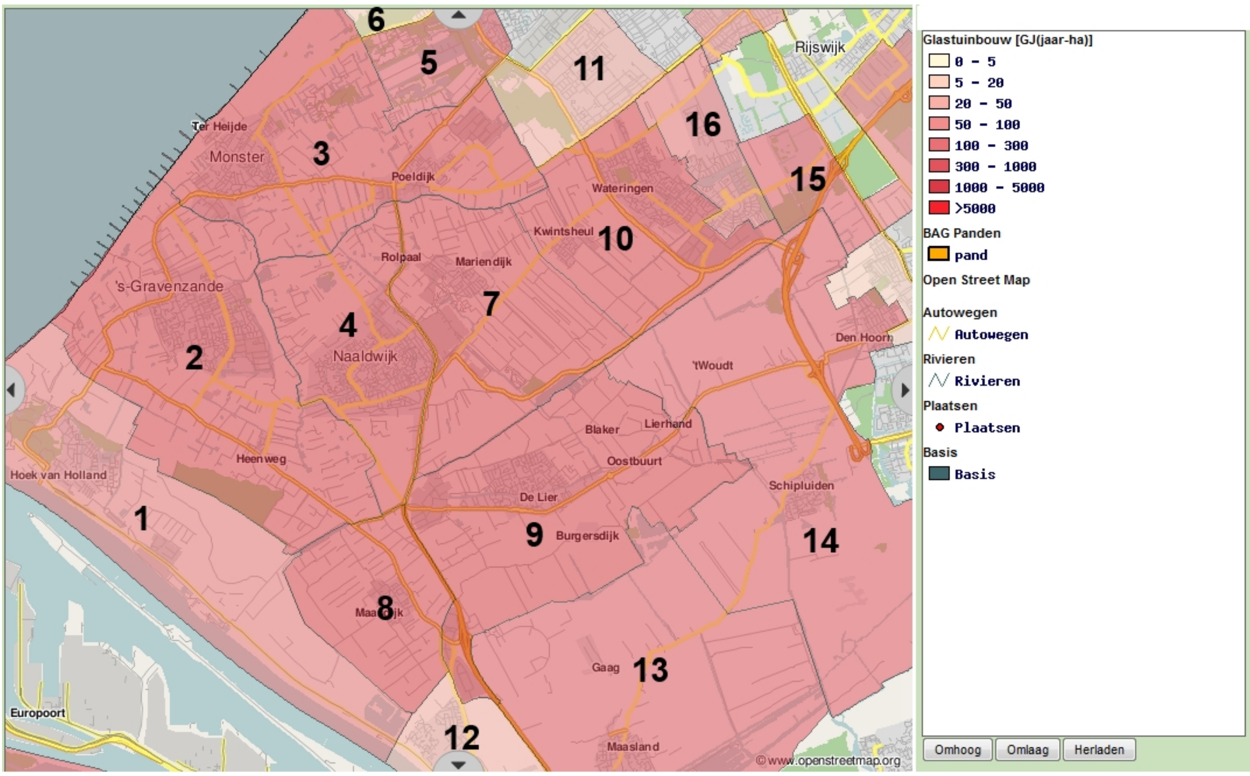

Figure 2.11 Heat use greenhouses (2008)

Table 2.2 shows 23.08 PJ/year of heat energy or 731.87 MW of heat power in Westland in 2008. The overall heat use of the greenhouses has risen with around 7 PJ in the last five years.

The thermal power in table 2.2 is calculated with the formula:

$$\frac{Heat\ use\ greenhouse[GJ/(ha-year)]}{time\ in\ one\ year[s]} * Surface[ha] = Thermal\ power[MW]$$

Table 2.2 Heat use greenhouses (2008)

Number	Community	Surface [ha]	Heat use greenhouse 2008 [GJ/(ha-year)]	Thermal energy [PJ/year]	Thermal power [MW/ha]	Thermal power [MW]
1	Rotterdam	1399	275	0.38	0.01	12.20
2	Westland	1709	2075	3.55	0.07	112.45
3	Westland	1424	1781	2.54	0.06	80.42
4	Westland	804	1714	1.38	0.05	43.70
5	's-Gravenhage	305	462	0.14	0.01	4.47
6	's-Gravenhage	436	19	0.01	0.00	0.26
7	Westland	1041	2920	3.04	0.09	96.39
8	Westland	609	3901	2.38	0.12	75.33
9	Westland	1480	3315	4.91	0.11	155.57
10	Westland	885	2263	2	0.07	63.51
11	's-Gravenhage	408	38	0.02	0.00	0.49
12	Maassluis	848	42	0.04	0.00	1.13
13	Midden-Delfland	1869	860	1.61	0.03	50.97
14	Midden-Delfland	2865	304	0.87	0.01	27.62
15	Rijswijk	274	559	0.15	0.02	4.86
16	's-Gravenhage	312	258	0.08	0.01	2.55
Total		**16668**	**20786**	**23.08**	**0.66**	**731.92**

2.5 CONCLUSION

- There is many research available for (waste) heat utilization in the Netherlands;
- There are existing initiatives and links in the Port of Rotterdam. Most of these links depart from Botlek. Waste heat utilization for Westland is not possible with these initiatives;
- There are no existing initiatives at Maasvlakte and Europoort for waste heat utilization for Westland, but there are visions.
- A large area still does not have CO_2 delivery;
- Expansion and distribution of OCAP is necessary for the greenhouses.
- Only one geothermal project is operational in the Westland at this moment. More geothermal projects are in process;
- A total geothermal heat power of 111 MW will be available in the near future.
- Westland has a total heat demand of around 1.1 GW.

3 TECHNICAL ASPECTS

This chapter provides an overall technical overview of the heat consumer and provider. It also defines the target groups and infrastructure.

RENEW (Renewable Energy Network Westland) is the optimized and integrated energy distribution system for Westland. This system is specially developed for Westland. More details are in the chapter 5 'business case'.

3.1 HEATING DISTRICT TO RENEW

A schematic example of a normal heat district in figure 3.1 below shows one main supplier. This main supplier is usually supported with a smaller boiler house to comprehend the heat demand at peak hours. The network between de supplier and de substation is called the primary network. These pipelines are usually very long and large in diameter.

The substation divides the hot water into several areas for the right amount of heat energy and temperature. For some consumers (tall buildings), as seen at heat consumers B, boosters are needed to give the water more pressure.

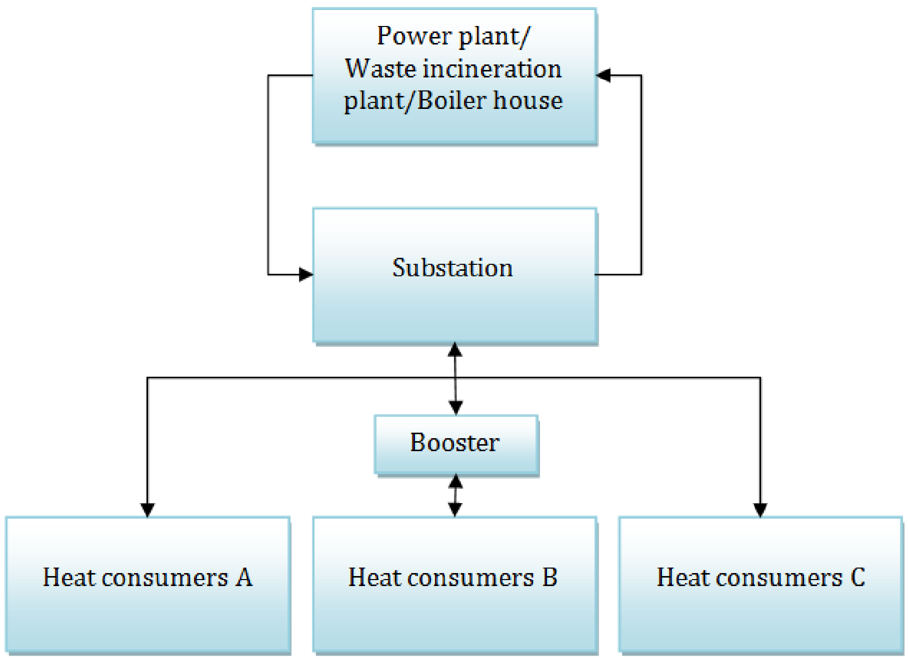

Figure 3.1 Schematic heating district

When the normal district heating system is used for a more integrated and optimized system, then a global overview of RENEW is given. Figure 3.2 shows the RENEW with multiple suppliers. These multiple suppliers are supported with boilers (houses) or CHPs from the greenhouses at peak hours. Seasonally, UTES systems can bring more heating or cooling to the district. The network between the suppliers; power plant/waste incineration/boiler house and the substation is called the primary network. The secondary network contains: geothermal/CHPs/boiler and UTES. These pipelines are also long, but have a lower energy output and a smaller diameter than the primary pipeline.

