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Financing Strategy, Environmental Impact Studies and Social Cost Benefit Analysis for Shore Power at Vopak Vlaardingen CEF

Project Report

ABBEL

Financing Strategy, Environmental Impact Studies and Social Cost Benefit Analysis for Shore Power at Vopak Vlaardingen CEF

Project Report

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Abbreviations

AIS	Automatic Identification System
BCR	Benefit-Cost Ratio
CEF	Connecting Europe Facility
CII	Carbon Intensity Indicator
CMS	Cable Management System
CO_2	Carbon dioxide
CPI	Consumer Price Index
DWT	Deadweight tonnage
ESD	Emergency Shut-Down Systems

ESI	Environmental Ship Index
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse gases
GT	Gross tonnage
HAZID	Hazard Identification
HICP	Harmonised Index of Consumer Prices
HVSC	High Voltage Shore Connection
LNG	Liquefied Natural Gas
LOA	Length overall
LPG	Liquefied Petroleum Gas
MGO	Marine gasoil
(M)VA	(Mega) Volt-Ampere (Apparent electric power)
(M)W	(Mega) Watt (Active electric power)
NO_x	Nitrogen oxide
OCIMF	Oil Companies International Marine Forum
OPS	Onshore Power Supply
PEIA	Preliminary Environmental Impact Assessment
PM10	Particulate Matter with a diameter of 10 microns or less
PoR	Port of Rotterdam
SCBA	Social Cost-Benefit Analysis
SO_x	Sulphur dioxide
VAT	Value-Added Tax
VLSFO	Very Low Sulphur Fuel Oil

1. Management Summary

1.1 Introduction

The Port of Rotterdam (PoR), Vopak and Stolt Tankers are jointly studying the feasibility of developing an OPS for chemical tankers at the Vopak Vlaardingen terminal berth 626.

Rebel was appointed in June 2023 to prepare a 'Financing Strategy, Environmental Impact Studies and Social Cost Benefit Analysis for Shower Power at Vopak Botlek CEF'. The main objective of our study is to prepare a financial- and economic analysis for:

- the proposed implementation of an OPS initially at the Vopak Botlek terminal which later was amended to the Vopak Vlaardingen terminal site
- the proposed ship conversion of the Stolt Breland to enable it to connect to shore power

The scope did not foresee interactions with for instance the end customers or other stakeholders.

The technical solution considers the erection of a monopile in between the far eastern end of berth 626 and the shore with the installation of a long-reach CMS crane on top of the monopile. The indicative location of the monopile and the proposed new shoreside substation is shown in Figure 1.

Figure 1 Indicative location shoreside substation and monopile at berth 626 (Source: Google Earth)

1.2 Assumptions

The key assumptions impacting the financial and economic analysis of both parties are summarised as follows:

1.2.1 Electricity offtake berth 626

Electricity offtake per call is based on historic ship call information as provided by Vopak and PoR and average and peak electricity demand profiles for five ship classes as shared by Stolt. The respective ship power demand per call is summarised in the table below.

	GT (min – max)	DWT (min – max)	Total demand per call (in MWh)	
			Loading	Discharging
Class 1	0 – 5,000	0 – 7,500	0.2	0.5
Class 2	5,001 – 10,000	7,501 – 15,000	0.3	0.6
Class 3	10,001 – 15,000	15,001 – 25,000	0.6	1.2
Class 4	15,001 – 25,000	25,001 – 38,000	0.9	1.5
Class 5	> 25,001	> 38,001	0.8	1.7

Table 1 Ship power demand per call

Figure 2 below shows the resulting electricity offtake during the model period for the Vopak 'high' uptake scenario, refer also paragraph 1.2.5.

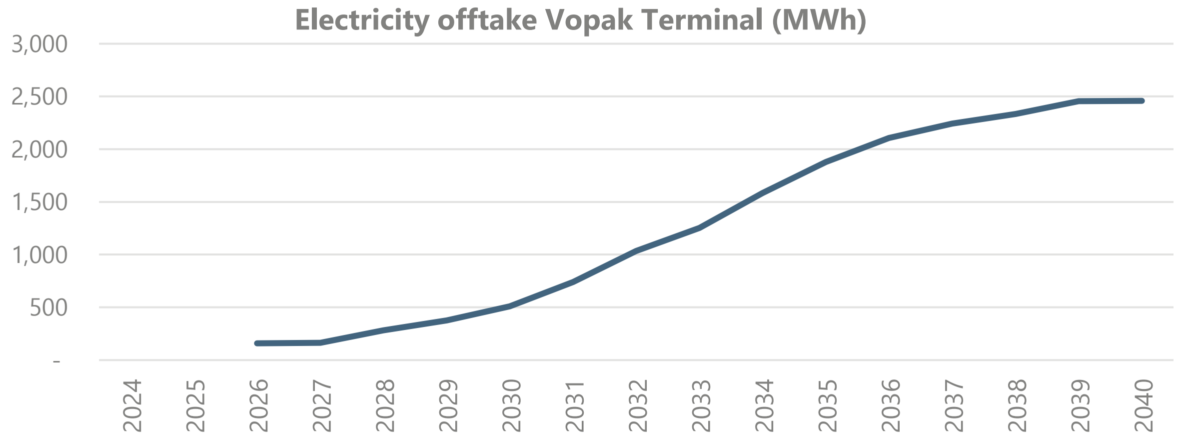


Figure 2 Electricity offtake Vopak Terminal - 'Base' scenario

1.2.2 Fuel bunker price

Both the pricing for new fuel types and the uptake of alternative fuels is very uncertain hence to reduce the complexity and number of scenarios it was agreed to only consider MGO fuel consumption in the financial and economic analysis. The MGO bunker price forecast for the model period has been taken from Oxford Economics, refer Figure 3 below. This is referred to as the base MGO fuel price scenario. It was agreed to introduce a low and high MGO fuel price scenario which is respectively 20% lower and 20% higher than the base price forecast scenario. Potential impact of the introduction of alternative fuels is assumed to be captured with the price variation scenarios for MGO fuel.

