Viability Study of Sustainable Shore Side Electricity for Container Vessels in the Port of Rotterdam.

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“Only when the last tree has died, and the last river has been poisoned and the last fish been caught will we realize we cannot eat money.” – Cree Indian Proverb

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Executive Summary

Ship emissions, from diesel, will cause an estimated 60 thousand people to die prematurely per year from emission related diseases such as, respiratory problems, cancer, high blood pressure and heart failure (Corbett, et al., 2007). Near shipping routes and coastlines these emissions are most dense, putting people living near the shipping routes at a higher risk of developing these diseases. One of the busiest shipping routes is the shipping route between China and Western-Europe, which includes the port of Rotterdam.

Currently, two main trends can be identified that replace the diesel auxiliary engines in and near the port area. The first trend is *shore side electricity* (SSE), which is implemented in the port of Long Beach and the port of Los Angeles to reduce emissions in port areas. Hereby, substituting the diesel engines whilst the container vessel is at berth. In China, a few ports implemented shore side electricity as well, for example, the port of Shekou and the port of Dalian. The port of Hamburg has a different approach to reduce the emission in the port areas. The port implements an LNG technology, in which a containerised LNG tank and generator are placed on board of the vessel. For the SSE and LNG technology there are several technical options to adjust the technology to the port. For the port of Rotterdam it is attractive to benefit from the positive network externalities by joining either technical trend, hereby expanding the network, therefore, this research focuses on the two main trends.

The reduction of these emissions is beneficial for (human) health, which is an important public value. However, other public values such as sustainability, job opportunities are involved as well. The decision-making process in the Rotterdam area is complex because of multiple values and different stakeholders. No including all stakeholders, such as local public, may have adverse effects, which was the case in developing the Maasvlakte II, where the public delayed and changed the development. For a sustainable decision that leads to a reduction in vessel emissions, it is important that all stakeholders participate, such that facts and stakeholder values can be considered. In sustainability issues, a balance must be found between people, planet and profit.

The purpose of this research is to determine which technical trend SSE or LNG, which option in these trends, is suitable and promising for the port of Rotterdam, accounting for a variety of stakeholder values using a multi-criteria analysis. The main question in this report is:

What is the most suitable and promising sustainable energy technology for container ships in the port of Rotterdam, focused on selecting technical options for and comparing shore side electricity and LNG?

To determine which technical options in the two technology trends are available and suitable for the port of Rotterdam, a desk research was performed and experts were interviewed. Semi-structured interviews allow the researcher to investigate relevant topics, it allows also to explore interesting topics that emerge during the dialogue.

First a desk research was performed to obtained technical options for the technologies, in the type of energy sources, frequency converter and the location of the converter and distribution of the energy. Then, the expert interviews revealed that a central stationary frequency converter is preferred, because it was more efficient and has less costs than a rotary converter or a decentral frequency converter. To generate electricity a renewable energy sources has a bigger impact on the reduction of emissions. The percentage of vessels supplied by mere off-shore wind turbines is similar the percentage of vessels supplied by a combination of wind turbines and PV solar panels in a Mediterranean port. For the port of Rotterdam in the Netherlands PV solar panels are less efficient, therefore mere off-shore wind turbines are selected. To resume, a containerised, grid connected SSE technology was selected which is powered by off-shore wind turbines.

The desk research reveals that a containerised gas tank, the LNG PowerPac®, is used for container vessels to replace the auxiliary diesel engine during their time at berth. The gas tanks can be distributed

to the vessel by boat or tank truck, the latter is used in this report because trucks are a relatively small investment and are flexible in distribution. Therefore, the LNG option is a containerised option where the equipment can be loaded on and off the vessel by gantry cranes.

To determine the impacts for the port of Rotterdam, positive and negative aspects were determined, hereto, two SWOT analyses were performed. The SWOT analysis was used, because it deals with external and internal aspects, it allows to include negative and positive aspects, and it is a tool for development rather than for implementation. The data was obtained by a literary research and interviews with independent experts.
The strengths of and opportunities for SSE were obtained. A positive aspect is that, the port can maintain its leading position and attractive business climate because it is an innovative, fossil independent technology. More so, the technology reduces the CO_2, NO_x and pm emissions and noise nuisance, because there are no (local) emissions during operation. This allows the port to improve the air quality in the port area and safety of port employees. The SSE technology has a smaller Carbon footprint and is therefore less vulnerable for increasing costs due to Carbon externalities. Further, SSE contributes currently to jobs in the renewable energy sector and has a forecasted net gain in future job opportunities in the port of Rotterdam.
However, SSE has weaknesses and threats for the port of Rotterdam. The doubt in the business case, which includes high investments in an electric grid and in a frequency converter and consequence demands investments from the shipping companies. Another negative aspect is the inability to implement SSE technology in many ports because of the requirement for a high capacity grid, which is not available or possible in many ports. This weakens the ability to create a network with other ports to battle the emission and improve the environment. More so, this grid is a smart grid, which is more vulnerable to cyber-attacks. These attacks are a threat for the privacy of data and security of operations for the port. Further, space inside and outside the port is limited. To preserve the nature and create green areas, an energy technology is required with a low energy sprawl. The energy sources are compared because the generation of energy exceeds the borders of the port but are relevant to the environment. The SSE technology has wind power as the preferred energy source, however, this energy sources has a bigger energy sprawl than LNG and it therefore threatens the available space for nature.
The strengths of LNG PowerPac® and the opportunities for the port of Rotterdam were determined. A strength of the LNG Powerpac® is the more confident business case, because it does not require high investments in a frequency converter nor in an electric grid. The LNG technology does not require a high capacity grid; therefore, more ports can implement the LNG PowerPac®. This spurs the possibility to create a network and collaborate with other ports. Another positive aspect is, the match between the required skills of the port employees and the available skills of port employees. The LNG technology fits better in the port of Rotterdam, because the port currently has large fossil industry. This knowledge can be applied to the LNG technology. Furthermore, the LNG technology is less vulnerable to cyber-attacks, because no smart grid is required. A smaller vulnerability to cyber-attacks enhances data security and security of operations. Further, the LNG PowerPac® has a smaller energy sprawl than for wind turbines, leaving more space for nature and recreation areas.
The weaknesses of and threats for LNG are: the local pollutions of CO, CO_2 and CH_4, and noise. These pollutions pose a risk for residents of nearby cities and port employees. The local emission for Carbon dioxide is implicit to the use of a fossil fuel. The use of fossil fuels is less innovative. More so, the LNG option has a bigger Carbon footprint that the SSE option, and therefore has a bigger pressure on the environment and global warming. The Carbon emission are a threat because of the stricter environmental regulations. Another weakness for the LNG technology is the slimmer job opportunities

in the conventional energy sector. Currently, there is a declining trend in job opportunities and a prospect of a net loss in job opportunities in the future in the conventional energy sector.

To determine the relevant stakeholders, a stakeholder analysis was performed. The snowball-sampling method was used, because it allows a one-on-one conversation in contrast to the focus group method, therefore the stakeholder can bring up relevant topics. From a preliminary stakeholder selection. Stakeholders were selected based on the type of organisation (government, business, non-governmental organisation, or a knowledge institute) and based on the stakeholders direct or indirect involvement.

The relevant stakeholders in this report are: Cavotec, Deltalinqs, Milieudefensie, the Municipality of Rotterdam, and the Port authority of Rotterdam.
Cavotec was selected because it is a company that is presumed to be in favour of the implementation of SSE. Further, it is a company and is directly involved in the construction and design with SSE.
Deltalinqs was selected because it is an organisation that is indirectly involved in the implementation of either SSE or the LNG PowerPac®. Further, they are closely related to innovations in the port of Rotterdam. The preference was assumed to be LNG, because the port of Rotterdam houses many fossil fuel-based business.
Milieudefensie is a non-governmental organisation that is assumed to prefer the SSE option. The Milieudefensie is an indirect stakeholder. They were involved in the development of the Maasvlakte II with a lawsuit.
The Municipality of Rotterdam is a governmental organisation and is indirect involved with the handling of the technologies. They have a legal power over the port and are a shareholder of the port of Rotterdam.
The port of Rotterdam was selected because they are directly involved in the implementation of the technologies. It is a business that presumably favours the LNG option, because of the port is one of the largest oil bunker ports. They were identified from a preliminary selection and the interviews, in which some of these stakeholders were mentioned and others were not. Therefore, marginal stakeholders are included.

The relevant public values in the development of the port area to prevent adverse effects were obtained by a document analysis and organised using value-focused thinking. The aim is to determine public values and define a general term to which all stakeholders endorse. These terms were determined by counting nouns and selecting the noun that appear most frequently. These general terms were used as initial values to compose the values trees.
To obtained general term for the public values a document analysis was performed, scanning for values. These specific values were categorised to determine the overarching values, the public values. From this analysis three relevant public values were identified: economic growth, safety and sustainability. These terms are used in the stakeholder value trees as initial values.

To determine which values the stakeholders appeal to and how they are rearticulated a document analysis was carried out, using value-focused thinking on strategic documents. Value focused thinking was used because it explicates values in measurable objective, “attributes”. These attributes are used to decide which technology meets these values best in the multi-criteria analysis.
The three public values, economic growth, safety and sustainability, were used as a starting point to perform the document analysis in order to reveal the stakeholders’ attributes.
The stakeholder appeal to the value “economic growth”: as being a niche actor, creating an attractive business climate, investing in knowledge and providing jobs in a responsible way. The attributes that were obtained are: the number of profitable and worthwhile euros, the interconnectivity represents the number of connections, the extent to be fossil fuel independent, the forecasted number of job

opportunities, the number of current job opportunities, the balance in higher and lower education jobs, the quantity of exchanged knowledge to maintain a leading market position, the extent to which the technology fits with the current skills and knowledge with the present employees, the extent to which the organisation accounts for the damage due to their activities.

The public value “safety” is articulated as: caring for the health of employees and nearby residents and secure the port infrastructure and digital data. This public value is measured by the stakeholders in the following attributes: the number of injuries and fatalities of employees, the number of injured residents, the number of attacks on the port’s infrastructure, the number of cyber-attacks.

“Sustainability” is articulated as: caring for the port area, city and nature by improving the air quality changing to electric machines and abandoning fossil fuels to reduce the Carbon use. Sustainability is measured the following attributes: the reduction of pollutions (%) compared to the use of a diesel engine, the Carbon footprint, the number of hectares available for the nature (forests, green areas and water) and the number of possible production sites for the SSE or LNG PowerPac®.

A weighted multi-criteria analysis was performed to determine which technology meets the values best and how the technologies meet these values, under the present conditions. The technologies are compared in a decision matrix on the obtained attributes, which are used as decision criteria. The technologies were given a score using an ordinal scale, a score of “1” was assigned to the winning technology and a “0” to the losing technology. The ordinal scale allows to assign scores without quantifying the difference. To account for the importance of the public values in the multi-criteria analysis weights have been assigned to the values, which were obtained from the stakeholder interviews.

the current situation the SSE technology meets the public values best because it has the highest score. The final scores for the technologies are 0.62 for Shore Side Electricity and the final score for the LNG PowerPac® is 0.53.

Under the present conditions, SSE is the best option because it contributes to the business climate of Rotterdam because it is an innovative technology that fossil fuel independent. Another public value is met by the SSE technology. SSE contributes more to current and future job opportunities. More so, SSE adds to a fairer economy by taking responsibility for pollutions and damage therefore prevent environmental damage to the living environment of and public health of the local population. Furthermore, the SSE adds to public safety health because it has no local pollutions. Furthermore, it has less Carbon emissions over its lifetime, hereby, a good air quality is met, whilst, preserving the environment and health of the population.

The LNG PowerPac® has an overall lower score and meets in the current situation the value “business climate”, amongst by creating jobs. This climate will attract more companies and contributes to the local population by jobs and affluence. The LNG technology meets with current skills of port employees and can therefore be adopted. The value security is met for port operations and data by the LNG technology, due to the ability to protect the grid more adequately from cyber-attacks. Sustainability is met by the LNG PowerPac® by the smaller energy sprawl, leaving more space for nature and green areas. Further, the values sustainability is met by the possible implementation sites for the polluting technology, hereby reducing the environmental pressure collectively with other ports.

Scenarios are used to determine which technology prevails in the future. It is unknown what the future will be therefore, an estimate what the future might be allows to estimate is an technology is a promising.

When fuel from algae comes available this would replace the fossil fuels, the LNG is the more promising solution. Reusing the LNG infrastructure makes the business case for the LNG PowerPac® stronger, because no investment in required in a new infrastructure. Reusing the LNG infrastructure spurs the local application of algae oil in ports because, the algae fuel can be distributed by the LNG infrastructure to other ports. Hereby, creating a network of algae using ports. More so, the algae energy can (re-)use the infrastructure of LNG in the port of Rotterdam. This implicates that this technology (partially) fits with the current skills and knowledge of the port employees. The fossil fuel option, the LNG PowerPac®, is a transitional technology towards a non-fossil energy source, namely, algae. Therefore, the LNG solutions meets on the long-term the value of being fossil fuel independent and therefore being innovative. Despite the opportunities that arise and values that are met by the LNG technology, SSE is more favourable.

In the scenario where energy costs include CO_2 externalities, the SSE technology is the winner because the business case for SSE is more reliable, due to the limited increase in costs compared to the forecasted costs for the LNG PowerPac®. If all costs include these Carbon externalities, the costs to manufacture, maintain and dismantle technologies increase. These activities use a Carbon source for energy or materials. These costs are included in the energy price. This implies that over a long period of time the costs form an energy sources that has more Carbon emissions in its lifetime increase more. The Carbon footprint, the emission of CO_2 equivalent over the lifetime of the technology, is bigger for the LNG technology than for the SSE technology. This implies that the electricity costs for a fossil energy sources increase more than the costs for electricity from renewable energy resources.

Concluding, to answer the main question the SSE technology is the most suitable and promising energy technology to implement in the port of Rotterdam. The SSE technology which is selected for the comparison is a grid connected system which is fed by off-shore wind turbines with a central static frequency converter. In the current situation this SSE technology has the highest score, therefore, meets under the current circumstances the values best. In the scenarios and in the scenarios the SSE technology meets the relevant values best.

The outcome of this analysis can be used by the port of Rotterdam to decide for a technology to develop the port area. By performing this analysis, the best suitable option is determined accounting for the values of relevant stakeholders.

However, despite the SSE is the most suitable and promising technology for the port of Rotterdam, it is possible that another technology or other options for the SSE technology are implemented instead, because another scenarios, practical issues or the decision process is biased by an strong and influential stakeholder.

To develop the port area and meeting the public values, the port of Rotterdam should attract more renewable energy companies in order to make a shift from a fossil-based industry. This creates enough job opportunities in the port area. More so, this allows to maintain its market leading position, hereby, creating new knowledge and skills. These renewable energy businesses contribute to jobs that range from low level education to high level education, such as, service desk employees in data centres to data analyst.

More so, the port of Rotterdam should take into account CO_2 externalities. These added costs make the consumption of fossil fuel less attractive and may spur the innovation to reduce emissions in the port area. In addition, this new revenue can be reinvested in research to improve the emissions and pollutions in the whole port area. From this research the pollutions (NO_x, SO_x, pm and noise) and CO_2 emissions should be reduced to sustain the environment in and outside the port area. Further, the reduction of these pollutions contributes to public health.

Further, the port of Rotterdam should initiate a collaboration with shipping companies that have traffic between the port of Rotterdam and ports in China and California. From this research, the legal necessity for vessels to have SSE in California spurs the implementation of SSE. This regulation applies to all Californian ports, which are the majority of ports on the West side of the USA and is therefore effective. In China a governmental regulation obliges the use of SSE. A European regulation would be necessary to cover all ports in Europe, this has been unsuccessful. Therefore, the port of Rotterdam can increase its attractiveness for these shipping companies by creating a better connectivity by providing SSE energy.

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List of Abbreviations

ABB	ASEA Brown Boveri
AE	Auxiliary Engine
AMP	Alternative Maritime Power
APM	A.P. Moller–Maersk Group
APS	Automatic Plug-in System
CADA	Central America Discussion Agreement
CARB	California Air Resources Board
CBA	Cost Benefit Analysis
CH_4	Methane
CO_2	Carbon dioxide
COPD	Chronic Obstructive Pulmonary Disease
CSI	Clean Shipping Index
CVD	Cardio Vascular Disease
DCMR	Dienst Centraal Milieubeheer Rijnmond
ECR	Engine Control Room
EEB	European Environmental Bureau
EEDI	Energy Efficiency Design Index
EF	Emission Factor
ESI	Environmental Ship Index
EU	European Union
EVG	Elektrische kranen
FNV	Federatie Nederlandse Vakbeweging
HAVC	Heating, Ventilation, Air Conditioning
GHG	Greenhouse Gas
GTL	Gas To Liquid
H_2S	Hydrogen sulphide
HC	Hydrocarbons
HFO	Heavy Fuel Oil
HOI	Human Operator Interface
HV	High Voltage
HVSC	High Voltage Shore Connection
LNG	Liquefied Natural Gas
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
IMSA	Instituut voor Milieu- en Systeemanalyse
ISO	International Organization for Standardization
KMS	Kabelmanagementsysteem
LV	Low Voltage
LVSC	Low Voltage Shore Connection
MARPOL	International Convention for the Prevention of Pollution from Ships
MCA	Multi-Criteria Analysis
MDO	Marine Diesel Oil
MNP	Milieu-en Natuur Planbureau
MTEU	Million Twenty Foot Equivalent
NGO	Nongovernmental organisation

NO_x	Nitrogen oxide
O_3	Ozone
OECD	Organisation for Economic Co-operation and Development
OPS	Onshore Power Supply
PIANC	Permanent International Commission for Navigation Congresses
PESTEL	Political, Economic, Socio-cultural, Technological, Legal and Environmental
PMS	Power Management System
pm	Particular Matter
QCA	Qualitative Content Analysis
RES	Renewable Energy Source
RIVM	Rijksinstituut voor Volksgezondheid en Milieu
RRC	Radio Remote Control
SECA	Sulphur Emission Control Area
SEEMP	Ship Energy Efficiency Management Plan
SMEs	Small and Medium Sized enterprises
SOAR	Strengths, Opportunities, Aspiration and Results
SO_x	Sulphur oxide
SV	Sustainability Value
SWOT	Strengths, Weaknesses, Opportunities & Threats
THC	Total Hydrocarbons
TNO	Organisatie voor Toegepaste Natuurwetenschappelijk Onderzoek
TTIP	Transatlantic Trade & Investment Partnership
USA	United States of America
VFT	Value-Focused Thinking
VOC	Volatile Organic Compound
VRR	Veiligheidsregio Rotterdam-Rijnmond
VSD	Value Sensitive Design
WPCI	World Ports Climate Initiative
WWF	World Wide Fund for Nature

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1 Introduction

In this chapter the storyline and outline of this report are presented to give a clear overview of this research. In section 1.1, the background information and the motivation for this research are given. In the second section, section 1.2, the problem which is at the core this research is stated. This problem is investigated according to the research questions in section 1.3. The approach to investigate this problem is explained in section 1.4. A brief description of the frameworks and methodologies is given in section 1.5. Lastly, the general outline of the thesis is presented in section 1.6.

1.1 Background

Globally, it has been estimated that 60 thousand people per year will die because of lung and heart failure due to pollution from sea vessels (Corbett, et al., 2007). The toxicity and harm are significant. The pollution of vessels mainly consists of CO_2, NO_x, SO_x and particular matter (pm_{10} and $pm_{2.5}$) (Velders & et al, 2014). Long-term exposure to CO_2, has led to lung malfunction, high blood pressure, bone deformation (Rice, 2004). SO_x has caused acidic precipitation and premature death (Levy, Bounocore, & Stackelberg, 2010). A relation has been obtained between exposure to Ozone (O_3) and premature death (Brunekreef & Holegate, 2002). The exposure to particular matter, pm_{10} and $pm_{2,5}$, has led to lung cancer (Arden Pope III & et al., 2002), premature death (Arden Pope III & et al., 2002), *Chronic Obstructive Pulmonary Disease* (COPD) (Brunekreef & Holegate, 2002) and *Cardio Vascular Disease* (CVD) (Brunekreef & Holegate, 2002).

The health of people in the Rotterdam area is at stake, considering that Corbett et al. (2007) have indicated that primarily the health of people near port areas and shipping routes will be affected by these air pollutions. More so, the trade lane between China and Europe is one of the most intensively sailed shipping lanes by container vessels (OECD, 2015). Adding to this is the fact that the port of Rotterdam is one of the main ports in the world, being the 11th (Lloyd's List, 2016a) busiest port of the world in 2015 shipping 12.2 *Million Twenty Foot Equivalent* (MTEU) (Lloyd's List, 2016b).

The last decades the port of Rotterdam needed to expand its quays and berths in order to keep up with the increasing number of containers and vessels at the port. One of the expansion projects into the North Sea was “Maasvlakte I”, which was realised in the 1960s.

The second addition, “Maasvlakte II”, the development was scheduled in the 1970s, although it was not executed because of environmental protests. This expansion was heavily debated in the 70s and fierce protest came from the local citizen and public pressure groups. The location of the Maasvlakte II and the expected industry, a furnace for the petrochemical industry, has been the main points of discussion (Koppenol, 2014). In the 70s the Municipality government and the port authority both favoured an expansion in the south instead of in the north. The southern expansion was preferred because it would have lower investment costs. This option would imply more environmental damage and pollution for the local population. The opposition from local parties turned into support after the process was put on hold for nearly 30 year. Koppenol (2014) has mentioned in his research that this is because the government responded to the public in the development of the Maasvlakte by adding 750 hectares of new nature reserve.

Based on the case of the development of the Maasvlakte II, inhabitants near the Rotterdam port area value their health and therefore are wary of pollution. Currently, there are pressure groups who plea for a better air quality in the city of Rotterdam, for example, Adem in Rotterdam (Beek, 2018), Stadslab Rotterdam (Stadslab voor schone lucht, 2018) and the *Luchtmeetnet Hillegersberg-Schiebroek* (LHiS) (Redactie Bewoners!HiS, 2017). Because of the many exhaust gasses, emissions, and particles, due to

of the high density of industries, traffic and population (Velders & et al, 2014), the Rotterdam area is one of the noisiest (RIVM, 2011) and polluted areas (Velders & et al, 2014) of the Netherlands.

Besides the public pressure for public health, there has been governmental pressure towards sustainable development to reduce emissions to alleviate the strain on the environment (Borrell Fontelles & Straw, 2005) (Schulz & Mavroyiannis, 2012). Examples are the directives 2005/33/EC (Borrell Fontelles & Straw, 2005) and 2012/33/EC (Schulz & Mavroyiannis, 2012), which have set a maximum limit for Sulphur in fuel. These directives do not prescribe a technology to comply with these limits. Beside the governmental pressure, specialised institutions like the *International Maritime Organization* (IMO) has given directives for the shipping industry, MARPOL 6 (IMO, n.d.), which stimulates to the reduction of NO_x, SO_x, and particles.

These regulations and requirements have been predicted to become stricter, now it is evident that the global warming effect occurs more rapidly (Berkenbosch, 2013). It is the government's responsibility to alter this warming trend, by undertaking more daring actions, as is stated in the Paris Climate agreement in 2015 (European Commission, 2015).

Vessel pollutions may be reduced through technological innovation; however, this has been a complex process because there is an economic strain between (shipping) companies, and the reluctance to make an investment from ports (Wiegmans & Geerlings, 2010). In Europe, Rotterdam has been the main gateway for containers (Reefer Containers, n.d.). However, in the last decade Hamburg has been a strong competitor for container vessels (Port of Rotterdam, 2015). If the port does not respond to the demand of companies or demands too much of companies, the port puts its attractiveness in jeopardy. The port of Rotterdam has adapted continuously to the demands of (shipping) companies to be able to be compete with other ports (Port of Rotterdam, 2011) (Bonjer, 2015). Expansions, like the Maasvlakte II, are necessary to meet the needs from shipping companies. Due to fierce competition, the companies form alliances to economise each shipping. (Lalkens, 2016). Each container ship has to carry a bigger load, causing the draught to be deeper and therefore, requires deeper navigation channels and berths. Rotterdam has been one of the few ports who can berth such mega (container) vessels (OECD, 2015).

Currently, container vessels have used polluting *auxiliary engines* (AEs) to manoeuvre in the port and to generate the required power during the transhipment of containers. Figure 1—1 shows the engines (Baldi, 2013). These engines are smaller than the propulsion engines, which are shut down during these operations. The auxiliary engines provide energy, to manoeuvre in the port area, to heat boilers, to drive ballast water pumps and for the *heating, ventilation, air conditioning* (HAVC).

The auxiliary engines have run on diesel, *Heavy Fuel Oil* (HFO) or *Marine Diesel Oil* (MDO) (Hulskotte & Denier van der Gon, 2010). For container vessels, a majority of this energy at berth is generated for the boilers, the remainder is for the power generators (Hulskotte & Denier van der Gon, 2010).

Utilising a cleaner fuel reduces the local emissions of (air) pollutions. However, despite the lower emissions, such as Carbon dioxide (CO_2), Sulphur oxide (SO_x), Nitrogen oxide (NO_x) and particular matter (pm_{10}), there still are local pollutions.

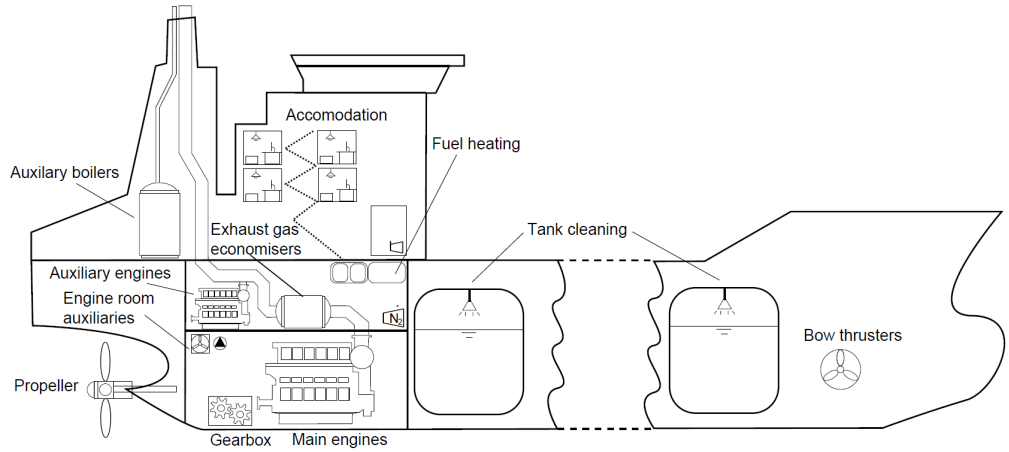

Figure 1—1 Schematic energy system on-board.

Source: Baldi, 2013

Winnes, Styhre & Fridell (2015) have proposed various approaches to reduce emissions from vessels in port areas, such as changing the fuel, changing the ship's design, or adjusting the modus of operation. Changing the fuel has been identified as an effective measure to reduce the GHG emissions (Styhre, Winnes, Black, Lee, & Le-Griffin, 2017). Alternative fuels to replace the diesel, such as, LNG, biofuels or Methanol have been considered. Another possibility has been identified, which is shore side electricity (Winnes, Styhre, & Fridell, 2015). Where the vessel's engines are switched off and power is supplied by cables to the vessel.

To deal with these emissions ports implemented *Short Side Electricity* (SSE) to specifically target the emissions from container vessels in port areas (Ports using OPS, n.d.). In 2004 the port of Los Angeles implemented the first container SSE successfully in 2004 (Alternative Maritime Power® (AMP®), n.d.). Shore side electricity has been compulsory in many ports in the California in the United States, for example in the Port of Los Angeles and Port of Long Beach (Ports using OPS, n.d.). In China ports invested heavily in SSE for container vessels and other vessels, examples of ports are the port of Shanghai (Schneider-Electric, 2015), the port of Shenzhen (Wang, Mao, & Rutherford, 2015), the port of Dalian and the port of Nansha. In Europe, the port of Gothenburg (Sweden) implemented SSE for ferries (Gothenburg, n.d.), Hoek van Holland in the Netherlands implemented a system for the Stena Line ferries (ABB, 2012) and Port of Rotterdam for cruise ships (Port of Rotterdam, 2015).

Another technology has been explored to reduce the vessel emissions, mostly in Europe, which is *Liquid Natural Gas* (LNG) based (Thomas, 2016). Here, generators are used with LNG tanks to provide energy during berth. The port of Hamburg has launched a pilot project with LNG barge (Thomas, 2016). An LNG network and LNG facilities have been explored and developed in Europa (Thomas, 2016) (Acciaro, Ghiara, & Cusano, 2014) (Wang & Notteboom, 2015).

The two technological trends, SSE and LNG, include different technical options. These technical options allows to adjust the technology to the port, which has a unique infrastructure and has a unique set of stakeholders. This implies that the technologies can be adjusted to the demands and values of the stakeholders in and near the port of Rotterdam.

Research has been dedicated to the sustainable development of ports by Winkel et al (2015) and Wiegmans & Geerlings (2010). However, in neither of the researches the public values have been included, therefore, a sustainable outcome is not possible (De Brucker, Macharis, & Verbeke, 2013).

Considering that for sustainable development a balance between people, planet and profit has been required (De Brucker, Macharis, & Verbeke, 2013).

Currently, there is room to meet the environmental targets in an economic efficient manner whilst neglecting the public health. Due to the lack of a dominant technology to replace the auxiliary engines in container vessels, nor is there a dictated technology in international directives from which the port of Rotterdam can gain certainty for this long-term investment. As a result, the port of Rotterdam has explored the LNG as well as the SSE option to meet the obligatory environmental regulations (Port of Rotterdam, 2015).

This prospect is detrimental for the local population and the risk of developing pollution related illnesses will increase. The past years there has been an increase in the number of transhipments (Port of Rotterdam, 2015), therefore, container ships will stay longer at berth (OECD, 2015).

1.2 Problem Statement

The port of Rotterdam should be a flourishing area with sufficient jobs, a clean and nourishing environment for people and wildlife. This state should be maintained and improved by innovations and developments. This will foster the quality in all three areas, people planet and profit, by contribution to public safety, by alleviating environmental pressure and by improving the financial opportunities.

In current innovation processes in the port area of Rotterdam, the public is not or not sufficiently engaged in the processes. As a consequence, development processes exist which violate public values, such as health.

Excluding the public or public values from the process impedes the innovation process in the port of Rotterdam. Such impedance is at the expense of the environment and money because, the investors miss their initial window of opportunity and the polluting technologies continue to operate.

The development of the Maasvlakte II is a case, where the pubic values were not included. This led to a lawsuit insisted by the public, which ultimately altered the development process. Another example is the development of CO_2 storage in Barendrecht. This project was three years delayed and eventually terminated due to lack of public support (Ministerie van EZ, Ministerie van IenM, 1 November 2016).

These cases could have been prevented if the public was consulted and their values were included (Koppenol, 2014) (Feenstra, Mikunda, & Brunsting, 2010). In the case of the Maasvlakte the public health and environment for local flora and fauna were relevant public values. Whereas, in the case of Barendrecht the public was concerned for their safety.

An example where the public engagement has led to success is in the development of the Maasvlakte II. In this case the public resistance did turn into support after the government responded to their values, implementing a 750 hectares nature reserve (Koppenol, 2014).

The obstruction of innovation projects in the Port area may be prevented by including public or accounting for public values in the decision process by the port of Rotterdam. Reed (2009) mentioned that public engagement in decision processes contributes to the successful implementation and long-term support of the decision.

To decide for a technology, that fits with global developments to improve the air quality in and near the port of Rotterdam and which is supported by the public in the long-term, the public (values) should be included this decision process. The shipping industry is a very polluting industry and two global

trends exist to reduce emissions from container vessels to improve public health are SSE technologies and LNG technologies. A long-term support is required due to the long recycle time of vessels and supporting infrastructure.

1.3 Research Questions

To determine which technical trend SSE or LNG, and which option in these trends, is suitable and promising for the port of Rotterdam the technological context and social context are relevant. The technology should fit in the port area and should meet the stakeholder values to avoid adverse events. To investigate this topic, the main question in this his research is:

What is the most suitable and promising sustainable energy technology for container ships in the port of Rotterdam, focused on selecting technical options for and comparing shore side electricity and LNG?

To guide this research toward a conclusion to the main question, sub-questions are formulated. These sub-questions are:

1. Which frameworks and methodologies are appropriate to determine which technology is most suitable considering public values?
2. What are the technical options for shore side electricity systems and LNG systems and which options are selected for this research?
3. What are the strengths, weaknesses, opportunities and threats of these technologies and for the port of Rotterdam?
4. Who are the relevant stakeholders?
5. What are the relevant public values?
6. How do the stakeholders understand these public values?
7. How do the selected sustainable energy technologies meet the relevant public values in the current situation and under future scenarios if the port of Rotterdam would implement this technology?

1.4 Scientific Approach

The first sub-question is composed to guide the researcher to investigate and to selected adequate methods for this research. Hereto, a literature research is performed to explore the different frameworks and methods, which are used in this research. *Value Sensitive Design* (VSD), is a methodological framework that, aims to design according to values.

In line with the conceptual investigation of VSD, a first attempt is made to determine an initial technology to conduct research with. The sub-questions 2 and 3 are concerned with this technical part of the conceptual investigation. The more social part of the conceptual investigation deals with the identification of the stakeholder and their values is. Hereto, sub-questions 4, 5 and 6 are composed. Sub-question 7 brings the sub-questions together and converges towards the final answer of this report.

In the second sub-question the technical options are identified and selected for the SSE technology and for the LNG technology. These options are important to describe the technologies in detail,

because the different technical options for each technology (SSE or LNG) may have different implication currently and for the future. More so, not all options may be suitable for the port of Rotterdam.

A desk research is performed to obtain different options for the technologies. The options that are included in this research, are implemented by ports. Documents from companies and scientific papers are used to deduct these options. Expert interviews are performed to determine the preferred technical options for SSE and for LNG. Semi-structure interviews are used to determine the preferred options. These interviews contain information for the technical selection and for the *Strengths, Weaknesses, Opportunities & Threats* (SWOT) analyses.

The third sub-question aims to determine strengths and weakness of and opportunities and threats for the technologies in the port of Rotterdam, hereto, SWOT analyses are performed. This broader view of positive and negative aspects is required to determine how the technologies meet the public values. The best suited technology meets the public values best. The most promising technology has the prospect to meet the values best in the future. To determine the scores and scenarios, which are used in the multi-criteria analysis, SWOT analyses are performed.

To involve the public in the decision process the relevant stakeholders needs to identified, hereto, sub-question 4 is composed. The relevant stakeholders and their values need to be determined, to decide for a technology.

Stakeholder interviews are carried out to determine the relevant public values and to identify the relevant stakeholders. These interviews are semi-structured interviews. These stakeholder interviews are analysed twice, once to obtain other stakeholders, and once to obtain data for the weight factor.

With sub-question 5 the relevant terms for public values are identified. With the relevant stakeholder identified, the terms for public values need are determined which are endorsed by all stakeholders. These public values are used a starting points for all stakeholder value trees, to easily combine the value tree into one tree.

Sub-question 6 is composed to determine how the stakeholders understand and contribute to the public values, for which terms have been determine in the previous sub-question.

From the relevant stakeholders, documents are analysed using value focused thinking, to determine how they understand the public values. Value trees can be constructed with attributes at the end of the branches. These attributes are used as design criteria in the multi-criteria analysis.

The last sub-question, sub-question 7, combines the technical part of the questions and the social part of the sub-question, in an MCA and describes how the technologies can meet the values under scenarios.

The multi-criteria analysis is performed to determine which technology meets the values under the current circumstances. Hereto, the scores are appointed to the criteria and the weight factor is composed. The weight factor is part of the MCA and accounts for the importance of the values. This weight factor is determined using a different, independent source from the scores of the criteria. The results from the SWOT are multiplied by the weight factor.

To determine a suitable and promising option, the MCA is performed for present circumstances and scenarios are used to determine which the most promising option for each scenario.

The outcome of the MCA can be used by the Port of Rotterdam to innovate the port area. By explicating the values and how the technologies meet these values in order to prevent adverse effects.

1.5 Introduction to Frameworks and Methodologies

Value sensitive design aims to design a well-suited and ethically sound technological innovation. VSD is an iterative methodological framework, that comprises of a conceptual investigation, an empirical investigation and a technical investigation. The theory behind VSD is Language pattern and acknowledges general opinions (values) as scientific data. Further, it underlines that a well-suited innovation depends on the technology and its surroundings.

The conceptual investigation of value sensitive design is the main framework for this research. This investigation aims to design a well-defined and ethically sound technology. The conceptual investigation is to determine the relevant values, which the technology either supports or undermines. Further, the relevant stakeholders are identified. The empirical investigation is an investigation that refines the conceptual design by empirical investigation. This objective is to determine in what way the values are met, compromised or prioritised. The technical investigation is the third investigation and includes, amongst, appointing opportunities to improve the technology.

A *multi-criteria analysis* (MCA) is performed to determine which technology meets the relevant stakeholder values best under current circumstance and scenarios are used to describe which technology flourishes in the future. Two technical trends to reduce emission in ports, SSE and LNG, are compared in the MCA.

To compose the matrix and to score the matrix supporting methods are carried out, such as, a stakeholder analysis, a value analysis using value-focused thinking and SWOT analyses. Further, an integral part of the MCA is the weight factor, which is determined using data from the stakeholder interviews. The data for the supporting analyses and the weight factor must be obtained from independent sources. This is necessary to avoid a bias outcome of the MCA.

A literary research is carried out to obtain technological options for the technological trends, shore side electricity and LNG. These technologies, SSE and LNG, are explored and adopted by leading world ports, with the aim to reduce the emissions in port areas. Each port has unique infrastructure and therefore, the technologies need to be tailor-made by selecting technical options.

These technical options are narrowed down selecting the options with the least emissions and by the expert's preference, using the expert interview. The two more detailed described technologies can be compared in the MCA. A more detailed description is important to decide for a technology, because this technology has an impact for the people, planet and profit.

To determine in what way the technologies have an impact on society, a SWOT analysis is carried out for the SSE technology and for the LNG technology. The data in the SWOT analysis cannot be obtained from the stakeholder, this would result in a biased outcome of the MCA.

The SWOT analyses use data from the expert interviews, in order to prevent a biased outcome of the MCA. Experts interviews are used to obtain data for the SWOT analyse, because there is few quantitative information about the LNG PowerPac®. This qualitative data from experts implies the use of an ordinal scale, to score the criteria in the MCA matrix. The ordinal scale allows to determine a winner without quantification difference.

Relevant stakeholders are determined by performing a stakeholder analysis. This analysis includes a stakeholder selection (snowball sampling). This is an important part, because to decide for a well-suited and ethically sound technology, all stakeholders should be involved in the decision-making

process. The stakeholder selection includes a broad spectrum of stakeholders to increase the support for the decision.

Stakeholder interviews are analysed using a qualitative content analysis to obtain other relevant stakeholders. The stakeholder interview is a semi-structure interview, because it allows the stakeholder to introduce important topics to the conversation and it allows to elaborate on valued topics. This freedom to introduce new topics is relevant because new stakeholders may be introduced and valued topics may emerge by the interviewee, without being overruled by the group or no even mentioning the relevant topic. Meanwhile, the researcher is able to ask deliberate questions. The stakeholder information is relevant for the stakeholder analysis and the data on valued topics is relevant to determine the weight factor.

From the relevant stakeholders, their values are determined and articulated by a document analysis using value focused thinking. For each stakeholder a value tree is composed. At the end of the branches are the attributes, measurable objectives that support the value higher in the value tree.

The document analysis is performed on strategic documents from the relevant stakeholders. This analysis codes for means, values and objectives. These objectives (means and values) are organised to obtain a value tree.

The weight factor, part of the multi-criteria analysis, is determined from the stakeholder interviews using the qualitative content analysis. The weight factor is a fixed part of the MCA and allows to account for the difference in importance for the criteria. The score of the criterion is multiplied by the weight. This weight is obtained by the structuring technique, which allows to quantify qualitative data with a predefined scale.

The multi-criteria analysis uses the results from the SWOT analyses and multiplies these scores by a weight factor. The decision matrix is composed from the two technologies and the attributes. The data from the SWOT are used to score these attributes and to determine scenarios. To score the criteria in the MCA matrix an ordinal scale is used.

The performance in the present scenario is determined by the MCA. The scores are multiplied by the weight factor to account for the importance of the values. The performance of the technologies in the future is described under scenarios, which are obtained in the SWOT analysis.

To avoid a biases outcome the criteria, the score for criteria and the weight factor are obtained from different, independent sources. Table 1—1 gives an overview of the analyses and data used in this report.

Table 1—1 Overview of the methods and techniques used in this research.

What	Why	Data Source	Data analysis
Qualitative Content Analysis	To select the technological options in the two technical trends, SSE and LNG, to pursue research	Desk research and interviews (expert)	Coding technique
Stakeholder Analysis	To determine the relevant stakeholders	Semi-structured interviews (stakeholder)	Snowball Sampling

Value-Focused Thinking	To determine which values and how their articulation	Strategic documents	Value-Focused Thinking
SWOT Analysis	To determine the positive and negative aspects of the technologies	Semi-structured interviews (expert) and desk research	Coding technique
Qualitative Content Analysis	To determine the weight factor	Semi-structured interviews (stakeholder)	Coding and structuring technique
Multi-Criteria Analysis	To determine the technology which scores the best on the stakeholder criteria at present and in future scenarios.	SWOT analysis and desk research	Qualitative Content Analysis - structuring technique

1.6 Thesis Outline

In chapter 1 the storyline of this thesis is presented, this includes the introduction of the topic, the research questions and the frameworks and methods that are used to conduct this research. Figure 1—2 on page 11 shows this layout of this research in an infographic. This infographic gives an overview of the chapters and their content.

Chapter 2 describes the theoretical and methodological background of this research. This research fits within the conceptual investigation of Value Sensitive Design. Further, the supporting methods are described to conduct this research.

In the next chapter, chapter 3, technological options for shore side electricity and the LNG technology for replacement of the diesel engine for container vessels are described. In the two technological trends, SSE and LNG, there are different options possible to adjust the technology to the port's infrastructure and demands. This report focuses on SSE and LNG because, these are the two main technologies are being implemented in globally, to benefit the public health by reducing emission. For the port of Rotterdam it is attractive to benefit from the positive network externalities by joining either technical trend, hereby expanding the network.

To determine in what way the technologies have an impact on society and hereby support or hinder the values of the stakeholders, a SWOT analysis is performed in chapter 4. The opportunities and threats may be external aspects in current situation and in future scenarios.

The stakeholder analysis in chapter 5, deals with the selection of stakeholders. These stakeholders are used to continue research.

This leads to chapter 6, where the values of the selected stakeholders are established using value focus-thinking. The values trees are combined into one tree, where at the end of the branches are attributes. These attributes are the decision criteria for the multi-criteria analysis.

In chapter 7, the information from the SWOT analyses and value analysis are combined in an MCA in order to determine which technology meets the public values best in the present situation and in future. To determine which technology meets the values best, the criteria are given a score. These

scores are multiplied by a weight factor. This weight factor is part of the *multi-criteria analysis* (MCA). The MCA is performed for the current situation to determine the most suitable technology. Scenarios are used to determine which technology is the most promising technology.

In the last chapter, chapter 8, the research question is answered, the most suitable and promising technology will be discussed. Further, a reflection on this thesis and promising fields for future research is given.

Chapter 1: Introduction

→ Motivation for this research and the outline of this report is given.

Chapter 2: Theoretical and Methodological Framework

Sub-question 1: *Which frameworks and methodologies are appropriate to determine which technology is most suitable considering public values?*
→ A description and motivation of the theoretical frameworks and methods are given.

Chapter 3: Technical Exploration

Sub-question 2: *What are the technical options for shore side electricity systems and LNG systems and which options are selected for this research?*
→ A desk study and expert interviews are used to explore technologies to reduces emissions and to determine the technical choices for SSE and LNG.

Chapter 4: SWOT Analysis

Sub-question 3: *What are the strengths, weaknesses, opportunities and threats of these technologies and for the port of Rotterdam?*
→ A SWOT analysis is performed on the technologies, using data obtained by desk research and expert interviews.

Chapter 5: The Relevant Stakeholders

Sub-question 4: *Who are the relevant stakeholders?*
→ Using a stakeholder analysis with interviews to determine the relevant stakeholders.

Chapter 6: The Articulation of the Stakeholder Values

Sub-question 5: *What are the relevant public values?*
Sub-question 6: *How do the stakeholders understand these public values?*
→ By desk research a selection of public values is determined. Using value-focused thinking a value tree is composed for each stakeholder and the list of criteria is composed by merging these value trees.

Chapter 7: A Weighted Multi-Criteria Analysis of the Part Outcomes

Sub-question 7: *How do the selected sustainable energy technologies meet the relevant public values in the current situation and under future scenarios if the port of Rotterdam would implement this technology?*
→ The weight factor is determined based on the data from the stakeholder interviews using the structuring technique from a quantitative content analysis. The MCA is performed under current conditions and in scenarios.

Chapter 8: Conclusion

Main question: *What is the most suitable and promising sustainable energy technology for container ships in the port of Rotterdam, focused on selecting technical options for and comparing shore side electricity and LNG?*
→ The main question is answered. The limitations and recommendations are given

Figure 1—2 Infographic of the outline of this report.

2 A Theoretical and Methodological Framework to Determine the Most Suitable Option

This chapter describes the theoretical background and determines appropriate methods for this research. Following from the introduction, there is a need to include the people's values in decision-making process to obtain a well-suited innovation. There are many ways to include stakeholders in a design or decision-making process. To find an answer for the main research questions, a variety of methods can be used.

This research is a conceptual investigation of VSD, therefore, it is relevant to determine which method deals with conceptual issues. Hereto, the technologies of interest, the relevant stakeholder and the relevant public values need to be determined.

The aim of a conceptual investigation is to decide for a technology, which meets the (public) values best. Hereto, it is necessary to determine which values the technologies meet. Therefore, a method is required to deal with multi-criteria decisions.

More so, the values at stake need to be identified, therefore, method is required to identify and articulate the values. The public values which are endorsed by the stakeholders may be measured in different ways by the stakeholders.

These values differ for each individual or group, therefore, it is relevant to determine who to include and how to include them in this research by a stakeholder analysis.

The technologies at choice have an impact on society, therefore, it is relevant to describe them best as possible to decide. Expert knowledge is required, to determine the positive and negative aspects of these technologies for society.

The first section, the main framework value sensitive design is described in section 2.1. This section includes the theoretical background of VSD and the three-part investigation of VSD is described. Then, the approach to determine the technical options for the technologies SSE and LNG, with which this research continues, are described in section 2.2. Next, methods to identify virtuous and vicious aspects of the selected technologies are described in section 2.3. The SWOT analysis is described in more detail in section 2.4. Then, the methods to determine relevant stakeholders are described in section 2.5. The selected stakeholder analysis is described in more detail in the next section, section 2.6. The method for the identification of the stakeholder values, value-focused thinking, is described in section 2.7. Then, in section 2.8 methods to deal with multi-criteria analysis are explored. This is followed by the explication of the multi-criteria analysis in section 2.9. Next, in section 2.10, the assumptions under which this research is carried out are mentioned. Further, section 2.11, describes the sources to obtain the data. Lastly, a summary of this chapter is given in section 2.12.

2.1 Introduction of Value Sensitive Design

In this section the main framework is introduced, hereto, An introduction is given about value sensitive design is given in section 2.1.1, here the objective and field of application are given. In the next section, section 2.1.2, the framework of VSD is described. The theory behind value sensitive design, language pattern, is briefly mentioned in section 2.1.3. This framework is used in this research. Further, the motivation for the use of VSD is given in section 2.1.3.

2.1.1 Concept of Value Sensitive Design

Friedman describes *Value Sensitive Design* (VSD) as: “a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process.” (Friedman, Kahn, & Borning, December 2002, p. 1). The word value refers to that what is valued. This framework has accounted for human value and more universally shared value (Friedman, Kahn, & Borning, December 2002).

The VSD framework aims to understand the role of values in the design process and to shape the novelty according to these values to obtain an ethically sound novelty (Friedman B. , 1996) (Friedman, Kahn, & Borning, December 2002). This framework can be seen as an extension to the theoretical framework of (Alexander, The Timeless Way of Building, 1979) as has been mentioned by Friedman (Friedman & Borning, Januari 2002).

Considering Alexander’s theory, the values in the VSD are the global invariant and their articulation and application in this design are the detailed variations. In current design processes these values are included to design an ethically sound and suitable technology.

The term, value, has been phrased in different contexts. In an economic context the value refers to the monetary value of an object or service. The Oxford dictionary describes it as: “The material or monetary worth of something”. However, in a more social context the meaning is:” Principles or standards of behaviour; one's judgement of what is important in life”. The latter phrase has been adopted by Friedman (2013, p. 57). This can be anything, a cup of tea, a hug or freedom of speech. These are concrete examples of what is valued by a human or possibly by society. More abstract universally held values may be referred to as public values, an example of a public value is “safety”.

2.1.2 Framework of Value Sensitive Design

Value sensitive design is a tripartite methodology, which consist of a conceptual analysis, technical analysis and an empirical analysis (Friedman, Kahn, & Borning, December 2002). These analyses are used in an iterative process to determine the more suited technology.

The conceptual investigation consists of investigations to determine the relevant stakeholders, the relevant values, how the technology undermines or support these values and how to deal with trade-offs (Friedman, Kahn, & Borning, December 2002).

This analysis is used to carefully investigate what is relevant and how the values, technology and stakeholder are related, to be able to make a draft technology. This investigation does not require empirical knowledge, desk research may be sufficient.

The empirical investigation deals with the human experience and the technology. This analysis is performed to determine if the values during operation are maintained or does the importance change. How the stakeholder deal with value trade-offs or conflicting values. Hereto, information from stakeholder with experience is required.

The third part is the technical analysis, which aims to determine how well the embedded technologies meet the stakeholder values. This analysis is performed to uncover conflicting values or short-comings and technical improvements.

This research is considered to be part of a conceptual analysis, which aims to determine which technology is the best option. This report aims to determine the most suitable option. Focussing on, SSE and LNG option. The sub-questions to investigate the main question are in line with the question

Friedman proposes. What is the technology? Who to include? What are the values? How do they understand these values?

2.1.3 Pattern Language and Value Sensitive Design

Alexander developed a theory, pattern language, to deal with difficulties in architecture (Alexander, 2003). At that time, the existing theories and methods in natural sciences were inadequate to deal with these architectural difficulties.

One of the difficulties in architectural design which Alexander has mentioned is the ambivalence of the design, because the object serves aesthetics as well as functionality (Alexander, 2003). In architectural design aesthetics and functionality are intertwined, a design cannot be mere functional or just aesthetical. As a consequence, the success of the design depends on the opinion of people and society. Another issue is the context which affects and is affected by the creation. The choices and decision that are made – whether virtuous or vicious – affect the society. Thus, architectural design has an impact on society and therefore the right decisions have to be made.

The aim of this theory is to derive at a creation that meets the values or requirements of people and complements the surroundings. Alexander refers to it as: *"The creation of a fine-tuned, well-adapted complexity."* (Alexander, 2003, p. 4).

Fundamental in this theory is that Alexander considers values/opinions, such as beauty, as scientific observations rather than a subjective opinion. Whether or not an object is perceived as beautiful depends how many "patterns" and to what extent these patterns are fulfilled.

A pattern is a *"generic solution to some system of forces in the world."* (Alexander, The Timeless Way of Building, 1979, p. 147). The pattern language theory recognises a pattern behind a design process which can be followed to obtain an object that is desired and has a root quality. In this pattern there are universally held patterns, global invariants, and variations, detailed variations (Alexander, 1979). This allows the existence of numerous, yet unique, objects.

To come to a suitable creation Alexander has mentioned that a universally held criteria are required (Alexander, 2003). These criteria have to be held by people, and surpasses borders of religion, culture or opinion, which values do.

The pattern language is used by researchers in different disciplines, amongst, architecture and computer design. Friedman has applied this theory in the field of ICT and has recognised the importance of balancing between value and function (Friedman & Borning, Januari 2002). Friedman has described that VSD can be considered as an extension of Alexander's pattern language (Friedman & Borning, Januari 2002) where, human values are patterns in the design process.

2.1.4 Motivation for Value Sensitive Design

The possible conflicting values and long-term ambitions of different stakeholders in the port area pose a challenge to innovate the port area, as previously mentioned in the introduction. To prevent a delay or unsatisfying innovation, value sensitive design can be applied.

The aim of VSD is to obtain a creation that is ethically sound and suits the values of stakeholders and fits in its surroundings. Hereby, including all relevant stakeholders and their values to make decisions for a suitable design. The stakeholder values are used as design criteria to obtain a creation to create

a design using their values as design criteria to prevent, hurdles such as obstruction, delay or an unsatisfying outcome.

Key is the theory behind VSD, which acknowledges the importance of a universally shared criterion/criteria for design and decision-making process. More so, it acknowledges that opinions are scientific observations. This allows to consider obtained values from the selected stakeholders as data instead of mere an opinion.

2.1.5 Explanation of Key Terms

In this section, key terms are explained such as, “values”, “sustainable” and “suitable and promising”. These terms relate to the theory of Alexander and the approach of value sensitive design. In view of Alexander’s theory, the creation and its surrounding are interdependent and to obtain a suitable and desired creation, universally held criteria, such as values, are used as design criteria.

Value is a term with different meanings, such as monetary value or social value, as is mentioned in section 2.1.2. Value sensitive design adopts the Oxford dictionary describes it as: “The material or monetary worth of something”. However, in a more social context the meaning is: “Principles or standards of behaviour; one's judgement of what is important in life”. The latter phrase has been adopted by Friedman (2013, p. 57). This can be anything, a cup of tea, a hug or freedom of speech. These are concrete examples of what is valued by a human or possibly by society. More abstract universally held values may be referred to as public values, an example of a public value is “safety”.

In Alexander’s theory, universally held criteria are required to compose a technology or creation, public values are such universally held values. A public value is something that is valued by the public, as has been mentioned by Kelly et all 2002 as is cited in the book of Benington and Moore (Public Value: Theory and Practice, 2011). This definition is in line with the definition which has been adopted by Friedman (2013, p. 57).

Sustainable development has been defined by Brundtland as: “the development which meets the needs of present without compromising the ability of future generations to meet their own needs.” (Brundtland & al, 1987). This development balances three aspects an economic, a social and an environmental aspect (De Brucker, Macharis, & Verbeke, 2013).

In the main question the term ‘sustainable’ refers to a technology that serves people, planet and profit for the current generation and future generations, this is in line with the Brundtland definition. The substitution of diesel auxiliary engines for a less polluting technology is a step in the development of the port area.

A *suitable and promising* technology is required to prevent a discrepancy between development of the port area for economic purposes and the public safety. The technology should suit the values of the current generation stakeholders and should

The oxford dictionary defines suitable as: “Right or appropriate for a particular person, purpose, or situation.” In this research the technology has fit with the values of the current stakeholders. This is in line with value sensitive design, where values are design criteria.

The definition of promising by the Oxford dictionary follows as: “Showing signs of future success.” When a new technology is implemented or introduces in the port area it should lead to improvement for the current generation and should not compromise future generations to do the same. This is in line with sustainable development.

2.2 Selection of Technical Options

To select the technical options suitable for the SSE technology and the LNG technology for the port of Rotterdam, a variety of decision methods are available, such as a multi-criteria analysis or a paired comparison analysis. A description of these analyses are given in section 2.8.1 and in section 2.8.3. However, these methods are not appropriate considering the researcher's inexperience in composing such technical systems in the Rotterdam area. Therefore, an expert is consulted to determine these technical options. An expert has been identified, to help in a decision-making process to gain more certainty or to solve complex problems (Homer, as cited in (Froschauer & Lueger, 2009)).

Three different types of experts have been identified to consult, experts with subject matter know-how, experts with reflective subject matter expertise, and experts with external expertise, where each requires a different interview technique (Froschauer & Lueger, 2009). A narrative interview with open question has been marked as most suitable for experts with matter know-how, because it allows the expert to introduce new knowledge to the interview. For experts with reflective subject matter expertise a similar interview technique has been proposed, although, the focus of this interview is on the relation with its environment instead of the work situation. For the third type of expertise, an interview in which the expert is given freedom to come fore with topics during the interview has been proposed. Afterwards, the interviewee uses questions to gather more in-depth information.

In this research open question semi-structured interviews are conducted to obtain information from experts. The motivation for the experts can be read in Appendix 1 Motivation for Experts. The data from the experts differs because they have different knowledge and are active in different work fields. The objective of this interview is that experts give information about their experience with the technology and information about the social-technological system in which these technologies is or will be embedded. The insight given by the experts is used in the technological analysis and in the SWOT analysis.

The information from the expert interviews was obtained by open questions, concerning predefined topics. The topics are in Appendix 2 Overview of the Interviews.

Because, the experts operate in different work fields the topics of the interviews differ a bit. The matter know-how experts from technical companies, from *ASEA Brown Boveri* (ABB) two persons, were mainly asked for details about the technology and possible advantageous and disadvantageous. The know-how expert with a business background from the Port of Rotterdam, was asked predominantly about positive and negative aspects about the SSE technology and about stimuli or inhibitors for the SSE technology. The external matter experts working at a knowledge institute, one from Deltares and one from the Technical University of Delft, were asked about legal and social stimuli or barriers for the technologies. The complete interviews are in appendix, Appendix 3 Interview with Expert 1e first ABB expert, Appendix 4 Interview with Expert 2 a second ABB expert, Appendix 5 Interview with Expert 3 the expert form the Port of Rotterdam, the TU Delft expert in Appendix 6 Interview with Expert 4 and Appendix 7 Interview with Expert 5 from Deltares.