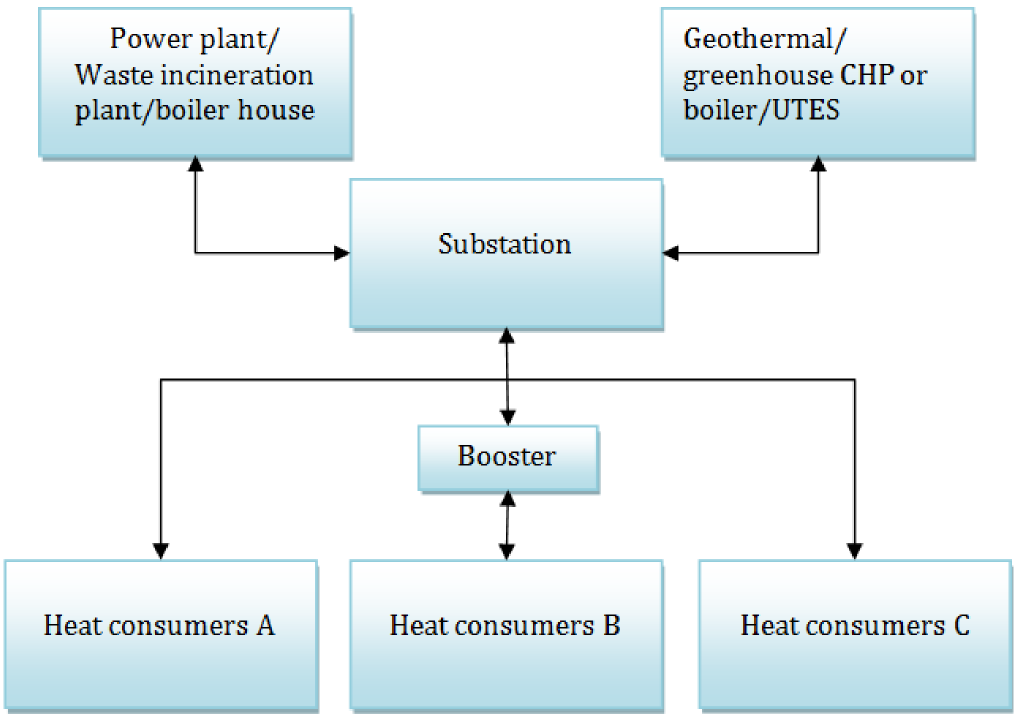

Figure 3.2 Renewable Energy Network Westland

3.2 Target Groups

The main heat suppliers are the industries in the Port of Rotterdam, greenhouses with CHPs or boilers, geothermal heat and greenhouses that need to lose heat on warm summer days. The last one is seasonal and will only be optional on warm days in combination with UTES and heat pump.

UTES (Underground Thermal Energy Storage) can storage heat and supply heat (seasonally), when it is necessary. It can provide enough heat energy to a few greenhouses or a part of a city.

Greenhouses, (non-)residential buildings[4], industries and cities are the consumers. These will consume heat from all other suppliers.

[4] The greenhouses and non-residential buildings are seasonal suppliers and/or consumers. The industry (consumer) is a different kind of firm that doesn't make energy or produce waste heat.

3.2.1 Consumers

As read, the main consumers are greenhouses, (non-)residential buildings, industries and cities.

In the concept position paper of Zuid-Holland (Province Zuid-Holland, 2011), the 'workgroup consumers' had scans performed on the target groups: owners associations (homeowners) and horticultures. The main question to the homeowners is how they experience there heating connection. The question for the greenhouses is what the heat experiences are. The following results are drawn by the targets groups:

- Both groups: connecting to external heat supply is not 'standard'. For them, connecting to an external heat supplier is complicated and a time consuming process.
- Greenhouses also have different needs, like CO_2 and electricity, which are often generated from one and the same system (CHP). Therefore, if a heat network will be their new primary energy source, then CO_2 delivery is a must.
- Reliability of the system is essential for business continuity.
- Costs have to compete with others. Avoiding risk is a priority. The lowest price has the most advantages.
- Greenhouses seem willing in clusters of associated heat and look further than CHP, but they don't always find it profitable enough, except for greenhouses with artificial lights.
- Although a cluster connection is negotiable, still they greatly appreciate their own decision.
- Independences: greenhouses want an open interaction between renewable source like geothermal heat and its own energy source.

These experiences and answers need to be considered and fulfilled for a feasible realization within the business case.

3.2.2 Suppliers

The large heat suppliers are mainly the companies at the Port of Rotterdam. The five largest heat suppliers are E.ON (Borsboom, 2008), BP (Smeenk, 2012), EnecoGen (EnecoGen, 2011), Electrabel (iob, 2013) and Indorama (Indorama, 2012) with a total heat output of 995 MW. In the table 3.1 are more companies that could provide waste heat. An accounting estimate of the waste heat of each company is calculated in appendix B. Other heat suppliers are: greenhouses with CHPs and geothermal with a thermal power between 10 and 40 MW.

Still, due to various reasons (Ministry of Economic Affairs, 2008) the market for dividing and supplying waste heat is not there:

At first, companies and governments have insufficient knowledge of the costs, benefits and performance of sustainable measures. Second, there are no records of heat demand and supply, and where those points meet. The coordination between consumers and suppliers is difficult. And final, heat supply is not a core business for industrial companies that produce heat as a by-product. The investments to make the industrial plant suitable for use are also high and complex, and the payback periods are long.

An overview in table 3.1 and figure 3.3 is given of the companies who can supply heat. For the business case only the companies on the Maasvlakte and Europoort are being taken into account.

Table 3.1 Overview companies heat supply

Companies	Waste heat power [MW]
Maasvlakte	
E.ON Benelux MPP3	250
E.ON Benelux MPP2	330
Electrabel	202
Europoort	
BP Oil refinery Rotterdam	40
EnecoGen	150
Indorama Holdings Rotterdam	25
Botlek	
AVR	-
Lyondell	-
Esso raffinaderij	-
Shell raffinaderij	-