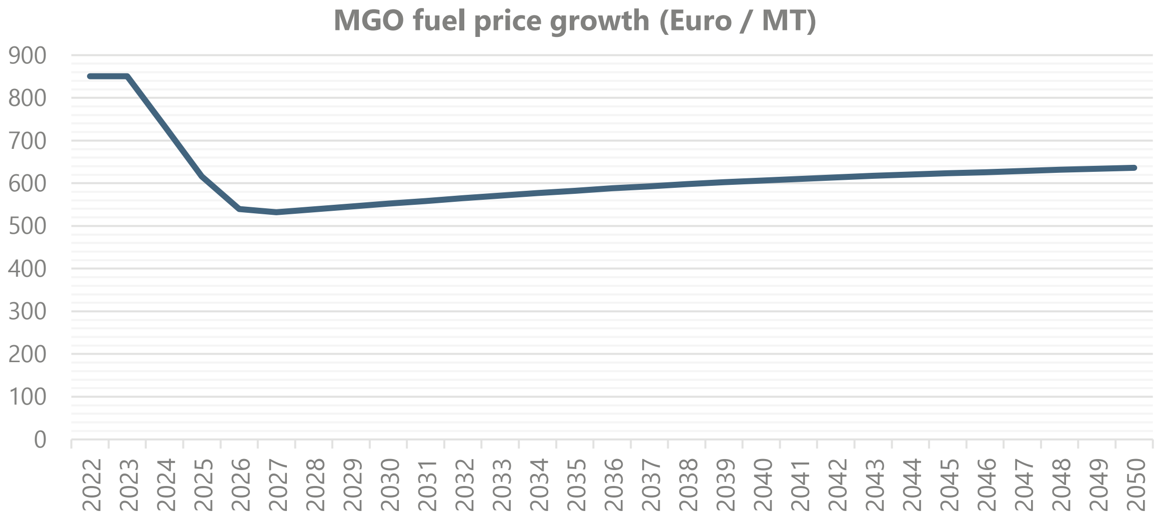
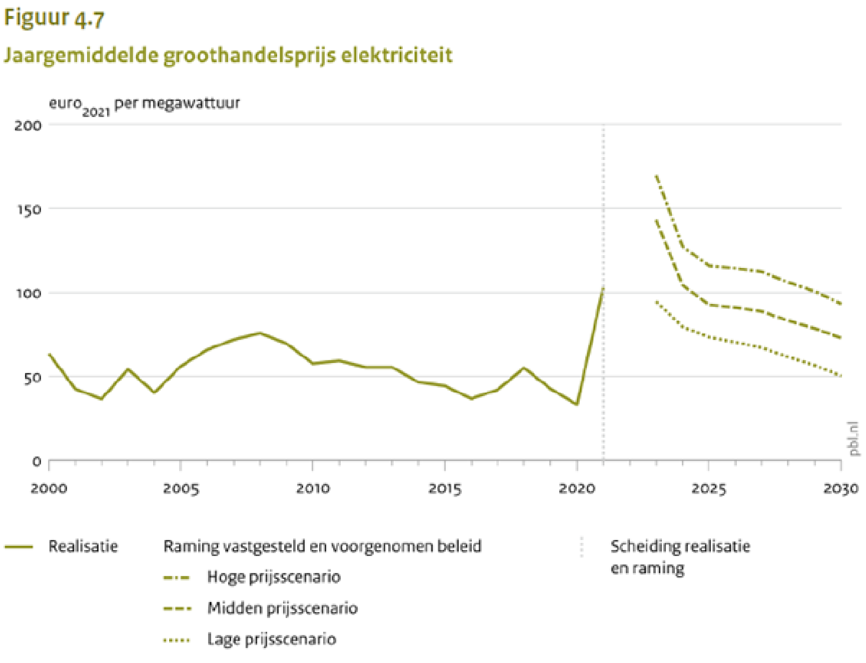


Figure 3 MGO bunker price forecast (real) – base fuel price scenario (Source: Oxford Economics, retrieved 25 October 2023)

1.2.3 Electricity intake price

For the present analysis it was agreed to use the forecast from the Planbureau voor de Leefomgeving (PBL) till 2030 and for the remainder model period to use the 2030 prices for the three scenarios as estimated by PBL, refer Figure 4 below.



Bron: CBS (realisatie); KEV-raming 2022

Figure 4 Yearly average electricity price forecast large consumers (Source: Klimaat- en Energieverkenning 2022, PBL)

1.2.4 CAPEX

A CAPEX estimate for the shoreside OPS substation, CMS, related shoreside works and onboard investment was provided at the start of the assignment which considered the three shortlisted technical options as per DNV's feasibility assessment study:

- Scenario 1 - Midships reel on platform (option A);
- Scenario 2 - Midships CMS crane on platform (option B);
- Scenario 3 - Stern long range CMS crane (option H).