The interviews were analysed using the Qualitative Content Analysis using the coding technique. Which narrows the content to relevant words, sentences or sections. The obtained data was processed in the report.

2.3 Strategic Decisions

At the core of this research is the decision-making, which involves development of (port) technology based on values. Such innovations have economic, sustainable or social consequences. Therefore, a decision model is required which includes and explicates these impacts of a decision. Three analyses which include impacts are described below.

2.3.1 PESTEL Analysis

The *Political, Economic, Socio-cultural, Technological, Legal and Environmental* (PESTEL) analysis reveals external factors that affect or influence the innovation. These aspects can be positive and negative and may come from different disciplines, being political, economic, social, technical, environmental and legal. Each aspect is listed in the area and is categorised by likeliness of affecting the organisation. Based on this likeliness a decision is made (Cadle, Paul, & Paul, 2010).

2.3.2 SOAR Analysis

The *Strengths, Opportunities, Aspiration, Results* (SOAR) analysis has the purpose to push the process into the right direction (results and possibilities), emphasising aspirations and results. Including the negative aspects is not necessary, in contrast to a SWOT analysis (Zarestky & Cole, 2017). The SOAR is more a planning tool that prepares for implementation, whereas a SWOT analysis focusses on the analysis and prepares for planning, as has been mentioned in the book of Stavros and Hinrichs (2009) cited by (Zarestky & Cole, 2017).

2.3.3 SWOT Analysis

A *strength, weakness, opportunity and threats* (SWOT) analysis is a tool that links a connection between the internal aspects and external aspects that are associated with an innovation. In a SWOT the attention is on positive as well as negative aspects (Bell & Rochford, 2016).

The SWOT analysis was performed in this research because it links internal to external factors and addresses positive and negative aspects, although positive and negative aspects can be ambiguous for different stakeholders. This research focusses on a decision-making process therefore a SWOT analysis is more appropriate than a SOAR. Since, a SWOT analysis focusses on the analysis and prepares for planning instead of implementation, as has been mentioned in the book of Stavros and Hinrichs (2009) cited by (Zarestky & Cole, 2017).

2.4 Strength, Weakness, Opportunity and Threat Analysis

The SWOT analysis is a strategic management tool (Helms & Nixon, 2010) that allows to analyse a product or process according to four components: strengths, weaknesses, opportunities and threats. It allows to determine missing links and matches between the policy/process and its environment. The SWOT enables this because it structures the information associated with the decision situation, internal or external factors (Helms & Nixon, 2010).

The SWOT analysis is commonly used by business researchers in the beginning of a decision-making process, for example a brainstorm session. The reasons that a SWOT is performed is the ease of use and little time is required and it allows to include different point of views (Helms & Nixon, 2010). Another reason, is that the analysis addresses internal factors as well as external factors, making a link

or gap between the product and its environment explicit (Helms & Nixon, 2010) (Bell & Rochford, 2016).

The SWOT analysis organises the factors in two by two matrix (Figure 2—1 gives the matrix), distinguishing between internal or external factors and stimulating or inhibiting factors. The method to determine these factors depends on the research, Helms & Nixon have proposed a brainstorm (Helms & Nixon, 2010).

	Virtues	**Inhibitors**
Internal	Strengths	Weaknesses
External	Opportunities	Threats

Figure 2—1 Matrix for a SWOT analysis.

The SWOT analysis is a commonly used tool, however, there are some limitations. Bell and Rochford (2016) have pointed out that the SWOT analysis indicates an external factor as an "opportunity" without adequately appointing the internal skills that are required to make it to a success.

The SWOT analysis is applied in this investigation to determine virtuous and vicious aspects besides the technical aspects. Hereto, independent experts are interviewed.

In chapter 7, the SWOT analyses are linked to the attributes of the stakeholders. The ideal situation would be if these attributes are similar or same as the obtained factors from the SWOT analyses.

2.5 How to Perform the Stakeholder Analysis

In this research the step, stakeholder selection is performed to identify the relevant stakeholders. The first part is the selection of stakeholders. The relevant methods to determine the selection of stakeholders are described in section 2.5.1.

In this research a semi-structure interview is used to obtain data from stakeholders. How this semi-structured interview is composed is described in section 2.5.2.

2.5.1 Methods for the Stakeholder Selection

In this research the snowball-sampling method is performed to identify new stakeholders based on the data obtained by the semi-structured interview. Reed has identified different methods to come to a stakeholder selection, such as, the focus group, the semi-structured interview or the snowball-sampling method (Reed, M. et al, 2009).

2.5.1.1 Focus Groups

A focus group (Reed, M. et al, 2009) is a method to identify stakeholders. In stakeholders discuss in small groups their interests, influences and they categorise them. The advantageous of this method has been its time effectiveness and the possibility to reach consensus with the stakeholders. This method has been proposed as most suitable, when there is a need to reach understanding about complex issues via discussion. A downside of this method has been its poor structure and consequence, the need for an adequate facilitation to obtain good qualitative results.

2.5.1.2 Semi-Structured Interview

A semi-structured interview (Reed, M. et al, 2009) is a powerful method to gain in-depth information from the stakeholders about other relevant stakeholders. This method is a follow up method to verify earlier obtained data from a focus group. The weaknesses of this method have been its timespan and its difficultly to reach consensus.

2.5.1.3 Snowball Sampling

Snowball sampling (Reed, M. et al, 2009) allows to identify new stakeholders mentioned in a one-on-one interview. This method identifies stakeholders using a preliminary stakeholder analysis, where each stakeholder represents a stakeholder category. From interviews with preliminary stakeholders a new batch of stakeholders is identified. A strength of this method has been its relative ease of use. A disadvantageous has the biasness, because the method builds on the preliminary analysis (Reed, M. et al, 2009).

In this research one-on-one interviews were conducted. The snowball sampling method was favoured over the use of a focus group, because influential parties may suppress less powerful parties in the discussion. The semi-structured interview was not utilised, because based on this literature, it is performed to validate the outcome of the focus group.

2.5.2 The Semi-Structured Interviews for Stakeholders

The semi-structured interview was designed, that the interviewees can elaborate freely on predefined topics. The predefined topics are a template for the interview to obtain information. These topics have made this type of interview more systematic compared to an unstructured interview, therefore a semi-structured interview is easier to interpret and to compare (Brinkman, 2000). The information about the topics varies per interview because of the different knowledge of the interviewees.

Open questions were used in these interviews. Comparing the answers of open questions is more difficult than for closed questions because of the broad range of possibilities (Brinkman, 2000) however, it allows the interviewees to give an expression in their wording. These wordings are necessary to gather information about their view about the technology and other parties.

The interview has two purposes, the first is to obtain information about other potential stakeholders, the second is to make their values explicit. These stakeholder interviews are analysed twice. Once to obtain other stakeholders, and one to obtain data for the weight factor.

During the semi-structured interview, the interviewee is given a space to introduce to him relevant topics, although, the researcher is able to ask deliberate questions. This space is relevant, because new stakeholders may be introduced and valued topics may emerge. The stakeholder's information is relevant for the stakeholder analysis, and to determine the weight factor.

The researcher occasionally intervened to redirect the interview to the research topic or to introduce a new topic. The predefined topics concern, amongst, public values. The interview is in Appendix 2 Overview of the Interviews.

The complete stakeholder interviews are in Appendix 8 Interview with Stakeholder 1, Appendix 9 Interview with Stakeholder 2, Appendix 10 Interview with Stakeholder 3, Appendix 11 Interview with Stakeholder 4 and Appendix 12 Interview with A. Castelein.

The stakeholder interviews are analysed using the Qualitative Content Analysis with the coding technique, the same technique as is used for the expert interviews. The coding technique narrows the content to relevant passages. The interviews were analysed several times, each time for different relevant topics, such as new stakeholders, stakeholder power and influence or their point of view. The deducted data from the stakeholder analysis for the weight factor was organised using the structuring techniques, which is described in more detail in section 2.9.1.

2.6 Stakeholder Analysis

Public participation in decision-making has gained weight in the last decade (Reed, M. et al, 2009; Brugha & Varvasovsky, 2000), because their engagement in the process has contributed to the long-term viability and support of innovations (Reed, M. et al, 2009). Numerous fields of expertise (for example, policy, business management, development and natural resource management) developed a stakeholder analysis for a specific purpose, therefore, there is a great variety in approaches and methods to perform a stakeholder analysis (Reed, M. et al, 2009).

This stakeholder analysis can be applied in a decision-making process for several purposes, Reed has identified three purposes (Reed, M. et al, 2009, p. 1933). The first application is to determine how the reference situation or behaviour is affected by the decision. Second, the stakeholder analysis can be used to determine stakeholders or stakeholder groups who are affected by the decision. Thirdly, the analysis may allow to establish a priority in stakeholders or stakeholder groups in the decision-making process. In this research the stakeholder analysis is performed in the conceptual investigation of the Value Sensitive Design process.

The stakeholders are key in this analysis. A *stakeholder* is defined as: "Any group or individual who can affect or is affected by the achievement of the organization's objectives" (Edward Freeman, 1984, p. 64).

In policy, development and natural resource management the stakeholder analysis is a tool that can give voice to the marginal stakeholders (Reed, M. et al, 2009). This is the reason to include a stakeholder analysis, that allows to involve all stakeholders in the design/decision-making process, in this research from an ethical perspective.

There are various ways to perform a stakeholder analysis, for example, Reed (2009), Egels-Zandén (2010) and Yang (2011), have proposed a classification based on their approach normative, instrumental or descriptive approach (Reed, M. et al, 2009).

A *descriptive* stakeholder analysis is performed to identify and describe the stakeholder and their interests and relations. This approach is rarely performed on its own, it is more often an explorative analysis which is followed by an instrumental or normative analysis, according to Donaldson & Preston, 1995 as cited in (Reed, M. et al, 2009).

The *instrumental* approach to perform a stakeholder analysis is more often used as a tool by managers and policy-makers to understand, identify and manage the stakeholders, that targets are achieved (Jonker & Foster, 2002; Reed, M. et al, 2009). With a strategic analysis there is no moral obligation to include marginal stakeholders in the decision-making process, only a selection of stakeholders is included for strategic reasons (Jonker & Foster, 2002). To determine which stakeholder is more likely to affect the decision-making process, the stakeholders are classified by power, legitimacy and urgency, or combinations. The stakeholder classes with highest power, legitimacy and urgency receive the most attention, hence, neglecting the marginal stakeholders.

The *normative* approach is commonly performed in policy, development and natural resource management. Here the objective of the analysis is to empower the stakeholders and to underline the importance and legitimacy of their engagement in the process (Reed, M. et al, 2009). Whether it is to defend a decision on base of such stakeholder analysis (Reed, M. et al, 2009); or whether it is to determine to whom the decision-makers are morally accountable to (Friedman & Miles, 2006a). The normative approach is commonly performed with complex issues, because it allows to include conflicting interests and opposing values. With this approach an objective is to gain understanding of the different values and interests and reach a consensus for solution by discussion and mutual understanding. In this report the term "stakeholder analysis" is used to refer to the "normative stakeholder analysis", which is described by Reed (2009).

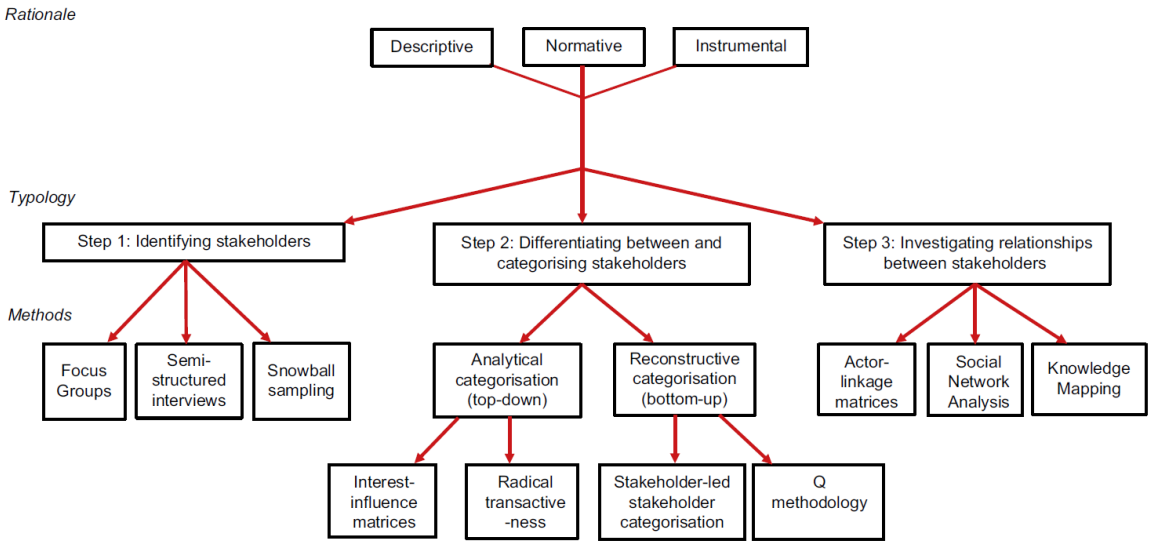

Figure 2—2 Overview of approaches, topologies, methods to perform a stakeholder analysis.

Source: (Reed et all 2009)

Reed has proposed that a stakeholder analysis consists of three steps, stakeholder selection,

stakeholder classification and investigation of relations and ties. This holds for all approaches, descriptive, normative, instrumental. Figure 2—2 (Reed et all 2009) gives an overview.

The first step, as Reeds has proposed, is the *identification* of stakeholders is an important step in the process and it is common to be part of an iterative process (Reed, M. et al, 2009). The relevant stakeholders to include or to omit depend on the purpose and method of the analysis.

The second step in the stakeholder analysis is *differentiating between and categorising stakeholders*, where two distinct approaches can be defines, the top-down and bottom-up approach. In a top-down approach the stakeholders are grouped by the researchers on basis of their observations. Methods related with this approach are for example, radical transactiveness and interest-influence matrices. The other approach is bottom-up, also known as reconstructive method, which allows to for categorisation of the stakeholders by criteria developed by the stakeholders. Methods are for bottom-up approach are stakeholder-led stakeholder categorisation and Q-methodology.

Thirdly, in the *investigating relationships between stakeholders,* the relation between the stakeholders should be investigated. Identification of these stakeholder relations is necessary to predict mismatches and prevent unintending impacts and events (Ulmer, 2001). It is necessary to determine how they affect each other and possibly affect the stakeholder analysis. Adequate insight in and management of stakeholder relations is the key for trust and credibility, and therefore the potential success of the project.

In this report a normative (Reed, M. et al, 2009) approach was selected to give all stakeholders, even the marginal stakeholders, a voice. The stakeholder analysis has an important role in value sensitive design, therefore, also in this report. The relevant stakeholders depend on the approach of the stakeholder analysis. By gathering information about the relevant stakeholders, hence their values, an attempt is made to determine the best suitable option.

The first step of the stakeholder analysis, the selection, is carried out in the research to identify the relevant stakeholders. Hereto, a preliminary list of stakeholders is composed, from which stakeholders are selected. The stakeholder analysis is described chapter 4.

2.7 Value-Focused Thinking

The purpose of value-focused thinking is to come to an option that is supported and satisfactory for the decision-maker (or other stakeholders) by making values explicit. This approach deals with decisions, though a framework which makes the objectives explicit in order to overcome the mismatch between the decisionmaker's values and a decision situation (Keeney R. L., 1992).

Value-focused thinking is used, to reveal the stakeholder values and to derive how these values are articulated, because it allows to determine the articulation of values. (Keeney R. , 1996).

Strategic documents are analysed to extract objectives. Objectives can be values, goals, or alternatives. These were organised into a value tree using value-focused thinking. To determine the position of the objective in the value tree, two questions were used. The first, "Which aspects does this value contain?", and the second "Of what is this an aspect?". The method to compose the value trees has been described in the book by Keeney (1992). The values trees were composed for each stakeholder, then, these trees were merged into one value tree. The value trees were combined per level and is described in more detail in section 6.7.

Keeney has developed this approach, value-focused thinking, for individuals who want to gain insight in their values by structuring objectives (Keeney R. L., 1992). VFT may be applied prior to a decision or in an early stage of the decision-making process. The structuring of the objectives is done in ways, a fundamental objective hierarchy and a means-end diagram. Organising the objectives in a hierarchy adds value to the decision process, because it leads to more insight to (hidden) essential values for the decision, a better value model and therefore a better quality of the VFT process. The means-end diagram makes explicit how the most desired decision could be achieved (Keeney R. L., 1992).

In VFT a decision situation can be described with a decision frame (Keeney R. L., 1992), which consists of a decision context and fundamental objectives. Figure 2—3 gives the decision frame (Keeney R. L., 1992). For example, a port authority needs to decide where to install onshore cubicles for shore power. The associated fundamental objectives could be profit, social acceptance, and sustainability. Where, an objective is something that one wants to achieve. In a broader context, "how to supply vessels with electricity?", the context of shore power could have alternatives such as, LNG containers, LNG barges or onboard fuel cells.

Fundamental objectives are ends which may be achieved through means objectives. Objectives have three characteristics a decision context, an object, and a direction. For example, a decision needs to be made about sustainable energy supply for vessels. The context is the decision about energy supply for vessels, the objective is sustainable, the direction is the more sustainable the better. The sustainable objectives may be reached through means objectives, like, reduction of NO_x emissions, reduction of SO_x emissions, less dependent on fossils fuels.
By definition the strategic objectives are the ultimate end objectives (Keeney R. L., 1992). All other objectives are means. For a port the strategic objectives could be values, such as, sustainability or safety.

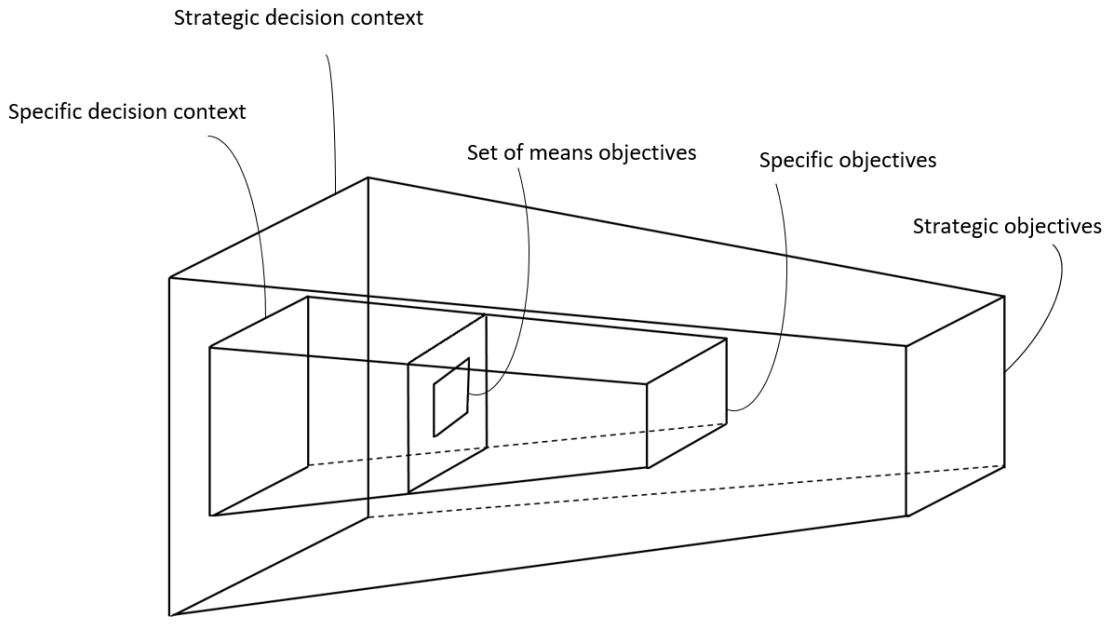

Figure 2—3 Framework for a decision situation described by value-focused thinking.

The strategy to determine the values can be applied in a brainstorm, to interviews or to documents, as has been used by Van der Lei & Ligtvoet (2015). The objectives may be identified bearing in mind alternatives, guidelines and goals (Keeney R. L., 1992). The identified objectives are than organised to

form a value tree using. The finest branches of the value tree should contain quantifiable objectives with a unit. These objectives are referred to as attributes.

There are several types of attribute, natural, constructed, and proxy. The natural attribute is an objective for which there is common consensus that it quantifies the objective. For example, to the objective to “minimise operation costs”, the attribute is money.

The constructed attribute is used when there is a less or no obvious attribute because, there is no clear definition of the objective entails, therefore, the attribute is developed for a particular decision context. An objective “increasing the public acceptance for shore power installations” could be measured with a three level constructed attributes.

The proxy attribute measures the objective indirectly, because there is no (way to create an) adequate attribute to measure the objective directly. An example of use of a proxy attribute is in the context of “decreasing the impact of noise pollution on the aquatic fauna” where the impact of the noise could be indirectly measured by the number of organisms living in a particular area. A proxy attribute may be used, because the inability to determine if aquatic organisms disappear due to the noise. Meanwhile the number of organisms may be affected by other factors (food, natural migration or climate).

The properties of attributes are measurability, operationality and understandability (Keeney R. L., 1992). The attribute should specify the objective in more detail. The choice of attribute is in itself a value judgement. Second, the attribute should be operational, which means it described the possible impacts to the objective, and when it gives an indication in which degrees the objective is served. The third property is understandability, which states that the attributes should be understandable. Selecting attributes is a crucial part in the analysis, hence, it has a strong impact on the process. Constructed attributes allow to quantify the objective precisely and it is easier to distinguish between consequences and value judgements. Constructed attributes may be less operational and understandable compared to natural and proxy attributes. The use of proxy attributes may reduce the number of attributes for a decision and makes the description of impact of the decision easier.

In this research the value sensitive design is the overall framework. In this framework it is key to establish and include stakeholder values in the process. Value-focused thinking is used to determine the stakeholders’ values for the conceptual part of the value sensitive design.

2.8 Dealing with Multi-Criteria Decisions

To decide for a suitable innovation and to prevent adverse effects after wards a multi-criteria decision needs to be made. Innovation in the port of Rotterdam involves many stakeholders. This implies many views, values, thus criteria. These stakeholders perceive issues differently and aspire to different values, therefore, this decision-making process has many criteria. To aid this decision-making process different methods are available.

2.8.1 Paired Comparison Analysis

This is a method that forms a matrix, with at the row and column the decision options (A, B, C…). The matrix compares decision options. This matrix indicates the preferred option by a corresponding letter and indicates to what extent this option is favoured by a number (Silverstein, Samue, & Decarlo, 2011). The explication why one option is favoured is in this analysis not necessary, therefore, little information is obtained about the reasoning why one option is preferred by a stakeholder.

2.8.2 Cost Benefit Analysis

The *cost benefit analysis* (CBA) aims to quantify the benefits and indicate the costs of the innovation of change. This analysis compares the investments costs against the obtained beneficial costs. If the investment out weights the benefits, then the innovation is favoured. This analysis includes non-monetised criteria, such as values, although this demands to express the criteria in a monetary value. The comparison on a monetary base has been considered biased (Drèze & Stern, 1987).

2.8.3 Multi-Criteria Analysis

The multi-criteria analysis aims to organise the criteria and options in columns and rows, so that a matrix is formed. Each criterion is expressed in its own unit, this may be monetary unit but is not obliged. The matrix is completed by filling in scores for each criterion by the option. The scores are standardised per criterion. Next the priority of the criteria is determined by establishing a weight factor. The next step is multiplication of the standardised score and the weight factor. The most preferred option has the highest score (Reinshagen, 2007).

This method was selected, because it allows to include qualitative and quantitative data. More so, this analysis unveils stakeholder criteria to for the decision-making. This would not have been the case when a paired comparison analysis was used. Further, a cost benefit analysis had not been used because of the economic bias. The economic feasibility can be a value, therefore, had not been selected.

2.9 Multi-Criteria Analysis

This analysis helps decision-makers or researcher to identify and understand design challenges by identifying and balancing conflicting values or criteria (Reinshagen, 2007). More so, the MCA enables to select an alternative in a systematic and transparent way (Janssen, 2001). This report is written for the Port of Rotterdam, providing support to decide for a suitable technical innovation.

An MCA is performed to determine which of the technologies meet the relevant stakeholder values best. Two technical trends to reduce emission in ports, SSE and LNG, are compared in the MCA matrix. To compose the matrix and to score the matrix supporting methods are carried out, such as, a stakeholder analysis, a value analysis using value-focused thinking and a SWOT analysis.

A weight factor is determined, to account for the importance of the values. The data for the supporting analyses and the weight factor must be obtained from independent sources. This is necessary to avoid a bias outcome of the MCA.

To determine which technology has the best score, a weighted average is used. How this average is determined is described in more detail in section 2.9.3. Hereto, the criteria are given a score. This score is an ordinal scale, because it allows to prioritise the criteria without quantifiable data. The data is obtained from the stakeholder interviews using QCA, and is described in section 2.9.1. The weight factor is described in section 2.9.2.

2.9.1 The Allocation of Weights

To obtain data for the weight factor form interviews the method *Qualitative Content Analysis* (QCA) (Flick, 2006) was performed. The coding unit was carried out to obtain data from the interview, which were later analysed the structuring content analysis.

The QCA is a method to analyse a broad variety of textual data, media, interview, reports by categorising the data. Flick (2006). has described three techniques to identify or obtain data: the coding unit, contextual unit, and the analytic unit. The coding unit specifies the smallest element of interest which may fall under a category. The contextual unit defines what the largest textual part of interests that fits in a category. The analytical unit determines in which order the parts are analysed.

Flick (2006) has described three techniques to organise the identified data: the content, summarising content analysis, explicative content analysis and structuring content analysis. Summarising the content can be done by paraphrasing (excluding less relevant or repeated passages) and generalisation (similar passages can be bundled). The explicative content analysis clarifies passages, via narrow and wide context analysis. The narrow context analysis identifies statements to clarify the passage/text. The wide context analysis adds information about the data besides the text. The last technique is structuring content analysis, which investigates patterns in the text by formal structures, typifying, regarding the content or scaling level. For example, if one research question would be: "How important is the value 'sustainability' for the stakeholder?". A scale can be developed concerning the sustainability value (SV). Each level is defined prior to the analysis. For example, a four-level scale SV1: High, SV2: Medium, SV3: Low, SV4: Not Clear.

To analyse the interviews QCA with the data was identified by coding and the structuring content technique was used to analyse the data. These techniques were used because coding allows to filter relevant passages from the interview and the structuring content technique was used because it enables to quantify concepts with scaling the content. This quantification was used to determine the weight factor for the multi-criteria analysis.

2.9.2 The Equation for the Weight Factor

For the multi-criteria analysis one weight factor is required. The weight factor was based on the individual weights of the stakeholder's values, which were determined by the qualitative content analysis. The weight factor for each value was calculated using an average for each specific criterion. More details about the stakeholder specific weight can be read in 7.1. The weight factor for each value was determined using, Equation 1:

$$\overline{v_i} = \frac{3 \cdot a_i + 2 \cdot b_i + 1 \cdot c_i + 0 \cdot d_i}{a_i + b_i + c_i + d_i} \quad \text{Equation 1}$$

The average weight of the value i, $\overline{v_i}$, is the summation of the number of stakeholders that contribute with a certain scaler (3, 2, 1, or 0) over the total number of stakeholders that participated. The symbols *a, b, c* or *d* represent the number of stakeholders.

2.9.3 The Equation for the Scores of the Technologies

The multi-criteria analysis allows to decide by comparing options on multiple criteria in a decision matrix. To construct the decision matrix, a technical analysis and a value analysis were carried out. The technical options, a grid connected SSE and LNG PowerPac®, were determined in chapter 3. The decision criteria (attributes) were determined by the value analysis in chapter 6.

The criteria in the decision matrix are given a score using the ordinal scale, either a “0” or a “1”. The scores are fixed to “1” and “0” therefore, the standardisation step unnecessary and was not performed.

Based on the data from the SWOT analysis and the value analysis, the scores were determined by the researcher, assigning either a “0” or “1”. The technology that wins receives a score of “1”, hence, the criterion is a strength of or an opportunity for the technology. The other technology loses and receives a “0”. When there is a drawl, the technologies receive a “1” when the criterion is a strength or an opportunity. They receive a “0” when there is a drawl for a weakness or threat. Table 7—3 shows the scores per criterion.

To determine the final scores of the technologies, the weighted scores for the criteria are averaged. The average score of the technological options was determined with the formula, Equation 2:

$$\overline{s_i} = \frac{\sum x_i \bar{v}_i}{\sum \bar{v}_i} \qquad \text{Equation 2}$$

In this formula the average score of technology, $\overline{s_i}$, is determined by division of the weighted score over the total score for that specific criterion. The score of the researcher is presented as, x_i, and the weight factor is $\overline{v_i}$.

2.10 Assumptions

When developing and applying this methodology as few assumptions were made. Changing the assumption when this research is performed a second time might change the outcome. For improvement or further development of this methodology it is relevant to mention the assumptions. The assumptions are be mentioned below.

- The experts were assumed to be unbiased and independent.
- The stakeholders were assumed to be independent from the other stakeholders.
- The selection of stakeholders was assumed to contain enough stakeholders, therefore the iterative step in the stakeholder analysis is not performed.
- The values trees were composed by the researcher bearing in mind that there may be a different perspective on what the value entails per stakeholder. To manage the difference in interpretation a preselected set of values is used to which the aspects obtained from the literature are assigned to.
- In composing the list of criteria for the MCA from the value trees, the values at the level were assumed to be equal in priority and independent. Therefore, the trees were added without further analysis described in the book of Keeney (Value-Focused Thinking, 1992).
- The identified values were independent.

2.11 Data Collection

To gain insight in the technologies for the technical selection a SWOT analysis, a desk research and interviews are performed. The information from the desk research is retrieved from about the websites from the manufacturers. More so, scientific articles and reports are used. To obtain information about the technologies, experts associated with port development were considered. The data is obtained by a semi-structured interview.

The information for the stakeholder analysis concerning the stakeholders is derived from their websites, annual reports or legal documents. Stakeholder interviews are used to gather information about their views, other stakeholders and their power and influence.

The stakeholder interviews are attached to this report in the appendix, Appendix 8 Interview with Stakeholder 1 till Appendix 12 Interview with A. Castelein. The information from the stakeholder Mr. Castelein (Port Authority of Rotterdam) was not obtained through an interview the researcher took, but instead two documented interviews were used.

To determine the value trees, a document is used which is written only by the stakeholder. These documents are preferably annual reports or long-term vision documents concerning this research topic (shore side electricity or LNG for container vessels). Documents written on behalf of multiple stakeholders implicates concessions and compromises in the document.

The weight factor for the MCA is determined using the stakeholder interviews. To obtain the data for the weight factor these interviews area second time analysed. Coding for action that are considered to spur the relevant public values.

2.12 Summary of the Selected Methods

In this chapter the methods for this research are outlined. The aim of this chapter is to determine the most appropriate methods to conducts this research, hereby, answering the first sub-question: Which frameworks and methodologies are appropriate to determine which technology is most suitable considering public values?

The conceptual investigation of value sensitive design is the main framework, because it aims to design a technology that is desired by the stakeholder and fits in its environment. More so, the underlying theory of VSD acknowledges universally share opinions as scientific observations.

For the conceptual investigation an initial technology is determined in this report to be able to determine what is values concerning these technologies. More so, the use of strategic documents in the value analysis, fit in the conceptual investigation, because these documents do not information about all available choices and decisions. Without this knowledge it is possible to determine if the motivation for a activity is valid, considering, that the decision is obtained from a strategic document.

A qualitative content analysis in combination with expert interviews allow to determine the technological options for both technologies. These interviews were selected because experts can give assistance in uncertain situations, because of their in-depth knowledge. A desk research was performed prior to the interviews to collect technological options as a preparation for the interviews.

A SWOT analysis allows to determine the broader impacts of the technologies. The SWOT analysis includes technical and non-technical aspects. A SWOT analysis was selected, because it explicates positive and negative aspects. More so, a SWOT analysis is a tool to develop a technology rather than implementing a technology; and it allows to link the technology (internal) to its environment (external), which fits with the objective of this thesis.

A stakeholder analysis, using a snow-ball sampling method, identifies the relevant stakeholders. The snowball sampling method was chosen, because it allows stakeholder to speak freely without group pressure. The data for these analyses was obtained by stakeholder interviews and a desk research.

Value-focused thinking is appropriate to articulate the relevant stakeholder values. The method was selected because it allows to deduct explicate values from documents. The data for this value analysis came from strategic documents.

A multi-criteria analysis deals with multi-criteria decisions. This analysis was selected because it explicates the arguments compared to a paired comparison analysis. More so, it is unbiased compared to a cost benefit analysis, which is biased toward a monetary value.

3 Technical Exploration of Shore Side Electricity and Liquified Natural Gas

The previous chapter describes the methods to obtain the data. In this chapter a qualitative content analysis is performed to determine the technical options for the two relevant technological trends, SSE and LNG. The data for this analysis is obtained from desk research and by expert interviews.

This report focuses on SSE and LNG because, these are the two main technologies are being implemented in globally, to benefit the public health by reducing emission. For the port of Rotterdam it is attractive to benefit from the positive network externalities by joining either technical trend, hereby expanding the network.

In the introduction of this report, the research focusses on shore side electricity and LNG, because these are two technological trends in ports. More so, these innovations have been identified as effective to improve the air quality (Styhre, Winnes, Black, Lee, & Le-Griffin, 2017).

The two technological trends, SSE and LNG, include different technical options. These technical options allows to adjust the technology to the port, which has a unique infrastructure and has a unique set of stakeholders. This implies that the technologies can be adjusted to the demands and values of the stakeholders in and near the port of Rotterdam.

In this chapter the technological options are determined and described in more detail to gain insight in the technologies. This insight is required to determine the positive and negative aspects of the technology and for its environment, which is in the next chapter. More so, to determine which technology meets the values of the stakeholder the best, because each technological option has implications, for example, the source of energy.

In the first section, the different technologies and topologies for SSE are described in section 3.1. In section 3.2 the selected SSE technology is described. Next the LNG options are is explored in section 3.3. In section 3.4, the selected LNG technology is described, which is used in this research.

3.1 Exploring the Shore Side Electricity Technology

Shore side electricity is an alternative for the diesel auxiliary engines and may be used to reduce the local pollutions, such as; noise, CO_2, SO_x, NO_x and pm. At berth, the grid provides power instead of the auxiliary engines, which during the electricity supply are switched-off. Cables connect the vessel to the energy source, for example to renewable energy sources such as wind turbines, solar photovoltaics or coal plants.

For the SSE technology different technical options and topologies are available, these need to be addressed for clarity reasons in order to pursue this research. These different options were identified by a desk research and are selected by data obtained from the expert interviews and complemented by desk research.

In this section the types of energy sources are investigated (section 3.1.1). In addition the location of the energy sources (section 3.1.2), the voltage (section 3.1.3), the frequency converter (section 3.1.4), the location of the frequency converter (section 3.1.5), and the network for SSE (section 3.1.6) are explored.

3.1.1 Type of Energy Source for Shore Side Electricity

The electricity for the SSE facility can be generated by thermal powerplants or a renewable energy source. The electricity can be transmitted via a grid to the terminals, this can be the national grid or a separate local grid.

The Port of Long Beach (WPCI, n.d.) and the Port of Los Angeles (WPCI, n.d.) are examples of American ports with a shore side electricity connection to the national grid. In these ports the electricity is generated by coal powerplants.

In China, a grid connected shore side electricity facility, which is generated by the national thermal powerplants, is implanted in the terminal of Waigaoqiao in the port of Shanghai (Schneider-Electric, 2015) and the port of Shenzhen (Wang, Mao, & Rutherford, 2015). The Shenzhen port has been connected to the grid of the city of Hong Kong (Wang, Mao, & Rutherford, 2015). Here, the electricity source is unknown, therefore, the power can be generated by either power stations or a wind farm. Power Hong Kong Limited and The Hong Kong Electric Company Limited are responsible for transmission and distribution of the electricity. Between their grid (34.5 kV) and the grid of the port a link is implemented of 720 MVA, to compensate for the demand in case of generator failure. This (secondary) substation has been connected via a primary substation to the main distribution and transmission network (Wang, Mao, & Rutherford, 2015).

For ports to reduce their emissions Nikitakos (2012) has preferred the use of renewable energy sources, because the use of fossil energy has less impact on the global reduction of emissions. The report of Nikitakos (2012) contributes to the development of a zero emission port, in which no emissions are produced. The use of SSE is considered as an alternative for the fossil engines. Therefore, because of the bigger contribution in reducing the emission, SSE with a renewable energy source is selected for this research.

Different renewable energy sources have been described by Nikitakos (2012) to provide electricity for SSE, such as solar energy, wind power, wave power or hydrogen fuel cells. The energy can be generated from traditional energy sources or from renewable energy source. These renewable energy sources are not fuelled by fossil fuel. The use of renewable energy sources has been preferred by Nikitakos because this will contribute to the reduction of port emissions.

Nikitakos (2012) has used off-shore wind turbines and PV solar panels for energy generation in a Mediterranean port, because there are the most suitable for generating energy, whereas other renewable sources are more suitable for storage. The use of wind turbines in large farms has been considered promising for medium applications, like, providing electricity to a medium-size community. PV solar power was mentioned to be adequate for medium applications in port areas. Wave power has been considered more interesting for storage applications. Hydrogen fuel cells are more advanced, according to Nikitakos (2012) and their capacity is not sufficient.

The research from Kotrikla, Lilas and Nikitakos (2017) aims to determine an alternative to fossil energy for vessels at berth by using SSE and renewable energy sources. Simulations with wind turbines and PV solar panels have been, changing the number of wind turbines, and PV solar panels. The system with 4 (1.5MW) wind turbines and PV solar panels (5 MW) can meet the energy demand of the vessesl for 92 % (Kotrikla, Lilas, & Nikitakos, 2017).

Kotrikla, Lilas and Nikitakos (2017) have calculated that four (1.5) MW wind turbines with 5 MW PV solar can meet the vessels' energy demand for 92 %. However, the option of only four (1.5 MW) wind turbines meets the vessles' demand second best, approximately 89 %.

The research Kotrikla, Lilas and Nikitakos (2017) focusses on Mediterranean port which has more sun hours compared to the port of Rotterdam in the Netherlands. Therefore, the second best option which entails mere wind turbines is considered in this research.

3.1.2 Location of the Energy Source for SSE

The previous section describes that SSE in combination with renewable energy is favoured, where, energy from wind turbines is the most preferable. These wind farms can be located on-shore or off-shore. For either option cables are used to transmit the electricity from the farm to the quay.

An off-shore windfarm has been preferred over an on-shore wind farm to generate electricity for SSE (PIANC, 2016). A decisive factor is the limited space on-shore in port areas, the available space is rather used for storage of logistics (Nikitakos, 2012). Another reason has been the higher electricity generation, due to (on average) higher wind speeds and more exposed wind turbines (PIANC, 2016).

3.1.3 High Voltage or Low Voltage Connection for SSE

High voltage or low voltage can be used to supply electricity to the vessel. The *Low Voltage Shore Connection* (LVSC) has mainly been used for vessels that require up to 1 MW (Peterson, Chaydarian, Islam, & Cayanan, 2009). The *High Voltage Shore Connection* (HVSC) has a typical output voltage of 1-11 kV and has been used for connections over 1 MW (Peterson, Chaydarian, Islam, & Cayanan, 2009). The majority of container vessels, with a length over 200 meters, require 3-6 MVA (Radu, Jeannot, Megdiche, & Sorrel, July 2013).

The HVSC is considered more appropriate because in the container vessels in the port of Rotterdam require more than 1 Megawatt, therefore an LVSC is not sufficient. The voltage of these vessels varies from 6.6 V till 11 kV. A transformer is required to adjust the voltage from shore to the ship's voltage.

3.1.4 The Frequency Converter for SSE

A frequency converter is required to transform the 50 Hz from the European grids to the desired vessels' 60 Hz. Most of the container vessels operate at 60 Hz (Radu, Jeannot, Megdiche, & Sorrel, July 2013). This frequency converter is required to prevent damage, because when a 60 Hz vessel is connected to a 50 Hz grid will cause damage to the onboard equipment pump and cranes, because the equipment cannot operate at its design speed (Nikitakos, 2012).

Two types of frequency converters have been available for SSE, a rotary and a static converter (Cissoko & Radu, March 2015). The rotary converter is a set of a synchronous motor, which is driven by the network, and a synchronous generator which has an output voltage at 60 Hz. The AC electrical energy is converted to mechanical energy in the motor. The generator converts the mechanical energy to electrical energy. The static converter has two steps and consists of an AC/DC rectifier and DC/AC inverter. The first step is the conversion of 50 Hz AC electricity to DC. In the second step the DC is converted to AC at 60 Hz (Cissoko & Radu, March 2015).

Both types of converters have their advantageous. The rotary converter is a well-known technology that has been used for decades (Cissoko & Radu, March 2015), whereas the static converter has been considered a more efficient technology with less installation and maintenance costs (Cissoko & Radu, March 2015).

Cissoko & Radu (March 2015) have compared the two frequency converters on several points, see Table 3—1 (Cissoko & Radu, March 2015) on the next page. The efficiency of the static frequency converter is at full load as well as on 20 % load better than the rotary converter (Cissoko & Radu, March 2015). The power factor of the output voltage is better for a static frequency converter. The power factor gives the quality of the output power, where a high number indicates a high active power. A lower power factor indicates the presence of more reactive power, this reactive power cannot be utilised (Cissoko & Radu, March 2015). The rotary converter cannot cope with fluctuations in voltage over 15 % from the designed voltage (100%), whereas the static converter can deal with voltage fluctuating between 70 % and 120 % (Cissoko & Radu, March 2015). These fluctuations are present in the electricity in the grid and may be devastating for electrical units, such as frequency converters. The reliability of the converter is another criterion, where, the overall power supply gives the percentage of uptime over the total time. The rotary and static converters show similar overall power supply. The life expectancy is an important criterion, considering that the frequency converter is one of the most expensive components in the SSE system. The lifetime of a rotary converter is a little shorter (20 years) compared to the lifetime of a static converter (more than 25 years). The static frequency converter has been considered more mobile and modular, because the converter can be relocated and can be connected in series.

For this research a static frequency converter was selected over a rotary converter, because the expert preferred a static converter. An example is given in the interview of an installation in Dalian, where a static frequency converter was used (Expert 1, personal communication, 18 April 2017).

Table 3—1 A comparison between rotary and static frequency converter.

	Rotary	**Static**
Efficiency at full load [%]	92	94
Efficiency at 20 % load [%]	75	93
Power factor (output)	0.95	0.99
Immunity to voltage grid variations [%]	Disturbance over 15 %	From 70 % to 120 % no disturbance
Overall power supply [%]	99.93	99.75
Life expectancy [yr]	20	>25
Mobility and flexibility	Permanent installation, not modular	Mobile, modular

3.1.5 Location of the Frequency Converter for SSE

In previous section the need to alter the frequency with a static frequency converter is described. This converter accounts for the mismatch between the (port) grid and the vessel, to prevent damage.

There have been several topologies investigated for an SSE system with a frequency converter, such as a central converted system, a system with a double busbar and a decentral converted system (Sciberras, Zahawi, Atkinson, Juandó, & Sarasquete, 2014). Each with its own advantageous and disadvantageous.

An advantageous of a centrally converted system has been the lower investment costs compared to the decentral topology, because this topology requires one frequency converter (Sciberras, Zahawi, Atkinson, Juandó, & Sarasquete, 2014). The frequency converter is one of the most expensive

components of the system, therefore, reducing the number of converters in the system results in lower investment costs. A disadvantageous of a central topology has been its inability to adjust to each vessel (Sciberras, Zahawi, Atkinson, Juandó, & Sarasquete, 2014). A 50 Hz network with one frequency converter can either serve 50 Hz vessels or 60 Hz vessels at the same time.
The double busbar topology has been investigated because it allows to serve 50 Hz and 60 Hz vessels at the same time with one frequency converter (Sciberras, Zahawi, Atkinson, Juandó, & Sarasquete, 2014). Hereto, a second electricity network must be implemented, which increases the investment costs and component use.

The topology with a decentral frequency converter has been investigated, because it allows to adjust the frequency for each individual vessel. This would imply converters at all berths. Therefore, this topology has been identified as a solution with a firm investment. (Sciberras, Zahawi, Atkinson, Juandó, & Sarasquete, 2014).
Another decentral option has been investigated, a DC network (Sciberras, Zahawi, Atkinson, Juandó, & Sarasquete, 2014). Here, a rectifier converts the incoming AC electricity at 50 Hz to DC. Then, the network transmits the DC electricity to each berth. At each berth an inverter transforms the electricity into AC at 60 Hz (Sciberras, Zahawi, Atkinson, Juandó, & Sarasquete, 2014).

Sciberras et al (2014) have considered a central converted system as most suitable for the port in southern Europe. The three options have been evaluated on: resilience, component count and berth footprint. The central topology has the least components and berth footprint. The decentral topology had the highest rates on all three criteria. The DC topology was in between, achieving the lowest on resilience.

The interview with Expert 1 revealed that he works with central converters. He referred to an example of two centrally placed frequency converters for container berths in Dalian. Which could either feed two smaller 3 MW container vessels or together one 6 MW vessel. The complete interview is in Appendix 3 Interview with Expert 1.

> *"China, we have executed one specific project with two 3 MVA conversion system which can feed two smaller container vessels or a bigger one of 6 MVA."* (Expert 1, personal communication, 18 April 2017).

> *"For these two installations in China we implemented a central transformation station. It was centrally converted although, it is not very far from the berth."* (Expert 1, personal communication, 18 April 2017).

The interview with Expert 2 revealed that a centrally converted system with double busbar is not possible because for safety and legal reasons (Expert 2, personal communication, 6 April 2017). These reasons were not explicated.

> *"No, this is due to safety aspects and liability."* (Expert 2, personal communication, 6 April 2017).

3.1.6 Network for SSE

In previous section the need for a central frequency converter is described to connect the SSE with an electricity network. This network can be an addition to the national network which operates at 50 Hz or it can be a separate network which operates at 60 Hz. In both cases a frequency converter is required to feed the 50 Hz and 60 Hz vessels.

The expansion of the national network by a local port network has been investigated in several researches to determine the implications for the European network and emissions (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, 2016) (Kotrikla, Lilas, & Nikitakos, 2017). For the European network a few positive aspects have been indicated, such as, the limited impact on the total energy demand; and the overlap between the investment in infrastructure and the long-term extension to the European grid. More so, the use of SSE in combination with renewable energy sources has been identified as an opportunity, hereby enabling to balance the demand and supply (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, 2016) (Prousalidis, Antonopoulos, Patsios, Greig, & Bucknall, 2014).

The expert interview with Expert 2 revealed that a second (local) grid is not desired. The negative attitude of this experts, Expert 2, was decisive to select a grid connected SSE solution.

> *"In a large port area implementing a second network is not desirable."* (Expert 2, personal communication, 6 April 2017)

3.2 Selected Shore Side Electricity Technology

To pursue this research a grid connected solution is selected, which is fed by off-shore wind turbine parks. A static frequency converter is used to account for the frequency mismatch between the 50 Hz European grid and the 60 Hz vessel. A central frequency converter is used to change the frequency.

The overall lay out of an SSE system was mentioned by one of the experts, expert 1, in the interview in Appendix 3 Interview with Expert 1. For the SSE system, a medium switch gear is required to connect to the grid at 50 Hz. The grid voltage (20 kV @ 50 Hz) is than converted by a power transformer to the input voltage of the frequency converter (440 V @ 60 Hz). The frequency converter converts 50 Hz to 60 Hz, whilst maintaining the voltage at 440 V. The output voltage (440 V @60 Hz) of the frequency converter is transformed to the required voltage a berth (6.6 kV @ 60 Hz). A cable transmitted this power from the transformer to the junction box at the berth. When the vessel arrives at the berth the cables (6.6 kV) are connected from the vessel to the junction box. Onboard a transformation to the operating voltages of the vessels are required. This description fits the image from the report of Radu et al (July 2013). Figure 3—1 shows the schematic overview of the system (Radu, Jeannot, Megdiche, & Sorrel, July 2013).

> *"Let's go step by step…6.6 kV to onboard voltage."* (Expert 1, personal communication, 18 April 2017).

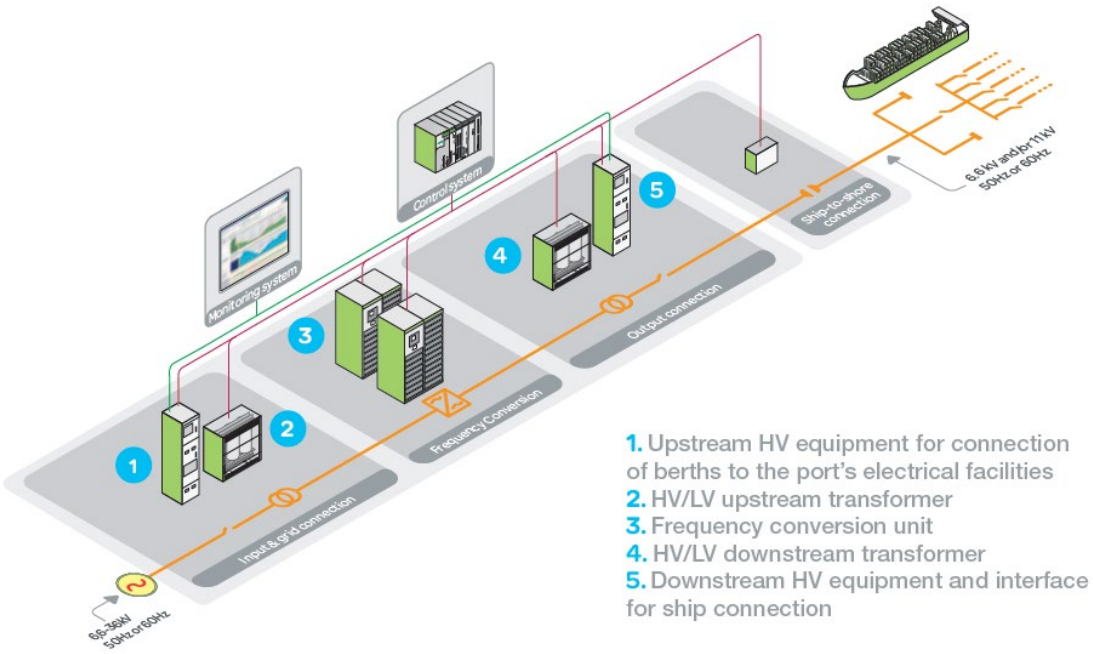

Figure 3—1 General lay out of onshore facilities of SSE with grid connection.

Sources: (Radu, Jeannot, Megdiche, & Sorrel, July 2013).

Connecting the vessel to the power system has been considered a delicate process and has to be handled with precision to guarantee safety. This connection procedure for (cruise) vessels has two phases and has been described by Sulligoi et al. (2015). A similar procedure has been described by Radu (Radu, Jeannot, Megdiche, & Sorrel, July 2013). This procedure is assumed to be similar for container vessels.

In phase 1, the conditions that need to be set up for the energy transfer from the shore to the vessels are prepared. These conditions are: 1) Just one diesel generator is connected to ships' network, 2) All circuit breakers are ready for operation, 3) All pugs are correctly connected, 4) No emergency stop is activated. When the operator in the *engine control room* (ECR) receives information from the *power management system* (PMS) the first phase is completed. The vessel is ready to receive voltage from the shore.

In the second phase, when the shore side circuit breakers are closed, the grid voltage, frequency and phase are checked. Then, the closing sequence is started. After the call, the ship shore circuit breakers are closed. And the diesel generator synchronising sequence starts. The ship's voltage is adapted to the shore's voltage and then the frequency phase angle is also adapted acting on a diesel alternator's speed regulator. When the circuit is synchronised, the breaker is closed, and PMS starts the ship to shore transfer.

3.3 Exploring the LNG Technology

A second trend, the use of LNG, to improve the air quality in port areas has been investigated (Winnes, Styhre, & Fridell, 2015). The LNG might be fed to the vessel directly or the LNG can be used to generate electricity locally, to meet the energy demand of the vessel.

For the LNG technology different technical options are available. These different options were identified by a desk research and are selected by data obtained from the expert interviews and complemented by desk research.

In this section the type of energy source for LNG (section 3.3.1), the bunkering options for LNG (section 3.3.2), the output voltage and frequency for the LNG generator (section 3.3.3) are described. The origin of the gas, the transportation and storage have implications for society, therefore, these aspects are relevant to determined them in more detail.

3.3.1 Type of Energy Source for the LNG technology

Natural gas is a mixture which consists primarily of 87-99 (mole %) Methane (CH_4) and contains some Ethane, Propane, Butane, Nitrogen, Sulphur and Carbon dioxide. The composition of this gas mixture varies from well to well (Mokhatab, Mak, Valappil, & Wood, 2014), because the origin of the organic matter and the geological structure influences the composition of the gas during the natural formation in the Earth's crust.

Currently, more than 50 % of the LNG has been exported by three countries, Qatar, Australia and Malaysia. The export of LNG has been estimated to grow over the coming years, especially in Australia and the USA and to a smaller degree in Russia (Luciani, 2016). In Europe 80 % of gas is imported by pipeline and 20 % as LNG origination from Russia (Luciani, 2016).

A liquification process is required to change the natural gas into LNG. Prior to the liquification process, where the gas undergoes a phase transition, the extracted gas needs to be purified, to remove the undesired components such as Mercury and Sulphur. The gas is cooled to a liquid using one or multiple refrigerants (Mokhatab, Mak, Valappil, & Wood, 2014). The 1 m^3 of LNG equals 600 Nm^3 of natural gas at standard conditions (Tarnapowicz & German-Galkin, 2016).

The LNG has been stored in tanks in the port area of Rotterdam, for example the Gate terminal at Maasvlakte II. At the terminal there is a filling facility to either fill containers or regasified LNG into the European grid (Port of Rotterdam, 2014).

3.3.2 Bunkering Options for LNG

To supply the LNG to the berths several ways have been identified, such as, by pipeline-to-ship, by tank truck-to-ship, ship-to-ship or terminal-to-ship (Danish Marine Authority, 2012). The pipeline-to-ship method allows to bunker directly from the terminal to the vessel via pipelines. This option has been proposed for bunkering large volumes of gas. The tank truck-to-ship bunkering method has been proposed for all sizes of terminals to bunker small volumes up to 200 m^3. Trucks are used to transport gas tanks in contains to the vessel, which can be loaded onboard. The ship-to-ship bunkering method has been proposed to bunker volumes over 100 m^3. Here, a bunker vessel is anchored next the LNG fuelled vessel at the quay or at sea (Danish Marine Authority, 2012).

The truck-to-ship and ship-to-ship option has been identified as a suitable option, to supply maritime vessels with LNG (Danish Marine Authority, 2012). The tank truck options with containerised tanks has been identified as promising option from vessel's perspective. From a supplier's perspective, the port of Rotterdam, trucks have been proposed to feed LNG to the end users. Trucks have been proposed because of the relatively small investment and its flexibility to provide customers with LNG without an LNG network. (Danish Marine Authority, 2012).

To determine the best option to transport the LNG to the vessel, an expert interview was conducted. The expert mentioned the use of an LNG barge or LNG PowerPac technology, where the gas tanks are transported by tank trucks. These gas tanks are fitted in a standard 20 ft or 40 ft containers. Therefore, the tank truck-to-ship options was selected.

Based on the interview with Expert 3, tank trucks were selected for the distribution of containerised LNG tanks. This interview revealed that the distribution of containerised gas tanks by barges is not favoured, because a barge (vessel) next the container vessel is not desired. This leaves the option to distribute the gas tank by truck. A containerised solution was preferred by the expert because of its flexibility (Expert 3, personal communication, 29 November 2016).

> *"Yes the terminals are designed to be efficient. A container next to a container ship is not convenient."* (Expert 3, personal communication, 29 November 2016).

> *"This is one of the reasons why the mobile solutions are attractive. The company Becker Marine in cooperation with KOTUG have therefore made that LNG barge for Hamburg, which was originally intended for cruise ships."* (Expert 3, personal communication, 29 November 2016).

The containerised tank truck option entails that the LNG tank is built in a container, which is filled at a filling station. The full containerised tank is transported by trucks to the desired berth, where cranes will load the tank container onboard of the container vessel (Danish Marine Authority, 2012).

Companies that provide such a system are, amongst, Wärtsilä and Becker Marine Systems. Wärtsilä developed the LNGpac^{TM} ISO, a flexible solution suitable for smaller vessels or when there is no bunkering possibility. LNGpac^{TM} ISO consists of a system that can handle fuel gas, docking station and evaporator skid and an LNG tank container. The system will be permanent on the vessel. In contrast to the tank container. The system needs to be installed on an open, natural ventilated deck. The containers with the LNG tank (Byggmästar & Karlsson , 2013). The containers are 20 ft, 40 ft or 45 ft, and have typical dimensions, this enables easy mounting on vessels using cranes.

For this research, the LNG PowerPac® by Becker is selected, because this system was mentioned in the interview (Expert 3, personal communication, 29 November 2016). The LNG Powerpac® is developed for container vessels (LNG PowerPac®, n.d.). The LNG tank is fitted into a 20 ft or 40 ft container. The required equipment, such as the generator, is in another container. The containers can be placed onboard by cranes, when the vessel is at berth. The difference with the LNGpac^{TM} ISO solution is that the equipment is placed in a container in contrast to the fixed evaporator skid, docking station and gas handling system of Wärtsilä.