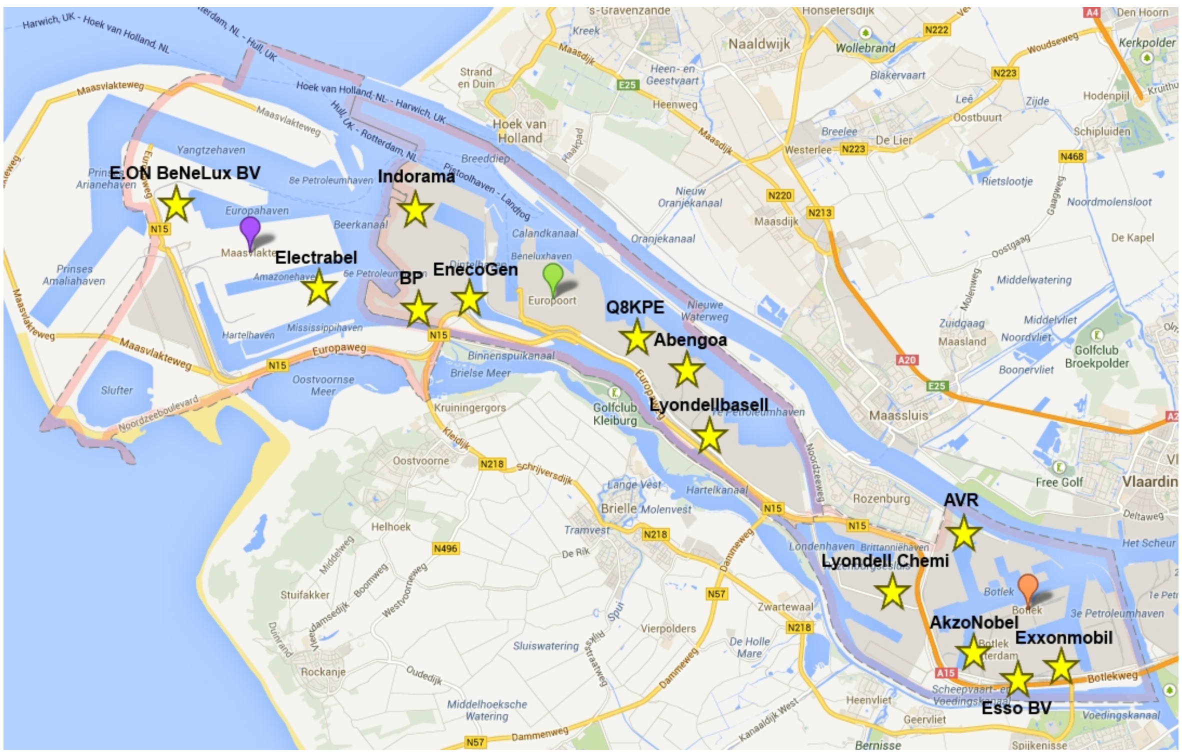

Figure 3.3 Geographical location companies

3.3 INFRASTRUCTURE

The space necessary for the large pipelines in the ground is sometimes difficult to find. The Port of Rotterdam has corridors for these pipelines so for that reason that will not be a problem. Westland however does not have space in the ground, because of its many underground pipelines. In view of that, a major problem occurs that would be a large operation to get around. Besides the limited space, the shortest way for pipelines is also important for the costs (more about the costs in chapter 4 & 5) and the minimal energy transmission loss. And finally, the diameter will be a large factor that determines the costs of the pipelines and the space it needs. Subsequently, future plans will also needed to be measured in this process. If larger grid, defined in visions of the future in chapter two, are possible, than a part of the diameters need to be adjusted for these plans in advance.

Pipelines and heat exchangers play an important part in the energy transmission of the infrastructure. The subparagraphs below give a short explanation of their functions.

3.3.1 PIPELINES

The distribution of waste heat is an important part of the process. This process needs a lot of attention. At first, the right pipelines have to be chosen. These are selected throughout the basis conditions:

- Good isolation;
- High sufficient pressure hold;
- High sufficient maximum temperature.

3.3.2 HEAT EXCHANGERS

Heat exchangers are necessary for the district heating process. These units are fitted at the substation and at the consumers. This ensures a closed water network and a lower pressure loss. The most commonly used heat exchangers are:

- Shell and tube heat exchangers
- Plate and shell heat exchangers
- Plate heat exchangers

The heat exchangers need to resist high pressures, high temperatures and have a high efficiency for a high heat transfer for the distribution of waste heat.

3.4 CONCLUSION

- RENEW is optimized heat district with waste heat, geothermal, greenhouses and UTES as suppliers;
- Target groups are:
  - Suppliers:
    - Industries in the Port of Rotterdam that could provide waste heat;
    - Greenhouses with CHPs or boilers that provide heat
    - Greenhouses seasonally;
    - Geothermal heat.
  - Heat storage
    - Underground thermal energy storage.
  - Consumers:
    - Greenhouses;
    - (non-)residential buildings;
    - Industries.
- A total of 995 MW waste heat is available.
- Greenhouses want:
  - Reliability;
  - Independence;
  - Low costs heat;
  - CO_2 delivery.
- The Port of Rotterdam has corridors in the ground that can be used to place the pipelines in;
- Westland has limited space for the large pipelines.
- An intelligent grid with multiple consumers and suppliers with a contract in which they tell how much they receive and supply is needed for a feasible business case.

4 ECONOMICAL ASPECTS

This chapter gives a summary of the general economical aspects for creating a heat network. This also describes potential cost-effective heat options.

4.1 HEAT CONSUMERS

The consumers find low costs very important. They usually go for the best prices, even if the lowest price is not good for the environment. Still, most of the greenhouses want a sustainable and reclusive heat supply, so the option to invest in new technology and sustainability is possible.

An overview of the estimate of RENEW project can be read in chapter five. But first: what are the reasons for the consumers to switch to alternative heat sourcing?

The gas and electricity prices are the main reasons the greenhouses for choosing their own boilers or CHPs. Their machines are still the cheapest way to produce heat, CO_2 and electricity. If they convert to waste heat from industries from the Port of Rotterdam, than they want the prices to be either lower or equal than it already is. This is only possible when the gas prices are rising and investing in this type of technology is more likeable.

Government subsidy is a possibility to convince consumers for new heat options. The SDE+ (Stimulering Duurzame Energieproductie) (AgentschapNL, 2013) subsidy stimulates the production of renewable energy and focuses on companies and (non-profit) institutions. The SDE+ compensates the difference between feed-in tariff in kWh_e and the production cost per kWh_e. Each year a few billion Euros are used for renewable projects in the Netherlands. An amount of three billion Euros can be spent for those projects this year.

The SDE+ subsidy for geothermal for the year 2013 says:

Table 4.1 Geothermal SDE+ 2013

Geothermal	Max. base price (€/GJ)	Provisional price adjustment 2013 (€/GJ)	Full load hours per year
Geothermal + CHP > 500 m deep Max. 178.129 GJ/year	24.0	7.1	4.158
Geothermal ≥ 500 m deep Max. 245.520 GJ/year	11.8	5.7	5.500
≥ 2700 m deep Max. 356.400 GJ/year	12.8	5.7	5.5

There is too little knowledge for depths from four to six kilometers to grant enough subsidies to make these projects feasible. In that case more greenhouses need to collaborate to finance this project like the geothermal project Noordland-Kapittelland in chapter two.

4.2 HEAT PROVIDERS

Providing waste heat for the consumers is a big task itself. As read in the previous chapter: “It is not a core business for industrial companies that produce heat as a by-product”. Large investments and a long pay-back time are usually enough to disapprove projects. But what if the investments needed for these kinds of projects came from somewhere else. It makes sense to promote renewable energy in this area.

The heat law may give possibilities to finance heat projects or may set boundaries for the dispose of waste heat; as a result, the companies are more motivated to reuse waste heat for other purposes.

4.3 INFRASTRUCTURE

The overall costs are determined by the lengths and the diameters of the different pipelines sections. The shortest way will lower costs and a minimal space occupation in the ground.

Permits are needed throughout the route. These permits costs money, but this will provide a license to ensure the safety for the environment.

4.4 COSTS AND BENEFITS

What do we get, when the costs are measured against the benefits? Using waste heat from the port with unlimited money to make this work is feasible; but who is going to pay for this and what do they get in return, when there is no unlimited money available.

For the companies in the Port of Rotterdam putting large investments into this kind of projects with possible efficiency loss in there system is a risk, but the benefits are more important. The CO_2 emissions are lower, which will result in lower CO_2 emissions costs. Also they get money from every MW_{th} they put in. More thermal power means a faster payback time. However, supply and demand should first be aligned.

Costs for the greenhouses are not as high as the companies in the port, but still need to invest in decentralized heat consumption. This means getting a heat pump if they do not have one or a small substation that passively exchanges heat.

Even though CHPs or boilers will be obsolete, they still got a purpose. Greenhouses will not have two contracts (gas contracts for the CHP/boiler and alternative heat) simultaneously. For that reason, they will have to choose, but when the demand is too high, needing the CHP/boiler is possible. The gas prices are even higher without the contract and this has to be avoided.

Rabobank is a large investor for the greenhouses (Straver, 2013). They have a great interest in sustaining and improving the market in Westland. As a result, Rabobank will be a great asset for financing the business case. Subsidy by the government will also provide some alleviation.

4.5 CONCLUSION

- The gas and electricity prices are playing an important part of the decisions made by greenhouses;
- Subsidy by the government is more likeable than long term investments. It also stimulates the renewable process;
- Setting boundaries on the disposal of waste heat will motivate companies to reuse the waste heat energy for other purposes.

5 BUSINESS CASE

Fluor B.V. has launched a study that examines the feasibility of waste heat arising in the Port of Rotterdam from Maasvlakte and Europoort. This waste heat can be reused for greenhouses and residents in Westland, between the cities Delft, The Hague and Rotterdam. The objective is making an applicable technical design concept of an integrated district heating process for the greenhouses and cities in Westland.

Fluor B.V. has already got some experience in a number of renewable projects, like OMV refinery in Austria, and CO_2 capture and storage from ROAD in Rotterdam. With a location in Rotterdam and their expertise Fluor can really contribute to a renewable future.

This chapter describes the case conditions and barriers, assumptions, the primary and secondary case, infrastructure, organization, calculations, climate results, estimation and the exploitation.

5.1 CASE CONDITIONS

There are a few conditions for making an applicable technical design concept of an integrated district heating process which must be held to. These conditions are made throughout the inventory and are intended for the target groups described in chapter three.