In the course of the study a fourth scenario was added which is a variant of Scenario 3 with the option to also charge a ship with an onboard battery.

Nr	**Description**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 3 + battery**
1	Connection to local distribution station (both feeder panels and HV cable connection to the shore-side substation)	1,000,000	1,000,000	1,000,000	1,100,000
2	Project hours, external engineering, shore power cabling and equipment at the terminal	1,645,500	1,700,500	1,750,500	1,925,550
3	Jetty civil modifications at the terminal	15,000	15,000	85,000	93,500
4	CMS system	775,000	1,550,000	1,185,000	1,303,500
5	Other costs and contingency	873,650	1,122,650	1,049,150	1,154,065
	Total Onshore CAPEX	**~ 4,310,000**	**~ 5,390,000**	**~ 5,070,000**	**~ 5,577,000**
1	Shore power equipment on the ship	2,500,000	2,500,000	1,500,000	2,500,000
2	Contingency	750,000	750,000	450,000	450,000
	Total Onboard CAPEX	**3,250,000**	**3,250,000**	**1,950,000**	**2,950,000**

Table 2 CAPEX estimate onshore and onboard investments Stolt Breland (in Euro) (Source: PoR, Vopak and Stolt)

As per Figure 1 the stern configuration is preferred hence the financial and economic analysis only evaluates scenarios with investments for 'Scenario 3' and 'Scenario 3 + battery'.

1.2.5 Uptake of shore power calls

Based on the discussions during the workshops the following 'Vopak' uptake scenarios were developed:

- Low scenario – 50% uptake in 2037
- Base scenario – 50% uptake in 2035
- High scenario – 50% uptake in 2033
- Optimistic scenario: 50% uptake in 2031 and 100% uptake in 2035
- Vopak High scenario: 50% uptake in 2027

An S-curve growth profile was assumed for all scenarios, refer Figure 5 below.

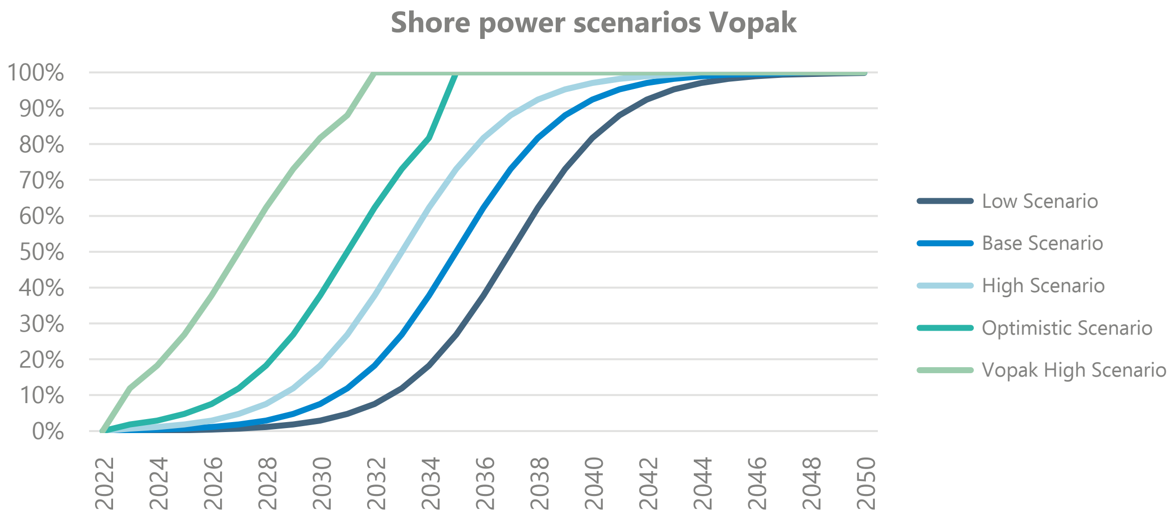


Figure 5 Shore power uptake scenarios Vopak expressed in % of calls

As per Figure 5 the 'high' uptake scenario approximately matches the resulting average of the five scenarios hence this traffic scenario was selected for the overall 'Base' scenario.

Similarly as for the Vlaardingen terminal, during the workshops various scenarios for the uptake of shore power calls for the Stolt Breland were discussed.

Based on the discussions during the workshops the following 'Stolt Breland' uptake scenarios were developed (in addition to the Stolt Breland calls at Vopak Vlaardingen);

- Low scenario – one additional terminal every 5 years;
- Base scenario – one additional terminal every 2 years;
- High scenario – one additional terminal every year.

For all additional terminals it is assumed that the shore power offtake per year per terminal is identical to the Stolt's Breland offtake at the Vopak Vlaardingen terminal.