> *"Yes, they invented a solution for container vessels based on this expertise. The barge generators heat as well, what can be fed to the heat network. Currently, an investigation is performed on these barges, if they may be a solution for the port of Rotterdam. The company Becker Marine Systems is given permission to perform German research on a pilot project with the PowerPac®."* (Expert 3, personal communication, 29 November 2016).

3.3.3 The type and setting of the LNG Generator

In the previous section the motivation for selection the LNG Powerpac ® is described. In the case of the LNG PowerPac®, the electricity is generated by an LNG gas generator (LNG PowerPac®, n.d.). The type of generator may differ; hence the emissions may differ.

For the LNG Powerpac® technology a gas generator of 1.5 MW has been used (LNG PowerPac®, n.d.), however, the type of generator or its performance have not been specified. To be able to determine the emissions an assumption was made.

The gas generator in the LNG PowerPac® is assumed to be the same as in an LNG barge system. One of the experts mentioned the evolution of the LNG Powerpac® from the barge technology (Expert 3, personal communication, 29 November 2016).

> *"Yes, for containers they [Becker marine Systems] have a solution based on the this [LNG barge] expertise."* (Expert 3, personal communication, 29 November 2016).

The type of generator which has been used by Becker in the LNG barge is a Caterpillar gen-set (Tarnapowicz & German-Galkin, 2016). This generator may be a Caterpillar Type CG170-16 which has been described by Tarnapowicz and German-Galkin (Tarnapowicz & German-Galkin, 2016). The output voltage of these generator is 11 kV at 60 Hz with an output power of 1550 kW (CG170-16).

3.4 Selected LNG Technology

The LNG PowerPac® was selected for further research, because it fits with the truck-to-ship distribution. A ship-to-ship distribution was not recommended by the expert. Further, this technology is a containerised solution which fits with the preferences of the expert.

The LNG PowerPac® is a solution, where trucks supply containerised gas tanks are supplied to the vessels. The gas tank is filled at a filing facility, from which it is transported to the berth by trucks or straddle carriers. The container is loaded on or off board using a crane, which is present in container terminal. As soon as the ship is arrived, the LNG PowerPac® is placed on-board using a gantry crane. Then, the LNG PowerPac® is connected to the ship and its auxiliary engine are shut down. When the ship is ready to leave the quayside, the auxiliary engine is switched on and the PowerPac® is disconnected, and the LNG container is off loaded. The gas tank container is transported to the terminal for a next vessel or the filling facility. Figure 3—2 (LNG PowerPac®, n.d.) gives a schematic overview.

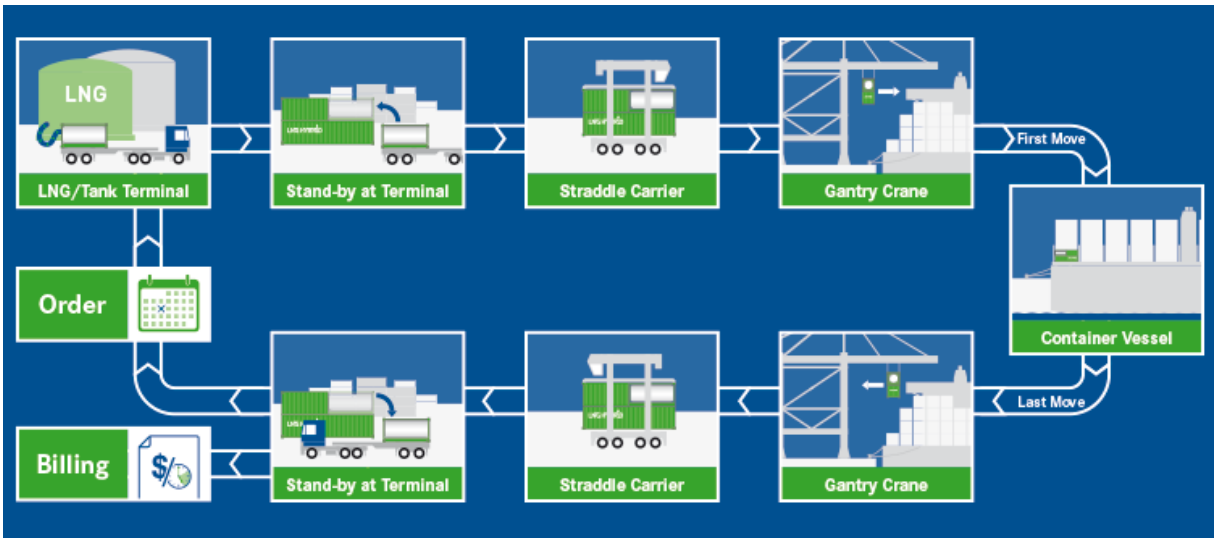

Figure 3—2 The logistic chain for LNG PowerPac®.

Source: (LNG PowerPac®, n.d.)

Two 40 ft containers are required, one for the tank and the other for the gas engine. The tank can hold 8.2 tons of LNG and may provide electricity for 30 hours at the rated power output if 1.5 MW (Federal Ministry of Transport and Digital Infrastructure (BMVI) promotes Becker Marine Systems' LNG PowerPac®– the world's first flexible solution for supplying power to container ships at ports, 2016).

The installations require an LNG storage tank, a generator, vaporisers, gas preheaters, reduction lines and a control system to gasify the liquid gas (CRYOGAS M&T Poland S.A., n.d.). The gas in liquid phase, which is about -162 degree Celsius, needs to be heated so that the phase transition in the vaporiser and gas preheater (CRYOGAS M&T Poland S.A., n.d.). The gas will reach a temperature of 60 degrees Celsius (Byggmästar & Karlsson , 2013). The gas is than led to the reduction station, which controls the gas pressure (CRYOGAS M&T Poland S.A., n.d.). This gas enters the gas engine where it is combusted. The generator has an output voltage of 380 V – 13800 V (Stroomopwekking CG170-16, n.d.) by adjusting the settings the requested 6.6 kV van be reached (Becker Marine Systems, May 2016). No frequency converter is required since the generator produces electricity at 60 Hz.

3.5 Summary of the Technical Exploration

In this chapter the technical options for the two main technologies, that are implemented by ports globally to combat air pollution, are described. This report focuses on SSE and LNG because, these are the two main technologies are being implemented in globally, to benefit the public health by reducing emission. For the port of Rotterdam it is attractive to benefit from the positive network externalities by joining either technical trend, hereby expanding the network. The sub-question which is answered in this chapter is: What are the technical options for shore side electricity systems and LNG systems and which options are selected for this research?

The aim of this chapter is to determine and describe the technological options for the two trends, hereby answering the sub-question. The technologies need to be determined more accurate, because different technical options have other implications. Hereto, technological options were obtained by and selected based on desk research and expert interviews.

Different options to generation and distribute the electricity for the SSE technology are available. The available and proposed energy sources are conventional energy sources or renewable energy sources, such as, off-shore wind power and solar PV. Further, a rotary and static frequency converter are available to convert the 50 Hz from the European grids to the required 60 Hz. This converter can either have a central position or a decentral position in the network.

The SSE technology of focus in this report is a containerised, grid connected option, which is powered by off-shore wind turbines. The electricity is generated by a renewable energy sources because it has less pollutions during operation. The percentage of vessels supplied by mere off-shore wind turbines is similar the percentage of vessels supplied by a combination of wind turbines and PV solar panels in a Mediterranean port. For the port of Rotterdam in the Netherlands PV solar panels are less efficient, therefore mere off-shore wind turbines are selected. A central, stationary frequency converter is required to convert the 50 Hz into 60 Hz. In this system, a central stationary converter converts the 50 Hz to 60 Hz, because it is more efficient and has less maintenance costs in comparison to a rotary converter or a decentral frequency converter. The containerised solution allows for easy on and off-loading of the equipment.

The desk research reveals different options for the LNG technology to use as energy sources and the method to supply the vessel with LNG. The different options to transport the LNG tot the vessel are by

tank trucks, or by vessels or via pipelines. To combust the fuel different type of generators are available.

The LNG technology of focus is a containerised option, where the containers are transported to the vessel by tank-trucks and are loaded on an off broad by gantry cranes. In a container is the equipment and in another is the fuel tanks. The containerised solution allows easy on and off loading of the containers. Tank truck transports the gas tank from the filling station to the vessel, because is a low investment and the distance from the filling station and berth is small.

4 Strength, Weakness, Opportunity, Threats Analysis of the Selected Technologies

In the previous chapter, chapter 3, the technical options for the two technologies of focus are described. This is necessary to determine more precise the positive and negative aspects of these technologies, because each technical option may have a different impact on society. To determine which of the two technologies is the most suitable and promising, a decision should be made which includes the stakeholder values.

In this chapter SWOT analyses are performed to obtained positive and negative aspects, which have an impact on society. These aspects encompass broader aspects than the technical virtues and harms. A SWOT analysis was used to determine for the SSE and LNG technologies, because it allows to include a broad spectrum of internal and external aspects.

The positive and negative aspects that resemble the attributes, which are obtained in chapter are used to determine scores for the criteria in the decision matrix in chapter 7. The scores are determined by an ordinal scale, which allows to determine the preferred option without quantifiable data.

These scores need to be obtained from an independent source, to prevent a biased out, because the criteria in the MCA matrix are derived from the stakeholders. Independent experts are used to obtain these aspects because of the ambivalence of these aspects for the stakeholders.

In the first section of this chapter, section 4.1, the SWOT analysis on the SSE technology is performed. Secondly in section 4.2, the SWOT is performed on the LNG technology. The quotes of the expert interview are added in this chapter. The complete interviews are in the Appendix 3 Interview with Expert 1, Appendix 4 Interview with Expert 2, Appendix 5 Interview with Expert 3, Appendix 6 Interview with Expert 4 and Appendix 7 Interview with Expert 5. Finally, a summary of the positive and negative aspects of the technologies are given in section 4.3.

4.1 Analysis of Shore Side Electricity

The purpose of this section is to determine the positive and negative internal factors of the shore side electricity technology and later the external factors. This is performed to determine the potential impact of technology, more so, these factors are used to determine the scores in the MCA.

The internal factors are the weaknesses and strengths of the technology, such as, the technical components of SSE and the pollutions. The external factors are the aspects that are affected by the SSE system, such as, the safety of the port employees and job opportunity. Figure 4—1 presents the aspects of the SWOT analysis for the SSE technology.

Strengths	Weaknesses
• Elimination local emissions • Abandons fossil fuel • Reduces noise pollution • Smaller Carbon footprint	• Doubtful business case, because high investment in grid and frequency converter • Restriction Location by availability of high capacity grid • Fatal injuries, although few
Opportunities	**Threats**
• Governmental support by subsidy • A balanced renewable energy network • Collaboration with international ports • Net gain future job opportunities • Current job opportunities • Positive attitude towards Balanced job opportunities • Balance in Job opportunity • Reduction Carbon footprint	• Port need to provide sufficient power from (national) grid • Port (financially) dependant of government • Cultural difference inhibit collaboration • Doubt about the technology • Attitude it has improved • Electric SSE demand big relative to port demand • No general regulations available • Legal ownership of the installation is unclear • Tax on electricity in the Netherlands • The required skill little match current skills • Vulnerable to cyber-attack • Bigger energy sprawl

Figure 4—1 SWOT analysis of the shore side electricity technology.

4.1.1 Strengths of Shore Side Electricity

Reduction of Pollutions

Researchers have pointed out that one of the strengths for SSE is the elimination of the local production of emission: Sulphur oxide, Nitrogen oxide, particular matter, Carbon dioxide and noise pollution (Radu, Jeannot, Megdiche, & Sorrel, July 2013) (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, 2015).

In our SSE system the energy is generated by off shore wind turbines, this eliminates the local production of particles in the air during operation. This implies a complete reduction in pollutions, such as, CO_2, NO_x, SO_x, pm and noise during operations.

However, the European Commission has compared the emissions for SSE, fed by the European energy mix, to the use of an auxiliary engines (European Commission , 2005). Compared to the use of an

auxiliary engine with marine diesel oil (0.1 %) the Nitrogen emission and pm emissions are reduced by at least 89 %. And the *volatile organic compounds* (VOCs) (which include Methane) are reduced by 94 %. The average *emission factors* (EFs) for shore side electricity are much lower compared to the use of 2.7 % Sulphur and 0.1 % Sulphur (European Commission , 2005).

The results from the from the European commission may be interpreted a conservative, because, the European commission used the average European energy mix to determine the SSE emissions, which includes a part fossil energy and a part renewable energy (European Commission , 2005). The share of RES is just 17 % In the Entec report (European Commission , 2005). The emissions may be even lower considering the increasing trend in the share of renewable energy in the EU consumption (Statistical Office of the European Communitie, 2018). Table 4—1 shows the emission reductions.

More so, the noise is eliminated when the vessels use shore power and the engines are switched off (European Commission , 2005). The diesel fuelled auxiliary engines typically produce a 90-120 dB noise.

Table 4—1 The average emissions for all vessel types in Europe. AE= auxiliary engine, MDO= marine diesel oil.

	NO_x	**SO_2**	**VOC**	**pm**
Emission factors AE engines using 2.7 % Sulphur fuel [g/kWh]	12.47	12.3	0.4	0.8
Emission factors AE engines using 0.1 % Sulphur fuel [g/kWh]	11.8	0.46	0.4	0.3
Emission factors for SSE (EU 25 electricity production) [g/kWh]	0.35	0.46	0.02	0.03
Emission reduction SSE to MDO (0.1 S%) [%]	97	0	94	89

The strengths of the SSE technology are the reduction of nitrogen emission and noise pollution according to experts. Two quotes are presented below.

> *"At the moment, an incentive for the implementation of shore power, is the reduction of nitrogen emissions."* (Expert 3, personal communication, 29 November 2016)
>
> *"Besides that, it may contribute to the reduction of noise pollutions in certain areas."* (Expert 3, personal communication, 29 November 2016)

Fossil Fuel Independent

The SSE technology may have positive implications for other technological developments, because of it uses a smart gird. This report focusses on an SSE technology with wind energy. To account for the energy fluctuations in supply and demand a smart grid is required.

Winkel, Weddige, Johnson, Hoen & Papaefthimiou (2015) have identified a positive impact of the SSE technology, namely, the energy demand of SSE gives an opportunity to balance (local) grids. The smart grid for the SSE technology is connected to (local) renewable energy grids. When these renewable energy grids have an excess of energy, the energy can be supplied to the vessels, to compensate for this excess.

Another strength was determined by Winkel, Weddige, Johnson, Hoen & Papaefthimiou (2015), the SSE technology, with wind energy, has a positive impact on the development of an adequate transmission system for renewable energy. The infrastructure to transmit energy from the wind turbines can be used by other wind parks, which have been estimated by Winkel, Weddige, Johnson, Hoen & Papaefthimiou (2015) to increase by 10.1 % - 20 %.

Smaller Carbon Footprint

Another positive aspect is that for the wind turbines, which generate electricity for SSE, have a net reduction in Carbon (Thomson & Harrison, June 2015). Although the wind turbines do not produce Carbon emissions during operation, the structure requires Carbon sources to manufacture the turbine. In this calculation the required equipment that is placed onboard of the vessel is not considered.

4.1.2 Weakness of Shore Side Electricity

Doubtful Business Case

The business case has been considered a weakness, because this ownership of the onboard and onshore installations and infrastructure is not clear (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015). And investors may not have financial benefit (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015).

The costs, as suggested by Expert 3, are mere the direct cost to generate electricity from either HFO or MDO or by SSE, then the SSE option is less favourable. The costs [Euro/kWh] to generate electricity are 2 to 4 times higher than when the auxiliary engine runs on HFO or MDO, Table 4—2 shows these costs (MariTerm AB, 2004). The shipping companies are interested in the direct costs, as was mentioned by on the of the experts:

> *"You compare the prices for marine fuel to the electricity price. A shipping company is mere interested in the costs for onboard combustion versus the use of electricity and additional equipment."* (Expert 3, personal communication, 29 November 2016).

The interviews with experts revealed weaknesses related to the business case and international competition. One of the interviewees, Expert 1, points out that the weakness of high investments can be overcome by a subsidy. The Chinese government gave support to the SSE by providing subsidies. However, this may be seen as a loss of autonomy of the port. The port will become financially dependent of the government.

> *"From the port's perspective, the will rely on the [Chinese] government subsidies to implement the solutions."* (Expert 1, personal communication, 18 April 2017).

Another weakness for the implementation of SSE, which is related to the business case, is the fact that European ports are not able to sell electricity. If ports could sell electricity, they could close the financial gap and may be willing to invest in the infrastructure. This is what happened in China, where grid operators invest in the (electrical) infrastructure, because they can sell the electricity. This is not the case in Europe nor for ports nor for grid operators.

> *"If I look in parallel in Europe where sometimes one of the big obstacles is the fact that the port authorities cannot sell electricity."* (Expert 1, personal communication, 18 April 2017).

> *"So, in a way having a potentially active role of the local distribution or grid operator would really be beneficial, they can sell electricity and they can be willing to invest. This is low or non-existing in Europe."* (Expert 1, personal communication, 18 April 2017).

The price for fuel or electricity relative to the rest of the continent or world is relevant. If sulphur limits are lowed to 3 % instead of 3.5 %, this fuel will become more expensive. Other ports may still accept the cheaper 3.5 % S containing fuel. This price difference may be enough to make a profitable business for the other less sustainable port. The same hold for a vast infrastructure. If the expenses of the infrastructure are too high, then, the electricity prices will increase and a business opportunity for a competing port emerges.

> *"They [the international bunker stations] can force it to be reduced from 3.5 % to 3 %, independent from international developments. This implicates that costs will be higher. And international there are ports seeking if they can make a business out of it."* (expert 4, personal communication, 30 November 2016).

The weaknesses deducted from the expert interviews are the high investment costs for the SSE installation for the port and vessels owner. Another weakness of SSE is the need for a new frequency converter. The frequency converter has issues with magnetisation, which causes the converter to degrade. Although, in this report a static frequency converter is selected, this expert refers to an SSE technology with a rotary frequency converter and its weakness.

> *"For maritime shipping, container vessels, it is a bigger investment, a million for a shore connection and 0.5 million for each vessel."* (Expert 3, personal communication, 29 November 2016).
>
> *"The frequency converter is magnetised and therefore it wears faster."* (Expert 3, personal communication, 29 November 2016).

Restriction to the Location by High Quality Grid

To supply the vessel with power a network is required that can support the demand and can deal with fluctuations in demand. The grid should reach from the energy source (wind turbine) to the vessel. Hereto, transmissions cables should be in the quays of the port.

However, such a complex and grid that can cope with high capacity is not available or possible in al ports, as Winkel et al have mentioned (2015). The requirement for a highly complex grid is therefore a weakness.

Injuries to Port Employees

Another weakness of the SSE technology is the potential for an electric shock for port workers. Radu, Jeannot, Megdiche & Sorrel (July 2013) have mentioned that internal arcs on the high voltage and low voltage switch board or during handling and (un)plugging the cables, can cause an electric shock.

No documents were found that predict the change or describe the number of fatal injuries during handling of SSE equipment due to an electric shock. Therefore, to estimate the number of electric shocks during handling of vessels a document from Barlas was used.

From the report of Barlas the number of fatal accidents in a Turkish shipyard from 2000-2010 were analysed. From the 115 fatal accidents, 18 accidents were due to an electric shock (Barlas, 2012).

4.1.3 Opportunities for Shore Side Electricity

Governmental Support

Governmental support and legislation have been linked to the successful implementation of SSE (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015). In the United States of America, a *California Air Resources Board* (CARB) policy, was introduced and made it compulsory for vessels to use SSE.

In Europe, programmes such as Marco Polo and ten-T support the implementation of SSE (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015). Marco polo is a program that supports innovation by giving financial support, offering financial compensation for losses of the investment not for profit.

The expert interviews revealed that governmental support plays an important role in the implementation of SSE. The Chinese government has a plan to reduce hazardous emissions. The aim is to reduce 65 % SO_x emissions, 20 % NO_x emission and 30 % of the particular matter. To achieve these emission targets, SSE is used. Besides the common goal of the government, the government gave financial support to implement measures such as SSE to reduce the emissions (Marco Polo, n.d.).

> *"In China shore to ship power is used in a strategic plan, with an implementation plan of pollution prevention of ships and ports."* (Expert 1, personal communication, 18 April 2017).
>
> *"The plan will be to reduce 65 % SO_x, 20 % NO_x and 30 % particular matters."* (Expert 1, personal communication, 18 April 2017).
>
> *"And the chines government is providing some subsidies for implementing such measures."* (Expert 1, personal communication, 18 April 2017).

Lower Operating Costs than MDO with Externalities

The interview with Expert 3 revealed that shipping companies are sensitive for economic opportunities, therefore, their decisions the most economically attractive option. For shore side electricity shipping companies will compare the costs for diesel fuel to electricity prices, mentioned in the interview with Expert 3.

> *"You compare the prices for marine fuel to the electricity price. A shipping company is mere interested in the costs for onboard combustion versus the use of electricity and additional equipment."* (Expert 3, personal communication, 29 November 2016).

However, if the costs include externalities, such as pollutions, the annual costs to run auxiliary engines on HFO or MDO are estimated to be 15 to 75 times higher, Table 4—2, than for the SSE option (MariTerm AB, 2004).

Table 4—2 The comparison between SSE and AE (HFO or MDO) for direct costs and costs including external costs.

	Average direct costs [€/kWh]	Average direct and external costs [€/kWh]
Auxiliary (HFO)	0.031	0.364
Auxiliary (MDO)	0.058	0.130
Shore Side Electricity	0.110	0.007

There are opportunities to make the electricity costs economic competitive with the fossil fuel. In Germany and Sweden, a reduction in the tax on electricity has been made, to make the costa more equal (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, 2015).

Small Increase in Port's Energy Demand

To determine the future energy demand of the port of Rotterdam, a forecasting study was carried out by Winkel, Weddige, Johnson, Hoen & Papaefthimiou (2015) performed. This study includes the impact of SSE on the port's energy demand. Factors that may contribute or limit the energy demand are included, for example the SSE.

In the study of Win Winkel, Weddige, Johnson, Hoen & Papaefthimiou (2015) the demand increase indicator for Rotterdam was determined to be relatively low, 0.3 % - 1.0 % (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, 2015). The demand increase indicator is the expected SSE demand increase over the electricity demand of the specific area at peak demand.

To implement the required capacity, the demand of the vessels is required. The containers vessels' demand depends on the number of refrigerated containers. The number of refrigerated containers varies from vessel to vessel or from shipment to shipment.

This gives uncertainty of the energy demand of the vessel. This variation in energy demand is not problematic as was mentioned in one of the interviews by Expert 1. Expert 1 mentioned: the vessel is aware of its energy demand.

> *"When you have a vessel coming in, knowing that the port can only deliver 3 MVA or 4 MVA is enough for them, because they know perfectly their consumption."* (Expert 1, personal communication, 18 April 2017).

Another expert, Expert 2, mentioned that: the energy demand can be managed by a smart system. This system is enables to keep the containers at the preferred temperature and at the same time maintaining the energy demand that can be delivered to the vessel. The smart system alternates the energy supply between containers.

> *"Usually the reefer containers are operated by a smart system, that is to say, that a system provides the containers with power in turn."* (Expert 2, personal communication, 6 April 2017).

Collaboration with Other Ports

To enhance the profitability of the investment, the investment costs need to be reduced or the operation time needs to be increased. Therefore, collaboration with other port may be rewarding. From the interview with Expert 3, a joint concept between ports in China and the port of Rotterdam may be an option (Expert 3), personal communication, 29 November 2016). This would be beneficial for shipping owners as well, considering one required investment that would be applicable in many ports.

> *"It is explored it we [China and Rotterdam] can jointly offer a shore power concept. This would be attractive for the port of Rotterdam."* (Expert 3, personal communication, 29 November 2016).

Current Job Opportunity

Another opportunity for the implementation of SSE, is that it creates job opportunities. Jobs are required for the population to earn money to sustain a living. By complying to the job opportunities, the port of Rotterdam can contribute to public well-fare.

The current renewable energy sector contributes for 155.5 % (2013) to workload in the energy sector and has an increasing trend. (Werkgelegenheid rond energievoorziening sterk gestegen, 2015). Work load is a measure for the total number of hours of labour in this work field.

Future Job Opportunity

For future generations the prospect of a job is important, because they will be able to sustain a living in the future. These technical innovations are implemented for a longer period of time and possibly outlive the current generation of workforce. Therefore, it is important to make a forecast of the future job opportunities to meet the demand from the industry and to meet the demand from the population for a job. therefore, it is important to future job opportunities are important to sustain the living.

In the Netherlands the job opportunity (expressed in labour years) will increase from 46 thousand labour year to an estimated 64 thousand labour years in 2020 (CBS, 2017). Hereby, overtaking the number of job opportunities in the conventional energy sector, which will decline from 2014-2020 from 73 to 62 thousand labour years. In the future the renewable energy sector will contribute to more jobs than the conventional energy sector.

Public Support for Innovation

The implementation may be spurred when there is a broad public support or when there is a social obligation to meet criteria. One of the interviewees mentioned, a social support to implement less polluting technologies (Expert 4, personal communication, 30 November 2016). He described that the voluntary *Environmental Ship Index* (ESI) regulation gained power because of the social status that was created, when one complied to the regulation. If one does not participate in the ESI-regulation, it is not socially accepted.

> *"Quite frankly it [the ESI regulation] is successfully implemented. It started with a few and there are currently many more."* (Expert 4, personal communication, 30 November 2016).

> *"There is not. There is an economic incentive although there is none actually. It is not much of an incentive. I have compared it with our attitude towards smokers in recent years."* (expert 4, personal communication, 30 November 2016).

Balance in Job Opportunities

The maintaining balanced job opportunities is considered an important contribution to society, especially for social well-fare. The renewable energy sector contributes to broad range of jobs, stretching from MBO level 2 to academic level. In general, the future jobs require more specialised skills and abstract thinking, however, the ICT and information systems will provide jobs for the MBO-1 and MBO-2 level jobs (Ligtvoet, Pickles, & van Barneveld, 2016). The job for MBO-1 and MBO-2 that are created by the energy transition are for example service desk employees.

International Environmental Agreements

Acciaro, Ghiara & Cusano have identified, that the introduction of international environmental agreements or local emission regulations, to foster the development and implementation of SSE systems (Acciaro, Ghiara, & Cusano, 2014). The regulations and laws create a need to develop new technologies, for example, the development of SSE to meet the legal emission limits (Acciaro, Ghiara, & Cusano, 2014). There is freedom for the port authorities to develop a suitable technology whether or not in collaboration with local government (Acciaro, Ghiara, & Cusano, 2014).

Examples for international emission regulations are the MARPOL annex VI (IMO, n.d.) is and *European Union* (EU) Directive 2008/50/EC (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, 2015) on ambient air quality and cleaner air for Europe. Reduce air pollution level and impacts on sensitive populations and environments.

The government can put restrictions on the emissions, as mentioned above, however, a more rigid regulation can be implemented. The government in of California introduced a regulation which makes the use of SSE obligatory in ports Long Beach and Los Angeles. The (local) government may make a technology obligatory (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015).

In Europe the Swedish government promotes the utilisation of SSE more appealing by decreasing the energy tax for electricity for SSE. The electricity tax is compliant to the minimum tax (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, 2015). In Germany a similar step was taken. The government set the energy tax for electricity for SSE to the minimum tax (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, 2015).

Individual ports can start an initiative to meet their environmental targets. Examples of the initiatives in Europa are, the *Environmental Ship index* (ESI) (WPCI, 2010) and the *Clean Shipping Index* (CSI) (Clean Shipping Index secretariat, 31 August 2015). The ESI and CSI are to motivate the shipping industry to reduce emission though innovating. These initiatives are not obligatory.

From the interviews different types of regulations are driving the implementation of SSE systems. An international regulation, MARPOL, which limits the emissions of Sulphur and Nitrogen (Expert 3, personal communication, 29 November 2016). A state regulation in California obliges the use of SSE in ports (Expert 3, personal communication, 29 November 2016).

> *"The Sulphur limits are indeed at sea reduced from 5.0 % to 3.5 % and in SECAs from 1 % to 0.1 %."* (Expert 3, personal communication, 29 November 2016).
>
> *"Currently, the incentive to implement shore side power is the reduction in Nitrogen emissions."* (Expert 3, personal communication, 29 November 2016).
>
> *"...in California is there a law that makes it obligatory."* (Expert 3, personal communication, 29 November 2016).

Local Port Regulations

Besides International and state-wide regulations. Local port initiatives were mentioned, the Rotterdam initiative of ESI. ESI may be a stimulus for the implementation of SSE (Expert 3, personal communication, 29 November 2016).

"We stimulate [with the ESI regulation] non-statutory performance." (Expert 3, personal communication, 29 November 2016).

4.1.4 Threats for Shore Side Electricity

Match Current Skills

Developing new jobs has been seen an opportunity for public, however it has an economic downside. The current skills of employees are not fit for the future jobs. This will require additional education besides the lifelong learning that is imposed by the knowledge economy, which the Netherlands is striving for (Ligtvoet, Pickles, & van Barneveld, 2016).

Development in the port area demands adaptation of the port employees. However, if the innovation is not in line with the current skills or knowledge of the port employees, the implementation stays off. Therefore, it is relevant to determine if an innovation is in line with the current knowledge and skills.

This aspect is a threat for SSE, because the LNG technology matches better with the fossil knowledge of the current port employees. Ligtvoet, Pickles & van Barneveld have mentioned that these existing skills in the fossil industry are important in an energy transition. Further they have mentioned that the job in the renewable energy sector require different skills (Ligtvoet, Pickles, & van Barneveld, 2016).

Negative Attitude

One of the threats Winkel et al (2015) have mentioned is: a reluctant attitude towards the SSE technology, due to the uncertainty in establishing the social and environmental benefits. A reason for this attitude is, that the monetary value for the social and environmental benefits are difficult to determine. Another reason is, that the technology is relatively new (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015), therefore, there may be some reservations about the reliability and beneficial impact.

The interviews with experts showed an attitude, of achievement of the environmental goal. The air quality and environmental awareness has already improved dramatically and therefor is less of a problem compared to what is used to be (Expert 4, personal communication, 30 November 2016).

"It is already só much better, it is so incredibly better compared to the 60s." (expert 4, personal communication, 30 November 2016).

The disbelieve in collaboration with other sea ports or international organisations is another social threat. The business cultures differ vastly and are insurmountable.

"Between Singapore and Rotterdam, it is barely impossible to collaborate." (expert 4, personal communication, 30 November 2016).

Required Frequency Converters

The frequency at which the electricity needs to be supplied differs between 50 and 60 Hertz. The container vessels over 140 meters long 94 % operates at 60 Hz and 6 % ate 50 Hz (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015). This implicates that the use of a frequency converter is required for the majority of the vessels, because the grid is 50 Hz, and for the other 6 % it needs to be customised by adding a frequency converter.

Some of these technical barriers are also deducted from the expert's interviews. The frequency difference and the capacity onboard are mentioned. The second threat is the estimated power demand of the vessels due to the changing numbers of reefer containers.

> *"The majority of the vessels operate at 60 Hz; however, the Dutch grid operates at 50 Hz."* (Expert 3, personal communication, 29 November 2016).

> *"The capacity and power requirement depend on the number of reefer containers and this number needs to be known to be able to dimension the installation."* (Expert 3, personal communication, 29 November 2016).

Vulnerability to Cyber-attacks

Another threat is the sensitivity of the smart grid to cyber-attacks. Besides the safety of port employees, the security of port data is relevant. The data and operation processes need to be protected from hacks that inhibit port operations and for privacy reasons, as has been mentioned by Mo et al (2012).

A smart grid has been required to deal with energy from wind turbines, compared to a traditional grid (2012) because the smart grid has bidirectional energy flows in contrast to the traditional grid, this allows storage during excess generation. A traditional coal power plant produces an excess of energy to meet the peak demand, when there is an excess of energy it is dissipated (shedded). This report focuses on an SSE technology with wind turbines to generate power, which will be transmitted via the grid to the berth.

This new ability makes this smart grid more complex, and as a consequence more vulnerable to cyber-attacks because it is more difficult to protect. Mo et al (2012) describes two steps of an attacks, first is to gain access via an entry point, a weak spot in the network. A smart grid has more entry point and therefore the chance to gain access is more likely than a traditional grid.

Bigger Energy Sprawl

The available space on the Earth is limited, therefore, there is a competition for space and a desire to be space efficient. Therefore, the required space for the technologies includes the space required in the port, more so, the required space on the Earth.

McDonald, Fargione, Kiesecker, Miller, & Powell have compared the energy technologies on their energy production per hectare, land sprawl. The less land sprawl the more space efficient the energy technology can operate. Compared to the LNG, wind turbines have a bigger energy sprawl. An energy sprawl is the surface area per energy unit. The area required for (on shore) wind turbines is 72.1 hectares per Tera Watt generated power (McDonald, Fargione, Kiesecker, Miller, & Powell, 2009).

When less surface or space is required by the energy technology the more is available for, for example food production, housing, or nature reserves.

4.2 Analysis of LNG PowerPac®

The purpose of this section is to determine the positive and negative internal factors of the LNG technology and later the external factors. The internal factors are the factors that are concerned with the strengths and weaknesses of the technology, such as, required equipment, type of fuel and emissions. The external factor is concern with aspects that are affected by the LNG PowerPac®, such as, the generation of LNG, safety and job opportunities. Figure 4—2 gives the aspects of the SWOT analysis.

Strengths	**Weaknesses**
• Almost no production NO_x and pm • Better confidence in Business case, no frequency converter nor a grid investment • LNG can work where there is no grid	• Local production CO_2, CO, CH_4 and noise • Still fossil fuel dependent • Bigger Carbon footprint • Fatal injuries, although few
Opportunities	**Threats**
• Alliance with nearby ports, Hamburg • Ports assist regulatory makers • Ports facilitate and coordinate LNG use • Ports raised public awareness • Ports set different tariffs • Hub activity supported by LNG infrastructure. • ESI voluntary stimulation • One fuel required for transport and hoteling • Applicable in all ports • Legal necessity to reduce emissions • Required skill better match current skills • Balanced job opportunities • Smaller possibility for cyber-attacks • Less energy sprawl	• Attitude it has improved • The location of LNG production • International competition • No standards or regulations for LNG vessels or bunkering facilities • Net loss future job opportunities •

Figure 4—2 SWOT analysis of the LNG PowerPac®.

4.2.1 Strengths of LNG PowerPac®

More Confident Business Case

Another strength may be a more solid business case for the LNG PowerPac®, because different experts mentioned and wrote about the “doubtful” business case for SSE, in section 4.1.2, because of the high initial investments for the grid and frequency converter.

The use of LNG PowerPac® eliminates the need to accommodate an electrical infrastructure. This eliminates additional costs for terminal operators (Federal Ministry of Transport and Digital

Infrastructure (BMVI) promotes Becker Marine Systems' LNG PowerPac®– the world's first flexible solution for supplying power to container ships at ports, 2016),who are likely to make this investment

More so, no frequency converter is required, because the generator can be matched to the required onboard frequency, either 50 or 60 Hertz. No additional frequency converter or transformers are required (Federal Ministry of Transport and Digital Infrastructure (BMVI) promotes Becker Marine Systems' LNG PowerPac®– the world's first flexible solution for supplying power to container ships at ports, 2016). The frequency converter is one of the most expensive units required for the SSE system, as was mentioned earlier in chapter 3.

The expert interviews gave similar results. The expert revealed that the use of LNG reduces the emissions of NO_x, SO_x and particular matter. More so, an LNG barge (and the LNG PowerPac®) is able to generate power at 50 hertz or 60 Hertz. Therefore, no frequency converter is required. This is a strength for the LNG technology.

> *"LNG produces barely NO_x, SO_x, and pm."* (Expert 3, personal communication, 29 November 2016).

> *"An advantage of a barge generator is, the ability to set the frequency to either 50 or 60 Hertz."* (Expert 3, personal communication, 29 November 2016).

Reduction of Local Emissions

The use of an LNG generator produces local emission, albeit there is a reduction has been determined by Tarnapowicz & German-Galkin (2016), Table 4—3 on page 55 shows the emissions and reductions. These emissions are compared to other options, using the AE with MDO or HFO for 1 MWh production for one year (Tarnapowicz & German-Galkin, 2016). In this research the methane slip issue is not considered. These numbers were converted to the unit [g/kWh] to compare with the LNG results from Anderson (2015) and the SSE results (European Commission , 2005).

Table 4—3 Emissions [g/kWh] for generating the Caterpillar auxiliary engine.

	CO_2	**NO_x**	**pm**	**SO_2**
HFO [g/kWh]	469	9.97	0.460	7.915
MDO [g/kWh]	469	9.97	0.308	0.733
LNG [g/kWh]	402	0.353	0.000	0.016
Emission reduction LNG rel. MDO [%]	14	96	100	98

One of the issues concerning LNG is the Methane that escapes through the generator. From the report of the composition of the emitted particles for a DFDE using LNG for a (cruise) vessel were determined. At berth the engine load was 29 % for LNG generators and 16 % for MGO fuelled generators (Anderson, Salo, & Fridell, 2015). The *emission factor* (EF) per component, NO_x, CO_2, CO and the *total hydrocarbons* (THC) is determined in the research (Anderson, Salo, & Fridell, 2015).

Although, the data cannot be deducted in detail from the tables in the report of Anderson, Salo & Fridell (2015), an estimation of the emissions [g/kWh] is made, Table 4—4 shows the emissions. The *Total Hydrocarbon Compound* (THC) is estimated to be an expression for the amount of Methane that leaves the engine, considering that the fuel is composed of 92.54 % mol CH_4.

Table 4—4 An indication of the emissions [g/kWh] factors per component at berth.

	EF NO_x	**EF CO**	**EF CO_2**	**EF THC**
Marine Gas Oils (16 %) [g/kWh]	~ 20-27.5	~ 2.00-3.00	~ 600-1800	~ 2.00
LNG (29 %) [g/kWh]	~ 0-2.5	~ 5.00	~ 500	~ 2.50-2.75
Emission reduction [%]	95	-100	58	-31

No Restrictions to the Location

The LNG solution has been proposed a solution for areas where there is no grid, or it is too weak or when there is very limited space at berth. (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015).

The port of Rotterdam has an LNG infrastructure (Wang & Notteboom, 2015). This gives the opportunity to build and expand the existing infrastructure. Less initial investments might be required for an operational system.

4.2.2 Weakness of LNG PowerPac®

Local Methane Emission and Noise

On the weaknesses of the LNG PowerPac® is the leakage (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015). This leakage is caused when the natural gas is combusted. Natural gas consists for a major part of Methane. The Methane that slips away results in a lower efficiency. This slip issue has another downside. The lost Methane contributes to the global warming, as Methane is a more potent GHG than CO_2 (Anderson, Salo, & Fridell, 2015).

Using an LNG PowerPac® enables to eliminate some emissions, as mentioned earlier. However, the local emission of Carbon mono-oxide and other hydrocarbons, such as Methane, are increased (Anderson, Salo, & Fridell, 2015). Besides the Carbon dioxide emissions, which are the consequence of combusting a fossil fuel (Other Techniques, n.d.).

More so, this LNG PowerPac® produces noise pollution during the generation, this is inherent to the combustion of fuels. Diesel engines produce approximately 100 dB (Tarnapowicz & German-Galkin, 2016). Tarnapowicz & German-Galkin (Tarnapowicz & German-Galkin, 2016) have mentioned that the noise pollution can be eliminated by SSE, not by the use of LNG.

LNG is Still Fossil Fuel

The implementation of LNG has been considered an option to continue the port's hub activities (Acciaro, Ghiara, & Cusano, 2014). The port of Rotterdam is currently a port that is supported by the oil bunkering facilities. Considering the possibility that oil will diminish, a new source income needs to be created for the port.

However, the use of a fossil fuel is a weakness, because the fossil reserves (oil and gas) are limited. In the future biofuels may be available for the shipping industry. These fuels replace the LNG and the LNG infrastructure can be reused (Acciaro, Ghiara, & Cusano, 2014).

In the interview with the experts the Methane slip issue was mentioned. Another weakness of this technology is that it sustains the fossil fuel consumption. (Expert 3, personal communication, 29 November 2016)

> *"However, it remains fossil therefore you keep the CO_2 and Methane slip issues."* (Expert 3, personal communication, 29 November 2016).

Bigger Carbon Footprint

Another weakness for the LNG option is the life cycle emission compared to the emission of a wind turbines (Thomson & Harrison, June 2015). The life cycle emission are the Carbon emissions corresponding to the lifetime of the technology. These correspond with the manufacturing, assembling and operating the technology.

Injuries to Port Employees

Another threat is the safety of the port employees. Working with compressed gas implies safety rules and potential explosion danger. From the analysis of the number of fatal accidents in a Turkish port between 2000-2010, the number of fatalities (Barlas, 2012) that are due to an explosion was determined. From the 115 fatal deaths, 18 deaths were due to an explosion.

4.2.3 Opportunities for LNG PowerPac®

Collaboration with Other Ports

Collaboration with other ports because of new regulatory role of the port, due to the lack of regulations for innovations, such as LNG.

The port tries to make a transition from being an oil hub to an LNG hub.

An opportunity for the LNG PowerPac® is the possibility to collaborate with other nearby ports and port business. Forming the alliances between, for example, Gothenburg and Antwerp (Wang & Notteboom, 2015) an LNG network is created, hereby creating more stable and reliable network through knowledge exchange.

Wang & Notteboom (2015) have determined that ports take on a more regulatory role to promote the implementation of LNG bunkering facilities. The lack of (inter)national policy creates an opportunity for port authorities to exploit tasks beyond their task of a landlord. The new tasks which have been identified are: 1) the port authority provides assistance to regulatory authorities, 2) coordination and development of regulations on maritime LNG, 3) assess the safety of bunkering facility by a checklist, and 4) set different tariffs for vessels that are LNG fuelled (Wang & Notteboom, 2015).

The regulations are composed from knowledge sharing between port companies and other ports. Therefore, the trend that ports take on a more regulatory role will increase knowledge sharing between the port of Rotterdam, governmental organisations and the port business.

This new regulatory role spurs the competence of the port in general, further is effectively promotes innovation in particulate in the chicken egg problem.

The port aims to maintain its hub activity, this is an opportunity for the LNG PowerPac® is the possibility to collaborate with other nearby ports. Forming the alliances between, for example, Gothenburg and Antwerp (Wang & Notteboom, 2015) an LNG network is created, hereby creating political support.

The ports use knowledge sharing with port businesses and other ports. This is performed by meetings and interactive sessions on the LNG bunkering facility. Rotterdam has the aim to maintain its hub function but changes from oil to gas.

Local Voluntary Stimuli

One expert mentioned a financial stimulus for shipping companies to implement less polluting technologies, such as, SSE and LNG. The ESI regulation allows for a reduction on port dues as a result of emitting less pollutants, such as SO_x, NO_x and pm (Expert 3, personal communication, 29 November 2016).

> *"We stimulate [with the ESI regulation] non-statutory performance."* (Expert 3, personal communication, 29 November 2016).

Match current skills

The skills that are required to fulfil jobs, that are created by the LNG sector, may differ from the current skills that are required. This may be due to the transition towards a knowledge economy. Lifelong learning will be the prospect. However, the required skills for the jobs in the conventional energy sector and the jobs that are available for employees differ (Ligtvoet, Pickles, & van Barneveld, 2016).

Public Support for Innovation

As earlier mentioned, the ESI regulation gives an ease on the financial obligation for shipping companies. However, this is mere a part of the reason for the increase in voluntary participation. The ESI regulation evokes a social standard on how to act.

> *"Quite frankly it [the ESI regulation] is successfully implemented. It started with a few and there are currently many more."* (Expert 4, personal communication, 30 November 2016).

> *"There is not. There is an economic incentive although there is none actually. It is not much of an incentive. I have compared it with our attitude towards smokers in recent years."* (Expert 4, personal communication, 30 November 2016).

Balance Job Opportunities

Another opportunity is the creation of balanced job opportunities, which have been considered an important contribution to society, especially for social well-fare. The renewable energy sector contributes to broad range of jobs, stretching from MBO level 2 to academic level. In general, the future jobs require more specialised skills and abstract thinking, however, the ICT and information systems will provide jobs for the MBO-1 and MBO-2 level jobs (Ligtvoet, Pickles, & van Barneveld, 2016).

Vulnerability to Cyber-attacks

Another opportunity is the smaller vulnerability to cyber-attacks compared to the SSE technology which makes use of a smart grid. To supply the fuel to the berth, gas tanks are transported by trucks to the vessel. For SSE a grid that is connected to turbines and the vessels should be managed, so that the demand equals the supply, hereto a smart grid is required to account for intermittency and local

production. This smart grid has been considered to be more vulnerable to cyber-attacks compared to the grid for the LNG PowerPac® (Mo, et al., 2012).

Smaller Energy Sprawl

Compared to the wind turbine supplied shore side electricity option the LNG option bigger energy sprawl. An energy sprawl is the surface area per energy unit. The area required for natural gas is 18.6 hectares per Tera Watt generated power (McDonald, Fargione, Kiesecker, Miller, & Powell, 2009). This report compared LNG to onshore wind turbines. The energy sprawl will be less for off shore wind turbines considering that off shore wind turbines generate more energy.

Local Port Regulations

The legal emission limits are necessary to reduce port emissions. This legal pressure may lead to innovations such as SSE (Acciaro, Ghiara, & Cusano, 2014). It is plausible that these limits may spur the development of other technologies, such as the LNG PowerPac®. These Nitrogen and Sulphur limits were mentioned in an interview (Expert 3, personal communication, 29 November 2016).

> *"The Sulphur limits are indeed at sea reduced from 5.0 % to 3.5 % and in SECAs from 1 % to 0.1 %."* (Expert 3, personal communication, 29 November 2016).

Local port initiatives were mentioned in one of the expert interviews, the Rotterdam initiative of ESI. ESI may be a stimulus for the implementation for an LNG technology, like the LNG PowerPac® (Expert 3, personal communication, 29 November 2016).

> *"We stimulate [with the ESI regulation] non-statutory performance."* (Expert 3, personal communication, 29 November 2016).

4.2.4 Threats for LNG PowerPac®

Less Current Job Opportunity

A threat is the loss of job opportunities in the fossil (conventional) energy sector. The current job opportunities in the conventional energy sector are already lower that in the renewable energy sector, LNG contributes to 137.6 % and has a declining trend (Werkgelegenheid rond energievoorziening sterk gestegen, 2015).

Less Future Job Opportunity

The prospects of future job opportunity are lower for LNG than for the renewable sector, therefore, is a threat. In the Netherlands an estimated has been made by the CBS to predict the number of jobs in the conventional energy sector. In the conventional energy sector from 73 thousand to 62 thousand labour years in the period 2016-2020 (CBS, 2017).

Negative Attitude

From the interviews an undermining attitude is discovered. The attitude that the current situation is already an improvement. Hence, the strain has already been reduced, therefore, it is not so much of a problem.

"It is already só much better, it is so incredibly better compared to the 60s." (Expert 4, personal communication, 30 November 2016).

Safety Issues for cities with LNG handling

There are problems concerning the distribution, the infrastructure and the location of the LNG bunkering facilities (Acciaro, Ghiara, & Cusano, 2014). The location of the LNG bunkering station would preferably be built close to the shipping lines, however, due to safety issues with handing of the LNG, some ports prohibit LNG operations in populated port areas (possible port areas near city or populated areas) (Wang & Notteboom, 2015).

LNG stations away from Populated Areas for Safety Reasons

The location of the LNG facilities for liquification and regasification are located away from populated areas (Acciaro, Ghiara, & Cusano, 2014). This may be for safety reasons; however, this implies that facilities are located at the edge of populated areas. For that reason, the LNG option poses a threat for the flora and fauna.

No international regulations

There are currently no regulations for LNG power for vessels or standards for bunkering LNG. As a reaction to the limited regulations and guidelines the individual port authorities take on a more regulatory role (Wang & Notteboom, 2015).

The interviews revealed the international competition on (bunkering) fuels. Where small price difference in the fuel can be a business case for competing ports. If the limits for Sulphur in the fuel are lowed to 3 % instead of 3.5 %, this fuel will become more expensive. Other ports may still accept the cheaper 3.5 % S containing fuel.

"They [the international bunker stations] can force it to be reduced from 3.5 % to 3 %, independent from international developments. This implicates that costs will be higher. And international there are ports seeking if they can make a business out of it." (Expert 4, personal communication, 30 November 2016).

4.3 Summary of the SWOT analyses

In this chapter, SWOT analyses were performed to determine vicious and virtuous aspect of the two selected technologies from the expert interviews. These aspects include internal technical aspects and external political, social or environmental aspects. This chapter focusses on the sub-question: What are the strengths, weaknesses, opportunities and threats of these technologies and for the port of Rotterdam?

This summary gives the results which are relevant to appoint scores in the MCA analysis, in chapter 7. The results from this chapter are used to score the criteria in the MCA, to determine which technology supports the most criteria.

These attributes are determined by a value analysis in chapter 6, later in this report. The attributes are measurable and are considered important by the stakeholders to meet their public values. The aspects that give information about the attributes/decision criteria are: Euros, Interconnectivity, Fossil fuel independent, Future job opportunity, Current job opportunity, Balance education, Knowledge

diffusion, Current skills, Responsibility, Incidents employees, vulnerability to cyber-attacks, Pollution reduction, Carbon footprint, Land use, Local production. Figure 4—3 gives the relevant strengths, weakness, opportunities and threats per attribute for the port of Rotterdam.

SSE		**LNG PowerPac®**	
Strengths	**Weaknesses**	**Strengths**	**Weaknesses**
• Local reduction NO_x CH_4, pm and noise • Abandons fossil fuel • Reduction Carbon footprint	• Weak business case • Grid required with good capacity • Fatal injuries, although few	• No additional costs for grid or frequency converter, more reliable business case • Applicable in all ports	• Local emissions CO_2, CO, CH_4 and noise • Uses fossil fuel • Bigger Carbon footprint • Fatal injuries, although few
Opportunities	**Threats**	**Opportunities**	**Threats**
• Collaboration with international ports • Net gain future job opportunity • Current job opportunities • Balanced job opportunities	• The required skill little match current skills • Vulnerable to cyber-attack • Bigger energy sprawl	• Alliance with nearby ports • Required skill better match current skills • Balanced job opportunities • Smaller possibility for cyber-attack • Less energy sprawl	• Net loss future job opportunities • Current job opportunities

Figure 4—3 The summary of important aspects of the SWOT analysis for SSE (left) and the summary of important aspects of the SWOT analysis for the LNG PowerPac® (right)

Euros

The business case is a weakness for SSE, because of the high investments in the grid and frequency converter(s). The SSE technology has a doubtful business case, as was mentioned in the interview with Expert 3. More so, Winkel, Weddige, Johnson, Hoen & Papaefthimiou (2015) have identified that the high investments for shore side and ship side are a weakness.

The business case is a strength for the LNG PowerPac®, because no investments in an electricity network or frequency converter are required. In the interview with Expert 3 the LNG PowerPac® was mentioned as an alternative because it does not require an expensive frequency converter.

Interconnectivity

An important aspect that supports the implementation of the technology is the collaboration with other ports. By collaborating with other ports, a more stable network emerges, for the vessels.

Both technologies support the collaboration with other ports (or organisations), therefore, this aspect is appointed as an opportunity for both technologies. Based on an expert interview, with Expert 3, the port of Rotterdam explored the collaboration with chines ports to implement SSE. For LNG forming alliance with German ports has been identified as an opportunity (Wang & Notteboom, 2015).

Fossil fuel independent

With depleting fossil reserves and it is a strength for SSE to be independent from fossil fuel during operation. This fossil free innovation SSE uses renewable energy sources, wind power, to supply electricity. This was not the case for LNG. In one of the interviews, the expert mentioned for the LNG PowerPac technology (Expert 3): “LNG still is fossil.”, emphasising *still.* Therefore, the dependence on fossil fuel is a weakness of the LNG PowerPac® and the independence is a strength for SSE.

Future job opportunity

For the next generations an opportunity of jobs is important to sustain livelihood. Increasing the job opportunity is considered virtuous, for socio-economics.

This aspect is an opportunity for SSE and a threat for the LNG PowerPac®, because CBS has estimated that by 2020 the labour in the renewable energy sector will overtake the conventional energy sector. From 2014 – 2016, the number of jobs increased from 46 to 52 thousand labour years in the renewable energy sector. And the forecast is that this will increase to 64 thousand labour years by 2020. For LNG this aspect is a threat, because, the job opportunities in the conventional energy sector has been estimated to decline from 73 to 62 thousand labour years in the period 2016 – 2020 (CBS, 2017).

Current job opportunity

The current generation needs to be able to sustain the livelihood, therefore, it is relevant that the technology contributes to job current job opportunities.

The current job opportunity is a strength for SSE, because it contributes to more labour volume (jobs) than the LNG PowerPac®. The current job opportunities are considered a threat for the LNG PowerPac®. The renewable energy sector contributed in (2013) with 155,5 % (labour volume) and had an increasing trend. The conventional energy sector contributed with 137,6 % (labour volume) in 2013 to the labour market and had a declining trend (Werkgelegenheid rond energievoorziening sterk gestegen, 2015).

Balance education

The workforce has different educational levels; therefore, the job opportunities need to include these differences. Ligtvoet, Pickles and Barneveld (2016) have mentioned an increasing trend in jobs that require abstraction ability. Therefore, to meet the needs of people who lack this skill, a technology that contributes to the supply of a broad range of jobs is considered an opportunity.

The contribution to balanced jobs is an opportunity for both technologies, because, both technologies will provide job opportunities for a broad range, varying from contractors to managers (Werkgelegenheid rond energievoorziening sterk gestegen, 2015). The job opportunities with a

technical background is required will be in abundance, ranging from MBO level 2 to academic level (Ligtvoet, Pickles, & van Barneveld, 2016).

Current skills

Development in the port area demands adaptation of the port employees. However, if the innovation is not in line with the current skills/knowledge of the port employees, the implementation stays off. Therefore, it is relevant to determine if an innovation is in line with the current knowledge and skills.

This aspect is a threat for SSE and an opportunity for the LNG technology, because the LNG technology matches better with the fossil knowledge of the current port employees. Ligtvoet, Pickles & van Barneveld have mentioned that these existing skills in the fossil industry are important in an energy transition. Further they have mentioned that the job in the renewable energy sector require different skills (Ligtvoet, Pickles, & van Barneveld, 2016).

Incidents employees

The technology has an impact on the safety of port employees. The port employees that work directly with the technology are subjected to health threats, such as an electric shock for SSE or an explosion for the LNG PowerPac®. The lower the chance for such an incident the better it is.

Radu, Jeannot, Megdiche & Sorrel (July 2013) have identified an electric shock during handling of the SSE system as a threat for the safety of port employees. Because SSE has the potential to electrocute port workers during handling of the cables. They have not determined the likelihood for such a shock. Therefore, the number of fatal accidents in a Turkish shipyard area were selected. Barlas (2012) has determined that from the 115 fatal accidents, 18 accidents were due to an electric shock.

Employees that handle the LNG PowerPac® are exposed to the risk of an explosion of lethal impact and is therefore a threat for port employees of and a weakness for the LNG technology. The report of Barlas identified 18 deaths due to explosion with fuels, such as LNG, from a total of 115 fatal accidents in a Turkish shipyard from 2000-2010 (Barlas, 2012).

Vulnerability to cyber-attacks

Besides the safety of port employees, the security of port data is relevant. The data and operation processes need to be protected from hacks that inhibit port operations and for privacy reasons, as has been mentioned by Mo et al (2012).

The cyber security is a threat for SSE with wind energy, because this system demands a smart energy grid. Mo et al have mentioned, that a smart grid is more vulnerable to attacks than the old fashion grid, due to the size and complexity of the grid.

The vulnerability to cyber-attacks is an opportunity for the LNG PowerPac®, because the LNG PowerPac® does not require such a smart grid, the likelihood of a cyber-attack is smaller.

Pollution reduction

A technology that does not pollute the environment is considered a strength, to comply with stricter environmental regulations. The pollutions of focus that need to be reduced are: NO_x, SO_x, particular matter and VOC (Methane) and noise.

The reduction of pollutions is a strength for SSE, because it can eliminate the local production of noise, NO_x, SO_x, CH_4, and particular matter, because the wind turbines are off-shore and the electricity is supplied to the vessel by an cable (European Commission , 2005). However, some other energy source may be used to some emissions (nitrogen sulphur, methane and pm) are produced to compensate for balancing the grid. The SSE (fuelled by a European energy mix which includes a meagre 17 % renewable

energy) have been calculated to reduce emissions 97% NO_x, 0% SO_2, 94 % VOC (Methane), 89% pm, and 100 % noise, compared to the diesel auxiliary engine with MDO (European Commission , 2005).

The local production of noise and Methane is a weakness of the LNG technology. Although the emissions of NO_x, SO_x and pm are reduced. Tarnapowicz & German-Galkin have compared to an MDO diesel engine to an LNG engine and have calculated the reduction in emissions: 96 % NO_x, 98 % SO_2 and 100 % pm (Tarnapowicz & German-Galkin, 2016), ignoring Methane. The noise that the generator produces is approximately 100 dB (Tarnapowicz & German-Galkin, 2016). Anderson, Salo & Fridell have calculated a reduction of 95 % in NO_x and an increase in Methane (total hydrocarbons) of 31 %.