- The heat network has at least two heat providers and consumers: if greenhouses are connected to geothermal or a waste heat network, then external CO_2 supply is necessary. Therefore, it is necessary that more CO_2 is available for horticulture with expansion of the pipeline network. It is important that there are several sources, because the current supply is vulnerable.
- There must at least be one pipeline to the consumer and one pipeline to the provider.
- Concurrency: unless the heat can be stored, it is necessary that the heat demand coincides with the time in which waste heat is produced.
- High temperatures and pressure for households, greenhouses and industries.
- Proximity: heat may be transported in the form of water.
- Continuous availability of CO_2 is essential for the greenhouses. Delivery reliability is a problem for many years. It is therefore important to search companies in the surrounding areas whom can deliver enough high quality CO_2.

There are also barriers to overcome:

- Consumers have alternative ways to produce their heat demand; therefore it is difficult to provide them with an enhanced sustainable energy source.
- Many companies place high demands on their investments. High efficiency ensures a shorter payback time. Feasibility of a project can vary, if the payback time is too long.
- The infrastructure required an overview, so that all stakeholders with different interests are involved.
- The construction of heat pipelines requires high investments, but companies choose security before investments at long term; trust is needed between projects and companies.

There are also risks, such as drilling for geothermal heat, uncoupling of waste heat and in the development of increased heat demand over the years. These risks are more manageable with a holistic approach with multiple providers and multiple heat consumers. In addition, cooperation leads to improvements of conditions.

The design concept has also a few assumptions; these assumptions can affect the future feasibility.

- Every consumer and supplier will participate with the RENEW project;
- Every supplier in the Port of Rotterdam exists;
- Each geothermal in figure 5.3 exists;
- Every pipeline will not have construction problems and will have enough construction space;
- Everyone can utilize a UTES;
- An area without CO_2 delivery cannot have decentralized heat;
- The heat energy needed for each heat demand is an approximation of the reality;
- Connection fees will not play a part in the payback time;
- Each greenhouse or household use the same amount of heat/electricity/natural gas;
- Temperature losses at pipelines are not taken into account.

5.2 CONCEPTUALIZATION

A grid with multiple suppliers and consumers are needed to integrate a modular applicable system for the consumers in the Westland. Therefore, RENEW (figure 5.1) might just work and will be a necessity for the future. Harmony can be created with multiple consumers and suppliers at decentralized points. This will provide an effective way for sustainability, a balance for both parties and an interesting case. Suppliers can compete with each other, making this a more improved system.

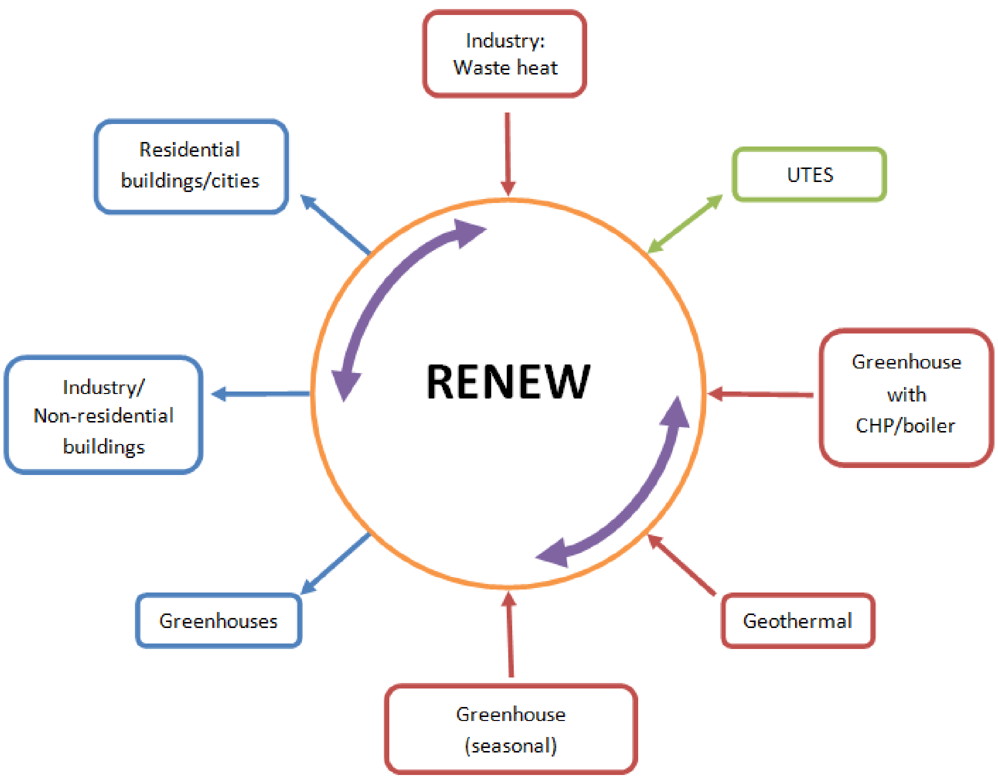

Figure 5.1 Renewable Energy Network Westland (RENEW)

RENEW consist out of three suppliers (industries, greenhouses and geothermal), one storage possibility (Underground Thermal Energy Storage) and four consumers (cities, industries, utilities and greenhouses). A contract can be made with an accurate approach for the right amount of energy supply or demand.

5.3 CASE

The case exists of a primary and a secondary network. The primary network will run in the Port of Rotterdam. The secondary network will run in the Westland area. The secondary network can run without the interference of the primary network (waste heat), but the primary network cannot run without the secondary network. Eventually, both networks will be put together to make one large infrastructure. A more detailed infrastructure will be shown in the next paragraph.

5.3.1 PRIMARY NETWORK

The primary network in the Port of Rotterdam runs from E.ON Benelux BV to Westland with links to Electrabel, BP, EnecoGen and Indorama/Utility Partners. These companies can provide high quality waste heat for the Westland.

5.3.2 SECONDARY NETWORK

The secondary network (figure 5.2) runs through Westland. With CO_2 delivery area (blue area) and future possibility (orange area), and the geothermal areas (yellow stars) in place, the following network can be realistic: the pipelines are divided in several sections. Each section can operate separately and can become a larger grid, when more pipelines are laid down. Each circle in the figure below represents a delivery area.