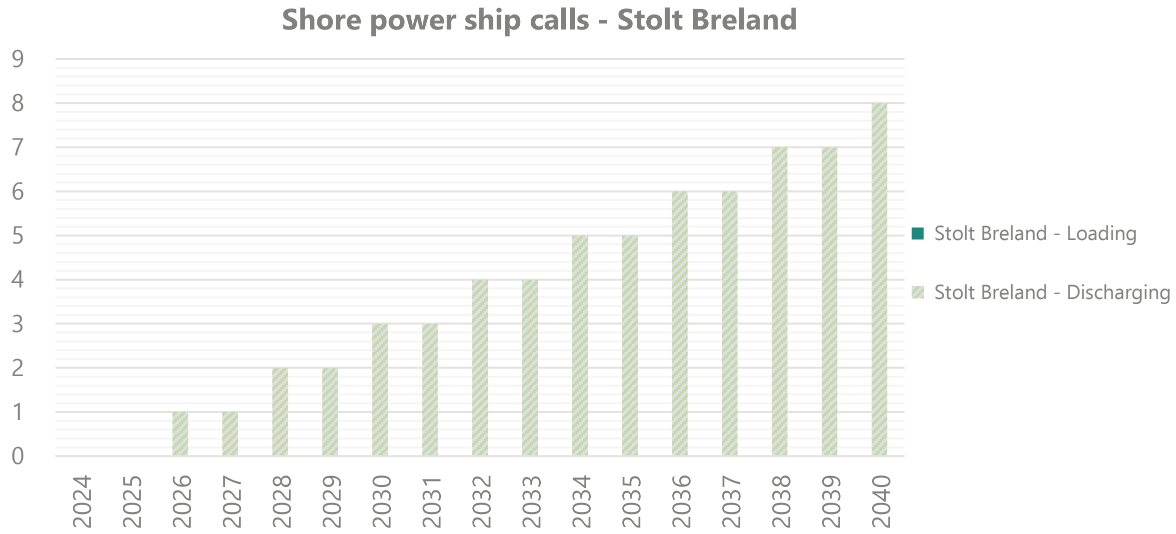


Figure 6 Shore power ship calls Stolt Breland – base uptake scenario

1.2.6 ETS

The EU Emissions Trading System (ETS) is a carbon emission trading scheme set up to combat climate change. The scheme has recently been extended to cover maritime transport emissions as well. From 2024 onwards the scheme includes carbon emissions from all large ships (> 5,000 GT) entering EU ports, regardless of their flag. During the past two years the maximum traded carbon price was approx. Euro 100 per tonne. Industry observers point out that carbon prices will not stay at this price level in the future and forecast higher prices. Based on the discussions during the workshops the following ETS carbon price scenarios were developed;

- Low scenario – Euro 100 per tonne until 2026, linear growth to reach Euro 200 per tonne in 2040;
- Base scenario – Euro 100 per tonne until 2026, linear growth to reach Euro 250 per tonne in 2040;
- High scenario – Euro 100 per tonne until 2026, linear growth to reach Euro 300 per tonne in 2040.

1.3 Business case results

1.3.1 Vopak

Based on the selected settings in the cockpit the model calculates Vopak's 'infrastructure fee'. Vopak's 'infrastructure fee' is the minimum fee per kWh it must charge to the users to meet its target project IRR of 6.5% over a 15 year operational period.

The below figure shows Vopak's cash flow for the high uptake scenario.

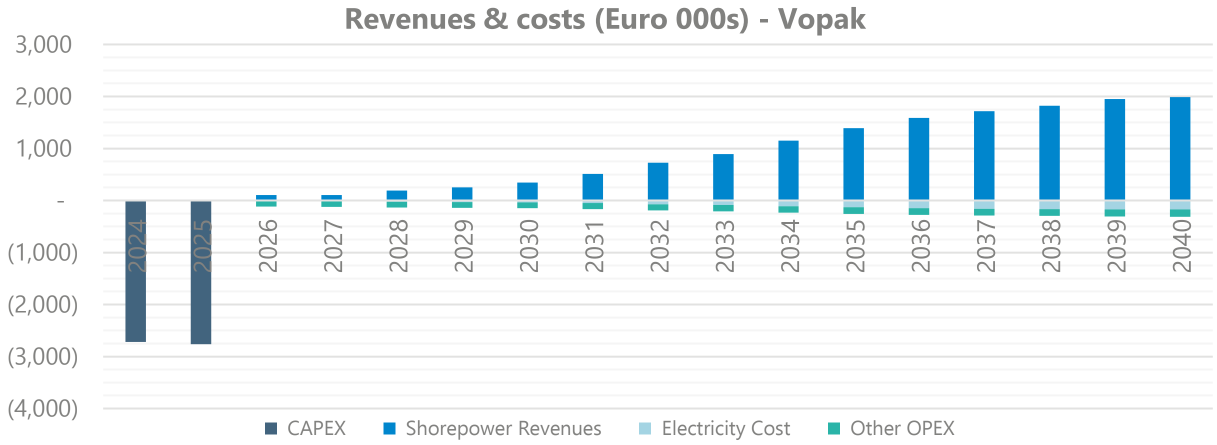


Figure 7 Vopak cash flow – high uptake scenario

Depending on the selected uptake scenario Vopak's required 'infrastructure fee' in 2026 varies between Euro 0.41 and 1.36 per kWh and increases in line with inflation. For the high uptake scenario the 'infrastructure fee' in 2026 is Euro 0.73 per kWh, which is broken down as follows:

- ~ Euro 0.56 per kWh for Vopak's CAPEX and OPEX
- ~ Euro 0.17 per kWh for the Stedin transportation cost

1.3.2 Stolt

Based on the selected settings in the cockpit the model calculates Stolt's 'willingness to pay'. Stolt's 'willingness to pay' is the fee per kWh they are willing to pay to receive shore power assuming identical cost as if the ship would use MGO to run its auxiliary engine whilst at berth. The cost comparison includes an expected project IRR of 8% for their investments.

The below figure shows Stolt's cash flow for the base uptake scenario.