Carbon footprint

The emission of Carbon dioxides over the technology's lifetime is expressed in a Carbon footprint. The Carbon footprint includes the emission during operation, production and dismantling.

The Carbon footprint is a strength for the SSE technology and a weakness for the LNG PowerPac®, because the life cycle analysis, which has been performed by Thomason & Harrison (June 2015), indicates a net reduction in Carbon over the life cycle for wind farms. The life cycle emission for wind farms are lower compared to those of oil and gas. A life cycle analysis that compared SSE with LNG was not found, therefore, the life cycle analysis which was performed on the energy sources was used in this research.

Land use

The available space in the port area is limited, as is the space outside the port area. The available space may be for port businesses, housing, recreational purposes or natural habitat. Therefore, the energy source with the smallest energy sprawl is an opportunity. This, energy sprawl, exceeds the borders of the port, therefore, it is relevant to look at the energy source, which has a bigger impact on the global space.

McDonald et al (2009) have compared the energy sources LNG and wind for land sprawl per energy amount. Land sprawl for wind energy is estimated to be higher than for oil and gas by 2030. From the study of McDonald et al (2009), wind power requires 72,1 ha and oil and natural gas 44,7 and 18,6 ha per TW power produced in the USA.

The energy sprawl is an opportunity for the LNG technology, because it is fed by an energy technology that has less land sprawl and as a consequence leaves more space for other purposes. The SSE technology has an energy source, which has a bigger energy sprawl and therefore, it is considered to be a threat.

Local production

It is considered a strength of the technology, if it is applicable in all ports or all areas. The ports are part of a logistic network and vessels sail from port to port. If a new port joins this network, the network will become bigger, thus better. If a technology cannot be implemented in all ports, this new technology may impede the network function.

The SWOT analysis revealed that the LNG PowerPac® can be implemented anywhere, where for SSE a decent electric grid is required and implying sufficient renewable energy capacity (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015). Therefore, the local application is considered a strength for the LNG technology and a weakness for the SSE technology.

5 The Relevant Stakeholders

The preceding chapters focussed on the technologies, describing the technologies, their technical strengths and weakness and their broader impacts on society and the port, as opportunities and threats. To come to a suitable and promising solution all the values should be included in the decision-making process. Therefore, it is important that this batch of stakeholders includes a variety of stakeholders with a different point of view and power.

In this chapter the relevant stakeholders are determined, hereto, a stakeholder analysis was performed. The snowball-sampling method was carried out, to obtain the relevant stakeholders. This method was used because it allows a one-on-one conversation from which new relevant stakeholders can be obtained, who are unknown. The one-on-one conversation is preferred over a focus group, because from the individual stakeholders, new stakeholders can be obtained without the pressure or bias from the group.

The it is important to include a broad spectrum of stakeholders to obtain a diverse set of values, to prevent that relevant values are left out. Including these values is relevant, to prevent that values are not considered.

In the next section, section 5.1, a preliminary stakeholder selection is performed. From the interview with the selected stakeholders potentially relevant stakeholders are identified in section 5.2.

5.1 Preliminary Stakeholder List

A brainstorm session was used to determine a preliminary list of stakeholders. These stakeholders include direct and indirect stakeholders. Direct stakeholders are stakeholders who operate with the technologies, such as mechanics, vessel owners and terminal operators. Indirect stakeholders are those who are indirectly involved, such as grid operators and LNG producers. More so, these stakeholders include different organisations; such as the government, non-governmental organisations, businesses, and knowledge institutes.

From this list the preliminary stakeholders from different disciplines were selected with presumably conflicting values. Table 5—1 shows the preliminary list of stakeholders. More so, the preliminary selection included direct and indirect stakeholders and stakeholder from different organisations.

The stakeholder that were selected are: Cavotec, Deltalinqs, Milieudefensie (Friends of the Earth Netherlands), Municipality Rotterdam and the Port Authority of Rotterdam were selected. Cavotec was selected because it is a company that is presumed to be in favour of the implementation of SSE. Further, it is a company and is directly involved in the construction and design with SSE.
Deltalinqs was selected because it is an organisation that is indirectly involved in the implementation of either SSE or the LNG PowerPac®. Further, they are closely related to innovations in the port of Rotterdam. The preference was assumed to be LNG, because the port of Rotterdam houses many fossil fuels related business.
Milieudefensie is a non-governmental organisation that is assumed to prefer the SSE option. The Milieudefensie is an indirect stakeholder. They were involved in the development of the Maasvlakte II with a lawsuit.
The Municipality of Rotterdam is a governmental organisation and is indirect involved with the handling of the technologies. They have a legal power over the port and are. More so, they are shareholder of the port of Rotterdam.
The port of Rotterdam was selected because they are directly involved in the implementation of the

technologies. It is a business that presumably favours the LNG option, because of the port is one of the largest oil bunker ports.

Table 5—1 Preliminary stakeholder list.

ASEA Brown Boveri (ABB)	European Commission	Rotterdams Milieucentrum
Adem in Rotterdam	Friends of the Earth	*Rotterdam World Gateway* (RWG) Terminal
A.P. Moller–Maersk Group (APM) Terminals Maasvlakte II	InlandLinks	Schneider Electric Shell
Becker Marine Systems	Innovation Quarters	Stedin
Cavotec	Maersk Line	Stichting De Noordzee
Container Logistiek Maasvlakte	Milieudefensie	Stichting Natuurbescherming de VlinderStrik
Dienst Centraal Milieubeheer Rijnmond (DCMR)	Ministry of Economic Affairs	*Organisatie voor Toegepaste Natuurwetenschappelijk Onderzoek* (TNO)
Deltalinqs	Ministry of Infrastructure and Environment	TU Delft
Deltares	Municipality of Rotterdam	*Veiligheidsraad Regio Rotterdam* (VVR)
ESPO	Port Authority of Rotterdam	WNF
Euromax Terminal	*Rotterdam Climate Initiative* (RCI)	

5.1.1 Cavotec

Cavotec is a company that designs, engineers and supplies electrical products for the aviation and the maritime sector. In 2016, the most revenues are from ports and the maritime sector, followed by aviation. This maritime sector has the most orders (Cavotec, 22 February 2017). Partially, due to the decrease in the mining and oil & gas industry the aviation and maritime sectors ware profitable. The company focusses on strengthening the investment climate for infrastructure projects, especially in port and airports (Cavotec, 22 February 2017).

The company originated in 1974, as an incorporation of Specimas AB in Sweden. Later, it evolved to Cavotec. Previous year the company was owned by Cavotec Inet. Currently, the company has three types of shareholders, private individual (33 %), institutions (38 %), and management (29 %) (Cavotec, 22 February 2017).

Cavotec was selected because it is a company that manufactures and designs the shore side electricity systems. Therefore, Cavotec is a direct stakeholder. Further, Cavotec is a company that is not a member of Deltalinqs. Cavotec was involved in the design of cable management system for ports in China and in the implementation of SSE in the port of Rotterdam for Stenaline.

5.1.2 Deltalinqs

Deltalinqs is an interest group for harbour companies in the port of Rotterdam. Its members are for 95 % harbour companies. More than 700 companies join the entrepreneur's society. These companies create direct and indirect jobs and contribute for 3,2 % to the Dutch Net Gross Product (Deltalinqs, 1 Februari 2017).

In negotiations for new policies for the main port, Deltalinqs represents its member port business. Aiming for a consistent governmental policy, a level playing field, improved accessibility, reinforcement of the industry clusters, stimulation of the energy transition and improve training facilities.

On behalf of its members, the organisation strives for enforcement of the market position and sustainable growth. Further, Deltalinqs lobbies for social and political support in decision processes. Deltalinqs deals with different issues in the port; such as safety and security, infrastructure and accessibility, environment and sustainability, business climate, innovation platforms, and education and labour market, however, the focus is on entrepreneurship and innovation (Deltalinqs, 1 Februari 2017) (Deltalinqs, 2015).

Deltalinqs represents (a part) of the port companies in the decision-making process and lobbies on local, national and European level. Serving interests for many businesses, amongst, APM terminal.

Deltalinqs was selected because it is an organisation the is indirect involved with either SSE ore the LNG PowerPac. Adding to this their ambition to represent the port companies in during decision-making process.

5.1.3 Milieudefensie

Friends of the Earth international (FOEi) is an international network which consists of 75 national associated organisations (FOE, 2009). *Friend of the Earth Europe* (FOEE) is a collaborating organisation of several European national organisations. Friends of the Earth represent the United States, Milieudefensie is the Dutch branch. Milieudefensie is financially supported by the Dutch government, the European Union, and sustainable companies.

The FOE organisation strives for a more sustainable and just world (FOE, 2009). The Dutch branch has similar goals, a more sustainable and just world, therefore collaboration with the citizen is fundamental (Milieudefensie, n.d.). Currently (2015), the Milieudefensie collaborates on four topics with FOEi; Food Sovereignty, Economic fairness and Resisting Neo-liberalism, Climate Justice and Forests and Biodiversity (Milieudefensie, 2015).

On a European level, the Dutch branch of FOE collaborates with *European Environmental Bureau* (EEB) and the European Federation for Transport and Environment. To the FOEE, Milieudefensie contributes to the Agrofuels campaign, the Land of Gabbing campaign and Resources Use, Food and Agriculture and Extractive Industries (Milieudefensie, 2015).

The Dutch organisation was closely involved in the planning and negotiations about the Maasvlakte II. In 2008 the Milieudefensie, Municipality Rotterdam and Port of Rotterdam signed a covenant. This was a more solid agreement, in which sustainable goals and public well-being were included.

Milieudefensie was selected because, it is a non-governmental organisation that aims to protect the environment. The Milieudefensie is an indirect stakeholder, who initiated a law suit against the port of Rotterdam and the Municipality during the development of the Maasvlakte II.

5.1.4 Municipality of Rotterdam

The Municipality has a town council which represent its inhabitants, Rotterdam has 45 members in the council, with the mayor as chairman. The council members are members of political parties and are directly chosen by votes of citizen. The executive board of the town council is the Mayor and Aldermen, under the chairmanship of the mayor, each councillor has its policy area, the aldermen are chosen from the town council members by democratic voting.

The council has different tasks, on is to represent the citizen in a decision process. (Taken, bevoegdheden en instrumenten van de Raad, n.d.). The other two tasks are: the composition of frameworks, and the verification of action of the board (Mayor and Aldermen) (Taken, bevoegdheden en instrumenten van de Raad, n.d.).

The Municipality of Rotterdam was selected because it is a governmental organisation that represents the citizen of Rotterdam. Further, they were involved in the development of the Maasvlakte II and got a lawsuit from Milieudefensie.

5.1.5 Port Authority of Rotterdam

The port authority is an independent organisation that manages and develops the port and port business and strives for smooth shipping dynamics in the port and coastal area. The port is not owned by the port authority, although it is owned by the Municipality of Rotterdam and the Government and other companies.

The organisation strives for an efficient, safe and sustainable port in collaboration with partners. This continuous improvement is performed to improve the competition position of the port and for the quality environment.

The Municipality was selected because they have daily supervision over the port and port area. Morse they are a company that had lawsuit against them due to the development of the Maasvlakte II.

5.2 Stakeholder Selection

In previous section, section 5.1, five stakeholders were selected from a preliminary list. This preliminary stakeholder selection may be incomplete. Therefore, interviews with these preliminary stakeholders are conducted, to obtain new relevant stakeholders.

New stakeholders were obtained from a preliminarily set of stakeholders is known as: snowball sampling. Like a snowball, the set of stakeholders starts out small and other stakeholders may be added to this set, from whom new relevant stakeholders can be obtained. After identification of these other stakeholders, the stakeholder selection can be adjusted, however, this iterative step was not performed. Hereto, an assumption was made that the preliminary stakeholder selection includes all relevant stakeholders.

The snowball method was used to identify new stakeholders from the semi-structured interviews, because it is easy to use and it allows to have a one-on-one conversation, in comparison to a focus group.

The obtained stakeholder by snowball sampling, can be included in a new stakeholder analysis. These stakeholders were obtained by deliberately asking questions about collaborations and by the

stakeholders that introduced them in their response. Hereby, the interviewee introduced the new parties in the conversation. The context, in which these new stakeholders were mentioned, is decisive. Stakeholders which were mentioned in the context of shore side electricity, alternatives of shore side electricity or improvement of vessels originated air pollution. Table 5—2 shows the obtained stakeholders from the snowball sampling method.

Table 5—2 Identified stakeholders from preliminary stakeholder selection.

(Appendix 7 Interview with Expert 5, Appendix 8 Interview with Stakeholder 1, Appendix 9 Interview with Stakeholder 2, Appendix 10 Interview with Stakeholder 3, Appendix 11 Interview with Stakeholder 4 and Appendix 12 Interview with A. Castelein), a) data obtained from interview with (Duursma & Postma, 2017)*, b) data obtained from* (Erasmus University Rotterdam, 12 September 2014).

Cavotec	**Deltalinqs**	**Milieudefensie**	**Municipality Rotterdam**	**Port Authority of Rotterdam**
ABB	European Union	*Instituut voor Milieu- en Systeemanalyse* (IMSA)	DCMR	The Cabinet[a]
Becker Marine Systems	Greeneries of the Westland	Knowledge institutes	European Parliament	Environmental organisations[a]
DHV Royal Haskoning	Petrochemical industry	Milieucentrum	Port of Amsterdam	House of Representatives[a]
Dutch government	Milieufederatie Zuid-Holland	Milieufederatie	Port of Antwerp	Port of Antwerp[a]
Port of Hamburg		Natuurmonumenten	Port of Bremen	Port of Hamburg[b]
Port of Los Angeles			Port of Hamburg	Port of Houston[b]
Schneider Electric		*Federatie Nederlandse Vakbeweging* (FNV)	Shell	Port le Havre[b]
Stedin		Zuid-Hollands landschap	VRR	TNO[a]
Stenaline				Wuppertal Institut[a]

5.2.1 Cavotec

Technical companies, a ferry company, a grid operator, ports, and a governmental organisation were identified as new relevant stakeholders from the interview with Cavotec. The complete interview with Stakeholder 1 (personal communication, 28 March 2017) is attached to this research in Appendix 8 Interview with Stakeholder 1.

The technical companies develop (partially) the shore power installation or supporting infrastructure. The companies ABB, Becker Marine Systems, Schneider Electrics were mentioned as collaboration partners. ABB provided frequency converters for shore power installations, that can bridge the gap between the 50 Hz grid and the 60 Hz vessel. Becker Marine System collaborated in the development of LNG barge for the port of Hamburg, Schneider Electric designs frequency converters.

Stenaline was mentioned as a ferry company that uses shore power during berth. This installation was designed by Cavotec according to Stenaline's requirements, amongst, universal connectivity. Additional capacity to feed the 11 kV vessels was implemented, cables with an optic fibre were designed for communication.

A Dutch grid operator was mentioned, possibly Stedin, whom was involved in the implementation of an extension to the grid to supply the Stenaline ferries. The availability of enough capacity and a grid that can support this capacity, was a hot point.

Other ports were mentioned, the port of Los Angeles and the port of Hamburg. In the port of Los Angeles, Cavotec delivered the cable management system. The port of Hamburg designed in collaboration with Becker Marine Systems the LNG barge.

The Government of California was mentioned because, it had a strong influence on the introduction of shore power in the Californian port (Port of Los Angeles). Further, the Dutch government was mentioned in the interview, with the emphasis on the government's power to make shore power compulsory, hereby taking the Californian government as an example.

5.2.2 Deltalinqs

Deltalinqs referred to the European Union, the petrochemical industry and the Milieufederatie Zuid-Holland in the context for a sustainable transition. The complete interview with Stakeholder 2 (personal communication, 14 April 2017) is added to this report in Appendix 9 Interview with Stakeholder 2.

In the interview the influence of the European Union was mentioned, it stimulates the port business to make sustainable decisions by regulations. However, these regulations can be interpreted as limitations by some port businesses.

The cooperation of the petrochemical industry was mentioned as an important part to make a transition in the energy infrastructure and emission reduction. However, to make this transition a financial barrier was mentioned, namely, if the industry moves away from fossil fuel than an alternative business model should be developed in order to survive. For this new model the collaboration with the greeneries is important.

Another party, the Milieufederatie Zuid-Holland, has a signal function in the development process of the port according to Deltalinqs. The Milieufederatie was appointed as an opponent of, what Deltalinqs sees as, sustainable development. Therefore, the Milieufederatie was seen as an important player for strategic reasons in the development process.

5.2.3 Milieudefensie

The interview with Stakeholder 3 (personal communication, 10 March 2017) from Milieudefensie, showed new stakeholders. The stakeholders were mainly: other environmental *non-governmental organisations* (NGOs), a union, "vakbond FNV" and an institute for environment and system analysis, IMSA (NL: *Instituut voor Milieu- en Systeemanalyse*). In general knowledge institutes were mentioned as partners to come up with solutions for environmental issues. More details are in the interview, which is in Appendix 10 Interview with Stakeholder 3.

The environmental NGOs that were deducted from the interview are the Milieucentrum, Milieufederatie, Natuurmonumenten, and Zuid-Hollands landschap. At that time, Milieudefensie and

the port of Rotterdam were negotiating the agreement. Milieudefensie approached the Milieucentrum, because they shared the critical stance about the air quality in Rotterdam. Although they shared this view, there was no cooperation between the parties. In the same period, a second covenant was active, including (Port of Rotterdam), Milieufederatie, Natuurmonumenten, Zuid-Hollands landschap. Despite approaching this covenant group, it was a separate covenant, that did not collaborate with Milieudefensie.

The union FNV was mentioned because an (energy) transition implicates a change in job opportunities or a change in job qualifications. In the port area there are agreements with unions for the opportunities and qualifications.

The IMSA was the neutral party in the covenant between the port of Rotterdam and Milieudefensie. The IMSA gave assistance during the negotiations.

Knowledge institutes were mentioned as relevant parties in development in the interview with Stakeholder 3. As mentioned, the Milieudefensie addresses an issue and collaborates with knowledge institutes to find a suitable solution. Knowledge is either internal present in the organisation (Milieudefensie) or is external present at a knowledge institute (personal communication, 10 March 2017).

> *"The problem was analysed and in cooperation with other knowledge institutes potential solutions were composed."* (Stakeholder 3, personal communication, 10 March 2017).

> *"Knowledge institutes can contribute by analysing the impacts by running a pilot."* (Stakeholder 3, personal communication, 10 March 2017).

5.2.4 Municipality of Rotterdam

The interview with the Municipality of Rotterdam (Stakeholder 4, personal communication, 22 February 2017) revealed other governmental organisations, ports, and a petrochemical company. The complete interview with stakeholder 4 from the Municipality is in the Appendix 11 Interview with Stakeholder 4 .

The *Dienst Centraal Milieubeheer Rijnmond* (DCMR) and *Veiligheidsregio Rotterdam-Rijnmond* (VRR) are governmental organisations that were mentioned. They were considered important players in the shore power discussion. These organisations may be seen a part of the Municipality, however, according to Stakeholder 4, DCMR and VRR are separate organisations because of the have different influence.
Another governmental organisation, which was brought up in the interview, is the European Parliament. The parliament can alter directives to support or undermine shore power. The municipality operates in compliance with these directives.

The ports of Amsterdam, Antwerp, Bremen, and Hamburg were mentioned by the municipality as important stakeholders in the transition. To accomplish an energy transition without jeopardising the market position of the port of Rotterdam, alliance with these nearby ports is crucial.

The petrochemical company Shell was mentioned in the energy transition. Shell may foster the energy transition by developing other fuels or processes, such as, *gas-to-liquid* (GTL).

5.2.5 Port Authority of Rotterdam

The Port of Rotterdam was mentioned in a news article (Duursma & Postma, 2017) and in an interview (Erasmus University Rotterdam, 12 September 2014) with the press. The transcript of the interview is attached in the appendix, Appendix 12 Interview with A. Castelein.

Governmental organisations were mentioned, the house of Representatives and the Cabinet (Duursma & Postma, 2017). From the interview the house of Representatives was a proponent for closing the coal plants. However, the Cabinet has the power to close these plants, but, it did not make that decision.

Environmental parties in general were mentioned (Duursma & Postma, 2017). They were in favour of closing the coal plants. Hereby, abandoning fossil fuel as a raw material, to become more sustainable.

In the interview by Duursma & Postma (2017) TNO was mentioned. This independent research institute doubted the necessity to abandon fossil fuel to become more sustainable. Another research institute, the Wuppertal Institut, that is specialised in climate, environment and energy, published two strategies to make the energy transition. The first was the recycling of CO_2 and the second was the implementation of renewable energy sources (Duursma & Postma, 2017).

The port of Houston was mentioned in the interview (Duursma & Postma, 2017). This American port is a key stakeholder in the global energy transition, like the Port of Rotterdam, because, the port of Rotterdam has an impact on the oil demand and the national income. Based on the interview, the port of Houston is convinced that oil and gas will be dominant, and business will continue, in contrast to the port of Rotterdam. This entails that the fossil fuels will be used in the future for raw materials and energy, for example, for energy supply for vessels at the quay.
In the interview (Erasmus University Rotterdam, 12 September 2014) the ports of Antwerp, Hamburg and Le Havre were mentioned as competitors of the port of Rotterdam. They compete to attract businesses; these businesses will invest in the port and will generate money.

5.3 Summary of the Stakeholder Analysis

This chapter aims to determine the relevant stakeholders. Selecting relevant stakeholders for the decision process is essential to determine a well-suited technology, hereby, using stakeholders' values as design criteria. To prevent an unsatisfying outcome all stakeholders, a set of representatives are selected for research. The marginal stakeholders should not be excluded. The sub-question which is answered in this chapter is: Who are the relevant stakeholders?

In this chapter the relevant stakeholders were identified and described by a stakeholder analysis. From a preliminary stakeholder list, stakeholders were selected. The selection includes stakeholders from different type of organisations (business, governmental organisation, non-governmental organisation or a knowledge institute). More so, the selection includes direct and indirect stakeholders.

To determine the relevant stakeholders and to identify other relevant stakeholders the snowball-sampling method was carried out. The relevant stakeholders in this report are: Cavotec, Deltalinqs, Milieudefensie, the Municipality of Rotterdam, and the Port authority of Rotterdam.

Cavotec is a company and is directly involved in the construction and design with SSE. Therefore, they are in favour of the implementation of SSE. They are involved in the design of cable management system for ports in China and in the implementation of SSE in the port of Rotterdam for Stenaline.

Deltalinqs is an organisation that lobbies for the interests of port businesses, therefore, they are closely related to innovation projects in the port of Rotterdam. They are indirectly involved in the implementation of either SSE or the LNG PowerPac®. The preference is assumed to be LNG, because the port of Rotterdam houses many fossil fuel-based business.

Milieudefensie is a non-governmental organisation which aims to protect the environment. Milieudefensie is an indirect stakeholder, because they are not direct users or producers of the technology. They can lobby for the technologies in decision-making processes. Milieudefensie was an opponent in the development of the Maasvlakte II and initiate a lawsuit against the port of Rotterdam and the Municipality of Rotterdam, to prevent the pressure on nature.

The Municipality of Rotterdam is a governmental organisation and is indirect involved with the handling of the technologies. They have a legal power over the port and are, shareholder of the port of Rotterdam.

The port of Rotterdam is an indirect stakeholder and is involved in the implementation of the technologies. The port is one of the largest oil bunker ports. In developing the Maasvlakte II, they got a lawsuit from Milieudefensie to create more space for nature and to improve the air quality.

Other relevant stakeholders, that were obtained and can be included in further research are: Milieufederatie, the national government, the port of Antwerp, petrochemical industry (Shell), knowledge institutes (TNO), Stedin, Becker Marine Systems, and the FNV vakbond.

6 The Articulation of the Stakeholder Values

In the previous chapter, chapter 5, relevant stakeholders are determined by a stakeholder analysis. These stakeholders have different work fields and favour different technologies to reduce the pollutions in the port area. To determine which technology is best suited, a decision should be made which incorporates the values of stakeholders.

The aim of this chapter is to deduct attributes from the document analysis and are relevant for the decision (SSE or LNG). Preferably these attributes are mentioned by the experts in the interviews and can therefore be obtained directly from the SWOT analysis. An attribute is a measurable objective that has an impact on the value(s).

Hereto, value tree will be composed using the defined public values as starting points. It is necessary to define terms for the public values because stakeholders (may) articulate these values differently, further, their nouns or vocabulary may be different for a similar value(s). To account for this mismatch, a document analysis, like in the value-focused thinking analysis, is performed to deduct public values. The document is composed by several relevant stakeholders, the port authority of Rotterdam, Deltalinqs and the Municipality of Rotterdam.

The stakeholder value tree are composed from the values, objectives and means from the document analysis. The terms in the values trees are organised using the questions from Reed. These questions are in section 2.7

The individual stakeholder value trees are determined using value-focused thinking. These are merged into one value tree, with attributes at the end of the branches. With these attributes are used int eh MCA in chapter 7.

In section 6.1, the relevant public values are defined. The articulation of these values are described for each stakeholder in sections 6.2– 6.6, in alphabetical order Cavotec, Deltalinqs, Milieudefensie, the Municipality of Rotterdam, and the Port authority of Rotterdam. Next in section 6.7, the list of criteria is described, which is composed from the values trees from the individual stakeholders. A summary of this chapter is given in section 6.9.

6.1 The Relevant Values for this Research

A public value is something that is valued by the public. This value is significant if, there is a willingness to make a sacrifice, as is mentioned by Kelly et all 2002 as is cited in the book of Benington and Moore (2011). This is mentioned in section 2.1.2.

In the main question the term ‘sustainable’ refers to a technology that serves the 3Ps (People, Planet and Profit) for the current generation and future generations. Therefore, three public values are defined, one for each “P”.

Because the stakeholders have different interpretations and vocabulary, miscommunication may be the possible. Therefore, the terms for the public values are deducted from a document using value focused-thinking. These pubic values are required as initial starting points to assemble the stakeholder values trees.

The aim of this section is to obtain universal terms for public values, which are endorsed by most or all stakeholders to prevent miscommunication. The articulation of these public values may differ and will be determined in sections 6.2– 6.6.

The document, from which the terms are obtained, is Havenvisie 2030 (Port of Rotterdam, 2011). This document is written by many parties, amongst three relevant stakeholders, namely, the port of Rotterdam, Deltalinqs, and the Municipality of Rotterdam. Other parties are the Province of Zuid-Holland and the Government of the Netherlands.

The method described by Reed, to obtained and categorise values was used to determine the public values. First a document analysis is performed, scanning for means, objectives, and values. These are then categorised to obtain the public values using the questions which are proposed by Reed. “This object is an aspect of what?” and “Which aspects does it contain?” (Reed, M. et al, 2009). This method is described in more detail in section 2.7.

From this analysis three public values were identified, economic growth, safety, and sustainability. These terms were used in the stakeholder value trees. Based on the document analysis of “Havenvisie 2030”, the term “economic growth” contributed to the public by business climate or companies, job opportunities, and knowledge. Therefore, the Oxford dictionary definition of economic growth is suitable: an increase in the economy of a country or an area, especially of the value of goods and services the country or area produces.

The Oxford definition of the term “safety” is: the condition of being protected from or unlikely to cause danger, risk, or injury. This definition was selected, because it fits with the mean objectives from the document analysis, such as; nuisance and health. This value entails the protection of people from hazardous chemicals and illegalities.

The definition by the Oxford dictionary which is adopted for the term “sustainability” is: the ability to be maintained at a certain rate or level. This definition was selected because it fits with the mean objectives, climate change, ecological footprint, and environment, which were obtained by the document analysis of the Havenvisie 2030. Sustainability aims to maintain the environment at the same level.

6.2 Cavotec

The public values where Cavotec appeals to are: economic growth, safety and sustainability and were obtained by a document analysis using value focused thinking. Values, means and objectives were obtained, and composed into a value tree to determine how they are articulated. The value tree, with at the end of the branches the attributes, is in Figure 6—1.

An attribute is a measurable objective, as is explained in section 2.7. The terms for the public values were obtained from a document analysis in section 6.1. The Cavotec objective and attributes were obtained from the 2016 annual report (Cavotec, 22 February 2017).

The aspects that contribute to economic growth, which were obtained from the document analysis, are: niche actor, job opportunity and long-term relations. *Niche Actor:* Cavotec desires to add value to the bigger network of companies by connecting existing companies to improve business. More so, new sophisticated systems are introduced to the market that allow companies to execute activities in a new or more efficient way. Examples of niche technologies are: the Moormaster which replaces lines by vacuum pads decreasing the mooring time (Cavotec, 22 February 2017) or the A*utomatic Plug-in System* (APS) which automatically connects electric vehicles or cranes to the electrical network (Cavotec, 22 February 2017). The attributes that were derived from the document are: the number of connections and the number of new, more efficient, electric systems to reduce emissions.

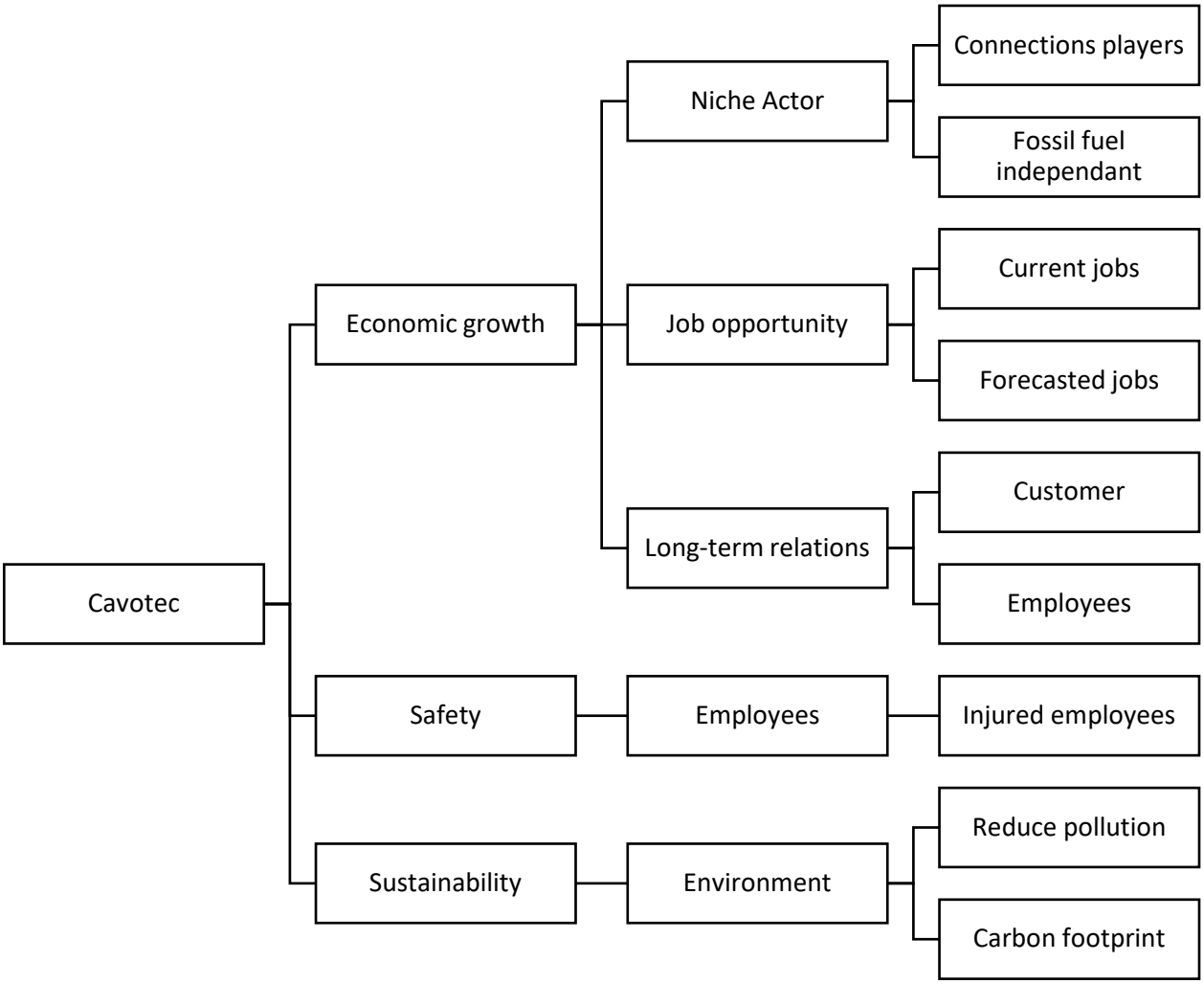

Figure 6—1 Value tree of Cavotec.

Job opportunity: The job in the business and for employees are important, hereto the supply and demand of good employees are essential, for present and future operations. This contributes to the job opportunities for current and future generations. To determine the number of job opportunities which Cavotec can offer, they had invested in the human resources department to develop projects to

gain insight in the number of current employees, vacancies and future job and skills. The attributes that were obtained to measure the jobs are: the number of current jobs and the future number of jobs. *Long-term relations:* to Cavotec long-term relations with customers and employees are important because it allows knowledge to be exchanged, to obtain better solutions for the customer and it fosters new creative ideas between employees. The knowledge to the customer is provided in either technical expertise or regulatory knowledge. Sharing this knowledge is favourable to solve complex problems and deal with complex situations. Besides the service of knowledge to their customers, Cavotec invests in the knowledge of employees. The knowledge exchange between employees is fostered by an open working environment to create new ideas and develop skills. The attributes that were obtained are: the number of customers with whom Cavotec shared knowledge and the number of employees with new knowledge.

Safety is a value that is articulated by Cavotec as: the safety for employees and customers to prevent human injuries. Further, safety includes the well-being or health of employees.
Employees: To prevent human injuries during operation a safe work environment is required, hereto, safety zones or remote control are implemented to create a safe operating distance. More so, injuries from exhaust emissions are minimised by reduction of emissions. To create a safe operating distance, systems such as *Human Operator Interface* (HOI) and *Radio Remote Control* (RRC) were developed. To minimise emissions *Alternative Marine Power* (AMP) systems and AMPBattery were developed, reducing the diesel consumption. The AMPBattery technology has zero emissions during operation (Cavotec, 22 February 2017). More so, the well-being and mental health of employees is important. Hereto, an inspiring work environment and a balance between work and private life prevents mental problems. From the document an example was obtained, Cavotec invested in analyses of key functions, to be able to match desired career paths with required vacancies (Cavotec, 22 February 2017). The attributes that was obtained from the document analysis is: injured employees.

To support public value “sustainability” the noise and emission pollutions need to be reduced by introducing electric alternatives for fossil fuel engines to preserve the environment. *Environment:* The noise and emissions that need to be reduced, originates from fossil fuel auxiliary engines. The use of these fuels is limited by creating more efficient systems and by introducing electric systems. More so, electric machines, which substitute the auxiliary engines, produce less noise during operation. Examples of technologies that reduce the consumption of fossil fuel were obtained by the document analysis, such as: the systems of *Alternative Marine Power* (AMP), AMPBattery and electric vehicles. The attributes that were obtained are: the reduction of pollution (noise) and the Carbon footprint.

6.3 Deltalinqs

The means objectives that were obtained can be classified in economic growth, safety, and sustainability. These values were determined by a document analysis on the document, Strong enterprises, Powerful Main Port (Deltalinqs, 2015). Figure 6—2 on page 78 shows the value tree.

Deltalinqs contributes to the value of economic growth by improving the business climate to attract more business. Further, economic growth is concerned with the number of jobs. More so, Deltalinqs considers economic growth with employees’ knowledge and skills and education as a business investment.

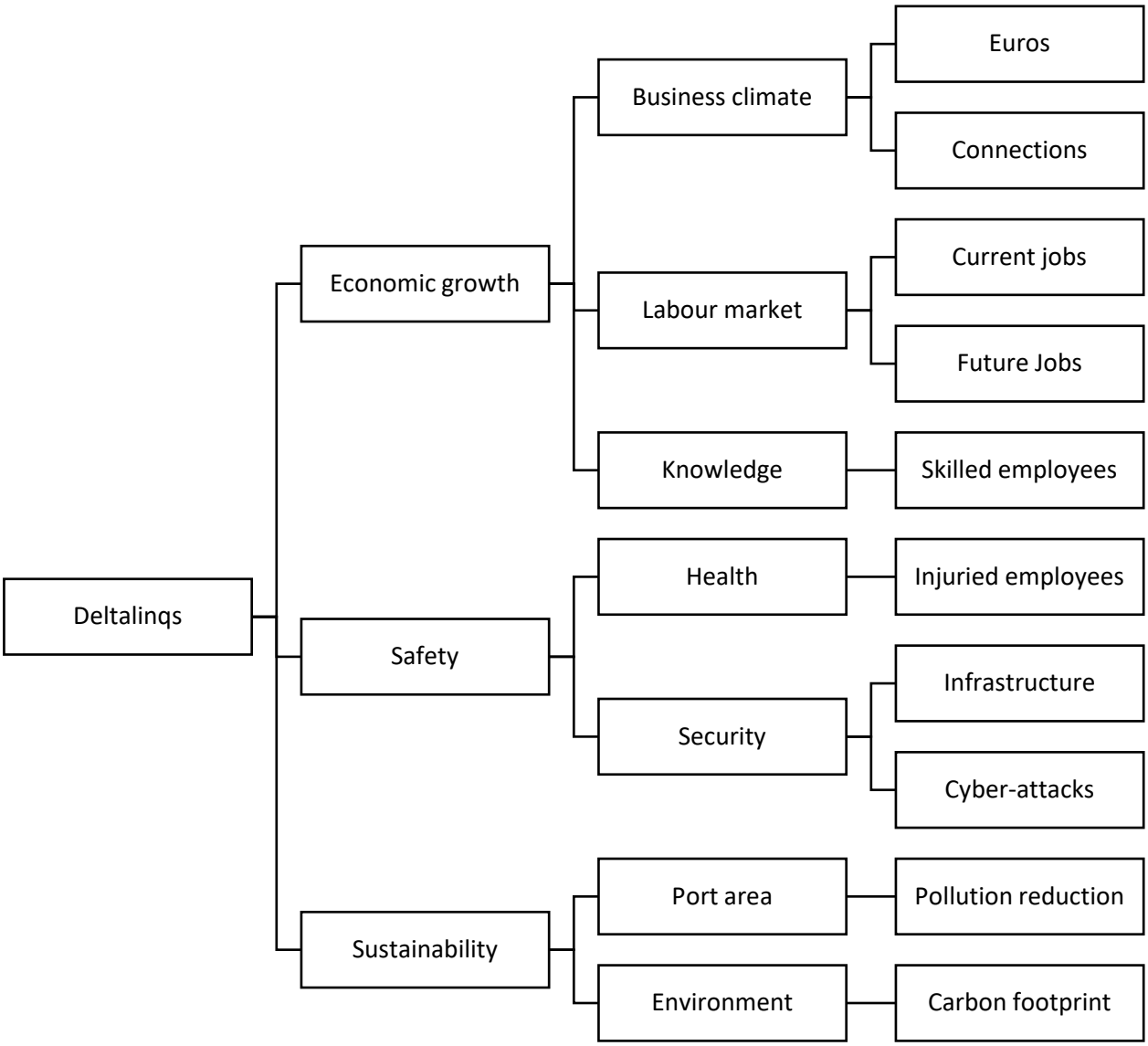

Figure 6—2 Value tree of Deltalinqs

The *business climate* is to improve the regulatory and financial conditions for business with the aim to make the port of Rotterdam an appealing location for business. Hereto, a profitable and reliable

business case is important, this implicates that the business wants to make profit. Further, the effort to comply with legal regulations needs to be more rewarding, hereto, long term contracts are required to increase the stability for the business and the amount of legal paper work needs to be decreased. Another aspect is that the port area needs to be easily accessible by boat, vehicle or via the digital network to improve the connection with others.
The attributes that were deducted from the document analysis are: the number profitable euros and the number of connections with other players. The number of euros and the number of connections are applicable as criteria for a decision between an SSE system or an LNG PowerPac.
The value of *Labour market:* is important for Deltalinqs and is concerned with achieving the right amount of current and future employees. Hereto, campaigns were organised to promote the port area as an attractive and inspiring work place. The attributes that were obtained are: the number of current job opportunities and the number of future job opportunities.
Knowledge: Knowledge is an important aspect for Deltalinqs of a good business climate, because knowledge is seen as an investment in current and future employees to achieve financial success. From the document analysis, Deltalinqs developed in education programs for pupils and employees. Hereto, Deltalinqs consulted with business to determine the required knowledge and skill for (current) employees. More so, training facilities were developed such as the RDM training plant. The attributes that were obtained are: to what extent do the current skills fit with the future.

Safety is a value that deals with the health and security of port employees and their work environment.
Health: is consists of the health of the port employees. The aim is to prevent human injuries and health problems for the port personnel. From the document analysis measures to effectuate the prevention of injuries were obtained, such as: the basic safety package. Adding to this, is the knowledge network which was introduced to improve the safety network by members and professionals sharing their knowledge and experiences. The attribute that was obtained is: the number of injuries for port employees.
Security: entails the security of the digital and physical infrastructures from cyber-attacks. The number of cyber-attacks did increase the last decade and post a serious threat for in the future. Deltalinqs is involved in the protection of the port businesses, as an overarching actor. The aim is to create infrastructure which are resilient to these attacks and to ward off cyber-attacks by sufficient security. The attributes that were derived from the document are: the probability of cyber hacks on the port infrastructures and the probability of cyber-attacks on the digital infrastructure and data.

Sustainability is a value that aims to improve the environment by reducing the use of fossil fuel and by minimising the production of pollutions, such as noise, odour and particles.
The surrounding *port area:* is important. Hereto, pollutions (noise, particles and odour) must be minimised to avoid soil pollution and nuisance of stakeholders in the port area. The particles that need to be reduces are NO_x emissions, Sulphur emissions, such as, *Hydrogen sulphide* (H_2S) and SO_2, and *volatile organic compounds* (VOCs). The attributes that were obtained from the document analysis are: the reduction of pollutions (noise, NO_x, SO_x).
Environment: is an important aspect of sustainability for Deltalinqs, hereto, the Carbon footprint needs to be reduced by limiting the consumption of fossil fuel and energy. The more energy efficient the port area is, the smaller the Carbon footprint will be. Hereto, cooperation between port business is required to reuse heat and CO_2. The attribute is: reduction of the Carbon footprint.

6.4 Milieudefensie

To derive a value tree from documentation a three-step analysis was performed. From the analysis of the annual report (Milieudefensie, 2015) a value-tree for Milieudefensie was composed. Figure 6—3 on page 80 give the value tree.

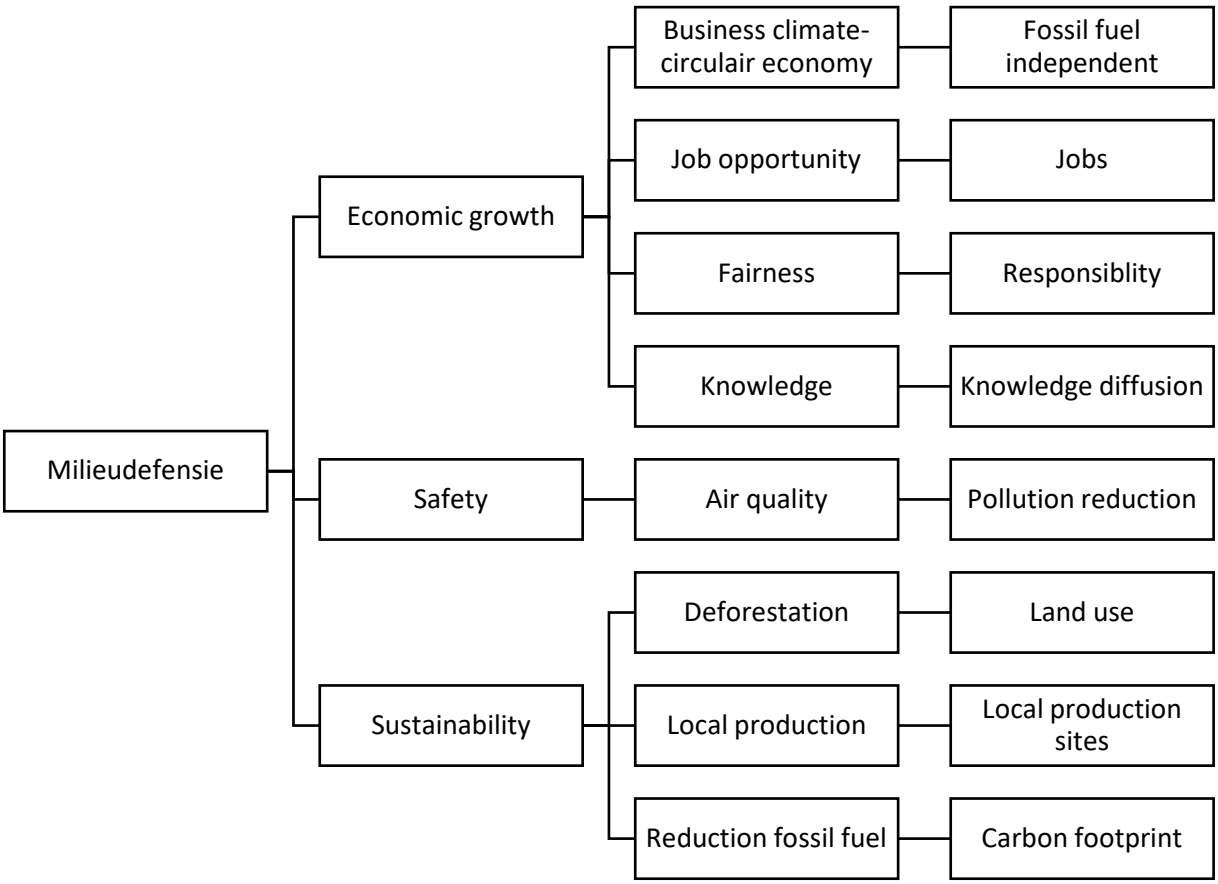

Figure 6—3 Value tree of Milieudefensie.

The value “economic growth” is important for Milieudefensie and implies economic improvement for the world population not just the population closely related to the port businesses. In this report the term “economy” had been used instead, because economic growth is not present in the report.

Milieudefensie recognises four sub values: the contribution to the business climate, the contribution of job opportunities, the contribution to fairness, and the contribution to public knowledge. The value *business climate:* is concerned with altering existing revenue streams to obtain more responsible revenue stream. Milieudefensie pushes business to invest merely in responsible (non-fossil) funds instead of in the land grabbing palm oil industry. Another aspect of the business climate, which was derived from the document analysis, is the implementation of a new economic system that includes social and environmental externalities besides the economic values. The attribute that was deducted is: the extend to be fossil fuel independent.
Job opportunity: Job opportunities are important to Milieudefensie to foster a global economic growth. Hereto, Milieudefensie aims to safeguard the job opportunity for “real jobs”, which allegedly will disappear, in a world that moves away from fossil fuels. The attribute that was obtained is: the number of jobs.
Fairness: fairness is important to Milieudefensie for economic growth where all benefit from, not mere the big companies but also the local population. Hereto, Milieudefensie stats that companies should take responsibility for environmental degradation and pollution for the local people and share the profit in a fair way. An example, which was obtained from the document analysis, is that Shell is held responsible for the environmental pollutions in the Niger delta. Another example for a fair business is, the energy transition that contributes to affluent in developing countries and in developed countries. The attributes that were derived from the document analysis are: the extent to which the company take responsibility for environmental degradation.
Knowledge: Knowledge is important aspect of economic growth for all people, because by awareness and education people have influence in the financial world. From the document analysis example were obtained, such as, the awareness was raised on health effects of poor environmental quality; or awareness was raised about the impacts of the value chain of soy; or the implications of TTIP (*Transatlantic Trade & Investment Partnership*). The attribute that was obtained from the document is: the extent to which knowledge is shared.

Safety is an important value for Milieudefensie and is articulated as the prevention of injuries or health problems from pollutions. Hereto, the *air quality* is important. Examples to prevent health hazards for the population were obtained from the document analysis, such as, the support to implement environmental zones un Utrecht. To improve the air quality in cities, Milieudefensie lobbies for stricter regulations and raises awareness for the poor air quality in cities. In the document Milieudefensie proposed to improve the air quality by reducing pollutions (noise, smog, NO_x and pm) and odour by downscaling farms. Therefore, the attribute to measure the air quality is: the reduction of emissions.

Sustainability is the protection of the Earth’s climate, flora and fauna, by reducing the impact and influence of human activity. Hereto, the air quality needs to be improved, the rich and living rain forests should be preserved, the biodiversity should be improved, and the consumption of fossil fuel should be reduced.
Deforestation: is the destruction of forests for soy or energy crop plantations for the food or energy demand of the West. The hectares of forests should be maintained to sustain the biodiversity and indigenous people. The obtained attribute for deforestation is: the hectares of land use.
Local production: More so, Milieudefensie proposed to produce food and energy locally, to prevent emissions from transport and to prevent pollutions from intensive mega farms. An example which was obtained from the document analysis is the local production of soy. The attribute for local production

is the number of possible locations to implement the technology.
Reduction fossil fuel: the last aspect is the reduction of fossil fuel consumption, because the emissions from fossil fuels contribute to the global warming. Fossil fuel is consumed for energy, transport and as a raw material. An energy transition is required to switch from fossil fuel to alternative sources to prevent global degradation. The attribute to measure this aspect is: The Carbon footprint.

6.5 Municipality of Rotterdam

The value tree for the Municipality of Rotterdam was derived by a document analysis on the document "Stadsvisie Rotterdam" (Gemeenteraad Rotterdam, 29 november 2007). Figure 6—4 on page 83 shows the value tree.

To determine the value economic growth, the term "economy" had been used to construct the value tree, because "economic growth" did not appear in the strategic document. Milieudefensie is a stakeholder whom was an author of the "horizon 2030" document.

The economic growth is an important value for the Municipality, by supporting an attractive business climate the municipality generates income. More so, the businesses provide job opportunities for the local population. The municipality contributes to economic growth by supporting knowledge, which is seen as a financial investment to maintain a high level of knowledge and skills. These skilled employees enhance the attractiveness of the business climate.
B*usiness climate:* is important for entrepreneurs to settle in the area of Rotterdam, they provide an income for the municipality. The municipality will reinvest the money in the municipality. Important are entrepreneurs whom create new, innovative businesses either as self-employed or *small and medium sized enterprises* (SMEs). New innovative business, such as, renewable energy businesses expand the current business climate.
Further, the municipality recognises that good connections between (inter)national business should be available for people and goods. Adequate connections by railway of air will enhance the trading. Based on the document analysis two attributes were obtained for the business climate: the extend to be fossil fuel independent, and the number of connections.
Job opportunity: Jobs contribute the social economic well-fare of the population. The municipality has the task to provide enough adequate job opportunities. Hereto, the municipality need to balance the ratio of higher and lower education jobs. Further, the supply and demand of enough qualified employees should be balanced. The attributes that were obtained are: the ration of high and lower education jobs, and the number of current and future job opportunities.
Knowledge: Knowledge is seen as an investment in a business climate to spur a high-level a of expertise. Hereto, knowledge cluster and knowledge networks are created. The knowledge clusters are Leiden Bio Science Park, Science Port Holland Schieveen, Technopolis Delft where knowledge is generated. Further, to foster the level of expertise and to meet the demand from the business, the number of skilled employees with a degree should be increased in Rotterdam. The attributes that were deducted from the document analysis are: the extent to which knowledge is shared, and to what extent do the current skills fit with the future.

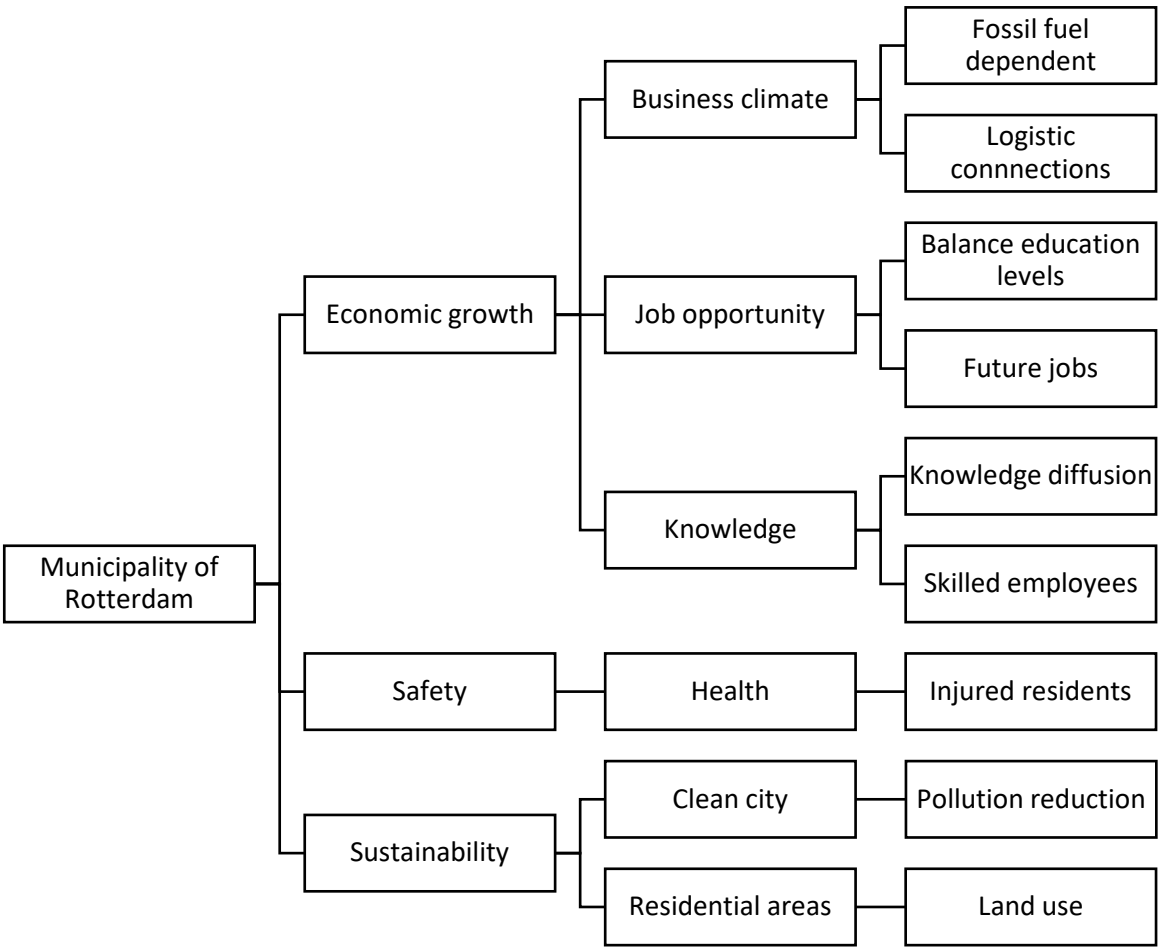

Figure 6—4 Value tree of the Municipality of Rotterdam.

The public value "safety" is concerned with the *health* of the local inhabitants of the municipality. Human injuries of health hazards are prevented by the municipality by accounting for external safety, noise, and air quality in projects. An example for external safety, which was obtained, is accounting for human health hazards due to the transport of harmful chemicals in a new housing project. To effectuate the safety of its inhabitants the municipality aims to reduce CO_2 emissions and noise pollutions. To measure this value (safety), the number of injuries of residents are monitored.

The sustainability is articulated as the care for the city's environment, to effectuate this the CO_2 emissions are reduced, and environmental-friendly residential areas are created.
Clean city: To enhance the cleanliness of the city and reduce the CO_2 emissions, alternative transportation and the use of alternative fuels are stimulated, such as, bicycles and hydrogen busses.
Residential areas: The other obtained sustainability aspect is designing environmentally friendly

residential area in the municipality of Rotterdam. These areas include more space for green areas and water. The obtained attributes to measure sustainability: the reduction in emissions and the number of hectares land that is used.

6.6 Port Authority of Rotterdam

To derive a value tree from documentation a document analysis was performed on an annual report of the port of Rotterdam (Port of Rotterdam, 2017). From the analysis, a value-tree for the port authority was composed, Figure 6—5 on page 85 shows that value tree.

Economic growth is important for the port of Rotterdam, it is a company which aims to increase profits, however, the port aims to contribute to society as well by the production and trade of products, and job opportunity. To foster economic growth, an attractive business climate is important to attract business which will invest in the Dutch economy.
Business climate: the business climate is an environment of regulations and revenues which apply to a company in the port area. To make this climate attractive, it should be easily accessible via digital or physical high ways or water ways. Further, the port should have a market leading business climate with innovative companies and technologies. For a healthy business climate to port has the ambition to maintain a market leader position. This includes a nodal position in the global shipping network. To maintain this nodal position in a changing business environment, investments in future business are required. For example, investing in renewable energy resources and circular economy. The attributes that were obtained from the document analysis are: the number of connections for the accessibility and the extent to which the port businesses are fossil fuel independent.
Job opportunity: The port of Rotterdam adds to job opportunities in the Rotterdam area for the public. It is relevant for society as well as for the port to match the supply and demand of job. To guarantee enough jobs for the society, the port of Rotterdam signed an agreement with unions. The associated attributes for job opportunity are: the number of current jobs and the number of future jobs.