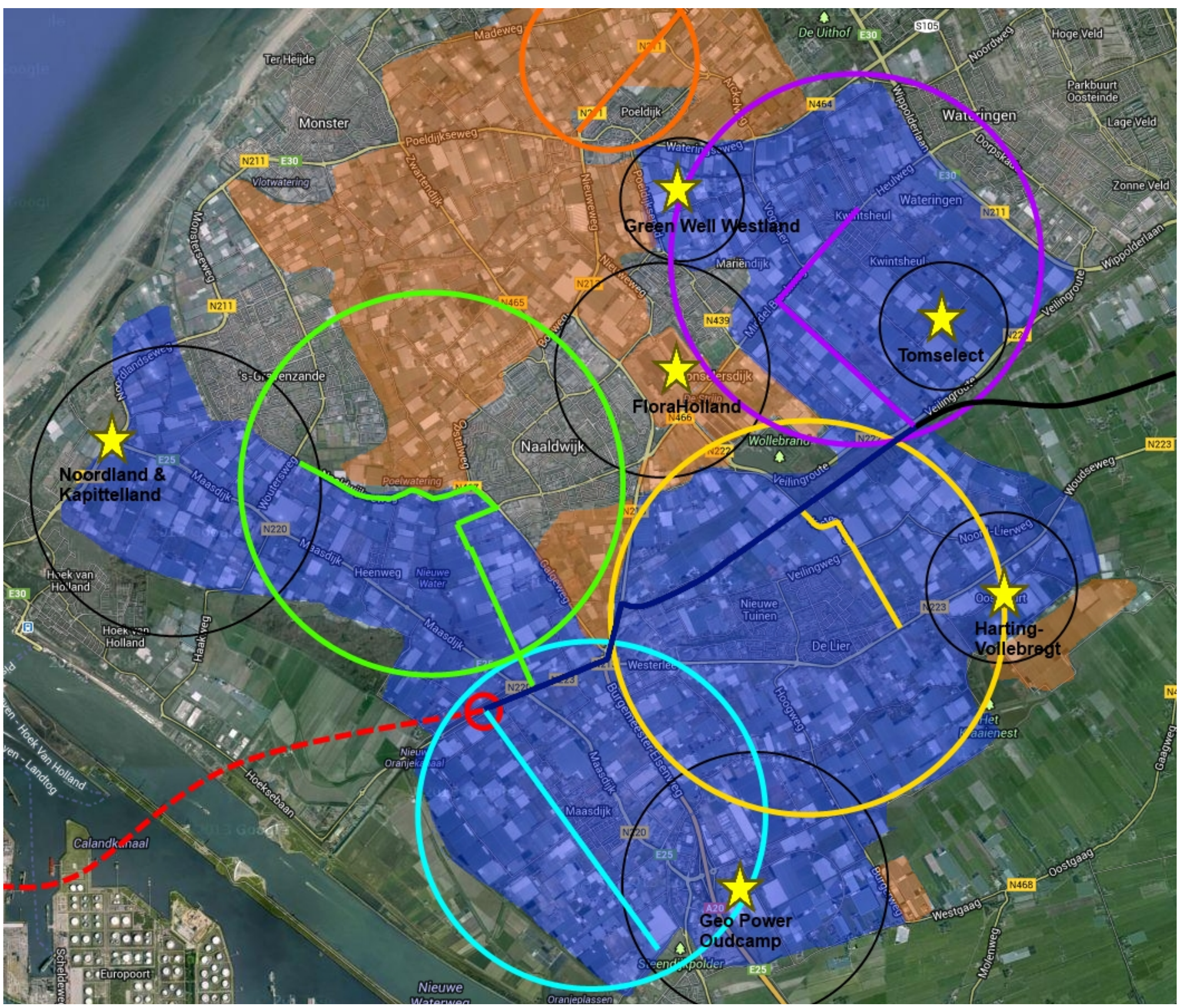

Figure 5.2 Overview secondary networks (circle areas) & CO2 delivery area (Blue)

The second network starts in the South-East of Westland (turquoise circle); this lies between the Geo Power Oudcamp geothermal and the substation (red circle) from the primary network. The second step is to expand the Green circle. This part will give most of the heat to the greenhouses and a part to the cities in that area. Noordland-Kapittelland will do the rest of the heating district. Further expansion starts as seen in the yellow area. Geothermal project Harting-vollebregt will give his heat in his designated area (black circle). At last, the purple circle will give heat to the delivery area as seen in the figure. All with all, each circle has its own delivery area.

The blue/black line in figure 5.2 is a pipeline to Delft, which in future references can be taken into account. Also, a pipeline (orange) from the geothermal Leyenburg (South of The Hague) can be constructed to North-East Westland. But the transition from central to decentralized energy production is not feasible without the CO_2 delivery. Expanding the orange area will require CO_2 delivery (figure 2.2); otherwise it contradicts the case condition in paragraph 5.1.

At peak hours, shortage of heat energy will result in low temperatures in the system. This temperature should or must be compensated. This is made possible by using the energy of CHPs from greenhouses to supply energy back to the thermal grid. This energy would stay inside the circle, so the greenhouses, who deliver heat, know who is consuming. The smaller grid can now also produce independently without the interference of the waste heat from the Port of Rotterdam or other greenhouses outside the circle. There will be a system that would regulate the above, which monitors the supply and demand and making this; a modular intelligent, independent and competitive circle grid.

If the necessity for heat energy, due low efficiency of the geothermal, is there, then an adjustment of the circle grid can be made to deliver heat to the geothermal circle area as well.

There are many UTES units in the area Westland (figure 2.7), which can be used to help at the winter peak hours and also, like the CHPs and can help their own grid to a better efficiency.

As shown in paragraph 5.1 this system meets the case conditions. The 'renew' relationship to all suppliers and consumers gives this system strength. Multiple suppliers also give a modular competitive system. Consumers can choose from whom they get their heat from.

5.3.3 CO_2

Expansion of the CO_2 pipelines of OCAP is a necessity for the greenhouses. The distribution network requires more high quality CO_2. For that reason, a new pipeline in the Port of Rotterdam from E.ON to Abengoa is needed or the ROAD project has to be re-proposed. Furthermore, a new CO_2 pipeline to the orange area in the Westland needs to be constructed before heat delivery can take place.

5.4 INFRASTRUCTURE

This paragraph describes the infrastructure (schematics) of the business case. The total distance of the primary network will be around 43.4 kilometers (km). This exists of 2 x 21.6 kilometers.

The secondary network can vary; therefore distance estimation for the large pipelines is made. The secondary network exists out of 2 x 23.85 km or 47.7 km.

5.4.1 SCHEMATICS RENEW

The schematic in appendix C shows a block diagram of RENEW. This system contains multiple suppliers (diamond shapes), consumer (square shape) and an underground thermal energy storage (hexagon shape). The waste heat, from the left diamond shape, exists of water of 140 °C. Meanwhile, the geothermal exists of multiple performances that could deliver around 80 °C or 140 °C depending on the depth of the geothermal as read in chapter two. Also, energy storage is possible with UTES units with 40 °C. And final, the CHP/boiler can produce 80 °C for the consumers. There are various heat consumers, each wanting a different temperature. This difference will be regulated with heat exchangers.

5.4.2 PRIMARY NETWORK

The following sub-paragraphs are divided into two parts: the primary and secondary network. This gives a more detailed overview about both networks in the business case.

Figure 5.3 shows the primary network. This has multiple suppliers with high quantity heat. The companies E.ON, Electrabel, BP, EnecoGen, and Indorama (Utility Partners) are connected to this line. The main roads are followed, because the corridors, next to the road, can be used to lay the pipelines in[5]. The dashed line to the Westland connects the primary and secondary network and goes deep underground. The total length to the primary network is around 43.4 kilometers. This includes the underground pipeline from Europoort to the Westland[6]. There are no problems expected during the construction.

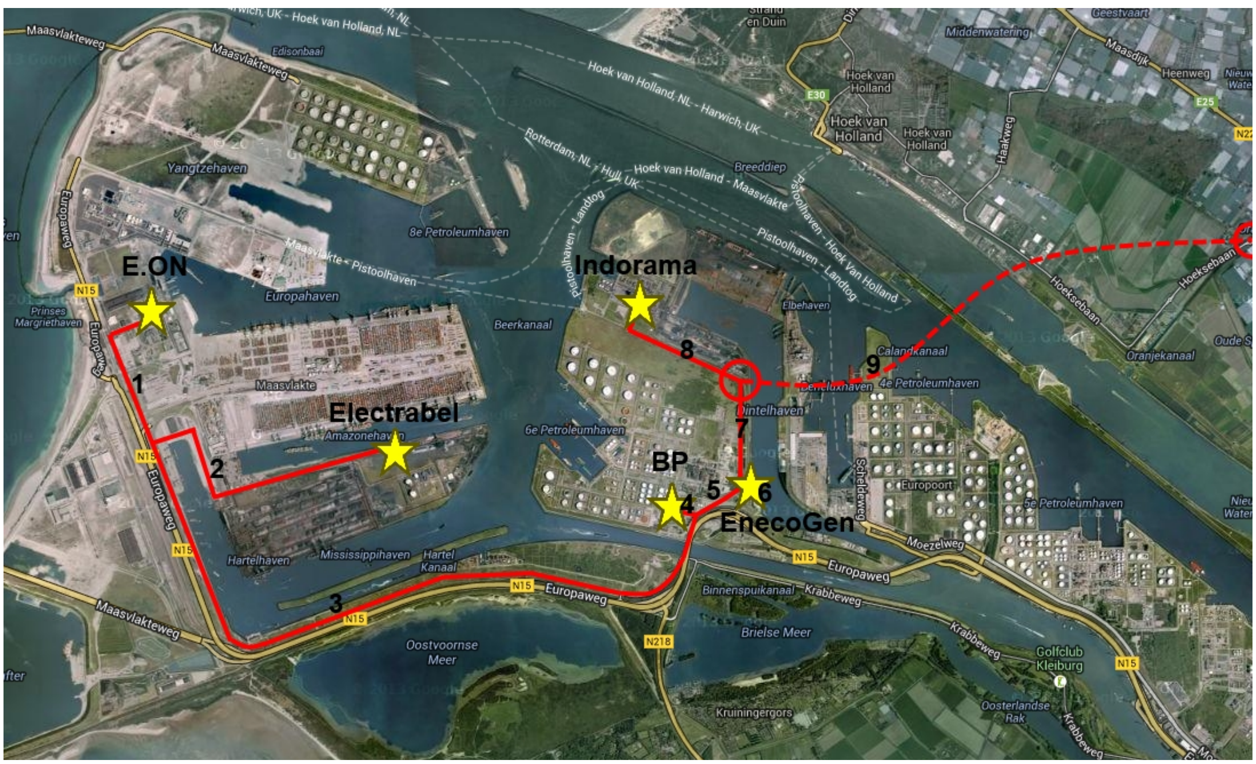

Figure 5.3 Primary network

[5] How the pipes are laid, may differ from future reality.
[6] The pipeline can also be constructed from middle of Europoort for a shorter crossover. The distance will not differ from the concept and has no influence on the calculation.