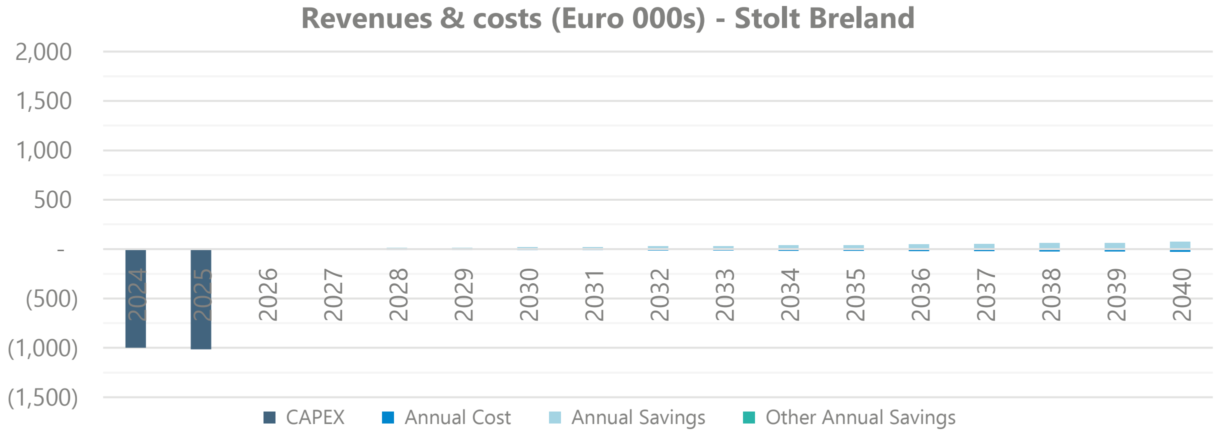


Figure 8 Stolt's cash flow – base uptake scenario

The ship conversion cost has a very high impact on Stolt's 'willingness to pay' due to the relatively modest uptake of shore power calls in all three scenarios.

Uptake scenario / Investment scenario	**Scenario 3**	**Scenario 3 + battery**
Low uptake scenario	Euro 1.76 / kWh	Euro 4.32 / kWh
Base uptake scenario	Euro 0.90 / kWh	Euro 2.36 / kWh
High uptake scenario	Euro 0.36 / kWh	Euro 1.15 / kWh

Table 3 Impact of Stolt Breland's conversion cost on willingness to pay during first year of operations (2026)

In case the conversion cost is considered in the 'willingness to pay' calculation in all cases the 'willingness to pay' is negative.

Stolt's total 'willingness to pay' excluding ship conversion cost for the first year of operations (2026) is Euro 0.15 per kWh which is broken down as follows:

- Electricity intake cost: Euro (0.09) per kWh
- Green electricity surcharge: Euro (0.003) per kWh
- Engine maintenance savings: Euro 0.003 per kWh
- Fuel cost savings: Euro 0.12 per kWh
- ETS savings: Euro 0.12 per kWh

1.3.3 'Base' scenario

The model includes a number of key assumptions impacting the financial analysis of either or both business case(s).

A number of assumptions are fixed in the model whilst other assumptions include optionality to select alterative scenarios by the user.

The key assumptions which can be manually adjusted by the user in the cockpit are summarised in Table 4. The table shows the selected inputs for the 'Base' scenario.

	Description	**'Base' scenario**
General Model Inputs		
Shore power construction start year[1]	default year is 2024	2024
Operations duration	default period is 15 years. In the sensitivity analysis a longer period is also evaluated	15 years
Main Scenarios		
Grid connectivity	default entry 'No delay', in case the entry 'Delayed' is selected the model will assess the impact of a one year delay in start of operations	No delay
Shore power scenarios – Vopak Terminal	one can select one of five uptake scenarios as defined in paragraph 1.2.5	High
Shore power scenarios – Stolt Breland	one can select one of three uptake scenarios as defined in paragraph 1.2.5	Base
Shore-side investments	one can select one of four investment scenarios as defined in 1.2.4, as mentioned previously in the analysis only onshore investment 'Scenario 3' and 'Scenario 3 + battery' are considered	Scenario 3
Ship investments	one can select one of four investment scenarios as defined in 1.2.4, as mentioned previously in the analysis only ship investment 'Scenario 3' and 'Scenario 3 + battery' are considered	Scenario 3
Electricity intake price	one can select one of three electricity intake scenarios as defined in paragraph 1.2.3	Base
MGO fuel price	one can select one of three MGO fuel price scenarios as defined in paragraph 1.2.2	Base
ETS price scenario	one can select one of three ETS price scenarios as defined in paragraph 1.2.6	Base
Shore power (compulsory implementation)	Estimated year that shore power for tankers is obligated, default year is 2041. The entry only impacts the social cost benefit analysis as further described in paragraph 1.4.	2041

Table 4 Model input by user and settings 'Base' scenario

The model cockpit includes a graph with Vopak's 'willingness to sell' (i.e. their required 'infrastructure fee') and Stolt's (and other liners') 'willingness to pay' based on retrofitting a ship. As per paragraph 1.3.2

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[1] The model includes a fixed two-year construction period before the start of operations

the conversion cost would lead to a negative 'willingness to pay' hence for the analysis of the above defined 'Base' scenario the ship conversion cost is ignored.