Safety is a top priority, as was written in the annual report (Port of Rotterdam, 2017). Safety includes the *health* of humans (port employees and nearby citizens) and the *security* of infrastructure and data. The incidents with vessels or illegal activities in the logistic chain should be prevented. The security of data and digital networks is to keep the networks operating and private. This will become increasingly important, according to a study performed by McKinsey (Port of Rotterdam, 2017), which forecasts an increase in global data flows. The obtained attributes for safety are: the number of incidents with employees, the number of incidents with residents, the number of damaged infrastructures and the vulnerability to cyber-attacks.

For sustainability two aspects were obtained from the document analysis, the air quality and the energy transition. *Air quality:* the air quality is important to sustain the environment. Hereto, harmful emissions (CO_2 and NO_x) should be decreased.
Energy transition: More so, an energy transition is required to substitute fossil fuel in the transport sector, the energy sector and as a raw material in the industry. The obtained attributes are the reduction of emissions and the extend to be fossil fuel independent.

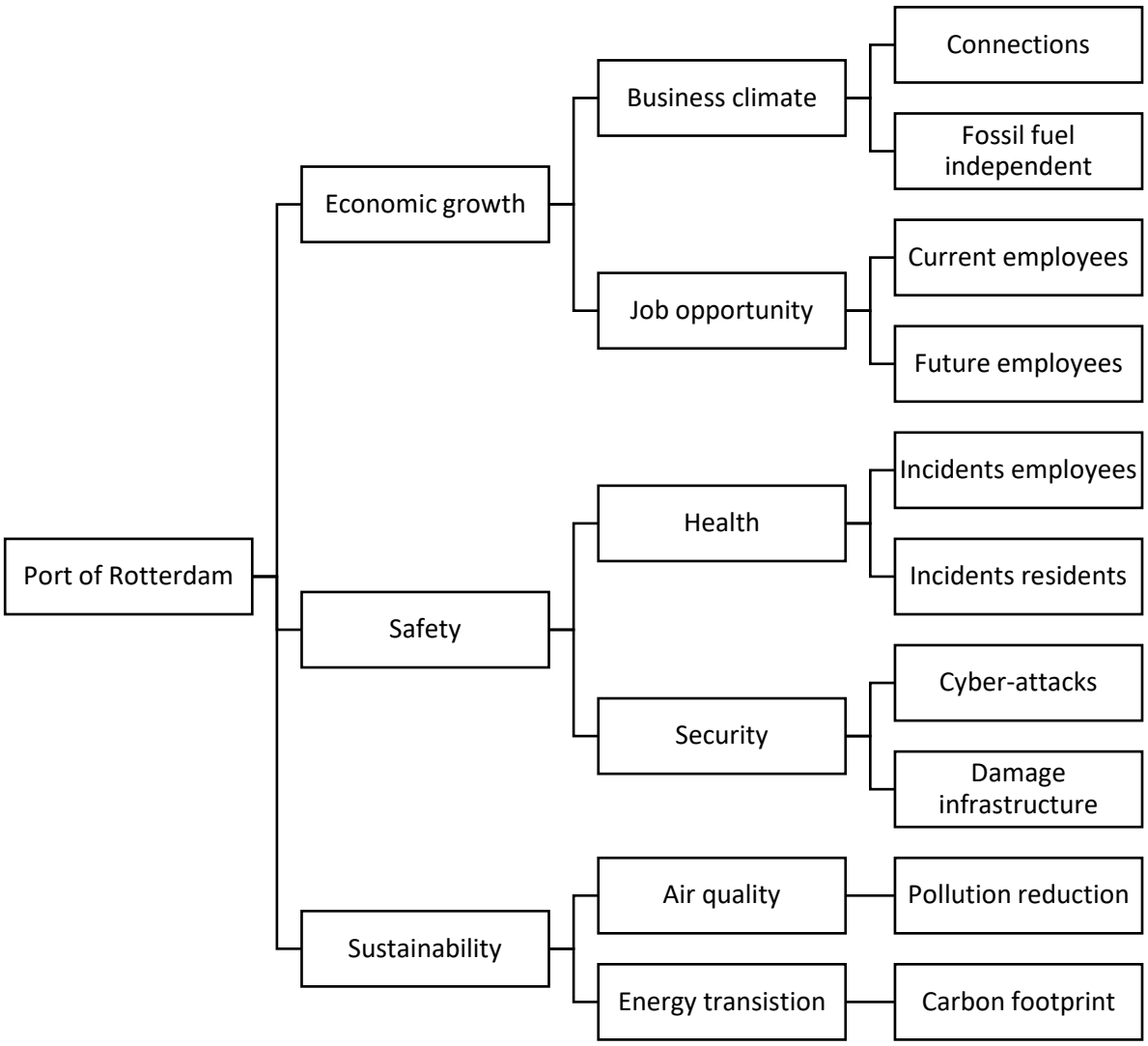

Figure 6—5 Value tree of the port authority of Rotterdam.

6.7 The List of Criteria from the Value Trees

In the previous sections the stakeholder value trees were obtained using a document analysis of strategic documents. At the branches of the value tree are the attributes, which are measurable objectives with a unit. These attributes are used as decision criteria in the multi-criteria analysis, which is carried out in chapter 7.

For the MCA a list of criteria is required. Hereto, the individual value trees are combined, as is described in the book of Keeney (Value-Focused Thinking, 1992), to obtain one value tree which includes all values and attributes.

The stakeholder value trees are combined per public value to determine the list of criteria, Figure 6—6 shows an example. The public value "A" is merged. The articulation of this public value may differ; therefore, the lower objectives should be investigated. If the lower objectives are similar, they can be represented in the value tree as one (green block). If this is not the case both objectives remain in the value tree (yellow block and blue block). In this report to determine if the sub-objectives are similar, one looks at the intended unit of the attribute. For example, amongst the sub-objectives of the public value safety are: "work environment" and "health" which can be clustered as "injured employees". The aim of the sub-objectives is to prevent injuries at employees. Another example, values associated with a business climate are a profitable business case and new innovative systems, their attributes are respectively "euros" and "the extend to be independent from fossil fuel". These values cannot be combined because their attribute, the unit in which they are measured, is different.

The combined value tree and the attributes are in Figure 6—7, and in Appendix 13 From Values to Attribute.

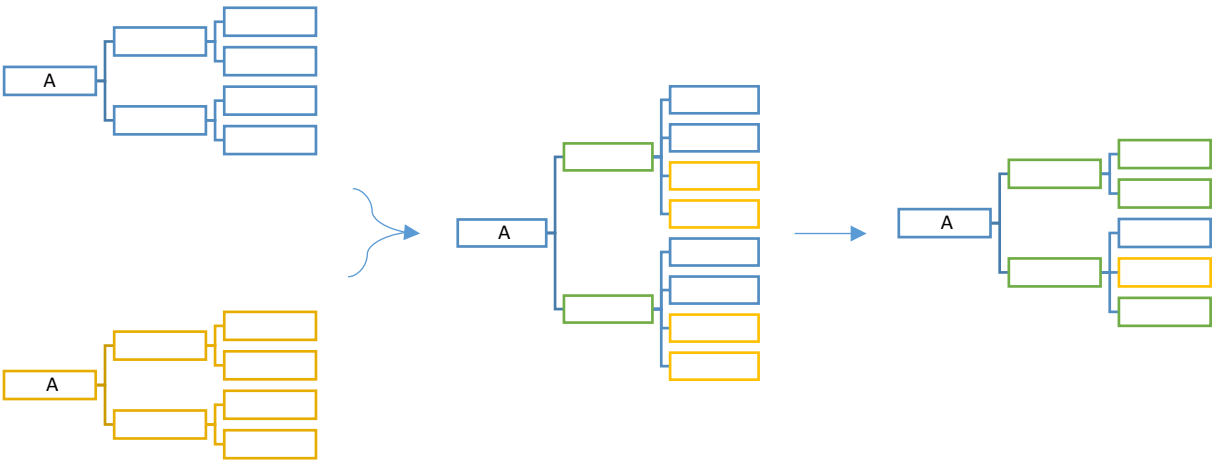

Figure 6—6 Merging the stakeholder value trees to one value tree.

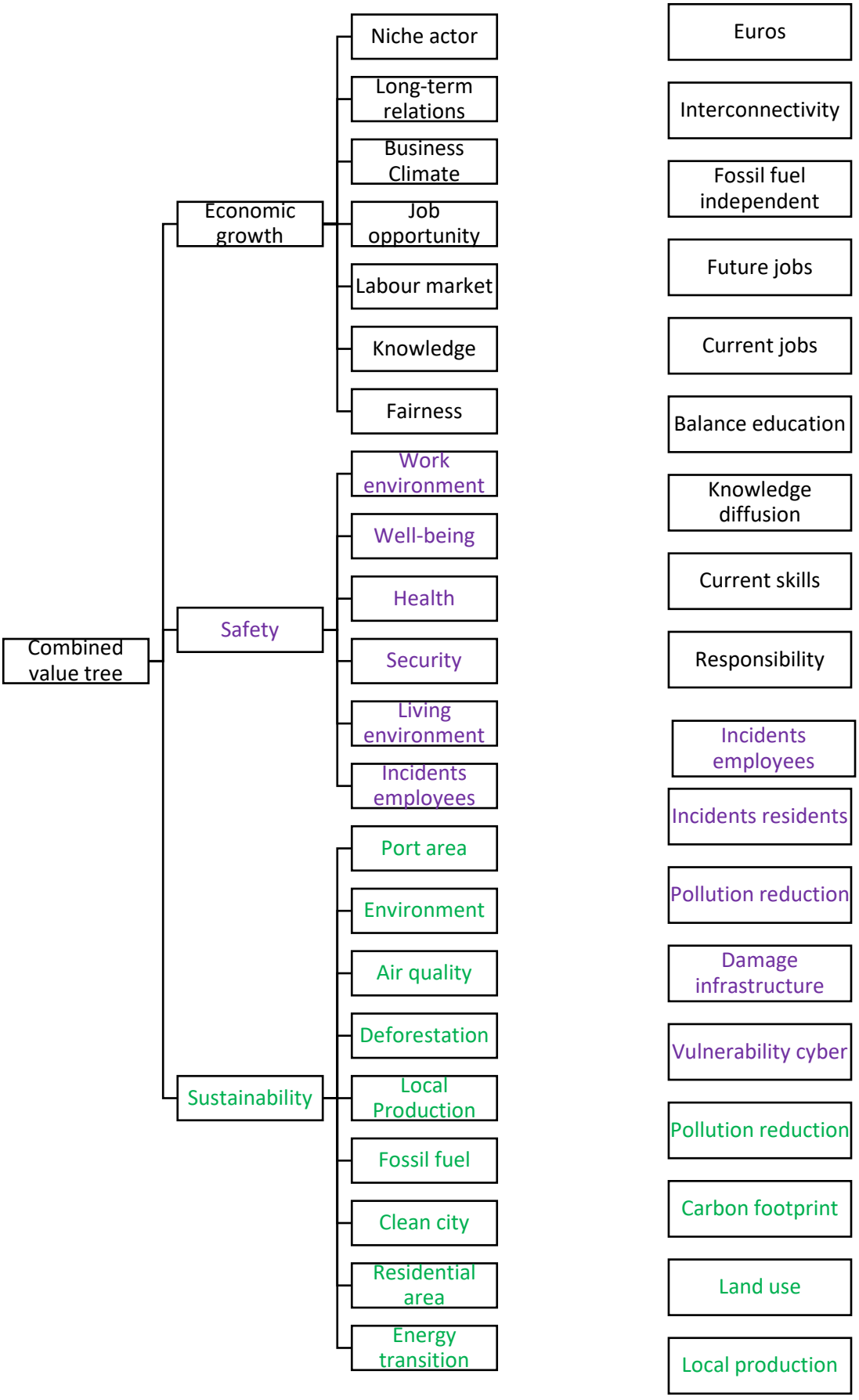

Figure 6—7 The combined value tree, with three public values and their attributes.

6.8 The Attributes

The attributes are constructed attributes, hence, no clear definition or unit was obtained from the documents to measure the performance of the technologies. Therefore, constructed attributes were determined to make a link between the stakeholder value and a measurable unit that is relevant to compare SSE and LNG Powerpac®.

The constructed attributes were determined using the means and objectives in the values analysis to construct the value trees. For example, Milieudefensie values the environment and therefore, the number of small scale farms for food production are relevant for the comparison between SSE and the PNG PowerPac®. Therefore, a constructed attributes was determined, the number of locations to implement the technology to prevent environmental damage.

Constructed attributes can be measured in an ordinal scale in the MCA analysis, which allows to determine a score without quantifying the difference in the score.

The attributes, measurable objectives, that were obtained from the value analysis are; and are articulated as:

Euros This attribute is the number of profitable euros. The value “business climate” aims to create a financial appealing climate for companies, in which the business case is profitable and worthwhile.

Interconnectivity The interconnectivity represents the number of connections. This attribute serves the values business climate (accessibility is an important aspect) and niche actor (business arise by connection companies).

Fossil fuel independent The attribute “fossil fuel independent” was obtained for the values: business climate (be a market leader) and niche actor (developing new businesses). This is a measure for innovativeness and is measured by a constructed attribute: the extent to be fossil fuel independent.

Future job opportunity This attribute gives the forecasted number of job opportunities and has the unit labour volume.

Current job opportunities This attribute gives the number of current job opportunities expressed in labour volume.

Balance education the workforce has different educational levels, therefore, the job opportunities need to account for these differences by maintaining a balance in higher and lower education jobs.

Knowledge diffusion To share knowledge, connections between knowledge institutes and employees are essential. The knowledge diffusion is a measure for the quantity of exchanged knowledge to maintain a leading market position.

Current skills This attribute measures the extent to which the technology fits with the current skills and knowledge with the present employees.

Responsibility This attribute measures extent to which the organisation accounts for the damage due to their activities.

Incidents employees One aspect of safety is the health of employees, counting the number of injuries and fatalities of employees.

Incidents residents From the value analysis the safety of nearby residents is important and measured in the number of injured residents.

Damage to infrastructure This attribute measures the number of attacks on the port's infrastructure.

Vulnerability to cyber-attacks The value safety implies security of data and information and measures the number of cyber-attacks.

Pollution reduction From the value analysis, pollutions need to be reduced to serve the public value sustainability and safety. This attribute measures with the pollutions that that need to be reduced, NO_x, SO_x, particular matter, CO_2 and noise giving the reduction (%) compared to the use of a diesel engine.

Carbon footprint The consumption of Carbon over the technology's lifetime is expressed in a Carbon footprint. The Carbon footprint includes the emission during operation as well as the Carbon emissions during production and dismantling.

Land use Based on the value analysis, the hectares available for the nature (forests, green areas and water) were considered relevant.

Local production The local production of energy is important, hereto, the attribute was obtained: the number of possible production sites for the SSE or LNG PowerPac®.

6.9 Summary of the Stakeholder Values

In this chapter the aim is to determine relevant public values and how the stakeholders articulate these values. The articulation of these values is necessary to determine relevant criteria to measure this value in the multi criteria analysis.

In this chapter two sub questions are answered. The first is: What are the relevant public values? The second sub-question is: How do the stakeholders understand these public values? The first question is used to determine general terms for the public values which is used in the value analysis to compose the stakeholder values trees. These general terms are required to compose the values trees, because the stakeholders may have different vocabulary. The second sub-question is used to determine how these public values are articulated, hence, which attributes are relevant to include in the decision-making model to support the stakeholders' values.

What are the relevant public values?

The relevant public values in this research are: economic growth, safety and sustainability. These public values were obtained by a document analysis on the document "Havenvisie 2030", searching for public values. To obtained general terms for the public values a document analysis was performed, scanning for values. These values were counted to determine the most frequent appearing value.

A document which is written by many relevant stakeholders was used to determine the general terms. This document was used to determine the terms, because all stakeholders would endorse these terms. Due to possible differences in understanding and nomenclature of values, overarching terms of public values were defined. These terms are initial staring points for the stakeholder value trees. A word count was used to determine these terms.

The term "economic growth" is: an increase in the economy of a country or an area, especially of the value of goods and services the country or area produces.

The Oxford definition for "safety" is: the condition of being protected from or unlikely to cause danger, risk, or injury.

The definition by the Oxford dictionary which is adopted for the term "sustainability" is: the ability to be maintained at a certain rate or level.

How do the stakeholders understand these public values?

To determine which technology is most suitable and promising, it is important to understand the stakeholder values. Hereto, public values were identified and articulated.

To determine how these values are articulated a document analysis is performed, from which a value tree is composed. The notion of what a value entails is important for the direction of further development of the technology or adapting functionalities.

To obtain the stakeholder values trees a document analysis was performed on strategic documents scanning for means, objectives, and values. These means, objective and values were then categorised to determine the value tree with attributes. The document which was used to determine the stakeholder value trees was written by merely the stakeholder.

The three terms for the public values, which were determined in the previous sub-question, are: economic growth, safety and sustainability. Along with these terms, definitions were determined based on the objectives, means, and values which were obtained by the document analysis.

The trees are composed from the obtained values and means, by the two questions, which have been proposed by Reed to determine the order of the objectives in the value tree.

Th attributes are constructed attributes, hence, no clear definition or unit was obtained from the documents to measure the performance of the technologies. Therefore, constructed attributes were determined to make a link between the stakeholder value and a measurable unit that is relevant to compare SSE and LNG Powerpac®.

Based on the value analysis, Cavotec relates to the public values: economic growth, safety and sustainability. The value of *economic growth* was articulated by Cavotec as the development of new system and collaboration of others as a niche actor. More so, the job opportunities of adequate employees, where the number of current and future job opportunities were relevant. Further, long-term relations with customer and employees were important to exchanging knowledge to improve to service.
Safety included the protection of employees and customers during measured by human injuries and by the (mental) well-being of employees. Air quality was mentioned as an important aspect of *sustainability*, to sustain the environment, because it allows the reduction of noise and emissions and it poses an alternative to fossil fuelled machines.

Deltalinqs articulated *economic growth* as an improvement of the business climate, by improving of financial conditions and the (virtual) accessibility for its members. Another aspect of economic growth was the labour market, hereto, Deltalinqs promoted the port area as an employer and lobbied for the development of adequate jobs for the industry. More so, “knowledge” was obtained to maintain at the top of the industry, hereto, pupils and employees are educated and retrained. *Safety* is a value that deals with the health and security of port employees and their work environment. Hereto, the number of injuries and cyber-attacks are to be minimised by safety standards and fire walls. The aspects that were obtained for s*ustainability* are the port area and air quality which aim to improve the environmental by reducing the use of fossil fuel (Carbon footprint) and by minimising the production of pollutions, such as noise, odour and particles for a clean port area.

The value “*economic growth*” is important for Milieudefensie and implies economic improvement for the world population not just the population closely related to the port businesses. To allow economic growth a new business climate is required, which aims at the responsible extraction of raw material from the Earth, investing in responsible projects, thus not in the fossil fuel industry. More so, the amount of real job should be maintained. Further, Milieudefensie sees fairness a as important aspect of economic growth, hereto, international businesses should take responsibility of to minimise the damage as a result of their activities for local population and nature. The value “knowledge” is seen as gaining awareness at local communities to prevent economic and ecologic extortion. *Safety* is an important value for Milieudefensie and is articulated as the prevention of injuries or health problems for humans. Hereto, the air quality be improved. *Sustainability* is the protection of the Earth’s climate, flora and fauna, by reducing the impact and influence of human activity. Hereto, the air quality needs to be improved, the rich and living rain forests should be preserved, the biodiversity should be improved, food and energy should be produced more locally, and the consumption of fossil fuel should be reduced.

According to the Municipality of Rotterdam *economic growth* consists of creating a business climate with many entrepreneurs to start businesses, a climate which stimulates innovative businesses, and a

climate with adequate digital and physical connections. Entrepreneurs create new, innovative businesses, which allow to be fossil fuel independent. Besides a business climate, the job opportunities are created in the service and knowledge sector and the created jobs should provide jobs for all levels of education. The knowledge is seen as an investment to maintain at the top of the market. Hereto knowledge diffusion is and the match with the current employees' skills are essential. The public value *"safety*" is concerned with the health of the local inhabitants of the municipality. To effectuate the safety of its inhabitants the municipality aims to reduce CO_2 emissions and noise pollutions. *Sustainability* was articulated as: the care for the city's environment. To effectuate this, the CO_2 emissions are reduced, and environmental-friendly residential areas are created. To effectuate sustainability the emissions should be reduced and the space for water and green areas number should increase.

Economic growth is important for the port of Rotterdam, it is a company which aims to increase profits, however, the port aims to contribute to society as well, by the production and trade of products and job opportunity. An Important aspect of economic growth is the business climate, which should be a market leading and easily accessible. Therefore, the number of connections for the accessibility and the extent to which the port businesses are fossil fuel independent (innovative). The port of Rotterdam adds to job opportunities in the Rotterdam area for the public. It is relevant for society as well as for the port to match the supply and demand of jobs.
Safety is a top priority and includes the health people and the *security* of infrastructure and data. Hereto, the number of incidents with employees, the number of incidents with residents, the number of damaged infrastructure and the number of possible cyber-attacks should be kept low.
For *sustainability* is a value that was comprised of air quality and an energy transition. To sustain the air quality, the production of harmful emissions (CO_2 and NO_x) should be minimised. Substitution of fossil fuel in the transport sector, the energy sector and as a raw material in the industry is required to meet the energy transition.

When the value trees were combined, the list of attributes to support the values (economic growth, safety and sustainability) was obtained.
Attributes that were obtained for the value "economic growth" are: euros, the number of connections, the extend to be independent from fossil fuel, the number of current jobs, the number of future jobs, the balance between lower and higher level education jobs, the extent to which knowledge is shared, the match with the current skills of employees and the extent to which the company take responsibility for environmental degradation.
The attributes that were obtained for the public value "safety" are: the number of incidents with employees, the number of incidents with residents, the number of incidents with employees, the number of incidents with residents, the number of damaged infrastructures and the vulnerability to cyber-attacks.
The attributes for "sustainability" that were obtained are: the amount of reduced emissions, the Carbon footprint, land use, and the possibilities for local production.

7 A Weighted Multi-Criteria Analysis of the Part Outcomes

The previous chapter, 6, aims to determine measurable objectives (attributes) by using a document analysis of strategic documents. These measurable objectives are used as decision criteria in the multi-criteria analysis to compare the technologies.

The technologies which are compared in this chapter are described in chapter 3. The first technology is SSE, which is a grid connected solution with a central frequency converter using off-shore wind turbines as energy source. The second technology is the LNG PowerPac®, which is a containerised LNG gas generator.

In this chapter the multi-criteria analysis is performed to determine how the selected technologies meet the values and which of the selected technologies meets the values best. The MCA is used because it allows to compare technologies on a broad spectrum of criteria. Further, there is no bias towards a monetary value.

To compare the technologies a matrix is used, which is assembled from the two selected technologies and the list of criteria (the attributes). The relevant technologies are described in sections 3.2 and 3.4, and the list of criteria is described in section 6.7.

The criteria are given a score, either a 1 or 0, using the results from the SWOT analysis. The SWOT analyses in chapter 3 revealed positive and negative aspects of the technologies, these are used to score the criteria, using the ordinal scale in the MCA-matrix.

The public values (economic growth, safety or sustainability) may have different value for the stakeholders. The public values are represented by criteria; therefore, the criteria have different importance.

To account for the difference in importance for the public values, hence, decision criteria, weights are determined. These weights are determined using data from the stakeholder interviews, coding for initiatives, projects or concrete ambitions. The score of the criterion is multiplied by the weight of that supported public value to give the weighted score.

The outcome of this analysis can be used by the port of Rotterdam to decide for a technology to develop the port area. By performing this analysis, the best suitable option is determined accounting for the values of relevant stakeholders.

To avoid a biased outcome the MCA uses data from the expert interviews, the stakeholder interviews and the strategic documents. The SWOT analyses use the expert interviews to score the criteria. The weight factor is determined using the stakeholder interviews. The criteria in the matrix are derived from the strategic documents. When the matrix is assembled, and scores are assigned to the criteria, a weight factor is used to account for the importance of the values for the stakeholders.

First, in section 7.1, the weight factor is determined, which is used to account for the importance of the public values for the stakeholders. Then, the scores are appointed to the criteria in the matrix in section 7.2. In this chapter the results are calculated using the weight factors and scores. The final scores for the technologies under the current situation are given section 7.3. Furthermore, section 7.4 describes the prevailing technology under scenarios. A summary of this multi criteria analyses for SSE and LNG is given in 7.5.

7.1 The Weight Factor

The weight factor is part of the multi-criteria analysis and is used to account for the importance of the criteria according to the stakeholder(s). To differentiate between the importance of the criteria the score of the criterion is multiplied by a weight.

The data to determine the weight factor and the criterion score must be independent to prevent a biased outcome. Therefore, the weight factor is determined based on the stakeholder interviews and the scores for the criteria are deducted from strategic documents.

To determine the weight factors for the public values (economic growth, safety and sustainability) a qualitative content analysis, with the structuring technique (in section 2.9.1), was performed on the stakeholder interviews. The data from the interviews was categorised by a scale to appoint a weight, therefore a scale was developed, as is described in section 7.1.1.

Then, the weight per value was determined, and is described in section 7.1.2. The weights of the public values per stakeholder are added.

The semi-structured interviews with the stakeholders were used to obtained information about the weight factor, hereby coding for actions that support a public value (economic growth, safety or sustainability).

7.1.1 The Scale to Quantify the Weight

A scale to determine the weight of the values was developed prior to the analysis of the interviews. Four levels were defined, whether or not the value is mentioned and how often actions that support that value are mentioned. Table 7—1 shows the scale that had been used.

The first level of the scale applies to the value if the public value is not mentioned in the interview. The value receives a weight of “0”. The second level corresponds to value which is mentioned in the interview, however not actions are obtained from the interview. This value receives a weight of “1”. The third level applies to values which are mentioned and actions, that support that value, are able to be obtained from the interview. This level has a weight of “2”. For the fourth level, the value needs to be mentioned and more than three actions are obtained from the interview. This corresponds to a weight of “3”.

Table 7—1 Table to determine the level and its associated weight factor.

Level	1	2	3	4
Criteria	Not mentioned	no actions	1 ≥ 3 actions	actions > 3
Weight	0	1	2	3

7.1.2 Average Weight per Value

The stakeholder interviews were analysed with the QCA to determine which values and which actions (initiatives, projects or concrete ambitions) that support those values were mentioned. The relevant actions that support the public values were determined by the value analysis in chapter 6.

Table 7—2 on page 97 gives the weights for the values from the analysis. The complete interviews with the stakeholders are in the appendices Appendix 8 Interview with Stakeholder 1 to Appendix 12 Interview with A. Castelein.

Cavotec

The weights for values "safety" and "sustainability" and "economic growth" were determined, Table 7—2 on page 97 presents the weights. The data was obtained from the interview with Stakeholder 1 (stakeholder 1, personal communication, 6 April 2017).

Safety is categorised in the third level, resulting in a weight of 2. Two actions were obtained that support safety. The first, is to dimension the SSE system properly. The second is, to account for sudden events, such as tide fluctuations or passing vessels.

The value sustainability was articulated as the reduction of emissions by the SSE system, however no actions were obtained from the interview. Therefore, sustainability received a weight 1.

No actions to support the economic growth were not obtained from the interview. However, interconnectivity, the connection to others is an aspect of economic growth, which was determined in section 6.2, was mentioned. Therefore, the weight of 1 was assigned to economic growth.

Deltalinqs

The weights of the values economy, safety and sustainability (Table 7—2 on page 97 presents the weights) were determined from the interview with Stakeholder 2 (personal communication, 14 April 2017).

The value economic growth had a weight of 3 and five actions were obtained. The first is action is the negotiation with other parties to come up with a new business model, which substitutes the petrochemical industry. The second is the lobby for adequate regulations for port business in (inter)national meetings. Thirdly, they aim to safeguard the number of jobs in the port area in decision-making processes. The fourth activity is, the initiative for the forums for Hydrogen and LNG, which allow knowledge diffusion. The last action is the development of education facilities to retrain employees.

Safety is placed in the second level and has a weight factor 1. The value was mentioned; however, no actions were obtained from the interview that are performed by Deltalinqs to safeguard the safety of port employees or the security of data.

Sustainability is the value with the weight, 3, because three actions were obtained from the interview that fit with the articulation of sustainability, as was determined in section 6.3.
The first action is assistance, by Letters of Cooperation, in the transition towards a new business model where port businesses use alternative fuels. Secondly, Deltalinqs is involved in development of electric vehicles. The third action is exploration of recycling of waste streams with businesses (Tronox), to reduce the Carbon footprint.

Milieudefensie

The weights of the values economic growth, safety and sustainability (Table 7—2 on page 97 presents the weights) were determined based on the actions obtained from the interview with Stakeholder 3 (personal communication, 10 March 2017).

Economic growth has a weight of 2. Two actions were identified. The first is the promotion of local non-fossil energy sources. Stakeholder 3 gave a successful example of the implementation of wind turbines in the port area, because this energy sources was promoted. The second action is addressing the problems in developing countries, where local farmers are driven away from their land for the energy production of the West.

For the public value "safety" a weight of 2 was determined based on two actions that were obtained from the interview that correspond to the attributes of the value analysis. The first action is: the collaboration with other parties, amongst the port of Rotterdam, to improve the air quality for public health at the time of the covenant. And the second action is the collaboration with the public to improve the air quality by the energy transition.

Sustainability received a weight factor of 2, because three distinct actions were obtained from the interview with Stakeholder 3. The first action is the promotion of less polluting energy sources, for example, wind energy. The second action is: the collaboration with knowledge institutes to perform research on the energy transition. The last action is the conversation with companies to discuss more sustainable innovations or decisions. These actions either fits with the reduction of pollutions or the reduction of the Carbon footprint.

Municipality of Rotterdam

The weights of the values: economic growth, safety and sustainability, were determined from the interview with Stakeholder 4 (personal communication, 22 February 2017). Table 7—2 on page 97 gives the weights of the public values.

Economic growth received a weight of 3 because four actions were obtained. The actions are similar to the attributes, which were obtained by the value analysis in chapter 6. The first action is, the financial support to create an incentive to innovate, which include businesses to become fossil fuel independent. The second, is the creation of a level playing field and the collaboration with other parties by complying to the Paris agreement. Thirdly, the number of job opportunities are accounted for in the development of zoning plans, because it is important that the population can sustain livelihood.

The public values "Safety" has a weigh of 3, and three actions were identified. The first action by the Municipality of Rotterdam is; making a prognosis for hindrance and resistance to develop projects [housing, business area, or introduction of a regulation]. The second action is, the introduction of a milieu zone and, thirdly, the development of electric vehicles to improve the air quality for public health.

The sustainability value had two actions and had a weight of 2. The reduction of gasses by the introduction of milieu zone. This zone contributes to the comply with the European standard for NO_x. The other action is; the exploration to substitute diesel by LNG in the shipping industry, in collaboration with the port of Rotterdam.

Port Authority of Rotterdam

The weights of the values for the Port of Rotterdam economic growth and sustainability were determined based on actions. These values and actions were obtained from a news article (Duursma & Postma, 2017) and an online interview (Erasmus University Rotterdam, 12 September 2014). Table 7—2 on page 97 gives the weights for the values.

The highest weight factor, 3, was assigned to economic growth based on four identified actions. The first is the intention to invest in projects for the transition, hereby, supporting the port business and industry (Duursma & Postma, 2017). The second is the strategic timing of implementing regulations, hereto contact is maintained with the business and industry (Duursma & Postma, 2017). Thirdly, the formation of alliances with transport business to maintain efficient operation of the port (Erasmus University Rotterdam, 12 September 2014). The fourth action is, the protection of jobs. Job opportunities are well documented, 150 thousand port employees (Erasmus University Rotterdam, 12 September 2014) and the number is protected (Duursma & Postma, 2017).

The value "safety" was not mentioned in the interview, nor, actions were obtained. Therefore, is was categorised in the first level and received a weight of zero.

Sustainability has three actions, resulting in weight of 2. The first action is the conformation to the Paris agreement (Duursma & Postma, 2017), to reduce GHG emissions to preserve the globe. The second action is the participation of the port the Energy Summit (Duursma & Postma, 2017), which is a congress to spur alternative energy sources to reduce the Carbon footprint. Lastly the third action is, the intentions to invest in new infrastructure to reduce the emissions of Carbon dioxide (Duursma & Postma, 2017).

Table 7—2 Weights for the values per stakeholder and the average weight per value.

	Cavotec	Deltalinqs	Milieudefensie	Municipality Rotterdam	Port of Rotterdam	Average weight
Economic growth	1	3	2	3	3	**2.4**
Safety	2	1	2	3	0	**1.6**
Sustainability	1	3	2	2	2	**2.0**

The most important value for the stakeholders is "economic growth" with an average score 2.4. Then, "sustainability" with an average weight of 2.0. And lastly, "safety" has an average weight of 1.6. It was not possible, given the stakeholder interviews, to assign weights for the values lower in the value tree.

To determine the average weight Equation 1 was used, this equation is explained in section 2.9.2. The average weight will be used to determine the best suitable option.

7.2 Scores for the Technologies

The multi-criteria analysis allows to decide for an option comparing on multiple criteria, using a decision matrix. To construct the decision matrix, a technical analysis and a value analysis were carried out. The technical options, a grid connected SSE and LNG PowerPac®, were determined in chapter 3. The decision criteria (attributes) were determined by the value analysis in chapter 6.

The criteria in the decision matrix are given a score using the ordinal scale, either a "0" or a "1". The scores are fixed to "1" and "0" therefore, the standardisation step unnecessary and was not performed.

Based on the data from the SWOT analysis and the value analysis, the scores were determined by the researcher, assigning either a "0" or "1". The technology that wins receives a score of "1", hence, the criterion is a strength of or an opportunity for the technology. The other technology loses and receives

a “0”. When there is a drawl, the technologies receive a “1” when the criterion is a strength or an opportunity. They receive a “0” when there is a drawl for a weakness or threat. Table 7—3 shows the scores per criterion.

Table 7—3 The scores for the MCA matrix for the shore side electricity and LNG PowerPac® in the current situation.

Value	Attribute	SSE	LNG PowerPac®
Economic growth	Euros	0	1
	Interconnectivity	1	1
	Fossil fuel independent	1	0
	Future job opportunities	1	0
	Current job opportunities	1	0
	Balance education	1	1
	Knowledge diffusion	1	1
	Current skills	0	1
	Responsibility	1	0
Safety	Incidents employees	0	0
	Incidents residents	1	0
	Damage to infrastructure	0	1
	Vulnerability to cyber-attacks	0	1
Sustaina-bility	Pollution reduction	1	0
	Carbon footprint	1	0
	Land required	0	1
	Local production	0	1

Euros

This attribute was determined in the chapter 6 to be: the number of profitable euros. The value “business climate” aims to create a financial appealing climate for companies, in which the business case is profitable and worthwhile.

The SSE received the score 0 and the LNG PowerPac® was given a 1. The SWOT analyses revealed, that the business case is a weakness for SSE, due to the high investments in the grid and frequency converter(s). The business case is a strength for the LNG PowerPac®, because no investments in an electricity network or frequency converter are required.

The SWOT analyses did not include the number of profitable euros, because no data was found about the cost of an LNG PowerPac®. Therefore, the statement of doubt and the proposed suggestion (the LNG technology) to avoid high investments in the grid were taken.

Interconnectivity

From the value analysis, this attribute (interconnectivity) supports the public value “economic growth” and is measured in the number of connections. This attribute serves the values business climate (accessibility is an important aspect) and niche actor (business arise by connection companies).

The SWOT analyses revealed that both technologies support and demand connections to (collaboration with) other parties. Therefore, this attribute is an opportunity for both technologies and both technologies received a score 1.

Fossil fuel independent

The attribute “fossil fuel independent” was obtained for the values: business climate (be a market leader) and niche actor (developing new businesses). And is measured by a constructed attribute: the extent to be fossil fuel independent.

The SSE technology received a 1 and the LNG technology a 0, based on the outcome of the SWOT analyses. The SWOT analyses revealed that the SSE technology is, during operation, fossil fuel independent, and is therefore considered to be more innovative. The LNG PowerPac® still uses fossil fuels to generate electricity, therefore, it is considered to be a weakness.

Future job opportunities

The value analysis in chapter 6 revealed that future job opportunities are an important aspect. This aspect is measured in the number of job opportunities in the future.

The future job opportunities were determined to be an opportunity for SSE and a threat for the LNG option. Forecasts were made by CBS (CBS, 2017) for the job opportunity in 2020 in the conventional and the renewable energy sector. These forecasts have revealed an increase in the number of jobs increased from 46 to 64 thousand labour years in the renewable energy sector from 2014 – 2020. The job opportunity in the conventional energy sector has been estimated to decline from 73 to 62 thousand labour years from 2016 to 2020.

Current job opportunities

This attribute gives the number of current job opportunities expressed in labour volume. The current job opportunity is a strength for SSE, because it contributes to more labour volume (jobs) and has an increasing trend. The LNG PowerPac® contributes to a smaller amount to the current job opportunity, and has a declining trend, therefore it is a weakness. Based on the appointed strength and weakness from the SWOT analyses, the SSE technology was given a score of 1 and the LNG technology was given a score of 0.

Balance education

The workforce has different educational levels, this needs to be considered in the development of job opportunities by maintaining a balance in higher and lower level education jobs.

The SWOT analyses revealed that both technologies contribute to this attribute and therefore were given a score of 1. Technologies will provide job opportunities for a broad range, varying from contractors to managers. The job opportunities with a technical background is required will be in abundance, ranging from MBO level 2 to academic level (Ligtvoet, Pickles, & van Barneveld, 2016). However, no number of jobs or ration in higher and lower job was not obtained in the SWOT analyses. Therefore, the statement was used to obtain data for this attribute.

Knowledge diffusion

The value analysis in chapter 6 did reveal the importance of sharing knowledge. This attribute, knowledge diffusion, measures the quantity of exchanged knowledge to maintain a leading market position.

No information about this attribute was not obtained by the SWOT analyses, therefore, an assumption had been made to quantify this attribute.

Both technologies require collaboration with third parties to survive. The interview with Expert 1 revealed that SSE allows collaboration. Therefore, both technologies can be used as a subject to share knowledge between knowledge institutes and colleagues.

For this reason, the same scores as for the attribute “interconnectivity” were taken. The score of 1 was appointed to both technologies.

Current skills

From the value analysis this attribute was obtained, which measures the extent to which the technology fits with the current skills and knowledge with the present employees. Development in the port area demands adaptation of the port employees. However, if the innovation is not in line with the current skills and knowledge of the port employees, the implementation stays off. Therefore, it is relevant to determine if an innovation is in line with the current knowledge and skills.

From the SWOT analyses, this aspect is a threat for SSE and an opportunity for the LNG technology, because the LNG technology matches better with the fossil knowledge of the current port employees. As a result, the SSE received a score of 0 and the LNG PowerPac a score of 1.

Responsibility

The value analysis revealed “responsibility” to be an attribute of economic growth. This attribute measures extent to which the organisation accounts for the damage to exploit their activities.

Economic growth is the increase of good and services for people. The increase of good and services includes fairness, based on the values analysis of Milieudefensie. Hereto, the company that desires to increase good and services should minimise the damage to the local people, herby taking responsibility. The owner is responsible for the environmental and social damage caused by the technology or its company.

This attribute was difficult to quantify based, because it is difficult to quantify what extent the companies will account for the damage. More so, it is unclear what is considered to be this damage.

Therefore, the extend to compensate for air pollution, which can be considered as damage to the local population has been selected. The same scores for SSE and LNG were appointed as for the attribute “reducing pollutions”., which gave a score of 1 for SSE and a score of 0 for LNG.

Incidents employees

The value analysis in chapter 6 revealed that one aspect of safety is the health of employees, counting the number of injuries.

From the SWOT analyses revealed that both technologies pose a threat for the health of port employees, either due to possibility of an electric shock or the possibility of an explosion during handling. This risk of injuries is a threat to the safety of port employees and a weakness of the technologies.

The number of fatal injuries in a Turkish ship yard were used to estimate the number of (fatal) injuries for the technologies, because no data or estimate was available for the number of injuries due to an electric shock for SSE or due to an explosion for the LNG PowerPac®.

The number of fatal injuries due to an explosion or due to an electric shock are equal, therefore, an equal score of 0 was appointed to the technologies. The score of zero was appointed because this attribute is a weakness of both technologies.

Incidents residents

From the value analysis the safety of nearby residents is important and measured in the number of injured residents.

However, no data during the SWOT analysis had been obtained to quantify the number of injuries at the local residents of the nearby cities. However, during the interviews a motivation for the

implementation of SSE was mentioned, aiming at the harmful emissions of the vessels in the port. Expert 3: "*The small distance between the residents and the berth" (*personal communication, 29 November 2016).

Therefore, the reduction in air pollution was selected to quantify this attribute. The reduction of pollutions is strength for the SSE technology and a weakness for the LNG PowerPac®, as a result a score of 1 was appointed to SSE and a score of 0 to LNG.

Damage to infrastructure

This attribute measures the number of attacks on the port's infrastructure and was obtained by the value analysis in chapter 6.

However, no data was obtained by the SWOT analyses to determine the number of (cyber-)attacks on the port's physical infrastructure. Nor was there any data to determine how often attacks were repelled.

Therefore, an assumption was made to quantify this attribute. The report of Mo et al (2012) has identified possibilities to attack a physical or digital infrastructure, by either a physical or a cyber-attack. Mo et al (2012) have mentioned that is it possible to attack a physical object by physical and cyber-attacks. Therefore, to quantify the number of attacks on the physical infrastructure of the port, the score from the attribute "Vulnerability to cyber-attacks" was used.

The score for SSE was determined to be 0, and the score for the LNG technology was determined to be 1. Because the likelihood of a cyber-attack is bigger for SSE due to the complex and big smart grid, which is more difficult to protect. The LNG technology does not require a smart grid.

Vulnerability to cyber-attacks

The value analysis reveals that cyber-security is an important aspect of safety. The attribute is measured by the number of cyber-attacks.

However, no data was obtained on the number of attacks the port wards-off or are fired at the port's digital infrastructure. To determine the score for this attribute the probability of cyber-attacks on the infrastructure was used.

The SWOT analysis on SSE revealed that an opportunity for SSE is the development of a smart grid, which connects and include (local) renewable resources. The LNG technology does not spur the development of a smart grid. Therefore, the technologies are compared on the probability of a cyber-attack based on their grid or smart grid.

Mo et al (2012) have mentioned that a smart grid is more vulnerable to attacks than the old fashion grid, due to the size and complexity of the grid. These factors make it difficult to protect the system. One of the most common methods to initiate an attack on a grid has been identified in which poor fire walls are used as an entry point to the system, Network-based intrusion (Mo, et al., 2012).

Based on this information from the SWOT analysis, cyber-attacks are a threat for SSE and an opportunity for the LNG PowerPac®. Therefore, a score of 0 was appointed to SSE and a score of 1 was given to LNG.

Pollution reduction

From the value analysis, pollutions need to be reduced to serve the public value sustainability. This attribute measures with the pollutions that that need to be reduced, NO_x, SO_x, particular matter, CO_2 and noise giving the reduction (%) compared to the use of a diesel engine.

From the SWOT analysis the reduction of pollutions is a strength for SSE and a weakness for the LNG PowerPac®. SSE can eliminate the local production of noise, NO_x, SO_x, CH_4, and particular matter, because the wind turbines are off-shore and the electricity is supplied to the vessel by a cable (European Commission , 2005). However, some other energy source may be used to some emissions (nitrogen sulphur, methane and pm) are produced to compensate for balancing the grid. The local production of noise and Methane is a weakness of the LNG technology. Although the emissions of NO_x, SO_x and pm are reduced. The noise that the generator produces is approximately 100 dB (Tarnapowicz & German-Galkin, 2016). Anderson, Salo & Fridell have calculated a reduction of 95 % in NO_x and an increase in Methane (total hydrocarbons) of 31 %. Based on the complete reduction of noise for SSE and almost the LNG PowerPac®.

Carbon footprint

The value analysis revealed that the attribute “Carbon footprint” is linked to the value sustainability. The Carbon footprint is an attribute that satisfies the values: air quality, energy transition and fossil fuel consumption in the port area, material and transport. The attribute “Carbon footprint” includes the emission of Carbon dioxide during operation, production and dismantling, hence the life cycle.

The Carbon footprint is a strength for the SSE technology and a weakness for the LNG PowerPac®, because the life cycle analysis, which has been performed by Thomason & Harrison (June 2015), indicates a net reduction in Carbon over the life cycle for wind farms. The life cycle emission for wind farms are lower compared to those of oil and gas. A life cycle analysis that compared SSE with LNG was not found, therefore, the life cycle analysis which was performed on the energy sources was used in this research. Therefore, SSE got score of 1 and LNG got a score of 0.

Land use

Based on the value analysis, the hectares available for the nature (forests, green areas and water) were considered relevant.

The number of hectares the technologies require in the port, and therefore compete for with nature and storage space, were not determined in the SWOT. This was not performed because an accurate or estimate would require a detailed design of the SSE and LNG technology, in which the amount and size of equipment is determined. This is beyond the scope of this research.
Another reason, the value exceeds the borders of the port and therefore it is relevant to look at the energy source, which has a bigger impact on the global space.

McDonald et al (2009) have compared the energy sources LNG and wind for land sprawl per energy amount. Land sprawl for wind energy is estimated to be higher than for oil and gas by 2030. From the study of McDonald et al (2009), wind power requires 72,1 ha and oil and natural gas 44,7 and 18,6 ha per TW power produced in the USA.

The energy sprawl is an opportunity for the LNG technology and received a score of 1, because it is fed by an energy technology that has less land sprawl and as a consequence leaves more space for other purposes. The energy source for SSE technology is consider a threat, therefore, SSE received a score of 0.

Local production

From the value analysis, the local production of food and energy is an aspect that supports the public value of ”sustainability”. The local production of energy prevents the extortion of local population from the energy demand. More so, local production allows the local population to fulfil their needs. This attribute is measured by: the number of possible production sites for the SSE or LNG PowerPac®

The SWOT analysis revealed that the LNG PowerPac® can be implemented anywhere, where for SSE a decent electric grid is required and implying sufficient renewable energy capacity (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015). Therefore, the local application is considered a strength for the LNG technology and a weakness for the SSE technology. Therefore, SSE was given a score of 0 and LNG was given a score of 1.

7.3 The Final Score in the Current Situation

The scores, which are in Table 7—3, were multiplied by the average weight factor for each public value (economic growth, safety and sustainability) which were determined in the section 7.1. The final score for each technology was determined using Equation 2, which is explained in section 2.9.3.

The criteria that represent "economic growth" were multiplied by 2.4, which are: Euros, Interconnectivity, Fossil fuel independent, Future job opportunities, Current job opportunities, Balance education, Knowledge diffusion, current skills and Responsibility. The criteria for the value "safety" were multiplied by a weight of 1.6. These criteria include: Incidents employees, incidents residents, Damage to infrastructure and Vulnerability to cyber-attacks. The decision criteria for "sustainability" were multiplied by the weight of 2.0. These criteria are: Pollution reduction, Carbon footprint, Land use and Local Production.

The final score for the Shore Side Electricity option is 0.6, and the final score for the LNG PowerPac® option is 0.5. In this analysis a maximum final score of 1 can be achieved and a minimum score of 0. Therefore, the SSE option is may be proposed to the Port of Rotterdam to be developed.

The SSE option is the winner, because it has the highest score, and therefore can be presented to the port of Rotterdam to be the most suitable and promising option. The SSE technology met the public values by receiving a higher score for the attributes are: Fossil fuel independent, Future job opportunities, Current job opportunities, Responsibility, Incidents residents, Pollution reduction and Carbon footprint. The LNG PowerPac® got a better score for the attributes: Euros, Damage to infrastructure, Vulnerability to cyber-attacks, Land use and the Location production. This implies if the Port of Rotterdam continues with the SSE option a trade-off is made for the attributes where LNG scored better.

By selecting the SSE option, the port would support the public value "economic growth" by meeting the attributes: Fossil fuel independent, Future job opportunities, Current job opportunities and Responsibility. The SSE meets the value of innovation and being a market leader by implementing SSE, which is a fossil fuel independent innovation. More so, they would contribute to job opportunities for the current generation of for the future generation, which allows the people to sustain a living in cities near the port of Rotterdam. Further, fairness for the local population was supported by SSE, the population not near the port area will not suffer from the energy production for the port, nor will the local population suffer from the emissions.

The public value "safety" is met by the SSE technology by the attribute: Incidents residents. This is a measure for the number of injuries and health damage for the residents in the cities nearby the port of Rotterdam. The number of victims in nearby cities was not determined, instead, to score this attribute the scores for the attribute "air pollution" were used.

A good air quality, air with few pollutions and noise, reduces the number of health problems and fatalities of residents in nearby cities due to the pollutions. Therefore, the SSE technology contributes to public health.

The SSE technology supports the public value “Sustainability” on these attributes: Pollution reduction and Carbon footprint. The reduction in pollutions (NO_x, SO_x, pm and noise) is a measure the supports a good air quality in general to sustain the environment.

If the port of Rotterdam would implement, it would meet with some stakeholder values, such as, the air quality in the port area and in the city, aiming to maintain a clean port area and city. The Carbon footprint is a measure, to which a Carbon dioxide is emitted, hence consumed. This attribute is a measure how well the technology contributes to the energy transition, or improves the energy efficiency, and reduces the consumption of fossil fuel in the industry. The aim is to reduce the Carbon emissions, by reducing the consumption of fossil fuel to preserve the Earth.

If the port of Rotterdam would implement the SSE technology, which is the best performing technology in the MCA, a trade-off is made for the values for which the LNG PowerPac® performed better. These attributes are: Euros, Current Skills, Damage to infrastructure, Vulnerability to cyber-attacks, Land use, and Local production.

The LNG PowerPac® met the public value “economic growth” by the attribute: Euros and Current Skills. The LNG technology got a higher score because one expert mentioned the weak business case, because of the high investment in the grid and frequency converter.

If the port would implement SSE, it demands an investment in a weak business case from the shipping companies. If this technology has a weak business case with high investments, not all shipping companies are willing to or able to make an investment. The required investment makes the port of Rotterdam less attractive, this damages the financial business climate of the port of Rotterdam.

Another attribute, which is in favour of the LNG PowerPac®, is the extent to which the technology fits with the present skills of port employees. The LNG technology requires less retraining from the current employees compared to the SSE technology, because the port has currently a big fossil infrastructure. This knowledge is more in line with the required skills for operating the LNG option.

The available skills are related to an attractive business climate in the port area, supporting the services of the port. Adequately skilled port employees make the implementation of or change to a new technology run smoothly. More so, no investments in retraining the employees is required.

The public value “safety” is best met by the LNG technology by the attributes: Damage to infrastructure, Vulnerability to cyber-attacks. These attributes articulated the security of the port area and are measured in the probability of attack on the physical and digital infrastructure in the port area by cyber-attacks.

The port’s security contributes to the public safety by protecting the port’s infrastructure from intruders, who can gain digital access to sensitive information or can take over control over the physical structures (such as cranes or gates).

To secure the port from cyber-attacks the LNG PowerPac® is the best option, because this grid is less vulnerable to cyber-attacks. The LNG technology does not require a smart grid and can operate with the traditional grid. The SSE technology requires a smart grid, which is more susceptible to cyber-attacks because of its size and complexity.

The public value “sustainability” was best met by the LNG PowerPac® for the attributes: Land use and the Location production. These attributes support the sustainable public value, by aiming to maintain the global environment (land, water and air). Hereto, the hectares of forests and green areas are relevant, preventing deforestation and creating more green residential areas.

Another aspect of sustainability, which is met best by the LNG technology, is the local production of energy. By producing locally, the pressure on the environment is eased, because less transportation is required and the generation facilities are smaller. Adding to this, when the technology can be implemented anywhere without restrictions, more ports can join, thereby reducing the environmental pressure collectively. The implementation of an LNG PowerPac® is not restricted by the requirement for a high capacity network, instead tanks can be filled and distributed.

7.4 The Promising Technology Under Scenarios

To determine which technology meets the values best in the future scenarios are used. Under different scenarios the technologies can meet different values. Therefore, to determine which technology meets the values in the future different scenarios are determined, using the same score “1”or “0”. The scenarios can point out

The first scenario is: an alternative for LNG, which can be algae and is described in section 7.4.1. The second scenario includes the costs for CO_2 externalities in the energy price for the consumers. This scenario is described in section 7.4.2.

7.4.1 Scenario 1: An alternative for LNG, algae energy, comes available.

In this scenario an alternative for the fossil LNG comes available, such as algae energy. The algae produce oil which can be refined into a fuel for vessels. When fuel from algae may replace the fossil fuels, such as LNG.

In this scenario, the infrastructure of the LNG PowerPac® can be reused, as was revealed in the SWOT analysis. The pipelines, tank trucks and vessels can be reused to provide energy to the vessels. The LNG containers and generator for the LNG PowerPac® can be reused to provide energy to vessels at berth.

The business case for the LNG technology is made stronger because the infrastructure for the LNG PowerPac® can be reused. This is because, the investment in the infrastructure and adaption of vessels need to be performed once.

More so, the algae energy fits with the currently presents skills and knowledge of port employees, because it makes use of the infrastructure in the port area. The handling of equipment and procedures of the port infrastructure can be maintained; therefore, retraining employees are not as strictly necessary as for SSE.

Another attribute that is met in this scenario is the local application of algae oil in ports. The algae fuel can be distributed by the LNG infrastructure to other ports. This allows to create a network of algae using ports.

In this scenario the LNG PowerPac® leads ultimately to a fossil free technology, therefore, under this scenario the LNG option meets the attribute “fossil fuel independence”.

In this scenario the LNG technology is a more promising option, given the opportunities that arise and values that are met by the LNG technology.

7.4.2 Scenario 2: Energy costs include the CO_2 externalities

In this scenario the costs of CO_2 externalities are included in the energy costs. The more CO_2 is emitted the more costs are added. This implies that the costs for Carbon fuels are increased more compared to renewable energy sources, because during the energy generation CO_2 is emitted.

When emitting CO_2 is charged the costs are elevated to manufacture, to maintain, to operate, or to dismantle energy technologies. These operations require energy and raw material to manufacture and maintain the SSE or LNG infrastructure. Further, at the end of the lifetime of the infrastructure the systems need to be dismantled, this requires energy. These costs for energy and material are accounted for in the energy price to the consumer.

To compare the energy systems on the amount of CO_2 emitted over the lifetime of the technology, the Carbon Footprint is used. The Carbon footprint are the emission of CO_2 equivalent over the lifetime of the technology. This Carbon footprint was determined to be a weakness in the SWOT analysis for the LNG technology and a strength for the SSE technology. The Carbon footprint for wind energy decreased and the Carbon footprint increased for LNG, which implies that the electricity costs form a fossil energy sources increase more than the costs for electricity from renewable energy resources.

In this scenario the business case for SSE is more reliable, because of the limited increase in costs compared to the forecasted costs for the LNG PowerPac®.

7.5 Summary of the Multi-Criteria Analysis

In this chapter the two technologies are compared in a multi criteria analysis. To construct the matrix, a technical analysis and a value analysis were carried out, in previous chapter. The attributes, which serve as decision criteria in the matrix, were obtained from the value analysis. The sub-question which is answered in this chapter is: How do the selected sustainable energy technologies meet the relevant public values in the current situation and under future scenarios if the port of Rotterdam would implement this technology?

The weight factor to account for the importance of the public values was determined by a qualitative content analysis on the stakeholder interviews. The quantify the weight of the public value (economic growth, safety or sustainability) a scale was developed, couniting the relevant actions that support these values which were mentioned in the interview.

The criteria in the matrix are given a score using an ordinal scale (1 or 0), based on data which was deducted from the SWOT analysis. The score of 1 was given to the best performing technology for each criterion. The other technology received a score of 0. When there was a drawl both received either a 1, when the criterion was considered a strength or opportunity. A score of 0 was given to both technologies, when the criterion was a weakness or threat.

The final score for the Shore Side Electricity option is 0.62, and the final score for the LNG PowerPac® option is 0.53.

The SSE technology supports “economic growth” by contributing more to innovativeness, hence being fossil fuel independent. More so, it contributes to job opportunities for the current generation of for the future generation, which allows the people to sustain a living in cities near the port of Rotterdam. Further, fairness for the local population was supported by SSE, the population not near the port area will not suffer from the energy production for the port, nor will the local population suffer from the emissions.

The public value “safety” is met by a good air quality, air with few pollutions and noise. The SSE technology does not emit NO_x, CO_2, pm and noise during operations. This reduces the number of health problems and fatalities of residents in nearby cities due to the pollutions.

The SSE technology supports the public value “Sustainability” by reducing the pollutions (NO_x, SO_x, pm and noise). More so, SSE contributes to the reduction in Carbon dioxide emissions during its lifetime, because less energy and Carbon as consumed during it lifetime. Hereby, contributing to the energy transition, or improving the energy efficiency, and reducing the consumption of fossil fuel in the industry.

The LNG PowerPac® met the public value “economic growth” best, because it has a more reliable business case. If the port would implement an innovation it demands an investment from the shipping companies. This required investment makes the port of Rotterdam less attractive, therefore damages the financial business climate of the port of Rotterdam.

Another attribute, which is in favour of the LNG PowerPac® that support economic growth, is the extent to which the technology fits with the present skills of port employees. The port has fossil infrastructure and the employees’ knowledge is more in line with the required skills for operating the LNG option. The available skills are related to an attractive business climate in the port area, supporting the services of the port.

The public value “safety” is best met by the LNG technology, because its grid is less vulnerable to cyber-attacks. The port’s security contributes to the public safety by protecting the port’s infrastructure from intruders, who can gain digital access to sensitive information or can take over control over the physical structures (such as cranes or gates).