5.4.3 SECONDARY NETWORK

The secondary network is divided in five delivery areas (figure 5.2). These areas have their own suppliers and consumers in their area and will be connected step by step as shown in figure 5.4. Problems with the limited space are expected, when constructing the pipelines in the ground.

The infrastructure plans for the total secondary network, before the primary network can be established, are as followed:

1. The ‘turquoise’ pipeline from the substation is constructed through South-West Westland;
2. A second ‘green’ pipeline is build through South-East Westland;
3. The third ‘yellow’ pipeline will supply West Westland and de Lier;
4. The ‘purple’ pipeline supplies the North East;
5. Geothermal heat from the Leyenburg area to the North-East of the Westland is given. This pipeline will only be feasible with CO_2 delivery;
6. The ‘blue line’ is an extension of the waste heat network. Between the ‘red’ and ‘blue line’ is a heat exchanger. The ‘blue’ pipeline is calculated until the ‘purple’. Further expansion will be possible as shown as a black line.

Each line has its own heating district. The amount needed for all consumers are weight and extra necessary measures are taken for the peak moments through geothermal, CHPs or UTES.

Figure 5.4 Main pipelines Westland

5.5 ORGANIZATION

An organization with clear distinction between main systems, parties and stakeholders is needed to obtain a functional business case. On one hand the consumers and on other hand the suppliers of waste heat, transportation, distribution, ownership and management are coordinated with an optimal economic in- and output perspective.

A form of contract to make each circle grid independent and competitive has to be established. With a modular intelligent system demand and supply can be optimized. The energy in and output will give the greenhouse a choice to also deliver heat, to himself and to others, when needed (Waerdt & Buitenhuis, 2013).

The greenhouses, the community Westland, Rabobank, Province Zuid-Holland and other subsidies from the government or the EU can help finance the project together.

A new ‘heat company’ for the exploitation of this heat network needs to be established

The project will be carried out by Fluor B.V. with sufficient expertise in engineering and the possibility to contract other sub-companies Fluor B.V. will be the best candidate to successfully lead this large project.

5.6 CALCULATION

This paragraph provides the calculations for the heating district in the Westland. Calculations, made in Microsoft Excel, are shown in appendix D.

5.6.1 OVERVIEW SCHEMATIC HEAT SUPPLY AND DEMAND

Table 5.1 gives multiple situations for the heat network in winter and summer time. The first situation describes a standard system with everyone working together to produce enough heat. The second situation described an interference of the power plants to the thermal grid. An additional energy source to provide enough heat to the greenhouses may be needed if required. Boilers and CHPs must still be available at any given time or more heat from geothermal, UTES or a portable boiler house is needed.

Eventually, the total amount of supply and demand has to be zero.

Table 5.1 Heat supply and demand per year

Supply & demand	**Situation/network 1 (MW) standard (winter)**	**Situation/network 2 (MW) (winter)**	**Situation/network 3 (MW) standard (summer)**
Power plant			
- E.ON (MPP2/3)	+ 580	0	+ 200
- Electrabel	+ 200	0	+ 100
- EnecoGen	+150	0	+ 75
Companies:			
- BP	+ 40	0	+ 10
- Indorama	+ 25	0	+ 25
Total waste heat	**+ 995**	**0**	+ **580**
Greenhouses with CHP/boilers	+ 0	+ 774	+
UTES	- 82	+ 189	- 180
Geothermal	+111	+ 111	+ 80
Residential buildings/cities/ Non-residential buildings/industries	- 123	-1 23	- 10
Greenhouses	- 951	- 951	- 300
Total heat demand	**1074**	**1074**	**310**
Total	**0**	**0**	**0**

5.6.2 SPECIFICATION PIPE SECTIONS

With measuring the length of the pipelines with Google Maps calculation of the diameter, pump power, pressure loss (pressure difference) and coefficient of friction can begin.

Fast calculating different kind of sections is done with the use of Microsoft Excel. The value for the diameter (Taal, Toegepaste Energieleer, 2008), pump power (Ouwehand, Papa, Taal, & Post, 2008), pressure loss, (Taal, Toegepaste Energieleer, 2008) and coefficient of friction (Wikipedia, 2013) can be determined. The formulas are shown in appendix DI Calculation.

The tables shown in appendix D-II give a specification of each network. This overview is made with the formulas shown in the first part of appendix D. The primary pipe sections (1, 3, 5, 7, and 9) are divided into two smaller pipelines and can also be separately used, when the demanding quantity is low.

The double and smaller pipelines will also be use at the pipelines 1 to 4 & 6 from the secondary network.

The calculated diameter and pump power is strongly dependend to the water flow. The speed in the primary pipeline and secondary pipelines will be around 2.5 m/s. This is chosen for a lower heat loss and smaller diameter.

5.7 CLIMATE RESULTS

Every year a total of 260 of 1,200 million m^3 natural gas (Velden & Smit, 2011) are consumed to drive the CHPs and hot water boilers for greenhouses in Westland. One m^3 natural gas gives 1.8 kg CO_2. That means approximately 300 million kg CO_2 could be saved through waste heat utilization if enough greenhouses and cities are involved to the RENEW project.

When natural gases are replaced from central to decentralized utilization, then more electricity is needed. Using the power plants at the Port of Rotterdam will give electricity and heat on a large scale. That results in a reduction of CO_2 emissions.

5.8 ESTIMATE

This paragraph describes the estimate. This will help determine the feasibility of this research and will only give an idea of the overall costs. Furthermore, an estimation of the overall costs of the infrastructure with substantiations in this paragraph is made. This is calculated with the (Dutch Association of Cost Engineers, 2012). The estimate has an accuracy of estimate class 4 described in AACE Practice No. 18R-97 (Christensen & Dysert, 2011). The expected accuracy range will be -20% to +40%. A more detailed estimation is shown in appendix E.

The estimation of the primary network goes as followed: the main parts of the process of each company are examined with the overall costs of each part. After the estimation of each separate company; the primary pipelines is calculated. The estimation contains, as seen in figure 5.5, the following: heat exchangers, pumps, pipelines, substation, a control building, 24 /7 control, water costs and maintenance.

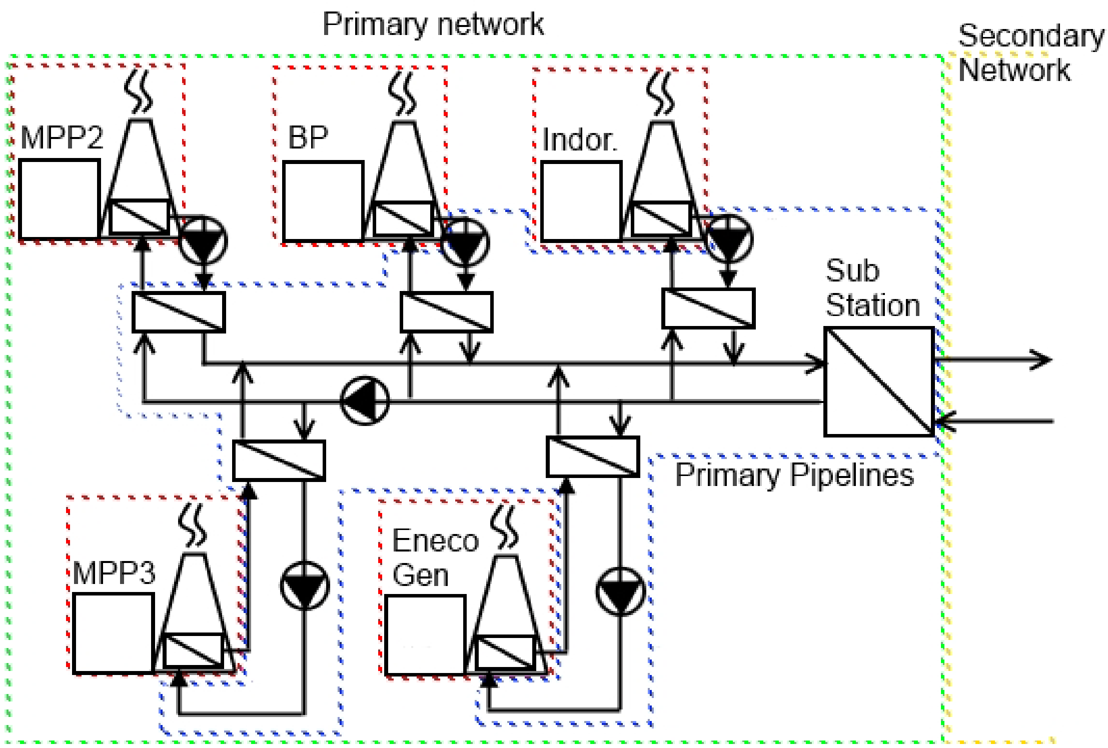

Figure 5.5 Limits Primary network

The secondary network in the Westland has the following sections (figure 5.6): geothermal and secondary network. The geothermal is calculated at 1.5 million Euros per MW_{th} (Gonzalez, 2012). The secondary network contains: heat exchangers, pipelines, pumps, control buildings, smaller district heating pipelines and fittings, maintenances and permits.