The below figure shows the evolution of Vopak's 'willingness to sell' and Stolt's 'willingness to pay' during the model period for the 'Base' scenario. As can be seen in the first year of operations the viability gap is around Euro 0.58 per kWh and reduces slightly during the model period.

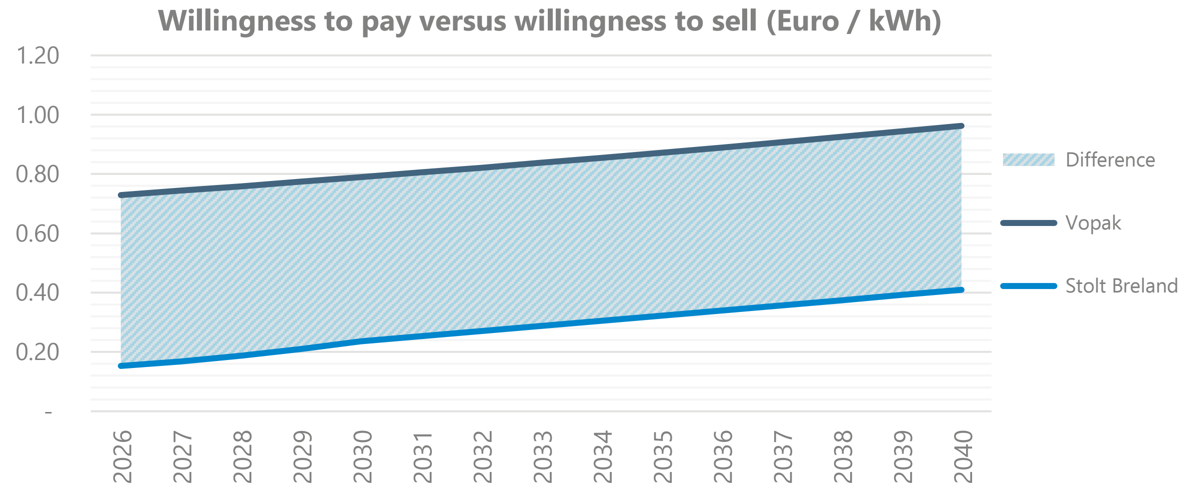


Figure 9 Willingness to pay vs Willingness to sell – 'Base' scenario

The same viability gap between 'willingness to sell' and 'willingness to pay' has also been expressed in a an average cost per shore power call, refer Figure 10.

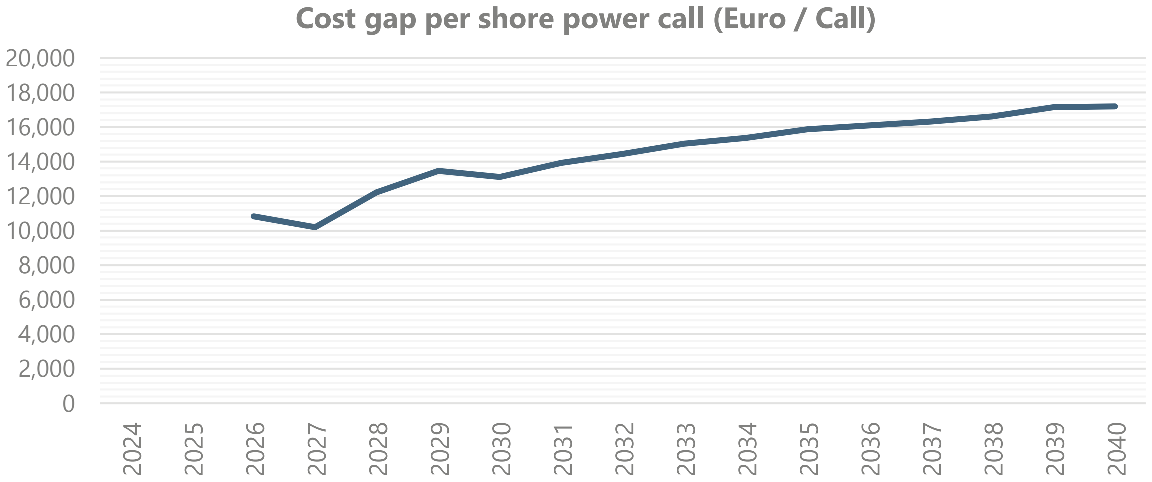
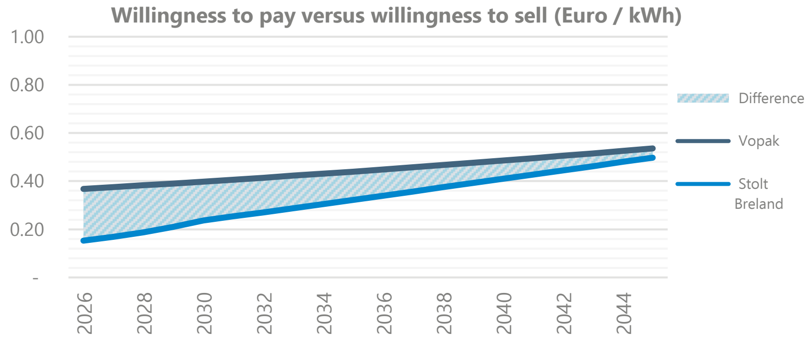


Figure 10 Gap expressed in additional cost per shore power call

A sensitive analysis was undertaken to assess whether certain variations in the input parameters can potentially narrow the viability gap between the two business cases. It should be noted however that the investment decision of Vopak not only depends on Stolt's willingness to pay but also on other shipping lines calling at Vopak Vlaardingen and the end customers. The table below summarises two out of eight sensitivity scenarios analysed and presents for the selected scenarios the evolution of the viability gap and main observations.