The public value “sustainability” was best met by the LNG PowerPac® aiming to preserve the global environment (land, water and air). Hereto, the number of hectares of forests and green areas are relevant, preventing deforestation and creating more green residential areas.

Another aspect of sustainability, which is met best by the LNG technology, is the local production of energy. The implementation of an LNG PowerPac® is not restricted by the requirement for a high capacity network, instead tanks can be filled and distributed. When the technology can be implemented anywhere without restrictions, more ports can join, thereby reducing the environmental pressure globally.

<u>Scenario 1: An alternative for LNG, algae energy, comes available.</u>

When fuel from algae comes available the fossil fuels, such as LNG, are substituted by algae. The infrastructure of the LNG PowerPac® can be reused to provide energy to vessels by tank trucks that transport containerised tanks.

Reusing the LNG infrastructure makes, the business case for LNG stronger. Because when a new technology of fuel emerges the existing infrastructure can be reused.

More so, the algae energy can use the infrastructure of LNG in the port of Rotterdam. This implicate that this technology (partially) fits with the current skills and knowledge of the port employees.

Another attribute that is met in this scenario is the local application of algae oil in ports. The algae fuel can be distributed by the LNG infrastructure to other ports. This allows to create a network of algae using ports.

In this scenario the LNG PowerPac® leads ultimately to a fossil free technology, therefore, under this scenario the LNG option meets the attribute “fossil fuel independence”.

In this scenario the LNG technology is a more promising option, given the opportunities that arise and values that are met by the LNG technology.

Scenario 2: Energy costs include the CO_2 externalities

This scenario includes the cost of CO_2 externalities to the energy costs. The more CO_2 is emitted the more costs are added. This implies that the costs for Carbon fuels are increased. More so, the costs to manufacture, maintain en dismantle, which demand energy are increased. These costs are included in the energy price.

The Carbon footprint, the emission of CO_2-equivalent over the lifetime of the technology, is bigger for the LNG technology than for the SSE technology. This implies that the electricity costs form a fossil energy sources increase more than the costs for electricity from renewable energy resources.

In this scenario the business case for SSE is more reliable, because of the limited increase in costs compared to the forecasted costs for the LNG PowerPac®.

8 Conclusion and Discussion

In the previous chapters the sub-questions were answered to be able to answer the main question. To answer the main question, which is an advice to the port of Rotterdam which technology is advised to prevent adverse events, the technologies need to be described and the relevant values need to be revealed.

The preceding chapters include the description of the two technologies (Chapter 3), which are compared in this research. Further, a good description of the technologies is required to decide which technology can meet the values best. To determine a broader impact on society, positive and negative aspect of the technologies are determined in chapter 4, some of these aspects are used to score the criteria in the multi-criteria matrix.

More so, the relevant stakeholders are identified (in chapter 5). From these stakeholders, public values and the articulation of these values are determined (chapter 6). How these values are articulated, expressed in attributes, is relevant to be able to measure which technology supports the values best. These attributes are used as criteria in the decision which technology is the best suited technology (chapter 7).

In this chapter the main question is answered. The main question is: *What is the most suitable and promising sustainable energy technology for container ships in the port of Rotterdam, focused on selecting technical options for and comparing shore side electricity and LNG?*

The conclusions from the sub-questions are given in section 8.1. The main conclusion is given in section 8.2. Recommendations for the port of Rotterdam are given regarding the decision in section 8.3. During the process and implicit to this method there are limitations, these will be mentioned, in section 8.4. In section 8.5, the last section, suggestions for future work are given.

8.1 Conclusion per Sub-question

Sub-question 1: Which frameworks and methodologies are appropriate to determine which technology is most suitable considering public values?

The conceptual investigation of value sensitive design is the main framework, because it aims to design a technology that is desired by the stakeholder and fits in its environment. More so, the underlying theory of VSD acknowledges universally share opinions as scientific observations.

A qualitative content analysis in combination with expert interviews allow to determine the technological options for both technologies. These interviews were selected because experts can give assistance in uncertain situations, because of their in-depth knowledge. A desk research was performed prior to the interviews to collect technological options as a preparation for the interviews.

A SWOT analysis allows to determine the broader impacts of the technologies. The SWOT analysis includes technical and non-technical aspects. A SWOT analysis was selected, because it explicates positive and negative aspects. More so, a SWOT analysis is a tool to develop a technology rather than implementing a technology; and it allows to link the technology (internal) to its environment (external), which fits with the objective of this thesis.

A stakeholder analysis, using a snow-ball sampling method, identifies the relevant stakeholders. The snowball sampling method was chosen, because it allows stakeholder to speak freely without group pressure. The data for these analyses was obtained by stakeholder interviews and a desk research.

Value-focused thinking is appropriate to articulate the relevant stakeholder values. The method was selected because it allows to deduct explicate values from documents. The data for this value analysis came from strategic documents.

A multi-criteria analysis deals with multi-criteria decisions. This analysis was selected because it explicates the arguments compared to a paired comparison analysis. More so, it is unbiased compared to a cost benefit analysis, which is biased toward a monetary value.

Sub-question 2: What are the technical options for shore side electricity systems and LNG systems and which options are selected for this research?

Different options to generation and distribute the electricity for the SSE technology are available. The available and proposed energy sources are conventional energy sources or renewable energy sources, such as, off-shore wind power and solar PV. Further, a rotary and static frequency converter are available to convert the 50 Hz from the European grids to the required 60 Hz. This converter can either have a central position or a decentral position in the network.

The SSE technology of focus in this report is a containerised, grid connected option, which is powered by off-shore wind turbines. The electricity is generated by a renewable energy sources because it has less pollutions during operation. The percentage of vessels supplied by mere off-shore wind turbines is similar the percentage of vessels supplied by a combination of wind turbines and PV solar panels in a Mediterranean port. For the port of Rotterdam in the Netherlands PV solar panels are less efficient, therefore mere off-shore wind turbines are selected. A central, stationary frequency converter is required to convert the 50 Hz into 60 Hz. In this system, a central stationary converter converts the 50 Hz to 60 Hz, because it is more efficient and has less maintenance costs in comparison to a rotary converter or a decentral frequency converter. The containerised solution allows for easy on and off-loading of the equipment.

The desk research reveals different options for the LNG technology to use as energy sources and the method to supply the vessel with LNG. The different options to transport the LNG tot the vessel are by tank trucks, or by vessels or via pipelines. To combust the fuel different type of generators are available.

The LNG technology of focus is a containerised option, where the containers are transported to the vessel by tank-trucks and are loaded on an off broad by gantry cranes. In a container is the equipment and in another is the fuel tanks. The containerised solution allows easy on and off loading of the containers. Tank truck transports the gas tank from the filling station to the vessel, because is a low investment and the distance from the filling station and berth is small.

Sub-question 3: What are the strengths, weaknesses, opportunities and threats of these technologies and for the port of Rotterdam?

The SWOT analyses determine broader impacts of the technologies vicious and virtuous aspect of the two selected technologies. These aspects include internal technical aspects and external aspects. Figure 8—1 gives the relevant strengths, weakness, opportunities and threats are described per attribute for the port of Rotterdam

SSE	
Strengths	**Weaknesses**
• Local reduction NO_x CH_4, pm and noise • Abandons fossil fuel • Reduction Carbon footprint	• Weak business case • Grid required with good capacity • Fatal injuries, although few
Opportunities	**Threats**
• Collaboration with international ports • Net gain future job opportunities • Current job opportunities • Balanced job opportunities	• The required skill little match current skills • Vulnerable to cyber-attack • Bigger energy sprawl

LNG PowerPac®	
Strengths	**Weaknesses**
• No additional costs for grid or frequency converter, more reliable business case • Applicable in all ports	• Local emissions CO_2, CO, CH_4 and noise • Uses fossil fuel • Bigger Carbon footprint • Fatal injuries, although few
Opportunities	**Threats**
• Alliance with nearby ports • Required skill better match current skills • Balanced job opportunities • Less possibility for cyber-attack • Less energy sprawls	• Net loss future job opportunities • Current job opportunities

Figure 8—1 The summary of important aspects of the SWOT analysis for SSE (left) and the summary of important aspects of the SWOT analysis for the LNG PowerPac® (right)

Euros

The business case is a weakness for SSE, because of the high investments in the grid and frequency converter(s). The SSE technology has a doubtful business case, as was mentioned in the interview with Expert 3. More so, Winkel, Weddige, Johnson, Hoen & Papaefthimiou (2015) have identified that the high investments for shore side and ship side are a weakness.

The business case is a strength for the LNG PowerPac®, because no investments in an electricity network or frequency converter are required. In the interview with Expert 3 the LNG PowerPac® was mentioned as an alternative, because it does not require an expensive frequency converter.

Interconnectivity

An important aspect that supports the implementation of the technology is the collaboration with other ports. By collaborating with other ports, a more stable network emerges for the vessels and ports.

Both technologies support the collaboration with other ports (or organisations), therefore, this aspect is appointed as an opportunity for both technologies. Based on an expert interview, with Expert 3, the port of Rotterdam explored the collaboration with chines ports to implement SSE. For LNG forming alliance with German ports has been identified as an opportunity (Wang & Notteboom, 2015).

Fossil fuel independent

With depleting fossil reserves and it is a strength to be independent from fossil fuel during operation. SSE is a fossil free innovation which makes use of renewable energy sources, such as wind power.

This was not the case for LNG PowerPac®. In one of the interviews, the expert mentioned for the LNG PowerPac technology (Expert 3): “LNG still is fossil.”, emphasising *still.* Therefore, the dependence on fossil fuel is a weakness of the LNG PowerPac® and the independence is a strength for SSE.

Future job opportunities

For the next generations an opportunity of jobs is important to sustain livelihood. Increasing the job opportunity is considered virtuous, for socio-economics.

This aspect is an opportunity for SSE and a threat for the LNG PowerPac®, because CBS has estimated that by 2020 the labour in the renewable energy sector will overtake the conventional energy sector. From 2014 – 2016, the number of jobs increased from 46 to 52 thousand labour years in the renewable energy sector. And the forecast is that this will increase to 64 thousand labour years by 2020. For LNG this aspect is a threat, because, the job opportunities in the conventional energy sector has been estimated to decline from 73 to 62 thousand labour years in the period 2016 – 2020. (CBS, 2017).

Current job opportunities

The current generation needs to be able to sustain the livelihood, therefore, it is relevant that the technology contributes to job current job opportunities.

The current job opportunity is a strength for SSE, because it contributes to more labour volume (jobs) than the LNG PowerPac®. The current job opportunities are considered a threat for the LNG PowerPac®. The renewable energy sector contributed in (2013) with 155,5 % (labour volume) and had an increasing trend. The conventional energy sector contributed with 137,6 % (labour volume) in 2013 to the labour market and had a declining trend. (Werkgelegenheid rond energievoorziening sterk gestegen, 2015).

Balance education

The workforce has different educational levels; therefore, the job opportunities need to include these differences. Ligtvoet, Pickles and Barneveld level (2016) have mentioned an increasing trend in jobs

that require abstraction ability. Therefore, to meet the needs of people who lack this skill, a technology that contributes to the supply of a broad range of jobs is considered an opportunity.

It is an opportunity for both technologies to contribute to a balanced job opportunity, because, both technologies will provide job opportunities for a broad range, varying from contractors to managers (Werkgelegenheid rond energievoorziening sterk gestegen, 2015). The job opportunities with a technical background will be in abundance, ranging from MBO level 2 to academic level (Ligtvoet, Pickles, & van Barneveld, 2016).

Current skills

Development in the port area demands adaptation of the port employees. However, if the innovation is not in line with the current skills and knowledge of the port employees, the implementation stays off. Therefore, it is relevant to determine if an innovation is in line with the current knowledge and skills.

This aspect is a threat for SSE and an opportunity for the LNG technology, because the LNG technology matches better with the fossil knowledge of the current port employees. Ligtvoet, Pickles & van Barneveld have mentioned that these existing skills in the fossil industry are important in an energy transition. Further they have mentioned that the job in the renewable energy sector require different skills (Ligtvoet, Pickles, & van Barneveld, 2016).

Incidents Employees

The technology has an impact on the safety of port employees. The port employees that work directly with the technology are subjected to health threats, such as an electric shock for SSE or an explosion for the LNG PowerPac®. The lower the chance for such an incident the better it is.

Radu, Jeannot, Megdiche & Sorrel (July 2013) have identified an electric shock as a weakness for the SSE system. During handling of the cables of the system, an electric arc can emerge which potentially can kill port employees. They have not determined the likelihood for such a shock. Therefore, the number of fatal accidents in a Turkish shipyard area were selected. Barlas (2012) has determined that from the 115 fatal accidents, 18 accidents were due to an electric shock.

Employees that handle the LNG PowerPac® are exposed to the risk of an explosion of lethal impact and is therefore a threat for port employees and a weakness of the LNG technology. The report of Barlas identified 18 deaths due to explosion with fuels, such as LNG, from a total of 115 fatal accidents in a Turkish shipyard from 2000-2010 (Barlas, 2012).

Vulnerability to cyber-attacks

Besides the safety of port employees, the security of the port data is relevant. The data and operation processes need to be protected from hacks that inhibit port operations and for privacy reasons, as is mentioned by Mo et al (2012).

The cyber security is a threat for SSE with wind energy, because this system demands a smart energy grid. Mo et al have mentioned, that a smart grid is more vulnerable to attacks than the old fashion grid, due to the size and complexity of the grid.

The vulnerability to cyber-attacks is an opportunity for the LNG PowerPac®, because the LNG PowerPac® does not require such a smart grid, the likelihood of a cyber-attack is smaller.

Pollution reduction

A technology that does not pollute the environment is considered a strength, to comply with stricter environmental regulations. The pollutions of focus that need to be reduced are: NO_x, SO_x, particular matter, VOC (amongst Methane) and noise.

The reduction of pollutions is a strength for SSE, because it can eliminate the local production of noise, NO_x, SO_x, CH_4, and particular matter, because the wind turbines are off-shore and the electricity is supplied to the vessel by an cable (European Commission , 2005). However, some other energy source may be used to some emissions (nitrogen sulphur, methane and pm) are produced to compensate for balancing the grid. The SSE (fuelled by a European energy mix which includes a meagre 17 % renewable energy) have been calculated to reduce emissions 97% NO_x, 0% SO_2, 94 % VOC (Methane), 89% pm, and 100 % noise compared to the diesel auxiliary engine with MDO (European Commission , 2005).

The local production of noise, Methane and NOx this is a weakness of the LNG technology. Although the emissions of NO_x, SO_x and pm are reduced. Tarnapowicz & German-Galkin have compared to an MDO diesel engine to an LNG engine and have calculated the reduction in emissions: 96 % NO_x, 98 % SO_2 and 100 % pm (Tarnapowicz & German-Galkin, 2016), ignoring Methane. The noise that the generator produces is approximately 100 dB (Tarnapowicz & German-Galkin, 2016). Anderson, Salo & Fridell have calculated a reduction of 95 % in NO_x and an increase in Methane (total hydrocarbons) of 31 %.

Carbon footprint

The consumption of Carbon over the technology's lifetime is expressed in a Carbon footprint. The Carbon footprint includes the emission during operation as well as the Carbon emissions during production and dismantling.

The Carbon footprint is a strength for the SSE technology and a weakness for the LNG PowerPac®, because the life cycle analysis, which has been performed by Thomason & Harrison (June 2015), indicates a net reduction in Carbon over the life cycle for wind farms. The life cycle emission for wind farms are lower compared to those of oil and gas. A life cycle analysis that compared SSE with LNG was not found, therefore, the life cycle analysis which was performed on the energy sources was used in this research.

Land use

The available space in the port area is limited, as is the space outside the port area. The available space may be for port businesses, housing, recreation or natural habitat for animals. Therefore, is an opportunity for technologies that support an energy source that has less land sprawl (the amount of land). This goes beyond the borders of the port; therefore, a comparison had been chosen to determine if land sprawl is an opportunity or threat for the technologies.

McDonald et al (2009) have compared the energy sources LNG and wind for land sprawl per energy amount. Land sprawl for wind energy is estimated to be higher than for oil and gas by 2030. From the study of McDonald et al (2009), wind power requires 72,1 ha and oil and natural gas 44,7 and 18,6 ha per TW power produced in the USA.

The energy sprawl is an opportunity for the LNG technology, because it is fed by an energy technology that has less land sprawl and as a consequence leaves more space for other purposes. The SSE technology has an energy source, which has a bigger energy sprawl and therefore, it is considered to be a threat.

Local production

It is considered a strength of the technology, if it is applicable in all ports or all areas. The ports are part of a logistic network and vessels sail from port to port. If a new port joins this network, the network will become bigger, thus better. If a technology cannot be implemented in all ports, this new technology may impede the network function.

The SWOT analysis revealed that the LNG PowerPac® can be implemented anywhere, where for SSE a decent electric grid is required and implying sufficient renewable energy capacity (Winkel, Weddige, Johnson, Hoen, & Papaefthimiou, Potential for Shore Side Electricity in Europe. Final Report, 2015). Therefore, the local application is considered a strength for the LNG technology and a weakness for the SSE technology.

Sub-question 4: Who are the relevant stakeholders?

The relevant stakeholders in this report are: Cavotec, Deltalinqs, Milieudefensie, the Municipality of Rotterdam, and the Port authority of Rotterdam. They were selected from a preliminary stakeholder list. The selection includes stakeholders from different type of organisations (business, governmental organisation, non-governmental organisation or a knowledge institute). More so, the selection includes direct and indirect stakeholders.

Cavotec is a company and is directly involved in the construction and design with SSE. Therefore, they are in favour of the implementation of SSE. They are involved in the design of cable management system for ports in China and in the implementation of SSE in the port of Rotterdam for Stenaline.

Deltalinqs is an organisation that lobbies for the interests of port businesses, therefore, they are closely related to innovation projects in the port of Rotterdam. They are indirectly involved in the implementation of either SSE or the LNG PowerPac®. The preference is assumed to be LNG, because the port of Rotterdam houses many fossil fuel-based business.

Milieudefensie is a non-governmental organisation which aims to protect the environment. Milieudefensie is an indirect stakeholder, because they are not direct users or producers of the technology. They can lobby for the technologies in decision-making processes. Milieudefensie was an opponent in the development of the Maasvlakte II and initiate a lawsuit against the port of Rotterdam and the Municipality of Rotterdam, to prevent the pressure on nature.

The Municipality of Rotterdam is a governmental organisation and is indirect involved with the handling of the technologies. They have a legal power over the port and are, shareholder of the port of Rotterdam.

The port of Rotterdam is an indirect stakeholder and is involved in the implementation of the technologies. The port is one of the largest oil bunker ports. In developing the Maasvlakte II, they got a lawsuit from Milieudefensie to create more space for nature and to improve the air quality.

Other relevant stakeholders that can be included in further research are: Milieufederatie, the national government, the port of Antwerp, petrochemical industry (Shell), knowledge institutes (TNO), Stedin, Becker Marine Systems, and the FNV vakbond.

Sub-question 5: What are the relevant public values?

The relevant public values in this research are: economic growth, safety and sustainability. These public values were obtained by a document analysis on the document “Havenvisie 2030”, searching for public values. The terms, economic growth, safety and sustainability had been selected because they appear the most frequent in the document.

Due to possible differences in understanding and nomenclature of values, overarching terms of public values were defined. These terms are initial staring points for the stakeholder value trees.

The term “economic growth” is: an increase in the economy of a country or an area, especially of the value of goods and services the country or area produces.

The Oxford definition for “safety” is: the condition of being protected from or unlikely to cause danger, risk, or injury.

The definition by the Oxford dictionary which is adopted for the term “sustainability” is: the ability to be maintained at a certain rate or level.

Sub-question 6: How do the stakeholders understand these public values?

To determine which technology is most suitable and promising, it is important to understand the stakeholder values. Hereto, public values were identified and articulated. The three terms for the public values, which were determined in the previous sub-question, are: economic growth, safety and sustainability. Along with these terms, definitions were determined based on the objectives, means, and values which were obtained by the document analysis.

Based on the value analysis, Cavotec relates to the public values: economic growth, safety and sustainability. The value of *economic growth* was articulated by Cavotec as the development of new systems and take on the role of a niche actor, to collaborate with others to spur fossil free innovations. Further, the job opportunities for well skilled employees are relevant for economic growth. Here, the number of current and future job opportunities were relevant. Another attributes that was obtained economic growth is the long-term relation with customer and employees, in which it is key to exchanging knowledge to improve to service.
Safety was articulated as the protection of employees and customers. It is important to reduce and is measured by human injuries and by the (mental) well-being of employees.
Air quality was mentioned as an important aspect of *sustainability*, to sustain the environment. The innovative systems of Cavotec contribute to the reduction of noise and emissions. More so, they pose an alternative to fossil fuelled machines, lowering the fossil fuel consumption

Deltalinqs articulated *economic growth* as an improvement of the business climate, by improving of financial conditions and the (virtual) accessibility for its members. Another aspect of economic growth were the job opportunities, hereto, Deltalinqs promoted the port area as an employer and lobbied for the development of adequate jobs for the industry. More so, “knowledge” was obtained to maintain at the top of the industry, hereto, pupils and employees are educated and retrained.
Safety is a value that deals with the health and security of port employees and their work environment. Hereto, the number of injuries and cyber-attacks are to be minimised by safety standards and fire walls.
The aspects that were obtained for s*ustainability* are the port area and air quality which aim to improve the environmental by reducing the use of fossil fuel (Carbon footprint) and by minimising the production of pollutions, such as noise, odour and particles for a clean port area.

The value “*economic growth*” is important for Milieudefensie and implies economic improvement for the world population not just the population closely related to the port businesses. To allow economic growth a new business climate is required, which aims at the responsible extraction of raw material from the Earth, investing in responsible projects, thus, no investments should be done in the fossil fuel industry. More so, the amount of job should be maintained. Further, Milieudefensie acknowledged social fairness a as important aspect of economic growth. Hereto, international businesses should take responsibility, minimising the damage as a result of their activities for local population and nature. The

value “knowledge” is seen as gaining awareness at local communities to prevent economic and ecologic extortion.
Safety is an important value for Milieudefensie and is articulated as the prevention of human injuries or health problems. Hereto, a nutrient rich and safe living environment is required for humans to settle. More so, the air quality should not pose a health hazard.
Sustainability is the protection of the Earth’s climate, flora and fauna, by reducing the impact and influence of human activity. Hereto, the air quality needs to be improved measuring the amount of pollutions. The rich and living rain forests should be preserved. The food and energy should be produced more locally to reduce the environmental unfriendly mega facilities and transportation, Further, the consumption of fossil fuel should be reduced.

According to the Municipality of Rotterdam *economic growth* consists of a business climate with much entrepreneurial activity, a climate which stimulates innovative businesses, and a climate with adequate digital and physical connections. Entrepreneurs create new, innovative businesses, which allow Rotterdam to become fossil fuel independent. Besides a business climate, job opportunities are created in the service and knowledge sector. These jobs should provide jobs for all levels of education. Another aspect is knowledge, which is seen as an investment to maintain at the top of the market. Hereto, knowledge diffusion is and the match with the current employees’ skills are essential.
The public value *“safety*” is concerned with the health of the local inhabitants of the municipality. To effectuate the safety of its inhabitants the municipality aims to reduce CO_2 emissions and noise pollutions.
Sustainability was articulated as: the care for the city’s environment. To effectuate this, the CO_2 emissions are reduced. More so, environmental-friendly residential areas are created, implementing more space for water and green areas in the Rotterdam area.

Economic growth is important for the port of Rotterdam, it is a company which aims to increase profits, however, the port aims to contribute to society as well, by the production and trade of products and job opportunities. An important aspect of economic growth is the business climate. This climate should be leading in market and should be easily accessible. Therefore, the number of connections for the accessibility and the extent to which the port businesses are fossil fuel independent (innovative). The port of Rotterdam adds to job opportunities in the Rotterdam area for the public. It is relevant for society as well as for the port to match the supply and demand of jobs.
Safety is a top priority and includes the health people and the security of infrastructure and data. Hereto, the number of incidents with employees, the number of incidents with residents, the number of damaged infrastructure and the number of possible cyber-attacks should be kept low.
For *sustainability* is a value that was comprised of air quality and an energy transition. To sustain the air quality, the production of harmful emissions (CO_2 and NO_x) should be minimised. Substitution of fossil fuel in the transport sector, the energy sector and as a raw material in the industry is required to meet the energy transition.

Sub-question 7: How do the selected sustainable energy technologies meet the relevant public values in the current situation and under future scenarios if the port of Rotterdam would implement this technology?

The final score for the Shore Side Electricity option is 0.6, and the final score for the LNG PowerPac® option is 0.5. In this analysis a maximum final score of 1 can be obtained and a minimum final score of 0. The SSE technology meets the public values best because it has the highest score, although the difference if small.

The SSE technology supports “economic growth” by contributing more to innovativeness, hence being fossil fuel independent. More so, it contributes to job opportunities for the current generation of for the future generation, which allows the people to sustain a living in cities near the port of Rotterdam. Further, fairness for the local population was supported by SSE, the population not near the port area will not suffer from the energy production for the port, nor will the local population suffer from the emissions.

The public value “safety” is met by a good air quality, air with few pollutions and noise. The SSE technology does not emit NO_x, CO_2, pm and noise during operations. This reduces the number of health problems and fatalities of residents in nearby cities due to the pollutions.

The SSE technology supports the public value “Sustainability” by reducing the pollutions (NO_x, SO_x, pm and noise). More so, SSE contributes to the reduction in Carbon dioxide emissions during its lifetime, because less energy and Carbon as consumed during it lifetime. Hereby, contributing to the energy transition, or improving the energy efficiency, and reducing the consumption of fossil fuel in the industry.

The LNG PowerPac® met the public value “economic growth” best, because it has a more reliable business case. If the port would implement an innovation it demands an investment from the shipping companies. This required investment makes the port of Rotterdam less attractive, therefore damages the financial business climate of the port of Rotterdam.

Another attribute, which is in favour of the LNG PowerPac® that support economic growth, is the extent to which the technology fits with the present skills of port employees. The port has fossil infrastructure and the employees’ knowledge is more in line with the required skills for operating the LNG option. The available skills are related to an attractive business climate in the port area, supporting the services of the port.

The public value “safety” is best met by the LNG technology, because its grid is less vulnerable to cyber-attacks. The port’s security contributes to the public safety by protecting the port’s infrastructure from intruders, who can gain digital access to sensitive information or can take over control over the physical structures (such as cranes or gates).

The public value “sustainability” was best met by the LNG PowerPac® aiming to preserve the global environment (land, water and air). Hereto, the number of hectares of forests and green areas are relevant, preventing deforestation and creating more green residential areas.

Another aspect of sustainability, which is met best by the LNG technology, is the local production of energy. The implementation of an LNG PowerPac® is not restricted by the requirement for a high capacity network, instead tanks can be filled and distributed. When the technology can be implemented anywhere without restrictions, more ports can join, thereby reducing the environmental pressure collectively.

<u>Scenario 1: An alternative for LNG, algae energy, comes available.</u>

When fuel from algae comes available the fossil fuels, such as LNG, are substituted by algae. The infrastructure of the LNG PowerPac® can be reused to provide energy to vessels by tank trucks that transport containerised tanks.

Reusing the LNG infrastructure makes, the business case for LNG stronger. Because when a new technology of fuel emerges the existing infrastructure can be reused.

More so, the algae energy can use the infrastructure of LNG in the port of Rotterdam. This implicate that this technology (partially) fits with the current skills and knowledge of the port employees.

Another attribute that is met in this scenario is the local application of algae oil in ports. The algae fuel can be distributed by the LNG infrastructure to other ports. This allows to create a network of algae using ports.

In this scenario the LNG PowerPac® leads ultimately to a fossil free technology, therefore, under this scenario the LNG option meets the attribute "fossil fuel independence".

In this scenario the LNG technology is a more promising option, given the opportunities that arise and values that are met by the LNG technology.

Scenario 2: Energy costs include the CO_2 externalities

This scenario includes the cost of CO_2 externalities to the energy costs. The more CO_2 is emitted the more costs are added. This implies that the costs for Carbon fuels are increased. More so, the costs to manufacture, maintain en dismantle, which demand energy are increased. These costs are included in the energy price.

The Carbon footprint, the emission of CO_2-equivalent over the lifetime of the technology, is bigger for the LNG technology than for the SSE technology. This implies that the electricity costs form a fossil energy sources increase more than the costs for electricity from renewable energy resources.

In this scenario the business case for SSE is more reliable, because of the limited increase in costs compared to the forecasted costs for the LNG PowerPac®.

8.2 The Main Conclusion

This report is written to determine which of the technologies is the most suitable and promising, to supply electrical energy to container vessels at berth in the Port of Rotterdam. Based on this report, an advice is given to the port of Rotterdam that contributes to decision making in order to develop the port of Rotterdam. In this report includes public values to avoid adverse effects such as opposition, delay or an unsatisfying decision. The main question of this report is:

What is the most suitable and promising sustainable energy technology for container ships in the port of Rotterdam, focused on selecting technical options for and comparing shore side electricity and LNG?

The technology should be suitable and promising, which implies that it should meet the current values of the involved stakeholders and it should give the prospect that it can meet the values successfully in the future.

To determine which technology meets the values best a multi-criteria analysis was performed to determine which technology prevails currently. This MCA includes decision criteria, which were obtained by a value analysis from stakeholder documents. More so, a SWOT analysis was performed to determine the scores for the MCA.

Scenarios are used to determine which technology prevails in the future. It is unknown what the future will be therefore, an estimate what the future might be allows to estimate is an technology is a promising.

Current Situation

In the current situation the final scores for the technologies are 0.62 for Shore Side Electricity and the final score for the LNG PowerPac® is 0.53. The SSE technology meets the public values best because it has the highest score, although the difference if small.

SSE is the best option because it is more innovative because it does not use fossil energy. Further, it contributes more to the value job opportunity providing more current and future job opportunities. More so, SSE adds to a fairer economy by taking responsibility, preventing environmental damage and pollutions of the living environment for the local population. More so, the SSE adds to public health because it has no local pollutions. More so, it has less Carbon emissions over its lifetime, hereby, a good air quality is met preserving the environment and health of the population.

The LNG PowerPac® has an overall lower score and meets in the current situation the value "business climate". This climate will attract more companies and contributes to the local population by jobs and affluence. The LNG technology meets with current skills of port employees and can therefore be adopted. The value security is met for port operations and data by the LNG technology, due to the ability to protect the grid more adequately from cyber-attacks. Sustainability is met by the LNG PowerPac® by the smaller energy sprawl, leaving more space for nature and green areas. Further, the values sustainability is met by the possible implementation sites for the polluting technology, hereby reducing the environmental pressure.

Scenario 1: An alternative for LNG, algae energy, comes available.

When fuel from algae comes available the fossil fuels, such as LNG, are substituted by algae. The infrastructure of the LNG PowerPac® can be reused to provide energy to vessels by tank trucks that transport containerised tanks.

Despite the higher outcome of the MCA for SSE , the LNG PowerPac® is the more promising option under this scenario, because of the opportunities that arise and values that will be met by the LNG technology.

Reusing the LNG infrastructure makes, the business case for LNG stronger. Because when a new technology of fuel emerges the existing infrastructure can be reused.

More so, the algae energy can use the infrastructure of LNG in the port of Rotterdam. This implicate that this technology (partially) fits with the current skills and knowledge of the port employees.

Another attribute that is met in this scenario is the local application of algae oil in ports. The algae fuel can be distributed by the LNG infrastructure to other ports. This allows to create a network of algae using ports.

Further, in this scenario the LNG PowerPac® leads ultimately to a fossil free technology, therefore, under this scenario the LNG option meets the attribute "fossil fuel independence".

Scenario 2: Energy costs include the CO_2 externalities

This scenario includes the cost of CO_2 externalities to the energy costs. The more CO_2 is emitted the more costs are added. This implies that the costs for Carbon fuels are increased. More so, the costs to

manufacture, maintain en dismantle, which demand energy are increased. These costs are included in the energy price.

In this scenario the business case for SSE is more reliable, because of the limited increase in costs compared to the forecasted costs for the LNG PowerPac®. This scenario is in line with the preferred technology from the MCA analysis.

The Carbon footprint, the emission of CO_2-equivalent over the lifetime of the technology, is bigger for the LNG technology than for the SSE technology. This implies that the electricity costs form a fossil energy sources increase more than the costs for electricity from renewable energy resources.

Concluding, to answer the main question the SSE technology is the most suitable and promising energy technology to implement in the port of Rotterdam. The SSE technology which is selected for the comparison is a grid connected system which is fed by off-shore wind turbines with a central static frequency converter. In the current situation this SSE technology has the highest score, therefore, meets under the current circumstances the values best. In the scenarios and in the scenarios the SSE technology meets the relevant values best.

The outcome of this analysis can be used by the port of Rotterdam to decide for a technology to develop the port area. By performing this analysis, the best suitable option is determined accounting for the values of relevant stakeholders.

However, despite the SSE is the most suitable and promising technology for the port of Rotterdam, it is possible that another technology or other options for the SSE technology are implemented instead, because another scenarios, practical issues or the decision process is biased by an strong and influential stakeholder.

8.3 Recommendations

The port of Rotterdam contributes to the Dutch economy by providing jobs and embracing innovative businesses in the port area. However, the port of Rotterdam contributes to emissions, which threaten the public health and environment. To protect the public health and to prevent environmental damage, these emissions need to be reduced over the coming years.

To develop the port of Rotterdam and to prevent impedance or delay from the public, their values should be included. A suitable and promising innovation is required, which contributes to public values economic growth, public safety and sustainability.

This research concludes, that shore side electricity is a suitable and promising energy technology and that meets relevant public values. The SSE can supply energy to (container) vessels in the port of Rotterdam, hereby develop the port area and to meet the public values. This is an innovative technology that reduces the noise and emission in the port area. More so, it allows for the implementation and development of a renewable energy resources and the balancing of this (smart) grid. Further it is an innovative fossil free technology, therefore, meets the value of being at the front of developments.

The port of Rotterdam should attract more renewable energy companies to make a shift from a fossil-based industry. This is required to maintain the job opportunities in the port area. More so, this allows to maintain its market leading position, hereby, creating new knowledge and skills. These renewable energy businesses contribute to jobs that range from low level education to high level education, such as, service engineers, service desk employees in data centres to data analyst.

The port of Rotterdam should take into account CO_2 externalities. These added costs make the consumption of fossil fuel less attractive and will spur the innovation to reduce emission of other port business. More so, this income can be reinvested in research to improve the emissions and pollutions in the whole port area. From this research the pollutions (NO_x, SO_x, pm and noise) and CO_2 emissions should be reduced to sustain the environment in and outside the port area. Further, the reduction of these pollutions contributes to public health.

The port of Rotterdam should initiate a collaboration with shipping companies that traffic between the port of Rotterdam and ports in China and California. From this research, the legal necessity for vessels to have SSE in California spurs the implementation of SSE. This regulation applies to all Californian ports, which are the majority of ports on the West side of the USA and is therefore effective. In China a governmental regulation obliges the use of SSE. A European regulation would be necessary to cover all ports in Europe, this has been unsuccessful. Therefore, the port of Rotterdam can increase its attractiveness for these shipping companies by creating a better connectivity by providing SSE energy.

8.4 Limitations

This research has limitations and the outcome of this research needs to be put into perspective. More so, reflecting upon this research I would have conducted this research differently. Some limitations, the outcome and decisions are summed below:

- The outcome of this research is an advice to parties that make long-term planning for the port area, such as the port of Rotterdam, Deltalinqs, and the Municipality of Rotterdam, however, complementary research should be carried out for a complete advice because this report does include all technical options nor does it include practical feasibility, nor the stakeholder's influence and power in the decision-making process.
- The technological choices that were made in chapter 3, that were made to obtain more detailed technologies for the MCA, could have been included in an MCA. This would allow the stakeholders to select their favourable technological options for the technologies.
- In hind side, in order to determine the most suitable and promising technical option, the stakeholder value trees should not have been combined into one value tree because information about the stakeholder's values and how the technologies meet these values is less explicit. In future research an MCA should be made from the stakeholder value trees per stakeholder to determine which technology is suitable and promising per stakeholder. The final technology can be reasoned using the outcome of the MCAs per stakeholders and scenarios, stakeholder's power and influence or practical issues.

  The reason to combine the value trees in this research is to come to a solution, albeit a technocratic one, in which all stakeholders have an equal share in the decision. This is why a stakeholder analysis was executed which includes all stakeholders, to give all a voice in this decision. The voice of all stakeholders is necessary to determine a suitable and promising decision, hence, a right decision.
- In retrospective, the method described by Van der Lei should have been used to compose the value trees because of the simplicity to repeat the analysis, despite the bias in the words which are obtained by an automated word count from strategic documents. The use of this method should be combined with composing individual stakeholder value trees and not create one overall value tree.

  In this report a combined value tree is composed from individual stakeholder value trees in order to obtain a suitable and promising sustainable technology. Hereto, the method of Van der Lei, which includes an automated word count, has not been used because the nouns that are counted lack context, the nouns can be used repetitively, or the nouns are articulated differently by various stakeholders. This is a problem when one overall value tree needs to be composed, because nouns can exist in the overall value tree with different meaning more so synonyms may exist. More so, the strategic documents, from which the nouns are obtained, are written to portray the stakeholder's achievements, ambitions and their values for the public. Hereby, improving their reputation by including topics and words that are valued by the public.

  In this research one value tree is used to come to a solution in which all stakeholders have an equal share in the decision, hereto, three terms for public values are determined. And strategic documents are analysed for achievements or future goals to determine how these public values are met by the stakeholders.
- The scenarios should have been more prominent in chapter 4 (the SWOT analysis). However, due to the flow of this investigation they are in chapter 7 where they describe the more promising technology referring to the numerical value of the MCA (0.62 and 0.53). More so, the scenario of a zero emission port with complete electric transport and renewable

energy resources should have been more explored in the SWOT, which would give another scenario.

- The outcome of the MCA could be different if the weights of the values and the scores of the criteria were chosen differently. In this study the values were used based on the scale (0 and 1,2, 3). The scores for the criteria are based on the ordinal scale (0,1). The use of the zero in the scores means that when a zero is assigned the technology loses all points for that value or score. This would not be the case if a score system and 1,2 had been chosen. Using the scores (0 and 1) means that the finals scores deviates less than when using, for example, a 1, 2 scores system.
- The final scores for the technologies do not differ that much, partly due to the ordinal scale, therefore it may be plausible that the "losing" technology is implemented in the port of Rotterdam because of additional criteria, such as practical feasibility, and future developments. Different technologies can be chosen under different scenarios. By including plausible scenarios in the research, the port of Rotterdam can prepare for future developments. This report focuses on a few scenarios, there may be other scenarios.
- The reliability of the data can be improved by, as I mentioned, earlier by sticking to the method of Van der Lei to create the values trees. More so, the questions in the interviews should have been more precisely formulated, especially in the expert interviews.

8.5 Suggestions for Future Research

In this section recommendations for future research are given. During my research I came across some information gaps and unmentioned developments, such as:

- Future research can build this research. This research can be seen as the conceptual investigation in the VSD methodology, therefore, an empirical investigation and a technical investigation can be performed in the future using the information in this report.
- The lack of (international) regulations or standardisation for SSE and LNG drives ports to explore new functions. Ports are cooperating and collaborating with governmental organisations, in order to develop of new regulations. This might implicate a change in the role of the port from advising to leading. It would be interesting to investigate this impact on the power balance between port and government, and what this change would imply for the public values.
- In one to the interviews a lack of information was mentioned. There is little detailed information about the current onboard equipment of container vessels and what modifications are required for a retrofit for either SSE or LNG. A database should be made with includes this information. This information may enable a more detailed cost-benefit analysis. When European ports collaborate using this information, a European solution may be implemented.
- During this research one of the shipping companies reached a mile stone. An ultra large container vessel was unloaded within 158 hours. Considering this trend, the increasing vessel capacity, it may be interesting how suitable and manageable the containerised LNG solution or the SSE solution is.
- The development of an all-electric vessel was not mentioned or described in the interviews or strategic documents. For further research it would be interesting to investigate, to what degree the stakeholders are willing to invest in an all-electric vessel with a supporting technology, SSE or LNG, to provide the vessel with electricity whilst in hotel function.
- Another development is the gain in LNG fuelled vessels. These vessels use LNG as a primary fuel at sea. It would be relevant to determine if and how this trend impacts the decision for the technologies.

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Appendix 1 Motivation for Experts

This appendix presents the motivation for the different experts. In this research open question semi-structured interviews are conducted to obtain information from experts with matter know-how expertise and external expertise. The data from the experts differs because they have different knowledge and are active in different work fields. The objective of this interview is that experts give information about their experience with the technology and information about the social-technological system in which these technologies is/will be embedded.

Expert 1 is a global product manager of ship-to-shore power at ABB. He is an expert in the implementation of shore side electricity installations. He deals with cost optimisation, aids to adjust the system to the consumer's requirements and is involved in the air quality of the port area. Expert 1 was suggested to me by expert 2. Expert 1 was selected to obtain more information about SSE systems in China, where, like in Europe, a 50 Hz grid demand a frequency converter for the 60 Hz vessels. Further, it would be interesting to gain more information about the energy source for the SSE installation in China.

Expert 2 is a market manager PGGI Benelux at ABB. ABB was selected because it is one of the leading companies in shore side electricity components. Expert 2 was involved in the implementation of the of the frequency converter, part of the SSE installation, for the Stenaline ferries in the port of Rotterdam.
It would be interesting to gain information about the requirements of the SSE components and design requirements in the port of Rotterdam. More so, information about other port grids and foreign SSE installations, especially in China, are welcome.

Expert 3 is senior advisor sustainable shipping at Port of Rotterdam. Therefore, he may have insight knowledge of the technology requirements and the existing infrastructure in the port in which the technology will be implemented. Further, he may be involved in projects to shape the future of the port.
It would be interesting to obtain information about the current situation in the port of Rotterdam, their view on the vicious and virtuous aspects of SSE. More so, alternatives for SSE and future prospects may be interesting too.

Expert 4 is the director of Center for port innovation at the TU Delft. He has experience in and knowledge of the petrochemical industry. However, the last time he focused on the development of the port of Rotterdam with the emphasis on infrastructure.
It would be interesting to obtain information about the required stimuli or barriers for ports and port industries to implement sustainable innovations, such as SSE.

Expert 5 is a marine biologist and focusses on sustainable port development at the independent research centre of Deltares.
Considering the opposing values economic growth and sustainability, it would be interesting to know more about the values or parameters that should change to spur sustainable development in port areas, such as the implementation of SSE.

Appendix 2 Overview of the Interviews

Table A — 1, gives an overview of the stakeholders and experts that were involved in this research. This table shows the contact persons and on behalf of the organisation or company they participated. In a last column of the table is mentioned whether the person is considered an expert or a stakeholder in this research. Under the table the questions or topics of interest are described for the expert interviews or stakeholder interviews.

Table A — 1 Overview of stakeholder and experts.

Expert # / contact	Organisation	Expert or stakeholder
1	ABB	Expert
2	ABB	Expert
3	Port of Rotterdam	Expert
4	Technical University of Delft	Expert
5	Deltares	Expert
6	Cavotec	Stakeholder
7	Deltalinqs	Stakeholder
8	Milieudefensie	Stakeholder
9	Municipality of Rotterdam	Stakeholder
Allard Castelein	Port of Rotterdam	Stakeholder

Questions and topics for the expert interviews:

Technical for shore side electricity in the port

- In China, SSE is implemented, what did they implement? In which ports?
    - AD/DC
    - Energy source
    - HV or LV
    - Frequency converter
    - Decentral or central
    - Energy source on vessel or at quay
- In USA, SSE is implemented what did they implement? What can we learn? In which ports?
    - AD/DC
    - Energy source
    - HV or LV
    - Frequency converter
    - Decentral or central
    - Energy source on vessel or at quay
- Welke techniek zou een goed basis zijn om op verder te gaan?
- Which SSE technologies are available or under investigation for (container) vessels?
- Welke technieken zijn volgens u kansrijk of zouden meer onderzocht moeten worden?

SWOT with PESTEL

- S: What are advantageous or positive aspects of SSE/LNG?
- W: What are disadvantageous or negative aspects of SSE/LNG?
- O and T (PESTEL):
    - Political: How is the international collaboration for implementation? Why are there no international laws? Who are we depending on when SSE/LNG are introduced?
    - Economic: What does is cost? What is the economic system? How is the competition? Are external costs internalised?
    - Social: What is current social attitude towards SSE/LNG implementation? What has changed under which cause? What should change?
    - Technological: How can the implementation evoke a cascade of technological developments? Are there other technologies?
    - Environmental:
    - Legal: ESI, what are current regulations/limits? What are short-comings in current regulations? voluntary or compulsory?

Questions and topics for the stakeholder interviews:

Stakeholder interaction

- Who are other parties involved in the design or implementation? (Cavotec, Deltalinqs, Milieudefensie, Municipality of Rotterdam, Port authority of Rotterdam – WWF, Maersk, Shell, Becker Marine Systems, other knowledge institutes. Etc.)
- How do or may these other stakeholders contribute to the innovation process?
- Does cooperation promote or inhibit competition?
- Who should act to implement SSE/LNG?

To obtain stakeholder values and actions concerning to achieve those values

- What can you tell about the communication process? (other stakeholders, influence, type of meeting)
- How do you deal with safety (sustainability? economic growth)
- What are actions concerning safety (sustainability, economic growth)
- What procedure is used to implement new technologies
- What is the long- term vision or ambition? (social, technical, environmental, political)

Appendix 3 Interview with Expert 1

Interview export 1 (ABB)

Interview taken at 10:10 - 10:50 at the 18th of April 2017

Expert 1 and Anniek van Lieshout (AvL)

AvL: What is the motivation for exploring the possibility for shore power?

E1: In China shore to ship power is used in a strategic plan, with an implementation plan of pollution preventions of ships and ports. And this is focussing on five years between 2015 and 2020. It basically means to introduce pollution preventive measures in shipping. Mostly on the river shipping, but also on the main coastal cruise and container terminals. The plan will be to reduce 65 % SOx, 20 % NOx and 30 % particulate matters. And this is realised using shore to ship power to the port facility. This is part of the implementation plan. And the Chinese government is providing some subsidies for implementing such measures. From a governmental side, you reduced pollution. From the port's perspective, they will rely on the government subsidies to implement the solution. The government has an essential role. And another essential role in the port is played by the state grid of china, which is the main utility of China. Which is directly investing in shore power. Of course, leveraging the subsidies given by the government. If I look in parallel in Europe where sometimes one of the big obstacles is the fact that the port authorities cannot sell electricity. So, in a way having a potentially active role of the local distribute or grid operator would really be beneficial. They can sell electricity and they can be willing to invest. This is low or non-existing in Europe. On the other hand, a key factor in China that is the fact that shore to ship power implementation in China is ramping up a lot, while in Europe on the part of notable exception is on a case by case basis.

AvL: Which energy sources are used for the shore power?

The plan, with shore power, is because China has to do something to stop the emissions in general. Because most of their power production in coming from old fashion coal power plants. Because most of their power production is coming from old fashion coal power plants. So, you have thermal power plants which are really polluting, and all-in-all this is a potential way to reduce the emission and to have a better utilisation of the thermal powerplants.

AvL: Does China make any attempts to introduce wind or solar energy in the grid?

E1: I think so but, I am not following the general policy in China. I am just focussing in my business area; therefore, I don't know about the full strategy of about the Chinese government about the renewables.

AvL: Earlier, you mentioned that shore power is implemented for land-in traffic for the local river, ferries and container vessels. What is the installed capacity of shore power for container vessels?

E1: In China, they have now up to three installations for cruise which are rated to 16 MVA each. They have several installations for container vessel, where the average single vessel consumption is estimated to be 3 MVA. But sometimes they have multiple vessel facilities, for example, they have 6 MVA facility delivering power to two different vessels. The typical sizing is 3 MVA but it may vary on a case by case basis. Because, the consumption of the shore power facility depends on the number of refrigerated containers on board of the vessels. And the size of the vessel. We estimate is 1.0 to 1.5 MVA as standard consumption of the vessel, all the rest is refrigerated containers. The maximum for the facility is determined by, the highest number of reefers and the biggest vessel size. I know that in

China we have executed one specific project with two 3 MVA conversion system, which can feed two smaller container vessels or a bigger one of 6 MVA.

AVL: And you mentioned multiple installations for container vessels, How many roughly?

E1: What I can tell, is what we have executed as ABB. Two installations for container vessels in China, where we can host one bigger vessel or two smaller vessels each rated 3 MVA or one 6 MVA.

AvL: And in which port was it?

E1: In Dalian and Nansha for ABB.

AvL: In the Netherlands, there is a need for a transformer. How is that in China because they have a 50 Hz grid?

E1: The container vessels have 60 Hz therefore, they need a 60 Hz static frequency converter substation. You need to have an incoming medium voltage switchgear and then the input transformer and frequency converter and output transformers. With the frequency converters, you convert the frequency from 50 to 60 Hz. And with the output transformer, you go to 6.6 kilovolt that is the standard voltage onboard of a container vessel. So, you need a frequency conversion substation to comply with the requirements.

AvL: Do all container vessels have 6.6 kV, because I read that some have 440 volts instead of 6.6 kilovolts?

E1: One thing is the onboard distribution, which could even be a low voltage one when the container vessel is small. And one thing is the shore connection. For container vessel, there is a specific international standard which is clearly stating that when there is a shore connection on the container vessel, the container vessel is connect at 6.6 kilovolts. So that is quite standard. So, when there is a container where you have 440 volts on board, then you need to bring a transformer on board of the container vessel which converts 6.6 kV to 440 V.

AvL: And this transformer is it mobile? Can ship owner put it on and off the vessels? Or does it need to be on the ship?

E1: It is usually on the ship. Then there could be also a solution, where you can place this transformer with the switchgear with cable reel inside a container and then you can bring this container on board. But usually, if you do this with the container then, the container is fixed onboard. I don't know about an installation where the vessel arrives at the port and bring the container on board and bring it off when the vessel goes away.

AvL: What is the complete SSE installation?

E1: Let's go step by step from the grid. Medium voltage switchgear for the grid interface at 50 Hz. Then you have a power transformer which is adapting the grid voltage, whatever it is, to the static frequency converter voltages, whatever it is. So, assume we have a static frequency converter working at 440 Volts 50 Hertz and you have a grid of 20 kilovolt. You need a power transformer for the 20 kilovolts to the 440 Volts. Than you have the static frequency converter which is converting the frequency from 50 to 60 Hertz, keeping the voltage at some level, let's assume again 440. But the frequency converter can be also medium voltage, so you can have a 3-kV frequency converter with 3 kV input a 3 kV output. That depends on the technology. Let's assume you have 440 V at 60 Hz in the output. And then you have a transformer to correct the voltage, which transforms the output of the static frequency converter, assuming 440 or 3 kV to 6.6 kV. Then you have a cable going to the berth and you have a

junction box that is installed in the port area. And you stop. From the vessel you have a cable that is coming down and connected to this junction box, 6.6 kV cable. You have a transformer 6.6 kV to some voltage on board, which could be 6.6 kV to 3.6 kV or 440 V or whatever. And this is onboard, and you have a medium voltage switchgear onboard that connects this 6.6 kV to onboard voltage.

AvL: Which technology is used to transform the energy? Because you mentioned the use of a static frequency converter is there a reason for?

E1: There are several ways to convert the frequency. First of all, the rotary frequency converter was the old way to do that. It is still very well-known and used in the navy basis, because of historical reasons. but nowadays static is the preferred one for several reasons. First of all, it is a much newer technology. The static frequency converter has easy maintenance because maintenance can be done by the port operator. Where for a rotating machine you need to call the supplier. You have better efficiency, usually, rather than a rotary converter. Because of specific and partial load, if the converter is not fully loaded you have a lot of losses in the converter. The static is easier to operate and to maintain usually they are also modular and in case you have a fault you can exchange one single module. So, it is easier to maintain and therefore more efficient. Usually it is also more compact in terms of space.

AvL: Do you work as well with rotary frequency converters or none at all?

E1: The decision was not to use rotary frequency converters. Of course, we might integrate them. ABB is producing also motor synchronous generators, so we could integrate a rotary frequency converter in principle. But this is not a standard product we use, because we see that the market is moving in a different direction. We might work with rotary frequency converter installation if it is required.

AvL: Is the frequency central or decentral transformed?

E1: For these two installations in China we implemented a central transformation station. It was centrally converted although, it is not very far from the berth. This is usually the cheapest option. In container terminals you can have one-to-one installation but, this will not help you with the utilisation factor. Because you may not have all the vessels connected at the same time or present in the port at the same time. Therefore, you may not have a good utilisation factor of a decentralised connection. For this reason, it is better to heave a centralised connection and you pay once for the centralised conversion station and then you can have a distribution to the different berths. Of course, there is a balance between the costs of the expenditure with the real utilisation factor. ABB can implement central and decentral installations according to local requirements. In my personal views is, that it is better to have centralised installation because it helps to maximise utilisation factor.

AvL: And those ports you mentioned are they big? Do they have a lot of traffic or transhipments? I can image when there is a smaller port, it is still easy to manage on a central point. But when you have a very big port and then one central converter it needs to convert very much and there is a big deviation in the occupation of berths.

E1: So, the point is when you have a small port, you can have a one-to-one installation. But when you have a big port, you may have different places where you to install shore power. Maybe, the container terminal of a port, for sure, will not have the same infrastructure of a cruise terminal because, they are multi-purpose ports. So usually you will buy this in segments. You will not have a centralised facility that will serve cruise, ferry and container. So usually you have a facility for container terminals that is separated from the ferry terminals and another one from the cruise terminals, also because of the

vessel requirements. In terms of the port as we were saying Dalian port looking at some statistic that I had in 2014, was 15 worldwide port. So, it is quite a big one. Nansha, I think, is a little bit smaller.

AvL: If you want to make such an installation like in Nansha or Dalian, what would be an estimate for the costs?

E1: That depends on a lot on the topology of the ports. First of all, it depends on the number of vessels you can connect.

AvL: How much would it roughly be per connection?

E1: This is a question that is very hard for me to answer. I can give you an estimate for the frequency conversion substation, but for the whole installation it becomes a little bit more tricky because I really don't know how long the distance between the frequency converter substation and the cable management system is, so how many connection points are there. For a frequency conversion substation, you can estimate 1.5 – 2.0 million for 5 MVA. For the whole installation, it is really more tricky because the civil walls and the cable have a big impact.

AvL: What is the lifetime of such frequency converter and of the whole installation?

E1: There is a general policy of ABB products that the lifetime is at least 20 years. Provided that of course maintenance is done according to the maintenance schedule. An example after 6 years you have to chance the ventilation fans.

AvL: What type of container vessels makes use of this shore power installation? Because we already mentioned a bit about the type of vessels, small ones of 3 MVA or one big one which is 6 MVA.

E1: Exactly. This is specific to container vessel of course if you go to another kind of vessel the consumption it totally different. The global international standard states that container vessels will never get more than 7.5 MVA. If we would be asked to design a container vessel shore power installation according to the standards. We would design that each and every vessel would get 7.5 MVA and then we can play a little bit with the utilisation factor to optimise the installation. On the other hand, when the customer is asking for a 3 MVA installation, it means that they already have a list of vessels that are coming in and already knows the average power that these vessels demand. In general, the vessel that uses shore power installation is more than 10,000 TEU. And all of those have an onboard cable management system. So, you put the socket box and junction box on the port side but the cable management system on board. This is a totally different story if we speak about cruise vessels. Where for cruise vessels, we need to provide complex cable management system on shore.

AvL: How did China account for possible reefer containers? Because they do not know how many reefers there are on the vessel.

E1: There is a way of computing. I don't remember if each and every reefer container has a power consumption of 4 kW. When you have a vessel coming in, knowing that the port can only deliver 3 MVA. The container vessel owner knows weather if 3 MVA or 4 MVA is enough for them, because they know perfectly their consumption. And in view of that they can make use of the full shore power connection they may decide to keep one onboard generator on. To just use partially the facility that depends on what they have on board. In generally you have to think the vessel is the master and the port is the slave. The vessel defines how to behave. Knowing what the capabilities are of the shore part in the port.

AvL: Is it possible to have it partially using the auxiliary generators and partially using shore power?

E1: Technically yes. This is not the standard situation. You connect the shore power when the generator is on. Then you switch-off gradually the onboard generator and you just keep the shore power running. Okay. And then it is the opposite when the vessel is leaving. So, you switch-on again the generator and switch-off the shore power. But there can be some situation when both systems are running at the same time apart from this temporal connection time. Sometimes there can be a situation but this is not the standard.

AvL: Is it actually allowed to have them both running, and that is basically insurance technically?

E1: From a technical perspective it is possible. Then if it is allowed or not depend on the local regulation.

Appendix 4 Interview with Expert 2

Interview expert 2 (ABB)

Interview afgenomen 16:19-16:54 op 6 April 2017 te Delft

Aanwezigen: Expert 2 (E2) en Anniek van Lieshout (AvL)

AvL: Welke type walstroomaansluitingen zijn er?

SR: Wij hebben een project gedaan voor Stenaline waarbij er een station op de kade staat met een spanningsomvormer en frequentieregelaar. Er worden kabels vanaf de kade getrokken naar het schip. Voor containerschepen is het anders, daar komen de kabels vanaf het schip naar de kade. In Amerika is het gebruik van een frequentieregelaar niet nodig omdat, zij daar een netwerk van 60 Hz hebben.