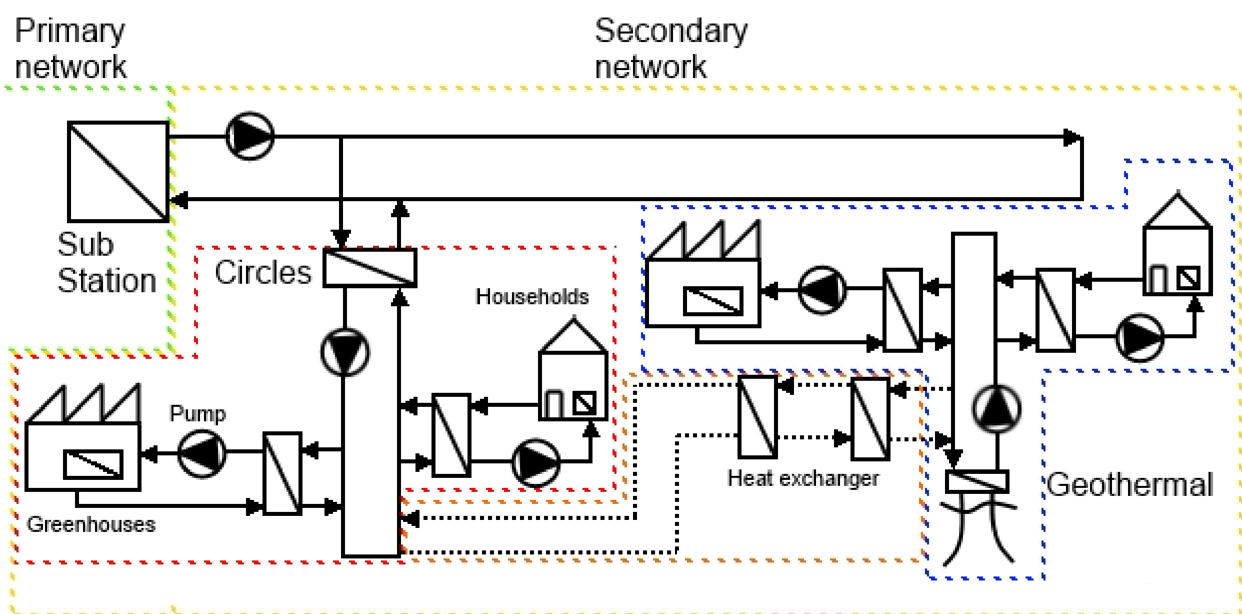

Figure 5.6 Limits secondary network

The total costs, seen below, are with an accuracy of -20% to +40%.

Primary Network	
Companies'	**€ 214,000,000.00**
Primary network	**€ 540,000,000.00 +**
Total	**€ 753,000,000.00**
Secondary Network	
Geothermal	**€ 182,000,000.00**
Secondary network	**€ 378,000,000,00 +**
Total	**€ 560,000,000.00**
	+
Total estimate	**€ 1,313,000,000.00**

A delivery area with greenhouses and a small city costs has an estimation of 51 to 77 million Euros (appendix E Estimate Circle).

5.9 EXPLOITATION

This paragraph describes the method of exploitation for the business case as followed:

The greenhouses have standard energy costs (appendix F) containing: costs for gas and electricity, with: electricity divided into two parts intake and decrease (refunds). These costs change for the greenhouses into electricity, thermal power and natural gas. The electricity will rise, and the amount of gas needed will be less. The households are also taken into account. The households will change from the usual natural gas and boiler to thermal energy.

The costs, like connection fees, periodic fees and other fees are determined with the rates of Stedin for electricity (Stedin, 2012) and the rates for gas from the gas company Westland Infra (ACM, 2013). The electricity consumption (input, consumption and refunds) for the greenhouses is determined by the source: (Velden & Smit, 2011), whereby the average per greenhouse could be determined through the source: (LEI Wageningen UR, CBS, 2012). This source says that 5,462 greenhouses have glass, which 44% (2451 greenhouses) from Zuid-Holland, in which approximately 50% (1225 greenhouses) in Westland. Not everyone will be involved with this project. For that reason this will be an estimated 975 greenhouses.

5.9.1 CIRCLE

As described in the paragraph 'infrastructure'; the turquoise color area will first be constructed. This delivery area contains greenhouses and a small city with households and has an estimation of 51 million to 77 million Euros (appendix E Estimate Circle). This estimate does not contain geothermal, UTES or the price for district heating in the city. All other delivery areas will also have an estimation of around 50 to 80 million Euros.

An estimated 200 greenhouses and 4,000 households are in the turquoise color circle. This estimate has to be calculated before the next step can begin, because following these steps gives the project a more dynamic approach and a greater chance of succeeding.

The city, with only the households, will be the only consumer in the beginning. The greenhouse delivers heat energy from his CHP and greenhouse to the residential buildings. At first, there will be extra costs for the greenhouse above the normal costs, because the greenhouse has to deliver more heat energy and therefore consumes more natural gas. These extra costs will be compensated by the extra reimbursement of electricity from the CHP, the payback price of the thermal power per kW and the payback difference between the old price per year and the new price. And so, the greenhouse will only be rewarded for the delivery of the amount of heat power to the heat network. The payback price of thermal power per kW will be 12.30 Euros per kW_{th}.

The residential buildings (households) will pay the same price for thermal power as with natural gas per year. A household pays will pay an amount of 177.60 Euros per kW_{th}.

Payback time

The estimated total profit is the total costs of residential building per year minus the thermal costs for the greenhouses minus the difference in costs per year (old and new) for the greenhouses (appendix F Phase 1). This will reach a yearly profit of an estimated 3.8 million Euros. The total investment divided through the yearly profit will calculate a payback time[7] of around 14 to 20 years[8].

5.9.2 Transition from circle to waste heat

The transition of heat suppliers from greenhouses to waste heat from the port of Rotterdam is a difficult procedure, because: how many circles are needed to make the payback time feasible enough and how will the exploitation convert to a new shape.

The primary network will be, like in Westland, financed by the government. The companies, who deliver waste heat, will also need to make an effort and invest in their own modification of their system. They could earn their investment back through delivering waste heat per kW.

The price for kW_{th} will stay at 12.30 Euros per kW for waste heat (appendix F Phase 2). Even the residential buildings will pay the same amount for their thermal power, namely: 177.60 Euros per kW. This means that a household will pay less with more heat connections to the network, than an average household with natural gas. The greenhouse will, just as the circle, get a refund of 12.30 Euros per kW_{th} and in addition a reimbursement so the greenhouses will not lose additional costs. As seen at the circle, the greenhouse will only get a reward for the delivery of thermal power.

Payback time

The payback time for the primary network is calculated through the amount of waste heat in MW, the amount of greenhouses and the amount of residential buildings in the cities. This is adjusted until everyone joins in with a maximum payback time limit of 25 years (the same amount of years for district heating). With this, a graph emerges with the payback time in years against circle quantity. Table 5.2 described the following: circles (1, 2, 3, 4, all), thermal power [MW] and the amount of greenhouses and residential buildings.