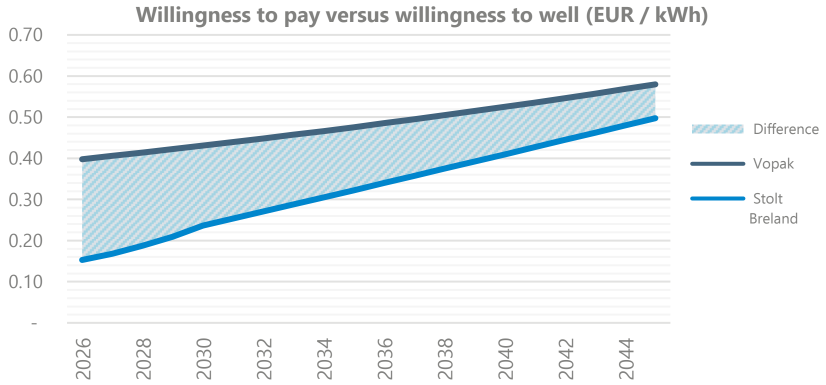
Sensitivity Scenario 3 – 20 years of operations & Vopak High uptake scenario & shore power becomes obligatory in 2050

- The gap reduces with approx. 63% compared to the 'Base' scenario to around Euro 0.21 / kWh at the start of operations
- During the extended operational period the gap steadily reduces reaching Euro 0.04 / kWh at the end of operations



Sensitivity Scenario 7 – 20 years of operations & high uptake scenario & shore power becomes obligatory in 2050, CAPEX subsidy of 70%

- The gap decreased by approx. 57% compared to the 'Base' scenario to around Euro 0.25 / kWh at the start of operations
- During the operational period the gap steadily reduces and almost closes at the end of operations to Euro 0.08 / kWh



It is understood that conversations have been initiated with the Province of South Holland for them to potentially provide a subsidy of up to 70% of the onshore works CAPEX. Sensitivity Scenario 7 as included above assumes a similar CAPEX subsidy amount and a longer operational period of 20 years.

1.4 Social cost benefit analysis

1.4.1 Introduction and general assumptions

In a social cost-benefit analysis (SCBA) the project is considered from the perspective of society as a whole. The scope is therefore wider than that of the business case analyses presented in earlier chapters. In the business case analysis, the focus is on the *expenditures* and *revenues* for the investor/operator. The SCBA, on the other hand considers *costs* and *benefits* for all members of society in the Netherlands or even the world.

The business cases of Vopak and Stolt have been studied and presented separately, although based on the same common assumptions. The same approach has been followed for the SCBA. The Vopak and Stolt projects constitute separate investments, respectively onshore and onboard. There is a small overlap of benefits since the Stolt Breland ship also calls the Vopak Vlaardingen terminal and will use its OPS. However, the share of Stolt Breland's calls in the total number of shore power calls at the Vopak terminal is small and hence also the overlap. For practical purposes the SCBA of the joint project can be obtained by simply adding the SCBAs of the two separate projects.

1.4.2 SCBA results

The results of the SCBA in the base scenario are presented in the table below. The Vopak and Stolt projects have a clear positive net present value, with a Benefit-Cost Ratio (BCR) of 1.6 and 1.23 respectively.

The positive result is largely due to the emission reduction benefits. These benefits accrue to the wider community (impact on health, environment and climate change) and not to the project investors.

	Vopak	**Stolt**
Ship Benefits	1,765	295
Emission Benefits	12,817	2,167
Project Investment Costs	(5,093)	(1,868)
Project O&M Costs	(4,010)	(382)
SCBA Net Present Value (S-NPV)	**5,274**	**453**
Benefit Cost Ratio (BCR)	**1.60**	**1.23**

Table 5 SCBA results of OPS Vopak and Stolt Breland shore power in Present value 000s Euro

1.5 Conclusions and recommendations

The main conclusions and recommendations are summarised below, a complete list is included in chapter 9.

1.5.1 Conclusions

- The two business cases result in a substantial viability gap for all scenarios and further optimisation is required to reduce the same, refer the recommendations below;
- The Stedin transportation cost make up a large portion of Vopak's required 'infrastructure fee' and exceeds the 'willingness to pay' for all ships;
- In case a 70% subsidy is provided of approx. Euro 2.85 million (70% of the CAPEX for the onshore electrical installation) and a longer operational period is assumed, the gap at the start of operations is approx. Euro 0.25 per kWh and reduces to approx. Euro 0.08 at the end of the operational period;
- The Stolt Breland uptake scenarios result in a very small shore power offtake which results in all cases in a negative 'willingness to pay' should the ship conversion cost be considered in its business case in other words the investment costs cannot be recouped by the additional savings generated;

- Based on the social cost benefit analysis it is concluded that Vopak's BCR is quite robust and exceeds 1 in all but the low uptake scenario;
- The Stolt BCR is less robust though also exceeds 1 in two out of three uptake scenarios;
- Based on the preliminary environmental impact conducted, it is concluded that the positive effects substantially outweigh the negative ones;
- Without a regulatory push the project is cumbersome to get invested as the viability gap without subsidies is quite large. Both Vopak and Stolt business cases would benefit from regulations to stimulate offtake.