AvL: Uit de literatuur stuitte ik op twee type regelaars, een stationaire en een roterende. Wat zijn de voor-en nadelen voor het gebruik van roterende regelaar voor de Rotterdamse haven?

E2: Rotary frequency converters zijn robuuster, zij hebben een generator en motor op één as. Een stationaire omvormer is een thyristor met gelijkrichters die van AC DC maken en dan weer AC. Bij walstroom moet je de omvormer aan-en uitzetten naar gelang van de vraag. Hierbij treedt slijtage op.

AvL: Graag zou ik meer informatie willen over de installaties in Shanghai en Shenzhen (Shekou). Wat is hun energiebron? Wordt de stroom omgevormd? Welke technologie gebruiken zij voor het omvormen? Welke topologie wordt gebruikt? Welke KMS gebruiken zij, in de internationale standaard wordt vermeld dat het KMS voor containerschepen aan boord zou moeten zijn. Terwijl van een foto een KMS op de kade staat.

E2: Wat zij in China hebben weet ik niet precies. Er zijn wel verschillende technologieën mogelijk, een vaste installatie op het schip maar ook een verplaatsbare haspel ingebouwd in een container. De containerschepen liggen echter nooit precies op dezelfde plek hierdoor is het praktisch om de kabels aan boord te hebben. De vraag centraal of decentraal omvormen? In een groothavengebied een tweede netwerk aanleggen is niet wenselijk. Voor meer informatie zou ik je graag willen doorverwijzen naar expert 1.

AvL: Stel dat er een 60 Hz netwerk komt met als energiebron windmolens. Zou het dan wenslijk kunnen zijn?

E2: Ja zeker, er wordt 60 Hz gegenereerd en je omzeilt de omvormer.

AvL: Een poos geleden was er een systeem onderzocht met een dubbele busbar, is dit wenselijk?

E2: Nee, dit komt door veiligheidsaspecten en aansprakelijkheid.

AvL: Een windmolenpark op zee heeft kabel nodig om de stroom naar de kade te brengen. Waar laat je de omvormstations (spanning)?

E2: Je hebt twee omvormstations nodig met daar tussen een kabel. Een station zal bij het windmolenpark staan en de ander in het havengebied.

AvL: Zou een samenwerking met België of Engeland wenselijk zijn voor het implementeren van het netwerk?

E2: Nee, de havens geven een deel van hun autonomie op. En een groot tweede netwerk lijkt mij niet realistisch.

AvL: Stel dat de EU een groot windmolenpark aanlegt wie gaat daarvoor betalen en in investeren?

E2: TENNET zou de aangewezen partij zijn om het netwerk dan aan te leggen. Of het netwerk wordt aangelegd door kleinere initiatieven, bijvoorbeeld Stenaline of het dubbele netwerk in Scheveningen voor vissersschepen en rijkswaterstaatschepen.

Appendix 5 Interview with Expert 3

Interview Expert 3 (Port of Rotterdam)

Interview afgenomen 11:00-12:00 op 29 november 2016 te Rotterdam

Aanwezigen: Expert 3 (E3), Expert 3b (E3b) en Anniek van Lieshout (AvL)

AvL: Wat is er aan walstoom aanwezig in het Rotterdamse havengebied?

E3: In de haven van Rotterdam zijn walstroomfaciliteiten geïmplementeerd voor binnenvaart op openbare ligplaatsen, daar zijn de investeringen van te overzien. In veel gevallen slapen mensen aan boord op een binnenvaartschip, dus het uitschakelen van generatoren is gunstig voor hun leefomgeving. Voor zeevaart, containerschepen is het een veel grotere investering, een miljoen voor een walaansluiting plus 0.5 miljoen voor een individueel schip. Walstroom voor de zeevaart speelt al 15 jaar. Bekijk het WPCI voor de business case.
De brandstof waar een groot deel van de schepen op vaart is stookolie, hoogzwavelige brandstof. IMO is onderdeel van VN, waarin onderling wereldwijde afspraken worden gemaakt voor de zeevaart. Voor het milieu is de MARPOL-conventie relevant. Hierin wordt vast gelegd welke brandstof je mag gebruiken en wat je in *Sulphur Emission Control Area* (SECA) mag gebruiken. De zwavellimieten zijn inderdaad op volle zee van 5.0 % naar 3.5 % gegaan en in SECAs is het van 1 % naar 0.1 %. Een maand geleden heeft het Marine Environmental Protection Committee in London besloten om de wereldwijde zwavellimiet in 2020 naar 005 % te verlagen, dat is enkel relevant voor wat op zee gebeurd.
Het is aan de andere kant wel relevant hoe rederijen ermee omgaan, je mag een hoogzwavelige brandstof gebruiken maar dan moet je het uit de uitstoot vissen met scrubbers. In de SECA is het lastig en aan de kade is het ook lastig, omdat een scrubber op de hoofdmotoren zit niet op de generatoren, die worden gebruik tijdens het hotelbedrijf.

AvL: Wat is een barrière voor walstroom?

E3: Er zijn vele rapporten geschreven over opties naar walstroom, voor containers of ferry's voor de kade van de Maasvlakte. Zeker in het verleden was de business case lastig. Je vergelijkt de prijs van de scheepsbrandstof met een elektriciteitsprijs. Een rederij kijkt enkel naar de kosten voor het aan boord stoken versus het gebruik van elektriciteit en additionele installaties.

AvL: Zou het eventueel met beleid gestuurd kunnen worden?

E3: Ja, dat zou in theorie kunnen, je kunt het verplichte of stimuleren. Voor een reder kunnen zwaarwegende redenen zijn om die meerprijs toch te willen betalen. Bij Rotterdam heeft de Stenaline een walstroomaansluiting. Een van de redenen voor hen om de aansluiting te nemen is omdat, zij dicht bij de bevolking hun ligplaatsen hebben.

AvL: Stel dat u op de lange termijn kijkt zijn er nog ander barrières?

E3: Een klassiek kip-eiprobleem. Een terminal wil niet investeren zolang er geen schepen zijn, die het hebben er rederijen zetten het niet aan boord als er niet voldoende plekken zijn waar ze het kunnen gebruiken. Dus daar zou een policy op kunnen zetten. Technische barrières, zijn er ook. Vaak is er geen aansluiting voor de capaciteiten die zo'n schip aan te sluiten. Op het moment dat het hoogspanningskabels moet leggen moet het investeren. De meeste schepen zijn uitgerust met 60 Hz, het Nederlandse netwerk is uitgerust met 50 Hz. In America is het 60 Hz en is het dus goedkoper om aan te sluiten en in Californië is er een wet, die het verplicht. Dat is de reden waarom het goedkoper

is om aan te sluiten in USA. In Californië is er een lokale wetgeving van kracht, die het gebruik feitelijk verplicht. Als je in het de haven ligt, is er geen kabel tot aan de kade. Als je kijkt naar de Californische havens onderling, is er één Californische wet die alle havens afdicht. Hier zijn allemaal verschillende landen. Naast Californië heb je geen andere staat aan die kan met havens. Dus als een land iets zou verplichten dan heb je wel een competitieve nadelen t.o.v. van de andere.

AvL: Kan de EU kunnen helpen?

E3: Ja, maar dat zal niet gebeuren. Er is wel een richtlijn 2014/94, dat is een richtlijn voor de infrastructuur voor alternatieve brandstoffen. In die richtlijnen staat volgens mij is het dat alle core porten aangesloten op het core netwerk alle core porten walstroomaansluiting zouden moeten zijn. In het trans-Europese netwerk wordt er onderscheid gemaakt tussen het core netwerk en het comprehensive netwerk. Dat betekent echter niet, dat er op alle terminals walstroomvoorzieningen aangelegd moet worden. Kijk het is aan de lidstaten om de beleidsambities neer te zetten, dus moet je bij het ministerie van infrastructuur en milieu zijn, om formeel te horen wat de opties zijn voor de Nederlands plannen.

AvL: Wat zijn de geschatte kosten voor een aansluiting?

E3: Per aansluiting 1-2 miljoen euro.

AvL: Zou walstroom tot de opties behoren door een samenwerking met grote rederijen die tussen, bijvoorbeeld, Shanghai en Rotterdam varen?

E3: Als je het over de containervaart hebt, dan is dat precies wat er gebeurd. Of thans, waar we naar aan het kijken zijn. In de Chinese havengebieden kampen zij met erbarmelijke luchtkwaliteit door NOx- en pm-uitstoot. Beleidsmatig is bepaald dat op korte termijn alle nieuwe terminals en voor een deel bestaande terminals uitgerust moeten worden met walstroom.

AvL: Welke walstroominstallaties of specifieke aansluitingen zouden dat zijn?

E3: In het verleden was er überhaupt geen standaardisatie. Tegenwoordig zijn de systemen min of meer gestandaardiseerd qua aansluiting, dat betekend niet dat je plug-en-playsysteem hebt. Je hebt de traditionele aansluiting waar je over de kade heen gaat met een aansluiting naar het net, een transformer, kabelmanagementsysteem enzovoort. Daarnaast heb je ook allerlei mobiele de LNG-barge of de hybride barge.

AvL: Volgens mij is er in 2015 een soort van standaardisatie gekomen voor HVSC dat inderdaad het kabelmanagementsysteem op het schip moet en voor ander schepen zal hij op de kade staan. En daar hebben zij ook gestandaardiseerde sockets, en dat je twee kabels hebt van 6.6 kV.

E3: Oké, maar dat wil niet zeggen dat de óplossing gestandaardiseerd is, en dat zie je. Eén van de bezwaren die de containerterminals aangeven. Een containerterminal ziet er voor buitenstaander altijd hetzelfde uit. Je hebt een soort kraan op de kade. Maar ongeveer elke terminal is een uniek ontwerp, zowel qua infrastructuur als ontwerp. Dat betekent dat in het ene geval de containers vlak langs de kade staan en in het andere geval staan meters ver van de kadekant. De vraag is waar je überhaupt die spullen kwijt kan en hoe het de terminalprocessen beperkt. Als je inderdaad zegt waar je kabelmanagementsysteem aan boord hebt, maar daar is geen verplichting toe. Je ziet dat er aanbieders zijn die containers hebben met een heel kabelmanagementsysteem erin. Dan moet een schip zo'n container standaard aan boord hebben, of de container aan boord plaatsen op het moment dat hij aan je kade ligt. Maar daar is geen standaardisatie voor.

AvL: Stel dat we toch kijken naar de Rotterdamse haven, RGW of APM-terminals. Voor de frequentie omvormer zijn verscheidene topologieën mogelijk en verschillende omvormers. Hoe kijkt u daartegenaan?

JS: Ja, dat is een van de barrières. De frequentieregelaar is het duurste van de elektrische systemen. De civiele werken zijn dus afhankelijk van de locatie, als je naar het systeem kijkt is dat het probleem. Dit is één van de reden waarom de mobiele oplossingen aantrekkelijk zijn. De firma Becker Marine in samenwerking met KOTUG hebben dus die LNG-barge gemaakt voor Hamburg, die is oorspronkelijk bedoeld voor is cruiseschepen. Je hebt een bak met zes LNG-motoren staan. Twee 2 x 40 ft containers met LNG staan naast elkaar op het dek en een enorme installatie en met dat schip kunnen ze op een schone wijze elektriciteit produceren. LNG produceert nauwelijks NO_x, SO_x en pm, Maar het blijft fossiel dus je houdt CO_2 en methaanslibissues. Een voordeel is dat je de barge kan verplaatsen naar gewenste locatie.

AvL: Deze technologie is voor cruiseschepen, is er ook een technologie voor containerschepen?

E3: Ja, voor containers hebben zij een oplossing bedacht op basis van deze expertise. Met de barge kan er ook warmte geproduceerd worden, wat aan het warmtenet gegeven kan worden. Momenteel wordt onderzocht of deze barges een oplossing kunnen zijn voor Rotterdam. De firma Becker Marine heeft een Duits onderzoek gekregen om een experiment te doen met een PowerPac®, 2x40 ft containers boven elkaar, met motoren en opslag. Het aardige is, dat je die gewoon volledige op zo'n schip kan zetten. Als je naar een businessmodel gaat kijken is het de vraag wat je gaat doen. Zet je de container standaard op de kade of je zet hem op het schip of je koop je hem en plaats je hem permanent op het schip.

AvL: Met LNG als brandstof. Hebt u ook naar waterstof gekeken?

E3: Ja, er is gekeken in samenwerking met een college in samenwerking met NEDstack een studie naar gedaan. Dit is vrij innovatieve technologie en de capaciteiten die zij kunnen leveren is 1 MW. De capaciteit voor een containerschip is over 3 MW en voor cruiseschepen is het 8 tot 16 MW. Daarnaast zijn er veiligheidsobstakels. Voor het gebruik van LNG en waterstof moet je voldoen aan eisen en de wet-en regelgeving moet erop worden aangepast.

AvL: Hoe is het met de ruimte in de Rotterdamse haven, ervan uitgaande dat de drijvende barges een investering is voor 50-60 jaar en de trend dat zeeschepen steeds groter worden?

E3: Jazeker de terminals worden ontworpen om maximaal efficiënt te zijn. Een barge naast een containerschip is niet handig.

AvL: Nu heb ik gekeken naar Amerika waar een deel van die barges varen en die overgaan op grid-connectie. En in China wordt walstroom geïmplementeerd,

E3: Ja maar het grote verschil is in Amerika heb je 60 Hz op het net hebt. En het voordeel van een barge generator is dat je die op 50 dan wel 60 hertz kan zetten. Door zo'n ding te gebruiken elimineer je de noodzaak om een frequentieregelaar aan te schaffen. Een van de leveranciers, Schneider Electric, duidde een slijtageprobleem. De frequentieregelaar wordt gemagnetiseerd en hierdoor slijt hij te hard. Want in tegenstelling tot een normaal grid je zet hem aan en je komt er niet meer aan, het moet heel de tijd aan-en afgeschakeld worden. Er moet een frequentieregelaar voor walstroom ontwikkeld worden.
In China wordt er walstroom in bepaalde havengebieden geïnvesteerd. Een deel van de haven zal dus een walstroom aansluiting hebben. Er wordt gekeken of wij gezamenlijk een walstroomconcept kunnen aanbieden. Dit zou aantrekkelijk zijn voor het havenbedrijf Rotterdam. Momenteel bevinden

wij ons in een voorstadium. De theoretische business case moet worden doorgerekend. Er zijn ook een aantal barrières, zoals, het ontbreken van een database met schepen die walstroomaansluiting hebben. Of het ontbreken van gegevens over de walstroominstallatie aan boord, mits die er is. Deze gegevens zijn belangrijk voor het bepalen van jouw potentieel. De capaciteit en de stroombehoefte, zijn afhankelijk van het aantal reefercontainers. Deze moeten bekend zijn voor het dimensioneren van de installatie. Het overdimensioneren zorgt voor zeer hoge kosten en het onderdimensioneren zal de stroombehoefte niet aankunnen.

AvL: Kan de SEEMP of EEDI (Energy Efficiency Design Index) *helpen de aansluiting in kaart te brengen?*

E3: Nee, deze zijn meer gericht op het varen dan op het hotelbedrijf. Aan de kade maak je gebruik van de generatoren en niet van de hoofdmotor.

AvL: Rotterdam wil slim, sustainable en winstgevend zijn. Wat zijn de kernwaarden voor het Rotterdamse havenbedrijf?

E3: Voor de waarden verwijs ik je graag door naar één van mijn collega's.

AvL: Walstroom zal een kleine bijdrage hebben voor het milieu en uitstoot van broeikasgassen. Wat zijn drijfveren voor het aanleggen van walstroom?

E3: Op dit moment is een drijfveer voor het implementeren van walstroom de reductie voor stikstof uitstoot. Daarnaast de uitstoot van pm en voor een klein deel CO_2. Het is overigens de vraag of het aanleggen van walstroom noodzakelijk is voor de reductie van deze vervuilstoffen met de komst van LNG. Voorlopig zal de containervaart geen gebruik gaan maken van LNG, voor ferry's is het aannemelijker.

AvL: Hoe past ESI bij de haven van Rotterdam?

E3: Wij stimuleren het bovenwettelijk presteren. Het is een laagdrempelig, wereldwijd stimulerend initiatief waarbij rederijen zich aansluiten. Voor het reduceren van uitstoot word je beloond door middel van een korting. De score wordt bepaald en boven 31 of 34 punten krijg je korting. Voor het reduceren van NO_x-uitstoot krijg je dubbelepunten. Voor het hebben van een walstroomaansluiting krijg je vaste waarde.

AvL: Naast walstroom wordt er gekeken naar LNG-barges, zijn er nog andere opties waar momenteel naar gekeken wordt?

E3: Nee, momenteel niet. Er zijn wel reders die experimenten met battery packs. De generatoren draaien vaak niet optimaal, ze leveren minder vermogen dan het maximaal. Als je de generator optimaal laat draaien kan je de batterijen vullen en deze gebruiken als alternatief voor walstroom. Dit is wellicht interessant op individueel scheepsniveau.

AvL: Wat voor soort cellen worden gebruikt?

E3: Geen idee.

AvL: Wat zijn voor-en nadelen voor het gebruik van walstroom?

E3: Het reduceren van stikstof omdat er stikstofplafons zijn. Het gaat hierbij om het reduceren van de uitstoot maar ook op de reductie van depositie in natura 2000-gebieden. Daarnaast kan het bijdragen aan het verminderen van geluidsoverlast in bepaalde gebieden. Voor cruiseschepen kan imago ook een reden zijn om in walstroom te investeren. Je hebt allerlei argumentatie nodig om walstroom te gebruiken want in het algemeen is het niet goedkoper.

AvL: Zou de haven ook een reden kunnen zijn voor het overstappen op walstroom, door bijvoorbeeld het reduceren van tarieven?

E3: Momenteel krijgen rederijen extra punten voor een walstroomaansluiting waarmee je over de drempelwaarde gaat. Als je al over de drempelwaarde gaat, hoef je niet te investeren in walstroom. Een haven zou er ook voor kunnen kiezen om een geldwaarde te koppelen aan emissiereductie, maar dat gebeurt niet zomaar. Het internaliseren van externe kosten, heb je het nu over?

E3: [Gericht tot E3b] Waarom, internaliseren wij de kosten niet met name rond de uitstoot? Kijk wij stimuleren wel bovenwettelijk presteren gebruik.

E3b: [E3] Bedoel jij de kosten die wij moeten maken?

E3: [Gericht tot E3b] Nee, in de discussie rond walstroom is er allerlei argumentatie waarom je dat zou willen doen, ondanks het feit dat het duurder is voor veel reders. Wij hebben er een bepaald belang bij bijvoorbeeld, stikstofuitstoot. Waarom koppelen wij daar geen geld aan? Is het antwoord gewoon dat wij een bedrijf zijn?

E3b: Wij hebben er geld voor over. Wij investeren in walstroomvoorzieningen. Daarnaast stimuleren wij een ander gedrag. Wij kunnen niet zomaar meer havengeld vragen, hiermee prijs je jezelf uit de markt. Er is een delicate balans. Daarom moeten wij samenwerken met andere havens om niet elkaar te beconcurreren. De haventarieven zijn er om de havenstructuur in stand te houden. Een vergroening van de haventarieven, zou betekenen dat ernaast baggeren, kadeonderhoud ook milieukosten in rekening worden gebracht. Dit zou leiden tot het veranderen van de hele berekeningssystematiek. Vragen zoals, waar moet je voor betalen, wie laat je meer betalen. Offshorebedrijven leveren geen havengelden op. Het internaliseren van kosten zou Europees geregeld moeten worden, Of zelfs wereldwijd, dan kunnen wij terugvallen op de EU.
De huidige lage olieprijs is dramatisch voor de verduurzaming. Eigenlijk zou men de olieprijs omhoog moeten duwen of er een toeslag op zetten. Maar dat gaat niet lukken. Momenteel worden groengascentrales gesloten en allerlei technische ontwikkelingen gaan langzamer.

Appendix 6 Interview with Expert 4

Interview Expert 4 (Technical University Delft)

Interview afgenomen 12:30-13:30 op 30 november 2016 te Delft

Aanwezigen: Expert 4 (E4) en Anniek van Lieshout (AvL)

AvL: Kunt u iets over u zelf zeggen?

E4: Mijn naam is Expert 4 en heb een promotie gedaan op aardolie destillatie en heb een poos in het Rotterdamse gewerkt dat was in eind jaren 80. Daarna ben ik begonnen bij het Delfts instituut voor schone technologie en daarvoor kwam project kwamen in verbinding met de Rotterdamse haven. En eigenlijk doe ik dat nog steeds behalve, dat ik bij TBM nog een aantal vakken geef als inleiding in Nederlands industrie voor een aantal mensen en ik val vaak in voor colleges. Achtergrond scheidingstechnologie naar destillatie.

AvL: Ik las ook dat u wel kijkt naar, om zeg maar planning en beleid samen te laten smelten tot een groter geheel en hoe je dat een beetje doet. Nu willen ze internationaal de luchtverontreinigingen van schepen aanpakken en een mondiale aanpak is daarbij nodigen, maar ook een aanpak vanuit de haven en de stad. Hebt u daar ideeën van hoe dat eventueel beter kan?

E4: Ik denk als eerste een heel ouderwets antwoord, maar wel gebaseerd op de feiten. Het ís al zó veel beter. Het is al zo ongelooflijk veel beter ten opzichte van de jaren zestig.

AvL: En wat is er dan per sé veranderd?

E4: De belangrijkste verandering is dat is dat, des tijds de interesse veel meer was dat Nederland moet groeien. Een aantal probleem werden nog helemaal niet gezien, deze waren gewoon nog niet bekend. Er was erg economisch gedreven groei. In de jaren vijftig en zestig groeide Rotterdam razendsnel, een voorbeeld is het Botlekgebied.
Het Botlek gebeid was aangelegd voor twintig, dertig jaar om daar bedrijven te kunnen vestigen. Binnen twee jaar zat het helemaal vol. En natuurlijk was het duidelijk dat zwarte rook smerig was. En je merkt pas dat in de jaren zestig meer tegengas en is er wetgeving over ontstaan. Die wetgevingen zijn uiteindelijk milieuvergunning geworden. De milieuvergunningen is echt opgekomen in de jaren zestig en in jaren zeventig meer geïnstitutionaliseerd en in de jaren tachtig strakker geworden en dat heeft een aantal dingen sterk verbeterd. Maar een milieuvergunning is niet waterdicht.

AvL: Kunt u een paar voorbeelden noemen?

E4: Ja een bekend verhaal is zure regen. De SO_2-uitstoot en daar is diep over nagedacht, hoe ze dat moesten aanpakken. In Amerika is er een handelssysteem voor SO_2 geweest. In Nederland had men grenzen gesteld aan wat je mag uitstoten, dat heeft die SO_2-uitstoot enorm teruggedrongen. Met als gevolg dat bedrijven daarvoor maatregelen moesten nemen. De limiet voor CO_2-uitstoot zit niet in de vergunningen ofschoon ze de beste technologie moeten gebruiken. Er is een handelssysteem. Nu is CO_2 ook anders dan SO_2 want, SO_2 is een stofje wat je niet moet emitteren maar CO_2 is vaak een stofje die je niet anders kan dan emitterend dus je zit er een beetje mee in de knel. Dus je ziet gewoon in al die trajecten dat de wetgeving ervoor gezorgd heeft dat er minder geëmitteerd wordt.

AvL: En kijkend naar de projecten no impact port, the port of the future en green port. Waar schiet de huidige regelgeving te kort?

E4: Ja, goede vraag. De trajecten die je noemt spelen al heel lang het is niet nieuw, alleen de havens zijn nieuw.

AvL: De luchtkwaliteit zou misschien veranderend kunnen worden maar, hoe zou u dat willen bewerkstelligen met welke trajecten met welke planning of wie zou u aanspreken?

E4: Ja nou als het ècht om problematische dingen gaat dan is wat mijn betreft wetgeving het enige. En natuurlijk een goede handhaving van die wetgeving. Dan is het duidelijk en er is geen grijs gebied.

AvL: Een grijs gebied zoals, bijvoorbeeld?

E4: Over CO_2-emissies, het is een wereldprobleem. Is het een lokaal probleem? Nee, ik bedoel het niet de CO_2-emissie in Rotterdam heeft niet een heel erg lokaal effect behalve dat er misschien van buiten wijzen. Maar moet je iets anders aanspreken. Als ik aan CO_2 denk, is het veel belangijker om de mentaliteit te veranderen dan met striktere regeltjes te komen. Het is bijna niet op te lossen het CO_2-probleem., De CCS-verhalen hebben we afgelopen jaar is wat minder gehoord wacht maar over twee jaar, dat heeft gewoon te maken met de economische stand van zaken het is, een er zijn allerlei initiatieven. Het gaat om wat de mentaliteit verandering plaats vindt maar dat vind ik dus voor de emissies vaak, waarvan je weet dat het niet in orde is maar waarvan je ook weet dat het lokaal niet het een erg urgent probleem is, een ander voorbeeld is fijnstof.

AvL; In het kader van toch die luchtverontreinigend, heeft Rotterdam om inderdaad toch tegemoet te komen aan de stakeholders en ESI, in het leven geroepen dat is een environmental shipping index dat is iets op vrijwillig basis. Hoe staat u daar tegenover omdat dat vrijwillig is.

E4: Ik heb er ben er erg bij betrokken geweest. Het is begonnen met een paar havens en de structuur is dat schepen beloond worden als ze wat minder emitteren. En het is op vrijwillige basis maar daar zit wel een beloningsstructuur achter, want dat moeten ze minder havengeld te betalen. Het is gewoon direct gekoppeld aan geld maar, ook die schepen moet inderdaad niet alleen ín de haven minder emitteren maar ook aantonen dat ze in de route náár de haven minder geëmitteerd hebben. Daar hebben ze een rekensommetje voor daar zijn een aantal regeltjes voor. En grappige is dat dat best wel goed aangeslagen is. Het begon met een paar en het zijn er veel meer. Wat zou wel weer interessant is, wat dit veroorzaakt. Er is niet, er is wel een economisch incentive maar eigenlijk niet. Het stelt niet zo veel voor. Ik heb het wel eens vergeleken met hoe er de laatste jaren met rokers wordt omgegaan.

AvL: Om het nog minder slechte te maken, Waar ontbreekt het aan bij ESI hoe zou het nog sterker, hoe zou hoe sterk hou zou je het nog meer kunnen stimuleren eventueel naast de ESI-regeling?

E4: Omdat het vrijwillig is, kan het sociale gevoel aanspreken waar ik het net over had op het moment dat je het gaat forceren, dan denk ik dat je het niet meer kan. En een als je meer zou willen aanspreken kan je met wetgeving komen. Wetgeving over emissies voor de scheepvaart die zal een tijdje geleden gemaakt, over hoeveel zwavel erin mag zitten.

AvL: En welk van de twee, het zal ongetwijfeld een combinatie moeten zijn. Welk van de twee zegt u welke sterker is? Want op een gegeven moment komt is er een emissieplafond dat gaat naar beneden maar de rederijen kunnen het op een gegeven moment niet meer aan voldoen, dus het zijn zulke grote spelers mondiaal hun poot stijf houden.

E4: Stel dat, jij vliegt over een schip en hij houdt zich er niet aan. Wat ga je doen? Internationaal recht moet je gaan rommelen, dit en dat, tis allemaal niet makkelijk. Er zal altijd tegengas zijn van de mensen die er last van hebben. Je komt niet door een economisch probleem heen, je kunt ze niet zover afknijpen dat ze failliet gaan. En internationaal recht, het is in Nederlands al haast onmogelijk om iets

voor elkaar te krijgen. Internationaal is het helemaal lastiger.
Veel mensen wijzen dan naar de politiek toe. Maar de politiek is geen onafhankelijk lichaam die maar wat regels verzint. Het is met een omweg verbonden met allerlei andere zaken. Als je gaat kijken naar het Nederlandse energiebeleid en dan reken ik behalve elektriciteit ook aardolie en dat soort dingen, Het is allemaal mooi en aardig maar er moet gewoon 3.5 miljard aan belasting binnen komen. Dat is de bottom line. Dus in die zin is de overheid, die mooie regeltjes maakt, gewoon een bedrijf met een economische gedachtegang.

AvL: En als er een sterke samenwerking komt tussen een Chinese haven en de Rotterdamse haven. Zou dan zo'n samenwerking dan voor internationaal regelgeving kunnen zorgen?

E4: We hebben een onderzoekje gedaan naar bunkerolie, brandstof voor de schepen. En waar komt het op neer, bunkerolie is heel goedkoop, want dat is eigenlijk waar echte concentratie van bunkerolie is, in Singapore en de ander is Rotterdam en de ander ligt nog in Texas. Dat de oorzaak van de SO_2-uitstoot, kort door de bocht. Als je kijkt kunnen die twee dan slim met elkaar omgaan, dan hebben ze de markt voor een groot deel in handen. Zij kunnen afdwingen dat het in plaats van 3.5 % naar 3 % gaat, los van internationale ontwikkelingen. Dit betekent dat het duurder wordt. En internationaal zitten er havens te kijken of zij er een business van kunnen maken. Op een gegeven moment waren wij op die studie bezig. En in de Perzische Golf heb je een haven, Furaja, die in vier jaar tijd is opgeklommen tot een enorm belangrijke bunkerhaven. Zo snel kan het gaan als je jezelf uit de markt prijst.
Een tweede conclusie is dat, de culturen, niet de sociale culturen maar de bedrijfscultuur en de economische cultuur, zo verschillen. Tussen Singapore en Rotterdam is het haast onmogelijk om samen te werken.

AvL: Wat zijn dan grote verschillen?

E4: Het grote verschil, in Nederland heeft niemand het voor het zeggen maar bepalen het met z'n alle, zeg maar poldermodel. In Singapore is het een hiërarchisch maar durft niemand de beslissing te nemen. De één is een wirwar van activiteiten en alles is bezig maar eigenlijk is het heel moeilijk om het voer elkaar te krijgen met z'n allen, aan de anderen kant is iemand die durft niks te zeggen want als hij wat zegt gebeurt meteen alles. En die systemen werken niet lekker samen. Dat hebben we alle een paar keer gezien. Dat ze het geprobeerd hebben.

Appendix 7 Interview with Expert 5

Interview Expert 5 (Deltares)

Interview afgenomen 10:00-11:30 op 30 november 2016 te Delft

Aanwezigen: Expert 5 (E5) en Anniek van Lieshout (AvL)

AvL: Kunt u iets vertellen waar u werkt en wat uw bezigheden zijn?

E5: Ik ben marine bioloog werkzaam bij Deltares voor een periode van 10 jaar. Ik heb mijn promotie bij Deltares gedaan op het onderwerp de impact van verontreinigende stoffen, dioxines, Pac's Pcb's, in Nederlandse havens. Ook de impact op het ecosysteem met name de invloed van stoffen op de voedselketen op bento's en vissen en hogere zoogdieren. Uit die studie is naar voren gekomen, dat de menselijke invloed in de havens groot is. Dit was de aanleiding om naar een andere aanpak van havenontwikkeling te kijken. Dit resulteerde in een duurzame havenontwikkeling, om de menselijke bijdragen van verontreinigingen te reduceren en te bepalen of deze ontwikkeling een positieve bijdrage zou kunnen hebben op de gehele omgeving.
Die aanpak heeft in 2014 tot een soort inventarisatie geleid, wat we verstaan onder een duurzame ontwikkeling. De Rotterdamse haven heeft aan de basis gestaan van dit begrip, met de ontwikkeling van de Maasvlakte II, hoewel veel concepten moeten worden uitgewerkt. De duurzame havenontwikkeling is een focuspunt in het onderzoeksprogramma, havens en vaarwegen, van Deltares.
In samenwerking met het havenbedrijf Rotterdam en TU Delft, is er een onderzoek geweest in Ghana, "integrated sustainable port development in African context". Parallel aan dit proces werd ik benaderd door het WNF om onderzoek uit te voeren voor een no impact port. En dit was een enorme stap voorwaarts. In de eerste instantie draagvlak, vooral bij het WNF en bij andere NGO's. En ook paradigma shift van denken, hoe zou je op een andere manier, de haven kunnen exploreren, exploiteren. Dit heeft ertoe gebracht dat we een deel van de ideeën in Ghana hebben kunnen implementeren. En daar was heel veel type kennis of het is ook vaak oude kennis maar op een andere manier aangewend of gecombineerd.

AvL: Een soort trade-off van allerlei vakgebieden?

E5: Ja, je hebt de multidisciplinaire aanpak om tot een nieuwe koers te komen. Waarbij je dat afweging moet maken wat is nieuwe en goed.
Een samenwerking met het ministerie van Infrastructuur en Milieu is een voorbeeld van een multidisciplinaire samenwerking. Waarbij de port of the future-onderzoekslijn naar Colombia werd geplaatst en het Nederlandse bedrijfsleven zou erbij worden betrokken. Dit leidde tot het ontwikkelen van Port of the Future Serious Game. Dit instrument is overal ter wereld te gebruiken. Hiermee kan je verschillende scenario's uitwerken, niet alleen klimaat, maar ook economische groei, human health en watervraagstukken. De vraag die centraal zou kunnen staan is, hoe kan je in stedelijk gebied menselijke gezondheid waarborgen in de toekomst? En waar zou je aan kunnen denken multidisciplinair, integraal om een duurzame stad te ontwikkelen? Wij zien dat je zo'n masterplan deels ontwikkeld voor een haven maar de stad die er tegenaan zit ontwikkelt ook een stedelijk masterplan. En om een, duurzame havenstad te maken zijn er zelfs masterplannen rond transport en logistiek nodig naar het achterland.

AvL: Ja u zei dat er een andere manier van denken nodig was, wat zijn eigenlijk de voornaamste switches of perspectieven die nodig zijn?

E5: Ja die paradigmashift wordt beïnvloed door een drietal grote pressures, global pressures. Als eerste, de druk vanuit de sterke verstedelijking, er is een enorme groei van de steden wereldwijd. De tweede is klimaatverandering en de derde is de zeespiegelstijging en eraan gekoppeld is. En daartoe zul je stappen moeten maken. Een paradigmaverandering van handelen, dat is in een handlingsperspectief is best wel groot, adaptatie is daar het belangrijkst. Ik denk zelf dat die pijlers, duurzaamheid vanuit sociaaleconomisch als milieukant, proberen beiden te bestrijken. En dat is die paradigmaverandering, dus niet een pijler eruit kiezen maar beiden te integreren. Die sectorale aanpak is vrij traditioneel. Je zult het veel meer moeten integreren.

AvL: U hebt gekeken naar bepaalde scenario's met de Game. Welke scenario's vindt u plausibel?

E5: Dat is een lastige vraag, want ook daarin zien we dat wetenschappelijke onderbouwing heel beperkt is. Mij voorkeur heeft het, om met indicatoren te gaan werken, performance indicators. Waarbij je dus een set van valide geteste performance indicators voor sociale vraagstukken en milieuvraagstukken en economische vraagstukken, kwantiteit en kwalitatief.
Kwalitatief worden een aantal aangewend maar die kunnen dan niet worden gekwantificeerd om dat er geen standaard is. Je wilt eigenlijk een standaard hebben, zodat je steden, havens of tansportvormen kan vergelijken. Bijvoorbeeld, met de GHG-discussies met CO_2. Men wil een standaard hebben om de klimaatverandering te minimaliseren maar er is geen consensus over de CO_2-emissies. Wel is men het erover eens dat het een uniforme aanpak zou moeten zijn, maar zover is het nog niet.

AvL: In die porten is wel wat uitstoot met namen vanwege varende schepen of wanneer zij aan de kade liggen. De uitstoot in de haven is relatief klein in vergelijking tot de uitstoot van de gehele vaarroute maar vanwege het ethische aspect is het wellicht wel van belang om te nemen. De haven zou verantwoordelijkheid kunnen nemen door een groen alternatief te bedenken voor de diesel generatoren. Ik vraag mij af, kunt u dat ook simuleren in de game of hebt u ideeën welke opties of alternatieven er mogelijk zijn. En welke hebben het beste resultaat?

E5: OPS is verwerkt in de game als een soort van renewable energy. Maar de vraag blijft of dat de luchtemissies oplost. Het zal in elk geval een bijdragen leveren. Op dit moment worden alleen cruiseschepen aan walstroom gezet, er kunnen wel uitzonderingen zijn maar dat weet ik niet.
Ik heb een studie gedaan naar tien wereldhavensteden waar ze walstroom hebben geïmplementeerd. Hieruit blijkt dat ze allemaal een vorm van walstoom hebben of aan het ontwikkelen zijn. De reden daartoe is enerzijds, dat een deel van de luxe cruiseschepen over een aansluiting reeds beschikken. En anderzijds,…,[?] Als je OPS groen wilt maken, moet men gebruik maken van windenergie of getijdenenergie. Er is echter een andere ontwikkeling van de LNG-schepen die veel groter is. Dus op de lange termijn kan ik mij voorstelen, dat de aansturing van zeeschepen op LNG een grotere bijdragen kan leveren. De cruiseschepen liggen vaak in het midden van de stad, dat zien we in Venetië, in Rotterdam, in Hamburg. Hier is het eigenlijk not done om NO_x en SO_x in de atmosfeer uit te stoten want, die concentraties zijn echt indrukwekkend hoog.

AvL: Met die "smart noses" werd de luchtkwaliteit in Rotterdam gemeten,

E5: Er is een nog indrukwekkender monitorsysteem, dat is door de chinezen ontwikkelend. Zij hebben een wereldwijde applicatie gemaakt. Hier kan de wereldwijd de luchtverontreiniging zien van NO_x, SO_x en fijnstof van 2.5 µm en 10 µm. De luchtverontreiniging is afhankelijk van de windrichting, het drukgebied den de economische groei.

AvL: Momenteel is het in Europa rood.

E5: Ja, op dit moment is het niet best, dit zal te maken hebben met het hogedrukgebied. Als we naar Oost Azië kijken zien wij eenheden van 150. Ik bekijk deze website regelmatig en kom in China waarden tegen van 500 eenheden. Dat is echt dramatisch voor de volksgezondheid. Deze problematiek zien we in havensteden als in steden in het binnenland langs een rivier. In elke geval als we het doortrekken naar jouw vraag; kan OPS een bijdrage kan leveren aan de vermindering van de luchtemissies? Ja het zal ongetwijfeld een bijdrage leveren. Maar ik kan mij niet voorstelen dat het toereikend is om met name het ongezonde leefklimaat te verbeteren.

AvL: Men is bezig om de sector naar LNG over te laten stappen. In hoeverre heeft dat een positieve impact, want je houdt nog steeds de emissies en de uitstoten van koolwaterstoffen?

E5: Stel dat in een ideale wereld alle zeeschepen op LNG zijn overgestapt. Dan zal dat een enorme verbetering opleveren, maar dan hebben wij nog wel vervuiling van het autoverkeer. Je ziet dat de gehele transportketen voor enorm veel verontreinigingen zorgen, niet alleen zeeschepen maar ook vrachtverkeer. Er is een verband aangetoond tussen gevallen van longkanker en zeevaartemissies. Om te verduurzamen, is de aanpak van de gehele logistieke keten noodzakelijk.

AvL: Wat zijn volgens u mogelijke verbeteringen of mogelijke verbeterpunten voor de schepen danwel voor de ketenefficiëntie?

E5: Het zijn eigenlijk een soort bouwstenen die je stap voor stap wilt aanpakken. In het kader van een no impact port zou je de sector er bewust van kunnen maken dat zeeschepen op LNG kunnen varen. Een andere stap zou kunnen zijn om onderzoek te doen om containerschepen op walstroom te zetten. Dit gebeurt momenteel wel bij cruiseschepen maar niet bij containerschepen, ofschoon de gehele logistieke keten op verduurzaming zou moeten inzetten.
Cruiseschip operators investeren in walstroom, omdat het een groen imago heeft en dit kan een verkoopargument zijn voor toeristen. Deze groene werkwijze wordt niet gehanteerd in de logistieke keten, waar zware trucks blijven rijden. De steden kunnen de vrachtwagens mijden uit het verkeer, de Betuweroute zou ook een bijdragen moeten leven aan de CO_2-reductie in de Maasvlakte II. Als de haven van Rotterdam in 2035 CO_2-neutraal wil zijn, kan ik mij indenken dat je andere sectoren erbij betrekt om van elkaar te leren.

AvL: Komt dat niet heel erg in een grijs gebied met wat je met andere sectoren wilt delen, kan delen in verband met concurrentie.

E5: Ja dat hoor ik vaak.

AvL: In hoeverre zou u de gemeente Rotterdam of Zuid-Holland kunnen assisteren, soort van collectief kennisbaken te zijn?

E5: Ik denk zelf dat de nationale aanpak heel belangrijk is. Op het moment dat je het op de nationale agenda hebt, bijvoorbeeld de GHG-reductie, dan kan je over de gehele keten trucks uit faseren, die oud en verontreinigd zijn. In Utrecht is het verboden om de binnenstad te rijden met auto's voor 1968, naar ik meen. De logistieke transportketen is internationaal en vereist een nationale aanpak en bij voorkeur een Europese aanpak. Dit zal meer effect hebben dan de vrijblijvendheid waarmee de tak groene ambities probeert neer te zetten.

AvL: De Rotterdamse haven heeft nu een ESI, een vrijwillige index, waarmee zij bewustzijn proberen te creëren en aanzetten tot actie bij rederijen en schipeigenaren. Zou deze regeling verplicht moeten worden of zou deze regeling mondiaal geïmplementeerd moeten worden?

E5: De ESI-regeling is er om rederijen te bewegen om schonere schipmotoren en schonere diesel te benutten. In feite krijgen zij een korting, mits zij met bepaalde specificaties aanmeren. Deze regeling geldt in een beperkt aantal Europese steden. De korting zet mensen aan tot het hanteren van schonere technologie. Ik kan enkel enthousiast zijn, ofschoon het helemaal niet in de paradigmashift.

AvL: Waar schiet de ESI te kort?

E5: Het is een te beperkte maatregel, met betrekking tot milieubelasting, sociale leefcondities en economische groei. Dat blijkt ook dat een zeer beperkt aantal steden die ESI hanteren. Ik ben benieuwd of het nu echt een globale bijdragen levert.

AvL: Welke waarden zijn belangrijk voor het bewerkstelligen van de paradigmashift, voor Rotterdam? Maar ook brede in een samenwerking met China.

E5: Culturele waarden spelen een belangrijke rol. In Nederland besteden wij veel aandacht aan waterveiligheid vanuit de geschiedenis. Wij zijn kien om het goed te regelen. In Vlaanderen, waar men een gelijk risico loopt, leeft die niet.
In Nederland speelt veiligheid een belangrijke rol dan duurzaamheid. Bestuurlijk gezien speelt duurzaamheid nauwelijks een rol bij het ministerie van Infrastructuur en Milieu. Je hoeft niet aan te kloppen met plannen voor een duurzame brug of verduurzaming van wegen.
In China, nu ben ik geen kenner van China, maar de verontreinigingen zijn flying high en het aantal chronische ziektes en longkanker zijn exponentieel hoog. Het is mogelijk dat veel van jouw familieleden aan longkanker overlijden, dit is een incentive waar veel waarden aan wordt gehecht. In Nederland wordt er ook veel waarden gehecht aan het ondersteunen van het kankerfonds. Iedereen is kien om te leveren, wandelen, fietsen enz. Dus blijkbaar is de volksgezondheid een belangrijke waarden. En hoe krijg je die waarden voor duurzaamheid? Volgens mij is dat toch informeren, kennis overbrengen het belang ervan benadrukken, risico's in beeld brengen en ook de kansen. De vraag is, hoe je die waarden kunt verdedigen en dat zijn ook politieke keuzes op basis van die Parijs. Maar dat is ook een culturele waarden dat we dat als Nederland willen. Andere landen rond ons heen zullen daar anderen waarden aan toekennen en dat is goed om te beseffen, dat duurzaamheid onderdeel is van je culturele waarden.

AvL: Deze vraag had wellicht aan het begin gemoeten maar, wat verstaat u onder het begrip duurzaamheid en verduurzaming?

E5: Ja dat is een goed punt. We zien dat er bij steden vaak over resiliant cities gesproken wordt en bij havens over sustainable ports. Ik persoonlijk hanteer ik het begrip sustainable bij voorkeur. Het begrip green vind ik ongelukkig gekozen. No impact port vind ik een makkelijk en prettig begrip, Port of the Future blijkt veel mensen te inspireren. Uit persoonlijke ervaring moet een begrip mensen kunnen inspireren.
Uit mijn studie kan ik constateren dat het belangrijk is om mensen te inspireren maar dat het ook ieder keer een tailor made invulling aan wordt gegeven. Bij het begrip verduurzaming gaat het om de waardes waar je het met elkaar over eens bent, bijvoorbeeld Latin en European context, African context, Rotterdamse context. De verschillen komen door lokale omstandigheden, door pressure van menselijke activiteit, kwetsbaarheden en veerkracht van het ecosysteem, sociale en economische verschillen. Dus rond duurzaamheid zou ik de People Planet Profit benadering proberen, op een tailor made wijze.

AvL: Voor de verduurzaming gunstig kunnen zijn om meerdere niche-projecten te hebben en door research à la learning-by-doing?

E5: Absoluut hoor, learning-by-doing en living lab, het zijn mooie voorbeelden. Hoe je nieuwe initiatieven kan lanceren en uiteindelijk als een gemeenschappelijk mogelijkheid op een gegeven moment gaat invoeren wat heel succesvol is. Maar dat is beredeneerd vanuit Nederland. Vanuit de internationale logistieke keten, waar zeehaven een onderdeel van uitmaken, zullen er verdragen, directive en richtlijnen van IMO, PIANC (*Permanent International Commission for Navigation Congresses*) of CADA (*Central America Discussion Agreement*) zijn. Deze organisaties willen een rol vervullen in de kennisoverdracht en kennisontwikkeling rond duurzaamheid. Werken met een overkoepelende organisatie zal het meest kansrijke zijn bij deze transcontinentale vraagstukken, waar zeehavens een onderdeel van zijn.

Appendix 8 Interview with Stakeholder 1

Interview Stakeholder 1 (Cavotec)

Interview afgenomen 09:06 – 09:47 op 28 maart 2017 en 13:53-14:30 op 6 april 2017

Aanwezigen: Stakeholder 1 (S1) en Anniek van Lieshout (AvL)

AvL: Ik ben aan het verkennen welke andere mogelijkheden er zijn. En nu is een walstroominstallatie geïmplementeerd in Shekou (China) voor containerschepen van Cavotec. Graag zou ik wat meer informatie willen over deze installaties.

S1: Wij hebben projecten in Amerika gedaan voor de haven van Los Angeles. Hier hebben wij aansluitboxen geleverd. De stroom (60 Hz) gebruikt in de installatie, komt uit het net. Er is in Amerika geen omvormer nodig, omdat de schepen ook 60 Hz gebruiken. In Nederland en in China is de frequentie van het net 50 Hz, er is dus een omvormer nodig. Het is mij niet bekent, hoe de stroom is omgevormd in China. Wel hebben wij [Cavotec] daar projecten gedaan en dat betrof een 'containerised solution' op een platte wagen en die haalt de stroom vanuit het net. Wij leverden het *kabelmanagementsysteem* (KMS). En in de haven van Hamburg hebben wij samen met Becker Marine Systems een LNG barge ontwikkeld. En dat ding [LNG-barge] komt naar Rotterdam.

AvL: Ik ben geïnteresseerd naar de aansluiting in China, omdat ze daar ook 50 Hz hebben. En u hebt een mobiel containerised systeem geleverd, walstroomaansluiting, die flexibel is.

S1: Ja, het voordeel is dat de meeste containerschepen wel een aansluiting hebben, zeker die naar Los Angels (LA) gaan hebben een mogelijkheid om walstroom te ontvangen. Dat is een vaste installatie op het dek, die kan verbinden met walstroom of zij hebben een container aan boord met alle materialen erin die je van boord kan halen.

AvL: Ik zag bij het project een China een KMS op de kade staan, wellicht kan deze op het schip gezet worden of misschien niet. Hoe houdt u daar rekening mee?

S1: Er is een standaardisatiecommissie voor HVSC (80005-1) en daar staat in dat normaal gesproken zou het KMS aan boord van het schip staan. In LA heb je aan de kade elke 50 of 60 meter een aansluitbox staan. Het maakt het niet uit waar je aanlegt, je kan het altijd gebruiken. Op een haspel van een KMS zit ongeveer 35 tot 40 meter kabel. Ik [vertegenwoordiger van centraal Europa] ben niet op de hoogte wat er in China geïnstalleerd is, hiervoor zou ik je graag willen verwijzen naar mijn Collega [wereldwijde vertegenwoordiger].

AvL: U bent meer op de centraal Europa marktgericht, hoe is het met de kaderuimte in Europa (met name Rotterdam) gesteld?

S1: Bij de aanleg van de kade van de Maasvlakte 2 is er rekening gehouden met walstroomaansluitpunten. In samenwerking met Royal Haskoning zijn er om de 60 meter uitsparingen gemaakt voor toekomstige walstroomvoorzieningen.

AvL: Er is nog geen kabel doorheen getrokken, toch?

S1: Ja klopt. In Californië is walstroom verplicht door de overheid. In 2025/2030 worden wij mogelijk ook verplicht tot het gebruiken van walstroom. Dus hebben zij tijdens de constructie van de kades pijpen aangelegd om later kabels in te leggen. Maar dat hebben ze nog niet gedaan. Dat kost een kapitaal. Later kunnen dan aansluitpunten, kabels en omvormers geïnstalleerd worden. De vraag is of

er voldoende vermogen geleverd kan worden.
Voor Stenaline was er eigenlijk niet voldoende vermogen in de buurt. Verschillende opties om voldoende vermogen te leveren passeerden de revue, zoals, het trekken van kabels vanuit de overkant of het opwekken met een dieselgenerator. Maar uiteindelijk heeft de netbeheerder, Stedin of zo, een netwerk aangelegd. Dit is zeker een barrière. De vraag voor een grote cruise kan rond de 20 MW zijn.

AvL: Containerschepen hebben 3-6 MW dus dat is lager.

S1: Wij gaan ervan uit dat containerschepen een vermogen vragen van 8 MW. De haspel die wij leveren kan maximaal 8 MW overbrengen. We moeten uitgaan van het slechtste geval, waarbij alle reefercontainers tegelijkertijd bediend worden. Normaal gesproken worden de reefercontainers smart bediend, dat wil zeggen, dat een systeem de containers om beurten van stroom voorziet. Maersk heeft zo'n systeem. Het exacte vermogen weet je niet, dat is afhankelijk van het aantal reefercontainers op het schip.

AvL: Veiligheid is een belangrijk thema. Hoe waarborgt u dat er geen spanningsboog vormt [arcing] of phase to phase problemen optreden?

S1: Er is allerlei beveiliging maar niet in de kabel. Bij het Stenalineproject hebben wij samengewerkt met ABB. En ABB levert alle elektrische apparatuur en wij hebben het KMS geleverd. Dit is allemaal tegen kabelbreuk. Als er te hard aan de kabel wordt getrokken dan schakelt de hoofdspanning af. De veiligheid is zo, dat als er wat gebeurt de spanning wordt afgesloten. In een hoofdstroomkabel heb je drie fases, een aarde en 7 koperen pilot-draden, die zou je kunnen gebruiken om contact te checken, en daarnaast zit ook een optic fiber cable. Pilots moeten van koper zijn, dat gebruikt Stenaline in Rotterdam ook. Voor containerschepen wordt niet gebruikt voor containerschepen.

AVL: De optic cable wordt niet gebruik voor container of is niet verplicht?

S1: Hij is niet verplicht. Stenaline gebruikt wel de kabel omdat het station ver van het schip af is. De optic fiber wordt voor, bijvoorbeeld, communicatie gebruikt. Dit zou in verband met de grote afstand niet over koperen draden kunnen vanwege het grote spanningsverschil. De spanningen over de kabel moeten wel veilig zijn. De optic fiber zit wel in de kabel maar moet apart aangesloten worden. Het zit in de kabel maar het moet wel apart worden verwerkt. De worden een voor een verwerkt in de stekker. Op een kabel van de Stena staat 11 kV, dit hebben alle Stena schepen. Dit komt de interconnectiviteit ten goede.

AvL: Welke verschillen zijn er tussen een ferry en een containerschipaansluiting? Waar houdt u rekening mee?

S1: Als wij een walstroomsysteem moeten ontwerpen werken wij samen met ABB, Schneider, Arcadia. Waarbij wij verantwoordelijk zijn voor het KMS. Voor het ontwerpen hiervan moeten wij gegevens hebben, zoals, locatie van de aansluitpunten op de kade en op het schip, wat zijn de getijdenverschillen, welke gebeurtenissen zijn er tijdens het laden/lossen, passing ship effect. Als wij een systeem aanleveren wat onvoldoende flexibel is, kan er te veel trekkracht op de kabel komen. De sensoren zullen inschakelen en de stroom zal afgesloten worden. Het opstarten van het schip neemt ongeveer anderhalf uur in beslag, in verband met onder andere radarsystemen.

AvL: Hoe is de procedure om de ship voltage en de shore voltage en frequency te alignen. Hoe gaat dat in zijn werk?

S1: Er is synchronisatieapparatuur aan boord van het schip. Bijvoorbeeld, bij Stenaline wordt er nagegaan of de stekkers erin zitten en er daadwerkelijk in zitten. In het schip is een paneel met waarop

men dat kan zien. Het aansturen van een kraan en het besturen van het KMS gebeurt vanaf de kant dan wel vanaf de kade met een afstandsbediening. Na het aankoppelen wordt een controle uitgevoerd of alle schakelaars goed staan voor overdracht. Voor de overdracht vanaf de wal moeten de stromen gesynchroniseerd worden. De generatoren produceren stroom, als het spanningsniveau overeenkomt met dat aan de kade, kan er stroom richting het schip overgebracht worden. Op het paneel kan dit grafische worden weergegeven, waarbij het schipvermogen afzwakt en het vermogen vanaf de kant opkomt.

AvL: Die standaard geeft aan dat het KMS voor containerschepen op het schip moet staan. Nu zie ik hier in Shekou dat het KMS op de kade staat. Kunt u daar meer over vertellen?

S1: Mijn collega kan hier beter antwoord op geven. Walstroominstallatie voor de marine hebben de gehele vrijheid. Zij hebben een eigen kade en eigen schepen. De marine kan de technologie kiezen en ontwerpen, mits het veilig is. Als je internationaal walstroom wilt gebruiken voor, bijvoorbeeld, containerschepen, dan is het makkelijk om hetzelfde systeem te gebruiken. Hierdoor verbetert de interconnectiviteit, een schip kan in zowel Rotterdam als in Los Angeles de voorziening gebruiken.

AvL: U bent specialist in de KMS in centraal Europa. Er worden KMS geleverd aan verschillende havens. Welke type KMS'en zijn er (grofweg)? Voor welke scheepstype zijn deze, ferrie-container-cruise?

S1: Er zijn veel verschillende KMS, bijvoorbeeld, LNG-barge of walstroom. Dit is afhankelijk van de geldende standaarden (ICE/ISO/IEEE 80005-1) en ICE. Walstroom heeft voor containerschepen een KMS op het schip. In LA staan deze op de kade. Containerschepen hebben soms wel een aansluiting, vast danwel tijdelijk. Bulkcarriers hebben dat niet.
Er was vanuit Duitsland laatst wel een aanvraag voor een retrofit voor een containerschip. Hierbij zou het systeem in een container gezet worden. Voor containerschepen is het als enige goed gestandaardiseerd.

AvL: Wat is het meest geleverde KMS voor containerschepen in Europa?

S1: Voor containerschepen zijn het kabels met 6.6 kV en voor bijvoorbeeld de Stenaline 11 kV. Het voltage is afhankelijk wat voor spanning op het schip gebruikt wordt. Spanning wordt niet omgevormd op het schip in een EPU (electrical power unit), in verband met de ruimte op het schip.

AvL: Wat is uw [Cavotec] definitie van duurzaamheid?

AvL: U [stakeholder 1] verwees naar jaarrapporten. Uit het jaarrapport van 2016 haal ik de visie van Cavotec welke is: Cavotec heeft de ambitie om producten te vormgeven, te ontwerpen en te leveren voor verschillende industrieën om zo veiligheid, productiviteit en duurzaamheid van het milieu te verbeteren. Uit hetzelfde rapport zijn de waarden van het bedrijf geformuleerd. Milieu is een waarde waar principes aan gekoppeld zijn (principe 7-9). Cavotec moet voorzorgsmaatregelen treffen ten aanzien van het milieu; initiatief nemen in het promoten van de verantwoordelijkheid voor het milieu; aanmoedigen van milieuvriendelijke technologieën.

S1: Het milieu kan gespaard worden door technologisch verbeteringen en efficiëntere processen. Duurzame verbetering zitten vernuftige vindingen en optimalisatie van processen.

AvL: Voor het ontwerpen van een walstroominstallatie is samenwerken met ABB (en andere) noodzakelijk. Met welke andere partijen werkt u samen, bijvoorbeeld een Milieudefensie, havenbedrijf Rotterdam, Wereld Natuurfonds, kennisinstituten en overheden of…?

S1: Er is contact geweest met het havenbedrijf ongeveer acht jaar geleden om aan te geven, dat wij walstroomvoorziening kunnen leveren. Met partijen als het Wereldnatuurfonds of Milieudefensie werken wij niet samen. Wel met havenbedrijven voor bewust zijn, dan het kan. WNF of Milieudefensie niet. Maersk of andere rederijen nemen contact op met onze vestiging in China, waar de schepen worden geassembleerd. Voor details over de installatie. Dit is in China, voor zekerheid zou je met mijn collega's in China contact op moeten nemen.