Table 5.2 Specification circle

Circle(s)	Thermal power [MW]	Greenhouses	Households
1	150	200	4,000
2	450	400	10,000
3	700	600	15,000
4	995	800	25,000
All	995	975	35,000

[7] The payback time is without subsidy or other variables, such as underground thermal energy storage or geothermal heat.
[8] Each delivery circle will also have the same estimated payback time as this circle. However, geothermal projects have different payback times.

These specifications are imported in the calculation sheets in appendix F. Gas prices are also taken into account. The current natural gas price is 0.25 Eurocent per m^3 (figure 5.7) with a possible rising of 5 to 10 Eurocent in the upcoming years.

Figure 5.7 Natural gas prices (Energie strategie, 2010)

The following payback times are calculated with the values and noted in table 5.3 below:

Table 5.3 Payback time in years

Circle - years	MIN € 0.35	MAX € 0.35	MIN € 0.30	MAX € 0.30	MIN € 0.25	MAX € 0.25
1	78	117	99	148	133	200
2	35	53	43	65	57	85
3	23	35	29	43	38	56
4	16	24	19	29	24	36
all	13	19	15	23	18	28

These values are plotted in a graph (figure 5.8). This will give a good overview of where the limit is.

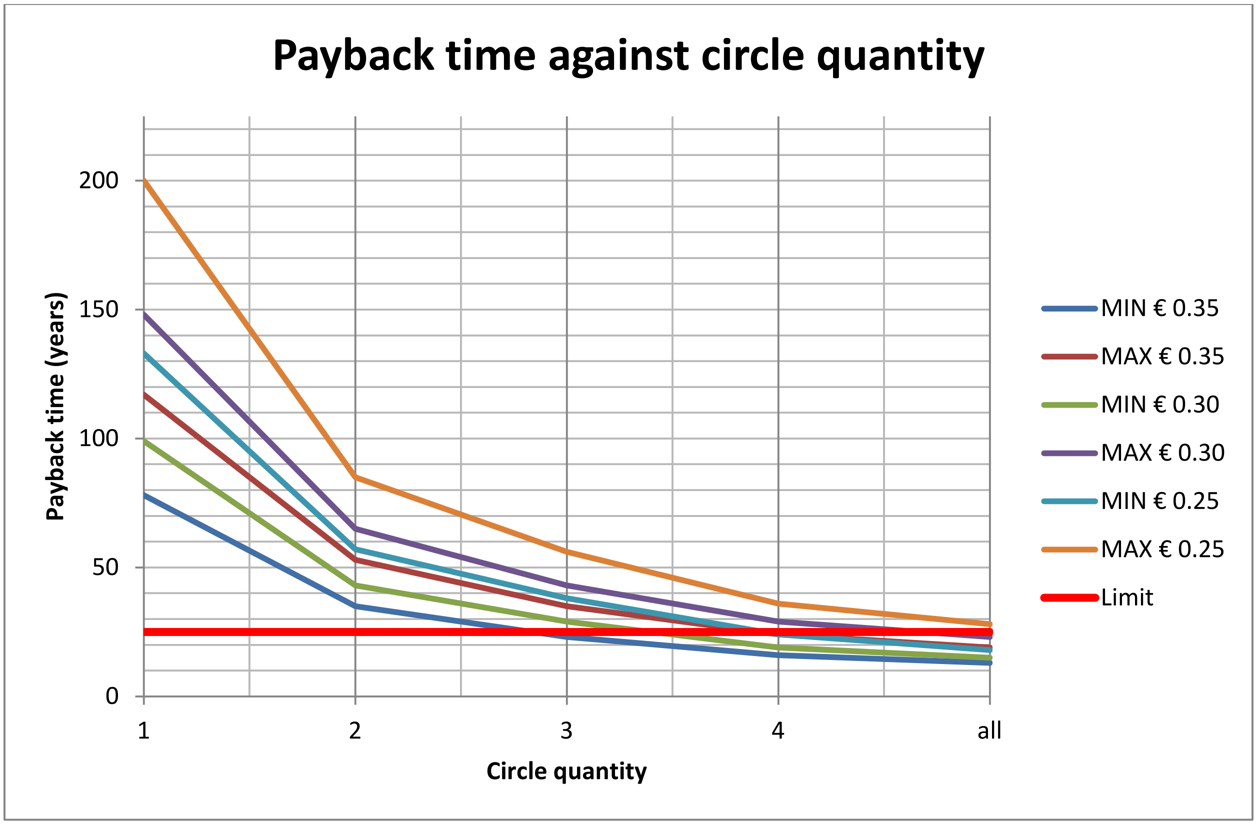

Figure 5.8 Payback time against circle quantity

As seen, the primary network is only feasible with a gas price of 0.25 eurocent if everyone joins. At 0.30 eurocent only four circles are needed. At 0.35 eurocent even three circles are a possibility[9].

5.10 Benefits

As read in the paragraph exploitation the payback time limit is 25 years for RENEW to be feasible. The project will be feasible if enough consumers and suppliers want to play a part in RENEW. The subsidy, like SDE+ for geothermal and other sustainable subsidies, had no influence. If a part of the investments are financed by the government, then the payback time will be even shorter. This will make the financial benefits very attractive.

The primary network contributes to a cleaner air quality, reduction of CO_2, using less fossil fuels and an improvement of energy efficiency.

[9] The payback time is without subsidy or other variables, such as underground thermal energy storage of geothermal heat.

6 CONCLUSION & RECOMMENDATION

There will not be enough waste heat in the Port of Rotterdam to support the big demanding question of heat energy in Westland. Approximately 1 GW thermal power is available. The thermal power needed for Westland is an estimated 1.1 GW. Therefore, approximately 90% of the energy is covered from the waste heat. Anno 1975, the power consumption in Westland was around 1.5 GW. As a result, the thermal power has decreased in the past 38 years. New technologies in isolation and efficiency of boilers and CHPs have improved the total energy consumption.

Continuous waste heat from the port would not be the best option, because there would not be any competition and the overall demanding question is too high. Therefore, application of the RENEW (Renewable Energy Network Westland) is needed to overcome the question. This grid will begin small and then develop in an increasingly larger grid. Multiple applications like UTES and geothermal have to be taken into account. There will be enough (waste) heat energy available with these applications to sustain seasonal heat and cold demand. CHPs are the last resort for the peek moments. In addition, mutual energy exchange is a must and is highly recommended for a modular heat network.

New pipe networks cost a lot of money, as well as new drilling units like UTES and geothermal. Several investors would have to invest to make this applicable. A bank, such as Rabobank, is a bank that could benefit from a stronger and firmer greenhouse culture in Westland.

Expansion of the CO_2 network in North-West Westland is a necessity before expanding the heating district in the North-West. Therefore, a CO_2 pipeline from E.ON MPP1/2 & MPP3 and/or Electrabel has to be constructed to the existing CO_2 network at Abengoa, Europoort. Also, another CO_2 pipeline has to be constructed through Westland that could deliver enough CO_2 to North-West Westland.

The payback time depends on the total investment. It would be difficult to maintain a feasible project if the payback time rises above the 25 years limit. Therefore, a holistic exploitation approach has to be taken into account. This will ensure a steady payback time. However, problems and longer payback time can occur through delays. But heat exchange, as seen in phase 1, between greenhouses and households give the circle an independent system and, if optimized, a better guarantee that the primary network can be paid back.

A heat delivery circle has an estimated payback time of 14 to 20 years. After completion of at least three circles, the primary network has a feasible payback time of under the 25 years. The payback time is calculated without subsides by the government. These subsidies could lower the payback time even further. This makes the project even more economical appealing.

A technical design concept, like RENEW, is a feasible and applicable and integrated district heating process for Westland. With a modular system and a two phase set-up ensures a solid renewable energy network.

Alternative sources like sun- and wind energy have to be taken into account to avoid problems for future generations and will give the consumers a more independent and reliable source of energy.

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APPENDICES

The appendices can be found in a separate report and contain the following sections:

Appendix A Contact list

- Name
- Company
- Address
- Telephone
- Mobile
- E-mail
- Website

Appendix B Calculation waste heat Port of Rotterdam

- Electric power output
- Waste heat quantity

Appendix C Business case

- Schematic block diagram RENEW

Appendix D I Calculation

- Water specification
- Formula diameter
- Formula pump power
- Formula pressure difference
- Formula coefficient of friction

Appendix D II Specification pipe sections

- Standard input
- Specification primary network
- Specification secondary network

Appendix E Estimate

- Primary network
- Secondary Network
- Circle

Appendix F Exploitation electric, gas & thermal power

- Phase 1: Circle
- Phase 2: Transition from circle to waste heat