AvL: Wat zou er moeten veranderen zodat jullie veel orders voor walstroom binnen krijgen?

S1: De nieuwe regering zou walstroom verplicht moeten stellen. Door deze verplichting moeten ze wel, kijk maar naar Californië. Er zijn verder allerlei mogelijkheden tot subsidies zoals, waddenfonds, TEN-T. Er zou ook aan een smart power grid gewerkt moeten worden om aan de energievraag te kunnen voldoen voor alle schepen. ABB werkt aan een smart-grid.

Appendix 9 Interview with Stakeholder 2

Interview Stakeholder 2 (Deltalinqs)

Interview is telefonisch afgenomen op 14 april 2017 te Delft (30-40 minutes)

Aanwezige: Stakeholder 2 (S2) en Anniek van Lieshout (AvL)

AvL: Kunt u vertellen over Deltalinqs, hoe Deltalinqs met duurzaamheidsaspecten omgaat en via welke kanalen duurzaamheidsspeerpunten op de agenda komen?

S2: Deltalinqs is belangenvereniging en wij vertegenwoordigen 700 bedrijven uit de Rotterdamse haven. Oorspronkelijk is het een lobbyclub en Deltalinqs heeft speciale programma's. Duurzaamheid is belangrijk arbeidsmarkt, veiligheid en security (digitalisering) ook, en ondernemingsklimaat. Maar duurzaamheid zeker. De bedrijven moeten, zouden meer duurzame beslissingen moeten nemen en zouden het niet meer als een bedreiging moeten zien vanuit de EU.
Zo is er een Deltalinqs Energy Forum gestart, door leden, zie website, waarbij wordt ingezet op het aanpakken van klimaatsveranderingen door duurzame aanpassingen. Een ander voorbeeld is het *Research, Design & Manufacturing* (RDM), die het mede mogelijk maakte om elektrische auto's te ontwikkelen, die in het havengebied gaan rijden. Het RDM-trainingsplant is ervoor om mensen op te leiden en om te scholen. De werkgelegenheid behouden maar wel verduurzamen.

AvL: Wat verstaat u onder het begrip duurzaamheid?

S2: Er zijn twee soorten duurzaamheid. De eerste is duurzame groei voor het bedrijf, heeft het bedrijf in de toekomst een bestaansrecht. De tweede, is het minder belasten van het milieu. Deltalinqs hanteert beide.

S2: Om het havengebied te verduurzamen moeten veel bedrijven uit de haven andere brandstoffen gebruiken en zal bijvoorbeeld de petrochemie uiteindelijk naar een ander businessmodel moeten. Hierover hebben wij projecten gestart, en deze worden ieder jaar vastgelegd in de *letters of cooperation* (LOC). Een aantal vertegenwoordigers van bedrijfssectoren zijn hier ambassadeur van en anderen werken mee, of financieren. Er zijn allerlei projecten bij om op korte termijn de CO_2-doelstellingen te behalen, zoals het opslaan van CO_2 in gasvelden voor de kust. Of het aanleggen van een leiding naar de tuinders in het Westland, zo zijn er ook andere mogelijkheden.
Het tweede programma is de warmteproductie en energie-efficiëntie, terminals en fabrieken doen hieraan mee en discussiëren hoe zij kunnen verduurzamen door onder andere elektrificatie van processen.

AvL: Waar wordt deze stroom opgewerkt?

S2: Ultiem wordt het uit windparken en zonnepanelen opgewekt, maar momenteel komt het uit fossiel. Het is nog niet altijd mogelijk voor bepaalde processen om de stroomvoorziening volledig uit duurzame energiebronnen te halen, omdat voor veel processen veel energie nodig is. De capaciteit is te groot, bijvoorbeeld, bij bepaalde processen waar de druk verhoogd moet worden. Hier wordt onderzoek naar gedaan.
Om fossiele brandstoffen te vervangen door bijvoorbeeld, LNG en waterstof. Hier zijn twee platforms voor, dit zijn platforms waarbij, zie LNG-platform en website NWP (waterstofplatform). Daarnaast wordt er ook gekeken om energie uit afval te halen en zo een circulaire economie te ontwikkelen, het is een soort gesloten keten. Wij zijn begonnen om reststromen te analyseren van onder andere van het bedrijf "Tronox".

AvL: Hoe gaat u om met wet-en regelgeving in verband met innovatie van bedrijven?

S2: Wet-en regelgeving is het belangrijkste maar er zijn meer regels. Innovatie is voor de wetgever lastig te stimuleren, soms bevordert de regelgeving niet de innovatie. Binnen de gestelde kaders proberen wij voldoende innovatie te stimuleren.

AvL: Hoe gaat u om met veiligheid en duurzaamheid? Bijvoorbeeld, als een optie duurzamer is maar wellicht minder veilig, of de gevolgen zijn nog niet duidelijk?

S2: Tussen veiligheid en duurzaamheid, heb ik geen dilemma. Ik heb persoonlijk nog geen afweging moeten maken tussen de één of de ander.

AvL: In de besluitvorming voor nieuwe energiebronnen, walstroom, zijn verschillende partijen betrokken. Hoe zou u de relatie tussen u en de andere stakeholders willen omschrijven, coöperatief, competitief of complementair?

S2: Met de terminal operator Maersk hebben wij een complementaire samenwerking. De terminal operator is ambassadeur van een project om terminals nog duurzamer en efficiënter te maken. Hun terminal is geavanceerd. Hij denkt mee hoe het beter kan. Ik heb het doel haven verduurzamen, en zijn willen goede randvoorwaarden. De lobby is belangrijker om te zorgen voor goede regels en voorzieningen.
Er zal ook wel een samenwerking zijn tussen Milieudefensie en Deltalinqs maar daar weet ik niet zo veel vanaf. Ik vermoed dat het complementair of competitief is.
Er is zeker een samenwerking met de gemeente Rotterdam, dus coöperatief. Zeker, die financiert een deel van mijn programma, om hun duurzaamheid doelstellingen te behalen. Deltalinqs Energy Forum, het havenbedrijf Rotterdam is beheerder van de haven en wij moeten nauw samenwerken, dus een complementair samenwerking. Bijvoorbeeld, als het over meerder partners gaat. Wie neemt het voortouw?

AvL: Kunt u toelichten hoe het communicatieproces verloopt? Wie bepaalt wie er aan tafel zitten? Hoe wordt er bepaald wie er mee mag doen? Wie bepaalt dat? Hoe is de machtsverhouding?

S2: Dat is verschillend. De samenstelling van het gezelschap wordt bepaald door, wie er het meeste belang heeft of last van heeft. Degene met het grootste belang bepaalt wie er mee doen. Bijvoorbeeld, bij het consortium “wind op zee”. Stel dat er veel wind op zee is. Dan peil ik hoe de leden er over denken. En ik toets bij de leden of het opstarten van een project nuttig is. Maar de probleemeigenaar bepaalt niet altijd wie er meedoen. Bijvoorbeeld, met de reststroomenquête, die ben ik gestart en toen heb ik hun (leden) erbij geroepen. Ik initieer het als er veel leden bij betrokken zijn en/of als het een concreet probleem is. Stel, dat er een bedrijf is met een probleem met het Havenbedrijf Rotterdam, dan doen zij het zonder ons. Bijvoorbeeld, de uitbreiding van stadswarmte, geïnitieerd door bedrijven en het Havenbedrijf Rotterdam, maar Deltalinqs kan helpen in het proces.

AvL: Zou er animo voor zijn voor het aanleggen van een 60 Hz netwerk?

S2: Dit zou mee genomen kunnen worden in gesprekken. Het zou kunnen als je schepen op walstroom hebt. Een tweede apart netwerk. De vraag is dan zal er voor iedereen werk zijn?

AvL: Wie zouden er nog meer bij betrokken zijn voor walstoom, het Havenbedrijf Rotterdam, Deltalinqs of Kotug Becker? Welke bedrijf wil wat?

S2: Bedrijven denken ook mee aan een duurzaam voortbestaan en moeten toe zijn aan een investering. De crisis is nog niet zover geleden gebeurd. En vervanging van processen en techniek naar een duurzamere variant komt, als de ondernemer dat ziet zitten.

AvL: Hoe zijn partijen zoals Milieudefensie of het Wereld Natuur Fonds bij duurzame ontwikkelingen.

S2: De milieufederatie en WNF zoek ik zelf op. Deze NGO's (o.a. Milieufederatie) hebben een goede signaalfunctie en houden ons scherp. Verder is het van strategische belang om tegenstanders vroeg erbij te betrekken. Ik heb veel stakeholder management gedaan, en weet uit ervaring dat het belangrijk is om alle belanghebbenden, en ook met potentiele tegenstanders in gesprek blijven. Maar die [NGO's] zitten niet in zo'n project, Wij werken meer met klankbordgroepen. Hierin praten wij met o.a. Zuid-Hollandse Milieufederatie, Milieudefensie ben ik ook nog niet echt tegen gekomen. Een belangrijk punt uit de gesprekken met NGO is dat, je de huidige systemen niet te veel moet optimaliseren, bijvoorbeeld een chemisch proces, want je verliest veel als het op de kop moet. Milieufederatie zorgt dat je niet vastraakt en openblijft voor nieuwe technieken.

Appendix 10 Interview with Stakeholder 3

Interview Stakeholder 3 (Milieudefensie)

Interview afgenomen 8:50-9:45 op 10 maart 2017 te Delft

Aanwezigen: Stakeholder 3 (S3) en Anniek van Lieshout (AvL)

AvL: Een aantal jaar geleden had u (Milieudefensie) een zaak aangespannen tegen het havenbedrijf Rotterdam. Hieruit volgde een akkoord, waarin vastgelegd was dat de Rotterdamse haven naar mogelijkheden van walstroom ging kijken. En vanaf 2017, dat is dit jaar, wordt er een LNG-barge, een drijvende generator, ter vervanging van die draaiende auxiliary engines geïmplementeerd. Deze gebruiken nog steeds fossiele brandstof, LNG. Hoe staat u tegenover deze vervangede technologie? Voldoet deze aan de toenmalig gestelde eisen? En wat zou er eventueel moeten veranderen?

S3: Ik ben het er niet helemaal mee eens met de keuze voor LNG-barges. Als je alle schepen wilt voorzien van groene stroom, zullen er veel barges nodig zijn. En dan zou het voordeliger kunnen zijn om een centraal netwerk aan te leggen. Het gebruik van LNG, wat behoort tot de fossiele brandstoffen, is een verbetering voor de luchtkwaliteit, wat beoogd was in het convenant. Het reduceert de uitstoot met 10 procent ten opzichte van de huidige situatie. Het is interessant om te weten of de LNG-barge al dan niet een tussenoplossing is.

AvL: Stel nu dat de LNG-barge een tussenoplossing is. Naar welk alternatief zal men overstappen na de LNG-barge?

S3: De barges zouden verbeterd kunnen worden, door gevuld te worden met een gas dat geproduceerd wordt door middel van power-to-gas technologie. Bijvoorbeeld, met windmolens als er een overschot aan elektriciteit is. Hierdoor zou het meer CO_2-neutraal kunnen zijn. Dus als flexibiliteit een belangrijk criterium is, dan zou er een oplossing kunnen komen waarbij het gas of brandstof duurzaam wordt opgewekt. Aan de ander kant kan het voordelig zijn om een netwerk aan te leggen, als er een grote stroombehoefte is, bijvoorbeeld bij cruiseschepen.

AvL: Welke ambities heeft Milieudefensie naast het beperken van broeikasgassen?

S3: Het implementeren van een circulaire economie binnen de grenzen, die de aarde stelt. En dan blijkt dat de Rotterdamse haven een belangrijke speler is, veel olie, aardgas, soja en agriproducten worden via de haven getransporteerd. Veel agriproducten worden in Nederland gebruikt voor de landbouw. De haven in Rotterdam heeft een mondiale impact op het klimaat en de economie.

AvL: De brandstoffen gemaakt uit agriproducten zouden onder biobrandstoffen kunnen vallen. Het gebruik van biobrandstoffen ligt vast in het Deltaplan. Wat is de reden dat u geen voorstander bent van biobrandstoffen?

S3: Er zijn meerdere redenen. De voornaamste redenen zijn, het verlies van het oerwoud en landbeslag. Een deel van het beschermde ecosysteem wordt opgeofferd en anderzijds wordt er een sociale ongelijkheid gecreëerd waarbij, de bevolking van derdewereldlanden slachtoffer wordt van onze energiebehoeften. Maar ook in Brazilië worden lokale boeren van het land gezet om suikerriet te verbouwen. De mensen in de derdewereldlanden die voor onze autobrandstof van het land worden gezet. Dit is het soort probleem wat wij aankaarten.

AvL: Hoe komen de milieuaspecten van Milieudefensie op de agenda van de Rotterdamse haven of de gemeente Rotterdam, nu en toentertijd?

S3: Momenteel loopt het contact tussen ons via incidentele contacten en indirect via de media. In de tijd van het convenant waren er stevige gesprekken tussen ons en het havenbedrijf onder toeziend oog van IMSA (Instituut voor Milieu-en Systeemanalyse). Het was een samenwerkingsgroep.

Bij het andere, bredere, convenant waren meerder partijen betrokken maar wij zelf niet. De belangrijkste partijen zijn het havenbedrijf, Milieufederatie, Natuurmonumenten en Zuid-Hollandslandschap.

AvL: Hoe beoordeelt u dit alternatief? Bekijkt u eerst de milieuaspecten, de financiële aspecten, sociale context of de normen waaraan de techniek moet voldoen?

S3: Dat gebeurde in twee fases. Na strategisch inzicht hebben wij gezamenlijk een maatregelenpakket samengesteld. Toen hebben wij een overeenstemming bereikt over de uitstoot van vervuilingsstoffen. Hoe de uitstoot gereduceerd zou worden stond niet beschreven.
Samen met het havenbedrijf en met behulp van IMSA hebben wij een maatregelenpakket opgesteld. Ook zijn de maatregelen doorgerekend. Het havenbedrijf kreeg de vrijheid om de meest financieel aantrekkelijke alternatieven te bekijken en bijbehorende uitstralingseffecten te bepalen. Het uitstralingseffect is van belang voor ons. Bijvoorbeeld bij het introduceren van Euro 6 vrachtwagens. Door te verschonen boekt niet enkel Rotterdam positief resultaat maar heel Nederland, doordat de vrachtwagens door heel Nederland rijden.

AvL: Bij het gebruik van windenergie is de opslag van energie essentieel om het intermittancy probleem op te vangen. U gaf aan dat power-to-gas een mogelijkheid zou kunnen zijn. Zou dit in de toekomst anders kunnen?

S3: Rotterdam is een interessant plek om hiermee te experimenteren. Een voorbeeld dat er naar mogelijkheden wordt gezocht is power-to-ammoniakgas. Hoewel deze technologie ook nadelen heeft. Voor een goed experimenttraject is het delen van informatie zeer belangrijk. Rotterdam experimenteerde al eerder met windmolens. Aanvankelijk was het havenbedrijf niet heel positief en zag geen mogelijk investeerders voor de molens. Anno nu worden er windmolens gebouwd op de Maasvlakte en worden er op de Maasvlakte onderdelen geproduceerd voor de windmolenparken, die voor de kust komen.

AvL: Is het mogelijk dat het implementatietraject van windmolens gesteund werd door de omgeving, conflict met Gronings gas, relatie met Rusland en MENA-landen?

S3: Ja. Momenteel onderzoek ik de gaswinning in Groningen. De problemen en conflicten zijn mij bekend. Het gebruik van LNG zien wij als het oprekken van het gebruik van fossiele brandstoffen.

AvL: Welke energiebron en energiedrager ziet u na het fossiele LNG?

S3: Hoe ik het nu zie, is dat boten en auto's meer gebruik maken van elektriciteit of elektrisch opgewekte gassen. In het havengebied zullen boten gebruik maken van walstroom en op zee zullen zeeschepen meer gebruik maken van zeilen en kites.

AvL: Eerder in het interview noemde u de wind als energiebron voor walstoom, Is de zon als energiebron overwogen?

S3: Nee, zonnepanelen hebben een te lage capaciteit, ofschoon er in het havengebied veel loodsen zijn, waar er een groot oppervlak aan zonnepanelen geïnstalleerd kan worden. Wel zouden de cellen een bijdrage kunnen leveren.

AvL: Hoe was de relatie tijdens de samenwerking met het havenbedrijf, coöperatief, competitief, complementair?

S3: In het begin was de relatie gespannen. Na het tekenen van het akkoord, ging het havenbedrijf aan de slag met het uitwerken van de ondertekende punten. De relatie verliep toen zakelijk. Een complementaire samenwerking. De plannen voor de Maasvlakte keurden wij niet af, er moesten dingen veranderen. Deze waren begroot. Een groot deel van de mensen waarmee wij samenwerkten kwam uit Rotterdam en had persoonlijk baat bij de een betere luchtkwaliteit.

AvL: Hebt u gesproken met de Rotterdamse bevolking over de luchtkwaliteit en hun beleving hiervan?

S3: Nee. Wij vertegenwoordigden de Rotterdamse bevolking. Toentertijd hebben wij geen interviews gedaan om de meningen te onderzoeken. Dit kwam door tijdsgebrek. Wel hadden wij de luchtkwaliteitskwestie onder de aandacht gebracht. Momenteel zijn wij wel bezig met het onderzoeken hiervan in verband met de energietransitie. Ook voeren wij gesprekken met de *Federatie Nederlandse Vakbeweging* (FNV) met betrekking tot de werkgelegenheid in de haven. Er zullen banen verdwijnen en bijkomen, hiervoor is het nodig dat werknemers omscholen.

AvL: Hebt u contact gehad met organisaties van het andere, bredere, convenant? Bijvoorbeeld het Wereld Natuurfonds? Het WNF is momenteel bezig met een onderzoek naar een "zero impact port".

S3: Nee, wij hadden geen contact met het WNF. Wel hadden wij contact proberen te leggen met Milieufederatie over het akkoord. Maar milieufederatie was niet geïnteresseerd, omdat zij met een eigen project bezig waren. Met het Milieucentrum hebben wij wel overleg gehad. Het Milieucentrum had net als ons ook een kritische houding ten aanzien van de luchtkwaliteit. Het centrum wordt gefinancierd door de gemeente hierdoor kunnen zij niet heel kritische uitlatingen doen over de haven.

AvL: Hoe was de machtsverhouding in de onderhandelingsgesprekken tussen u en het havenbedrijf? Heeft het havenbedrijf veel invloed op het proces, aangezien de gemeente veel inkomsten van de krijgt?

S3: Wij hadden invloed omdat wij een rechtszaak als stok achter de deur hadden. Deze rechtszaak maakte het debat mogelijk.

AvL: Zonder welvaart (liquide middelen) is het lastig om een energietransitie te weeg te brengen. Wanneer zou je meer moeten investeren in duurzame energie ten opzichte van de welvaart.

S3: In de toekomst, met een circulaire economie, zal de Rotterdamse haven wat kleiner worden. Er zal minder getransporteerd worden. Wel zal de haven voor nog aanzienlijke tijd geld blijven genereren. Wanneer je investeert in duurzaamheid is afhankelijk van de snelheid waarmee de samenleving zich kan aanpassen. De sociale verandering moet de maatschappij aan kunnen, dit is meer bepalend dan de geldkwestie. De financiële kant is zeker belangrijk maar als de maatschappij van een oplossing overtuigd is heb je geen andere keuze dan deze te implementeren. Een belangrijk punt is het voortouw nemen in de transitie en medespelers (internationaal en nationaal) mee te krijgen.

AvL: Een paradigmashift zou dus wenselijk zijn (duurzaamheid als investering zien om te kunnen groeien in plaats dat het ten koste gaat van groei). Is de zekerheid van een level playing field en gelijke doelen noodzakelijk om in een transitie de concurrentiepositie van de haven te waarborgen?

S3: Een level playing field geldt meer voor de Nederlandse samenleving. Als enkel in Nederland een CO_2-belasting wordt ingevoerd zal dat leiden tot faillissement van de hoogovens. Een level playing field kan dit verhelpen, door belasting in te voeren per sector mondiaal. Dit level playing field is voornamelijk belangrijk voor de bedrijven en niet zo zeer voor het havenbedrijf, het havenbedrijf

transporteert goederen van en voor deze bedrijven. Voor de bedrijven is bescherming van belang. De overheid kan bescherming en richting geven aan innovaties.

AvL: Stel dat de Rotterdamse haven een leidende rol neemt in het verplichten van biobrandstoffen, conform het Deltaplan, wat zou hiertoe moeten gebeuren?

S3: Er zou bescherming moeten komen voor Nederlandse en buitenlandse bedrijven. De overheid zou hier een actieve rol moeten nemen.

AvL: Milieudefensie heeft contact met verschillende partijen. Zou u het proces kunnen beschrijven?

S3: Milieudefensie draagt oplossingen aan in samenwerking met kennisinstituten, maar de kennis kan ook intern vanuit Milieudefensie komen. Bijvoorbeeld mij veevoer, Milieudefensie ging direct naar bedrijven. Het probleem werd geanalyseerd en in samenwerking met andere kennisinstituten werden mogelijke oplossingen opgesteld. Hiermee gingen wij naar bedrijven. Bij de energietransitie neemt Milieudefensie contact op met kennisinstituten voor alternatieven en mogelijkheden. En legt het dan voor aan de overheid, dan is de overheid aan zet. Deze oplossingen komen tot stand door eigen kennis en gesprekken met derden. Kennisinstituten kunnen ook helpen bij het kijken naar effecten door een pilot fase op te zetten. Door een pilot fase succesvol af te ronden, kunnen wij dit als motivatie gebruiken.

AvL: Werkt u samen met innovatieve bedrijven om tot milieuvriendelijkere en duurzamere oplossing te komen?

S3: Er is geen samenwerking met bedrijven, noch financiële steun. Wel voeren wij gesprekken met hen.

Appendix 11 Interview with Stakeholder 4

Interview: Stakeholder 4 (Municipality of Rotterdam)

Interview afgenomen 10:00-11:00 op 22 February 2017 te Rotterdam

Aanwezigen: Stakeholder 4 (S4) en Anniek van Lieshout (AvL)

AvL: Kunt u vertellen hoe de gemeente Rotterdam met duurzaamheid en economie omgaat?

S4: Het is een afweging tussen de kosten van een investering om de duurzame doelen te bereiken en wat de investering oplevert.

AvL: Wat en zijn criteria of belangen die u meeneemt?

S4: Voor het verduurzamen van de scheepvaart kijken wij enerzijds naar, welke investeringen moeten er gedaan worden voor het aanleggen van een installatie, bijvoorbeeld wat de jaarlijkse onderhoudskosten zijn, anderzijds wordt er een schatting gemaakt van het gebruik van de installatie. In principe willen we wel investeren maar het moet ook een opbrengst hebben. De investeringen zijn fors dus je moet zekerheid hebben qua afnamen.

AvL: Voor welke kosten zou de gemeente moeten opdraaien?

S4: De gemeente is vaak niet de eigenaar van de ruimtes waar de schepen afmeren, dat is het havenbedrijf Rotterdam. Het havenbedrijf Rotterdam heeft een bepaald beleid en heft ook havengelden. Momenteel krijgen schepen korting als ze schoner zijn, hierdoor is er een financiële prikkel ingebouwd om te gaan verschonen. De gemeente staat hierbuiten. Wij hebben geen directe rol. Wel heeft de gemeente het havenbeleid goedgekeurd. De scheepvaart is internationaal geregeld. De vaarwegen van de schepen vallen onder het ministerie. De gemeente is verantwoordelijk voor een smalle strook langs de kade.

AvL: Kunt u iets vertellen over de afweging die u maakt tussen de woonomgeving Rotterdam en de economie? Want je hebt werk nodig, economische zekerheid, maar ook een soort van gezondheidszekerheid.

S4: Bij de ontwikkeling van locaties wordt er rekening gehouden met de normen die gelden. Er wordt gekeken of de plannen passen binnen de wettelijke kaders. Ook wordt er een prognose gemaakt zodat, geanticipeerd kan worden op overlast bij het ontwikkelen van het project.

AvL: Hoe zou dat vertalen naar concrete handelingen of acties?

S4: Dat je gebouwen anders positioneert of dat je maatregelen treft aan kaders, mits deze onder onze bevoegdheid vallen. Je probeert dusdanig te anticiperen op de ontwikkeling die komen, dat het wel past bij het huidige gebruik maar ook bij het verwachter gebruik bij zowel van de scheepvaart als het wonen.

AvL: In hoeverre is de gemeente Rotterdam betrokken bij het in kaart brengen en verbeteren van de uitstoot?

S4: Er zijn luchtkwaliteitsnormen voor concentraties van de stoffen, NO_2, pm_{10} en $pm_{2.5}$. De directe emissies in de woonomgeving zijn veelal gerelateerd aan het verkeer en indirect aan scheepvaart en de industrie. Als gemeente zetten wij fors in op het aandeel wegverkeer naar beneden te krijgen. Samen met het havenbedrijf zijn wij bezig om bij de industrie en scheepvaart emissies te reduceren.

AvL: En wat zijn belangrijk speerpunten voor het verkeer, die gehaald moeten worden en punten die in zeevaart gehaald moeten worden voor de gemeente Rotterdam?

S4: Wij richten ons op factoren in de direct leefomgeving. Met de introductie van de milieuzone willen wij in ieder geval zorgen dat de uitstoot van roet naar beneden gaat. Dat is van belang voor de volksgezondheid. Ook dient het om aan de Europese norm van NO_2 te kunnen gaan voldoen. Daarnaast promoten wij het elektrisch rijden. We zijn bezig met de verschoning van het openbaar vervoer en wat we in de binnenvaart kunnen. Samen met het havenbedrijf kijken wij naar mogelijke verbeteringen in de scheepvaart, bijvoorbeeld naar de rol van LNG. Zeker voor op de korte termijn.

AvL: Als alternatief voor dieselgenerator zouden de PowerPac®s van Becker een optie zijn?

S4: De PowerPac®s zijn een soort van grote accu, die je kan gebruiken als een soort tijdelijke walstoom voorziening. Maar deze hebben eigenlijk te weinig vermogen. Daarom kijken wij meer naar een LNG-barge. Dit is een drijvende energiecentrale, die ter plekke energie opwekt voor de scheepvaart tijdens het wachten of tijdens de hotelfunctie. Naast het piekvermogen is de tijdelijke stroomvraag een probleem. De AIDAprima komt eens per week, dit maakt de business case lastig. Een drijvende elektriciteitscentrale heeft de mogelijkheid om te verplaatsen in de haven, PowerPac®s zijn wat minder mobiel.

AvL: PowerPac®s zijn een oplossing voor containerschepen, die een gemiddeld een lagere energiebehoefte hebben van 3 tot 6 MW in vergelijking met cruiseschepen 16 MW. Welke technologie kiest u voor containerschepen?

S4: Vanwege de flexibiliteit kijken wij voor containerschepen ook naar de LNG-barge. Traditioneel vaart alles op diesel, zowel de cruise als de zeevaart. Ons doel voor in de hele verre toekomst is, dat schepen op schone brandstof varen. Welke technologie ze gebruiken is niet duidelijk. Het zou wellicht elektrisch kunnen worden. In de haven is het doel dat schepen gebruik maken van walstroom in plaat van zelf energie opwekken (…). Hiertoe zijn veel aanpassingen nodig zowel aan de kade als op de schepen. Voor deze transitie is samenwerking met andere havensteden noodzakelijk om niet onze markpositie te verliezen.

AvL: De concurrentiepositie en de revenu streams zijn voor het havenbedrijf belangrijk. Heeft de gemeente verantwoordelijkheden of mogelijkheden tot financiële hulp bij het investeren in alternatieve energie?

S4: Het havenbedrijf zal zelf een investering moeten doen. De gemeente zou wel financiële steun kunnen geven in de vorm van subsidies. Aan deze staatssteun zijn richtlijnen verbonden vanuit Europa. Voor het geven van subsidies moet er een degelijke business case zijn en dat is bij walstroom het probleem. Aanleg is een forse investering 5-6 miljoen euro per cruiseschip, waarbij het terugverdienen van de investering onzeker is. Het kan soms lonen om te wachten met het investeren zodat, er meer schepen gebruik van de walstroomaansluiting kunnen maken. Momenteel is 10 procent van de schepen geschikt voor het aansluiten op walstroom.

AvL: Voor een Europese samenwerking moet Rotterdam openheid van zaken geven tegelijkertijd moet je jouw concurrentiepositie niet verliezen. Hoe gaat u daar mee om?

S4: Het introduceren van een nieuwe technologie moet gezamenlijk gebeuren maar er moet ook een markt gecreëerd worden. Havenbedrijf Rotterdam kan een hele hoop gaan introduceren en verplicht stellen maar dan wijken de schepen uit naar de andere havens. Er moet een markt voor gecreëerd worden waarin marktpartijen bereid zijn te investeren. Het klimaatakkoord van Parijs maakt de

samenwerking makkelijker. Omdat we een gezamenlijke doelenstelling om dat klimaatakkoord te bereiken, Hieraan kan je gezamenlijk invulling geven.

AvL: Met welke partijen werkt u samen?

S4: Dat zijn ander havensteden zoals Bremen, Hamburg, Antwerpen, Amsterdam.

AvL: Welke concrete stappen maakt u hierin of doelen zet u voor met de groep?

S4: Daar zijn wij nu mee bezig om die stappen te zetten. Welke technieken zijn er? Welke ontwikkelingen zien we op ons afkomen? Wie moet die investeringen moeten doen en wat zijn terugverdientijden of terug verdienmodellen?

AvL: Rotterdam kampt met een luchtprobleem en er zijn burgerinitiatieven zoals Adem in Rotterdam voor het wegverkeer en Friends of the Earth en de bewoners van Oostvoorne toen de plannen werden uitgerold voor Maasvlakte 2. Hoe gaat u daar mee om?

S4: Dan komt de rol van gemeente Rotterdam komt daar om de hoek kijken qua bestemmingsplan. Voor dat gebied moest er een bestemmingsplan worden gemaakt om al die activiteiten te kunnen ontplooien daar. En daar zijn wel afspraken over gemaakt over wat de bijdrage moest zijn van het nieuwe gebied. Destijds is gekozen om een emissiezone aan te leggen zodat er alleen maar Euro 6 vrachtwagens over mogen rijden en dat in de containeroverslag alleen met elektrische EVG (elektrische kranen) gebeurt.

AvL: Stel, u hebt plannen voor een economische zone maar er komt een burgerinitiatief. Hoe gaat er mee om?

S4: Er wordt gekeken naar de wettelijke kaders en of het binnen de kaders past. Er wordt dus eerst naar de normen gekeken en dan naar de ruimte binnen de normen. Dan het economisch perspectief om de hoek komt kijken. Wat levert deze activiteit op voor de gemeente qua werkgelegenheid en wat zijn eventueel negatieve effecten dat neem je wel mee.

AvL: De werkgelegenheid is sociaaleconomische aspect. Hoe zit het met het sociaalmilieukundig aspect, als de normen, van bijvoorbeeld de WHO, worden overschreven?

S4: Dat zijn niet de officiële normen waaraan wij toetsen. De WHO-normen zijn in sommige gevallen strenger dan de fungerende normering. De WHO-norm voor NO_2, pm 10 en 2.5 hebben we gehaald. De norm voor NO_2 van de WHO is 40 [ug], daar is verwarring over, sommige mensen denken dat het 20 [ug] is. Men wil naar 20 omdat het voor de gezondheid beter is. Dit is niet realistisch in Nederland binnen een korte periode van een jaar, vanwege een achtergrond van 30. Dat betekent dat in de huidige situatie met je huidige activiteiten ver daarboven zit. De achtergrond is 30 en sommige gebieden lagen en sommige gebieden wat hoger. Ongeveer 10 microgram is onze eigen bijdrage als gevolg van wegverkeer en scheepvaart.

AvL: De achtergrond waar komt hij voornamelijk vandaar?

S4: Het komt uit het buitenland aanwaaien en van rijkswegen is. Het vliegverkeer draagt bij en alle hoge schoorstenen van de industrie, die zorgen voor die achtergrondconcentratie maar ook de vervuiling vanuit het buitenland, bijvoorbeeld het Ruhrgebied.

AvL: Aan welke criteria moet de nieuwe ideale technologie aan voldoen?

S4: De reductie van NO_2 en pm_{10} en roet en CO_2. Het moet een duurzame brandstof zijn, waar elders geen milieuschade van komt. En deze brandstof moet toekomst bestendig zijn.

AvL: Moet de technologie nog een bepaalt economisch voordeel hebben?

S4: Nee, daar toetsen wij eigenlijk niet aan. Wij als gemeente Rotterdam hebben geen direct belang erbij, of LNG of dieselolie verhandeld wordt.

AvL: Wat is uw belang bij het verduurzamen van de haven Rotterdam?

S4: Dat je ook in voor de toekomst, met alle veranderen die op ons afkomen, bijvoorbeeld het opraken van die fossiele brandstoffen, zorgt dat de huidige activiteiten doorgezet kunnen worden maar in een duurzamere variant. Zodat je wel die activiteiten behoud qua werkgelegenheid en dergelijke, het zullen wel andere type activiteiten zijn.

S4: Gemeente Rotterdam is heel breed en daar horen ook DCMR en VRR bij. Die zou je eigenlijk onder gemeente kunnen scharen. En dat zijn wel belangrijke. Dus dat is wel een hele belangrijke speler. Ik zou er drie groepen van willen maken.

Groep 1 zijn initiatiefnemers om te verduurzamen. Wij creëren mogelijkheden met beleid. Wij hebben ook een faciliterende rol voor degene die vanuit de markt willen verduurzamen.

Groep 2 is het bedrijfsleven, waar ook initiatieven kunnen komen om te verduurzamen.

Groep 3 zijn de Non-governmental organisations, NOG's

AvL: Zijn er bedrijven/organisaties waarmee u een competitieve of competitieve relatie hebt?

S4: Ja maar dat is meer met ander steden en niet zo zeer in de Rotterdamse haven als het waren. Rotterdam is aandeelhouder, het havenbedrijf beheerd voor ons de gronden de geeft uit in erfpacht. Wij zijn door diverse zaken aan elkaar verbonden. Het havenbedrijf en de gemeente moeten er samen uitkomen, soms escaleert dat. En gaat het naar directieniveau of gaat het via het bestuur, zeker als het over financiële en beleidsmatige keuzes gaat.

AvL: Hoe maakt u de afweging tussen het langer termijn doel of het korte termijn doel, bij de implementatie van walstroom of alternatief?

S4: Er wordt een keuze gemaakt waartoe diverse aspecten, voors en tegens, belicht moeten worden voor het maken van een afwegingen. De financiële consequenties moeten in kaart worden gebracht zoals, de initiële investeringskosten, de onderhoudskosten, de investeringskosten in de schepen en de terugverdientijd. Er wordt ook gekeken naar externe veiligheid, geluid en luchtkwaliteit. Momenteel zijn wij bezig om de mogelijkheden van een brandstof van Shell, gas-to-liquid (GTL) te verkennen. Dit zien wij niet als eindoplossing maar wel als tussenstap omdat je GTL kun je bijvoorbeeld nu in vrachtauto tanken dan hoeft je geen aanpassingen te doen. Maar uiteindelijk willen wij dat die vrachtwagen duurzamer wordt. En je hebt een bepaalde levensduur en versneld aflossen kan niet altijd.

AvL: Shell is een belangrijke speler. In hoeverre kan je onafhankelijk van Shell een keuze maken?

S4: Wij maken onafhankelijk een keuze voor een technologie. Wij zullen nooit op schrijven dat je een bepaald type brandstof moet gebruiken dat is aan de markt. Zo zullen wij ook zeker en dat mag ook gewoon niet een op een voorschrijven wat waardoor een leverancier geleverd kan worden, dat mag gewoon niet. Wij willen niet marktverstorend werken. En dat is altijd de balans zoeken. Soms wil je wel iets maar is dat heel lastig uitvoerbaar.

AvL: Hoe verloopt het communieproces tussen de stakeholders bij het implementeren van een nieuwe technologie?

S4: Je gaat met een aantal om tafel hoe je kunt zorgen dat het geïmplementeerd dan gaat worden.

AvL: Hoe is de onderlinge machtsverhouding tussen de stakeholders?

S4: Belangrijke spelers zijn Deltalinqs en havenbedrijf Rotterdam maar ook de DCMR en de veiligheidsregio Rotterdam (VRR). Kijk soms komen initiatieven ook via het DCMR bij ons terecht. DCMR doet vergunningverlening toezicht en handhaving, die zien natuurlijk ook veel bij de bedrijven.

AvL: Hoe wordt bepaald wie er mee mag doen? Wie bepaald dat en wie mag er mee doen?

S4: Deltalinqs bepaalt wie er mee mag onderhandelen. Deltalinqs heeft een samenwerkingsverband met bedrijven in het havengebied. Niet ieder bedrijf mag meedoen aan de onderhandelingen.

Appendix 12 Interview with A. Castelein

interview — A. Castelein (Port Authority of Rotterdam)

Opgenomen interview afgenomen 12 September 2014

Aanwezigen: Allard Castelein (AC) en de *Presentator (P)*

P: Het kwam vanavond al eerder even aan de orde in de actualiteit. Afgelopen woensdag sneuvelde in de gemeenteraad het voorstel om vanuit, in ieder geval, die zijde de mogelijkheid van bouw van een Russische olieterminal tegen te houden. Hoe volgt u dat nieuws of die discussie daarover in de gemeenteraad? Is dat een factor van belang voor u?

AC: Ja uiteraard. Het is al eerder vanavond aangestipt. De vraag wie is de baas? De aandeelhouder is de baas, De aandeelhouder benoemt een directie en keurt een strategie goed. En dat voeren wij uit. Ik luister goed naar degenen, die een belangen hebben in het havenbedrijf. Bovendien vind ik dat wij als havenbedrijf een rol hebben in de gemeente en in de gemeenschap. Dus natuurlijk luister ik naar belanghebbenden. Het is dat ook mijn taak om de partijen, die daar een mening over te hebben om helpen begrijpen wat de precies positie is. Politiek gezien hebben wij een conflict met Rusland, dat is klont en klaar en daar kan ik als privépersoon enorm veel van vinden. Maar het is ook zo dat wij geen ruzie hebben met een Russische kind of arts. Of Russische bedrijven, die niet op lijst van boycot staan, of die worden geleid door mensen die ook niet op een lijst van boycot staan. Wij worden geleid door politiek, dat onderschrijf ik en ondersteun ik. Maar wat betreffend het bedrijf, dat een Nederlandse bv is, geen conflict. Nog belangrijker wellicht in dit stadium er is een formeel juridisch heel hard contract. En als bestuurder van een onderneming moet ik de onderneming zo leiden, dat ik handel in het in beste belang van die onderneming. Zouden wij nu het contract willen verbreken, dan hebben wij daar geen juridische grond voor. Dan praat je over 100 miljoen claims plus reputatieschade voor de stad Rotterdam, dat je een niet-betrouwbare plek bent die aan alle wetten en eisen voldoen om te investeren. Dus dat is een hellend vlak. Dus mijn rol is om te zorgen dat de partijen voldoende goed geïnformeerd zijn en dat zij daarop hun eigen besluiten kunnen nemen. En daarom zijn wij blij dat raadscommissie, want het was niet in het college, dat de raadscommissie besloten heeft dat het contract door kan en zou moeten gaan.

P: De gesprekken die u voert om goed te informeren, betekent dat er ook gelobbyd wordt? Om bepaalde sancties waar het havenbedrijf mogelijk last van heeft, die tegen te houden of het minimaliseren.

AC: Nee niet gelobbyd, dat zou een verkeerd woord zijn.

P: Waarom eigenlijk? Dat is toch niet raar om te doen als bedrijf?

AC: Wat ik probeer uit te leggen. Wij voorzien de gemeenteraad en regering van informatie, waar zij om vragen. Als zij vragen: “wat is de impact van een energieboycot?”, dan hebben wij al die gegevens op een rijtjes staan en dan kunnen wij de implicaties geven wat dat heeft voor de haven, voor de werkgelegenheid, voor groei en voor de energie zekerheid en dergelijk. Nogmaals als de politiek een besluit neemt dat wij die route opgaan onderschrijf ik dat, ondersteun ik dat. Maar het is mijn zaak dat de politiek de juiste informatie heeft. Ik ben geen politicus, Ik maak geen beleid, ik ondersteun het.

P: Wie is er machtiger de burgermeester van Rotterdam of de CEO van het havenbedrijf?

AC: Ik heb het net al gezegd. De aandeelhouder is de baas van het bedrijf. De aandeelhouder benoemt mij. De burgermeester vertegenwoordigt de aandeelhouders voor 70 % eigenaar van het havenbedrijf.

Zij keuren het beleid goed. De burgermeester heeft mijn benoeming goedgekeurd. Zonder zijn steun kan ik hier niet zitten, waar ik nu zit.

P: 1 januari u volgde u Hans Smits op. Wat is het belangrijkste verschil met uw voorganger?

AC: Dat moet u eerder aan mijn directe omgeving vragen.

P: De directe omgeving zei dat Allard Castelein wat commerciëler is. Hans Smits heeft een achtergrond in non-profit en heeft bij overheden gewerkt. Klopt dat eigenlijk?

AC: Nogmaals, ik heb nooit met Hans Smits gewerkt. Ik respecteer hem zeer. We hebben een goede periode gehad van overdracht. Ik weet wel, dat ik veel nadruk op klantgericht oplossingen dat ik veel nadruk leg naar het luisteren wat zij wensen, ten einden daar op te kunnen reageren, ageren en mede-ontwikkelen. Ik denk wel, dat ik erg probeer te zoeken naar een heel goede balans tussen economisch rendement en duurzaam. Ik wil dat Rotterdam de beste ter wereld is en de meest duurzame. Ik wil dat we veel aandacht schenken aan bestaande industrie zoals, de petrochemie en raffinage wereld maar, ik wil ook biomassa naar Rotterdam halen en circulaire economie en ik wil innovatie starten.

P: Kunt u een vergezicht schetsen? Waar zijn wij over 20, 30 jaar?

AC: Dan is Rotterdam beoordeeld door de markt, door de klanten, de beste haven ter wereld. Met de meest efficiëntie afhandeling van goederen met het beste investeringsklimaat in Noordwest-Europa in alle segmenten waarin de Rotterdamse haven ervoor kiest in te spelen. Als je van west naar oost redeneert hebben wij 54 kilometer lengte en wij beheren 12.5 duizend hectare. Zijn wij de beste in droge bulk (kolen, ijzererts) en de beste in petrochemie en de beste in biomassa en de beste raffinage en het beste en circulair en het best in nautische en in duurzaam.

P: Ik wil dat wel geloven maar kan dat eigenlijk wel? Want bijvoorbeeld, er een reden is dat Rotterdam een belangrijk petrochemisch centrum is, namelijk dat er in de loop der jaren die petrochemie naar toe kwamen dat andere landen waar die olie vandaan kwam niet stabiel genoeg waren. En misschien nu wel. Dus Rusland en Saudi-Arabië, die gaan dat zelf doen, Rotterdam hoeft dat niet meer te doen.

AC: Heel goed punt. En dat is een goed punt des ondanks en das niettemin. En dat moeten wij over 20, 30 jaar kunnen borgen. De beste plek in Europa om 500 miljoen Europeanen te bereiken. Wij zullen nooit meer de grootste haven ter wereld kunnen worden. Want Rotterdam is momenteel nummer 7 in tonnage. 1-6 is chinees 8 Singapore en 9-10 zijn chinees. Dat gaan wij nooit meer inhalen. Vroeger was Rotterdam de grootste haven ter wereld. Dat zijn wij niet meer en worden wij ook niet meer, dat hoeft ook niet.

P: Blijven wij wel de grootste van Europa?

AC: Ja, als je de beste bent en de beste aanlandingsplek voor die bestaande industrieën die ook naar de VS en ook in het verre oosten gaan investeren maar nog steeds 500 miljoen Europeanen willen bereiken. Dan kun je dus en dan moetje in al die sectoren die ik noemde en dat biedt die veelzijdigheid van die haven. Dan moet je daar de beste willen zijn, opdat de bedrijven in Rotterdam business willen investeren en hier willen zijn en niet in Antwerpen, Hambrug en le Havre. Dat is een forse opgave.

P: Ik las in een Duits transportblad: Allard Castelein wil meer invloed in het achterland.

AC: Kijk wat essentieel is om heel in het kort even. De massa, die vervoerd wordt, wordt groter en groter. Dus wat er gebeurd is dat er een enorme piek komt op de kade van een goederen soort. Dan kunnen wij het als haven nog zo efficiënt, op dat moment, daar af te handel als haven maar, uiteindelijk gaat het erom dat, die product of goederen niet naar Nederland komen maar naar die 500 miljoen

Europeanen. En voor ons om dat te bereiken is niet alleen belangrijk, dat de infrastuur in Rotterdam het beste is, maar ook, allianties te sluiten met Duits spoor, rivier of weg verbindingen en depots en terminals (etc.,) om te zorgen. Dat het product van die kade van Rotterdam naar Polen of diep in Duitsland en Zwitserland en dergelijke gaat. Dus ja, ik wil meer invloed in het achterland om diezelfde kwaliteit in afhandeling te kunnen garanderen aan de klanten, die ervoor kiezen in Rotterdam aan te leggenen en niet in Hamburg, waar ze een fantastische spoorverbinding hebbend door Duitsland. Dus we moeten verder dan Rotterdamse grenzen denken, om die eisen waar te kunnen maken.

P: We hebben die havendagen achter de rug wat is het leukste dat u gedaan hebt?

AC: Nou eerlijk is dat, Het leukste week 's avonds hardlopen langs treinen, onderzeeboot of de stormbaan of voor de Karel Doorman. Het deed mij denken aan het Nederlands elftal. Je loop met z'n alle rond hartstikke trots op de Nederlands industrie nautische activiteiten, kennis, kunde, innovatie investeringen van allerlei partijen.

P: Zijn wij als Rotterdam genoeg trots op Rotterdam?

AC: Nee. Ik wil graag bewerkstelligen dat haven en stad niet de vraag hebben: "wie is de baas?". Maar, "hoe kunnen wij zo goed mogelijk samenwerken?". Als je beseft dat een kleine 150 duizend mensen werken in de haven. Als een student in de zaal zit elke tak van sport die je hier in Leiden of Delft kan studeren vind je terug in de haven. Het is een fantastische omgeving van wereldreputatie. Ik kom net terug uit Koeweit, als je met de Koeweitse minister spreekt, spreekt hij vol lof over de Rotterdamse haven. Wij als haven moeten ons best doen om het te verkopen en zorgen dat rotterdammers er mee in aanraking komen.

Appendix 13 From Values to Attributes

The stakeholder value trees were combined to form one value tree. This value tree is shown per public value. The value economic growth is in Figure A — 1. The value safety is in Figure A — 2. Figure A — 3 shows the public value "sustainability.

Some attributes are considered to be equal: Knowledge diffusion and knowledge exchange. Emission reduction and pollution reduction.

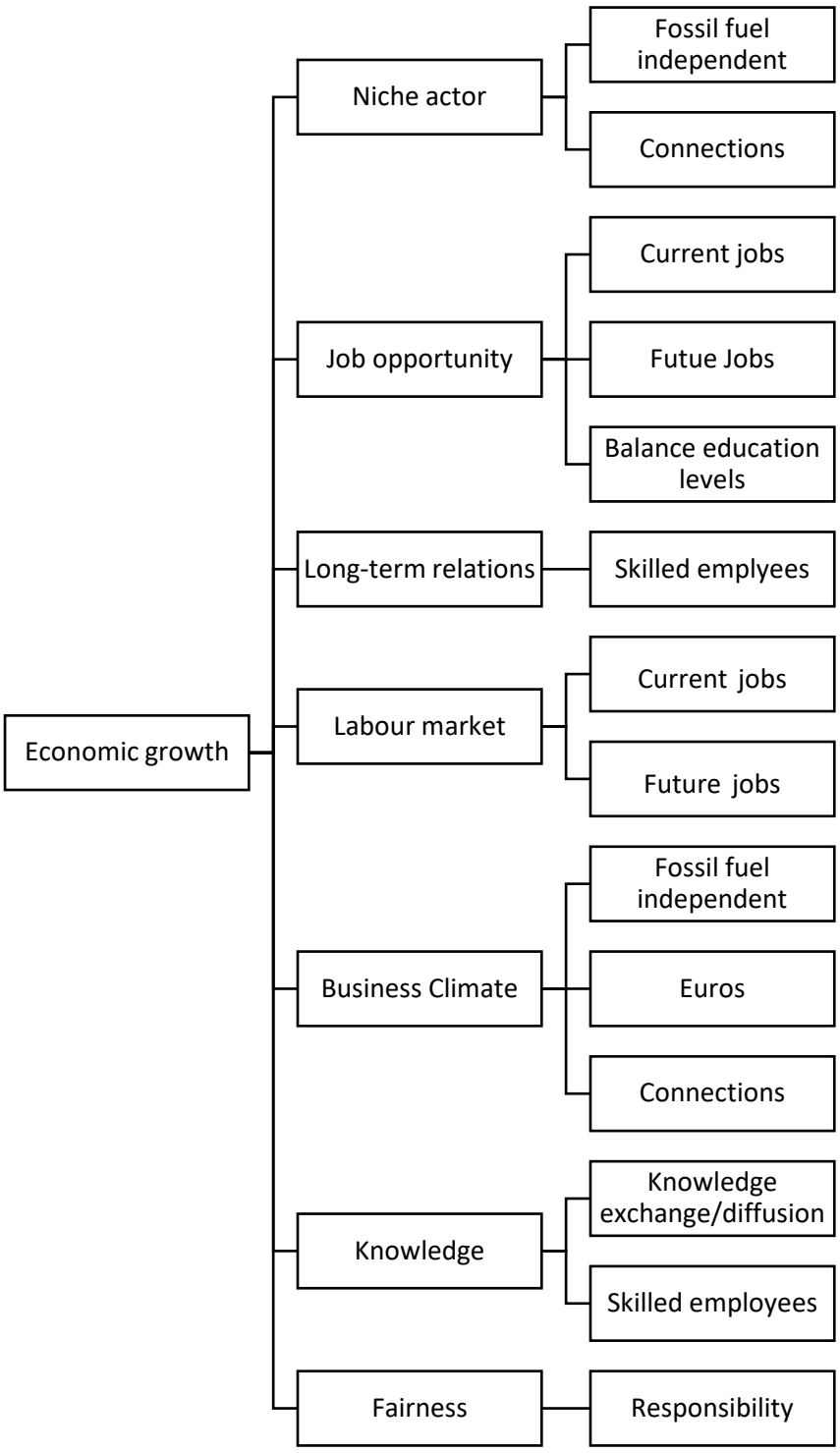

Figure A — 1 Overall value tree for the public value "economic growth".

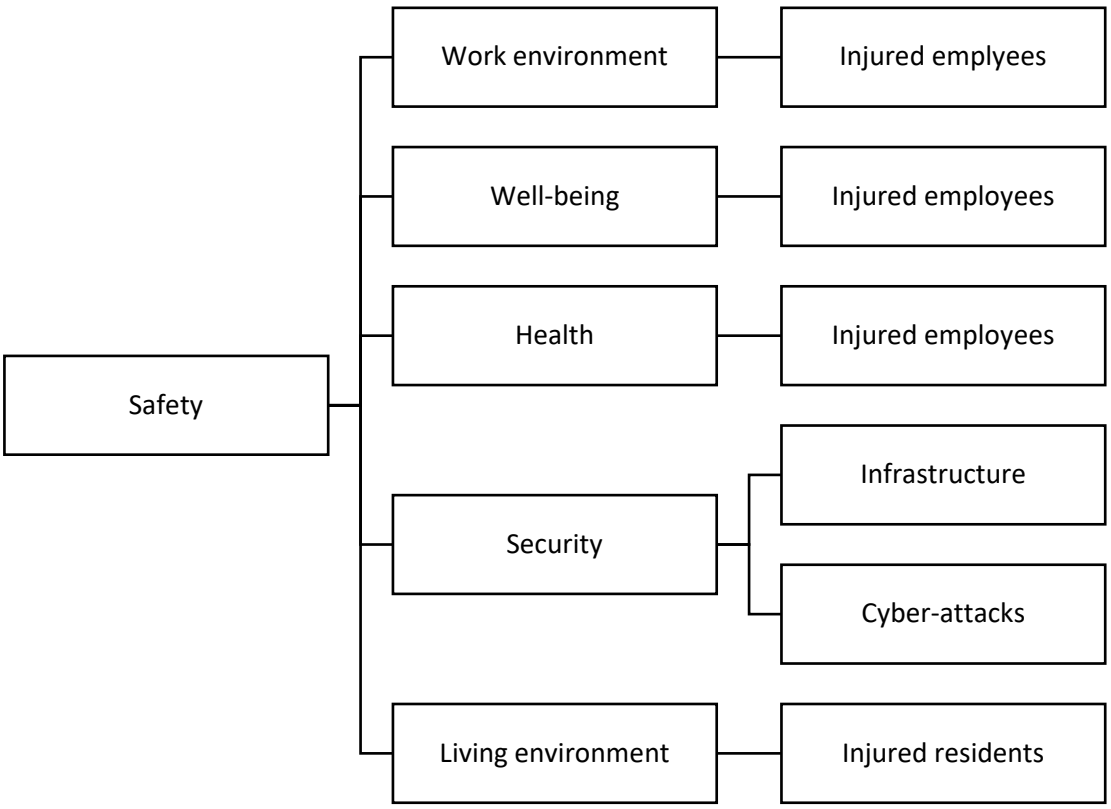

Figure A — 2 Overall value tree for the public value "safety".

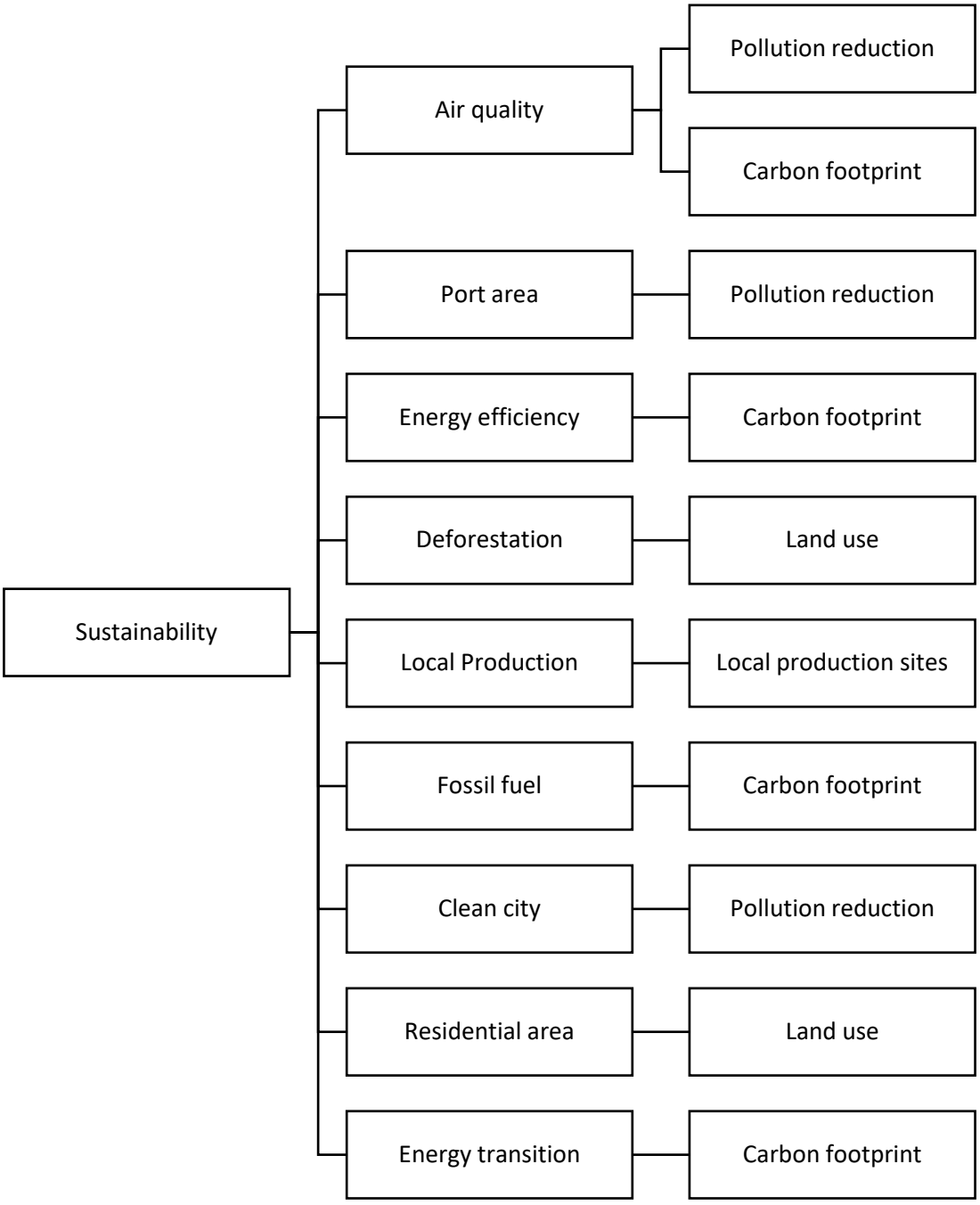

Figure A — 3 Overall value tree for the public value "sustainability".