1.5.2 Recommendations

In the next project phases it is suggested to:

Port of Rotterdam

- initiate discussions with other potential subsidy providers such as the Province of South Holland;
- initiate discussions with Stedin to discuss the availability of electricity at the nearby distribution station in view of the current grid issues and the high impact of their transportation cost on the Vopak (and other shore power) business cases;
- further investigate the potential monetisation of the nitrogen space;
- internally discuss options to provide additional incentives to; shipping lines via the port's tariff book and operators via concession agreements.

Vopak

- undertake a value engineering exercise with a view to lower the CAPEX of the onshore investment;
- investigate options to increase the berth occupancy at berth 626 with a view to increase the shore power offtake. Alternatively investigate options to supply shore power to other nearby berths using the same OPS substation;
- investigate options to use the existing grid capacity at the terminal with a view to reduce the Stedin cost in the business case such that it is burdened only with the electricity intake price for each kWh consumed;
- the uptake of shore power calls at berth 626 is largely dependent on the willingness of both the shipping lines and end customers to use the OPS and assume both the electricity price risk and pay an additional 'infrastructure fee'. Recently Vopak sent a questionnaire to 23 shipping lines to gauge their interest to use shore power whilst berthed at Vopak Vlaardingen. It is understood that interest was limited. As a follow up it is suggested that interest from end customers is jointly verified together with Stolt as they control the products and indirectly the shipping lines;
- include marketing benefits of showcasing the first shore power connection for tankers in the ARA region in the internal decision making process;
- further investigate the potential monetisation of the nitrogen space.

Stolt

- review port uptake scenarios. The uptake of shore power calls for the Stolt Breland is largely dependent on the willingness of the end customers to use the shore power connection. As a follow up it is suggested that interest from end customers is jointly verified together with Vopak as they control the products and indirectly the deployment of the Stolt Breland at Vopak Vlaardingen and other terminals;
- investigate the possibility to maximise deployment of the Stolt Breland (and the six newbuilds) to terminals with a shore power connection;
- further analyse the risk of electricity price volatility and bunker fuels and if required adjust model inputs to assess impact on the business case;
- include marketing benefits of showcasing the first shore power connection for tankers in the ARA region in the internal decision making process.

2. Introduction

2.1 General

Reduction of emissions of nitrogen oxides (NO_x), carbon dioxides (CO_2) and other emissions are on the agenda of the Port of Rotterdam (PoR). Vopak and Stolt Tankers also are committed to make sustainability a key part of their business strategies and as part of this aim to reduce their environmental and carbon footprint.

Onshore Power Supply (OPS) could play an important role to reduce emissions of ships whilst berthed in ports.

The three parties are jointly studying the feasibility of developing an OPS for chemical tankers at the Vopak Vlaardingen terminal. If proven feasible the consortium intends to jointly develop a showcase OPS at the Vopak site.

Rebel was appointed in June 2023 to prepare a 'Financing Strategy, Environmental Impact Studies and Social Cost Benefit Analysis for Shower Power at Vopak Botlek CEF'. The main objective of our study is to prepare a financial- and economic analysis for:

- the proposed implementation of an OPS initially at the Vopak Botlek terminal which later was amended to the Vopak Vlaardingen terminal site
- the proposed ship conversion of the Stolt Breland to enable it to connect to shore power

The financial- and economic analysis has been prepared based on information available within PoR, Vopak and Stolt and during the course of the study this was further complemented through joint workshops and meetings. The scope did not foresee interactions with for instance the end customers or other stakeholders though it is suggested that these are consulted in the next project phase to allow further refinement of the analysis and its conclusions.

In addition, a preliminary Environmental Impact Assessment was prepared to assess both environmental and safety impacts of the OPS installation at Vopak Vlaardingen.

The outcome of the financial and economic analysis is intended to be used for investment decision purposes and potential subsidy applications for the showcase OPS.

In addition to the present report, the deliverables include:

- a tailored financial and economic model in excel format. The model is FAST compliant and is based on the F1F9 modelling standard;
- a separate model user manual which includes additional details regarding the scope and usage of the model.

2.2 Structure of the Report

- The following two paragraphs of chapter 2 provide a general description of onshore power supply and a project description.
- The next chapter (chapter 3) is dedicated to the technical design aspects of the proposed OPS.
- The common assumptions for both the Vopak and Stolt business cases and economic analysis are described in chapter 4.

- The business case analysis from both the Vopak and Stolt points of view are presented in chapters 5 and 6 respectively.
- Chapter 7 summarises the outcome of the two business cases and includes a sensitivity analysis and suggestions to overcome the gap between the two business cases as described.
- Chapter 8 includes a description of the costs and benefits studied in the economic analysis and its results.
- The conclusions and recommendations are presented in chapter 9.
- The Preliminary Environmental Impact Assessment is described in Appendix 1.
- Appendix 2 includes the Aerius calculations.
- Finally Appendix 3 includes suggested design considerations for the next project phases.

2.3 Onshore Power Supply

2.3.1 Introduction

Onshore power is the process of providing shoreside electrical power to a ship at berth while its main and auxiliary engines are switched off. Shore power permits emergency equipment, refrigeration, cooling, heating, lighting and other equipment to receive continuous electrical power while the ship loads or unloads its cargo.

Shutting down the main engines while in port is common practice. However, auxiliary engines which power cargo handling equipment and other ship's services while in port are the primary source of air emissions from ships in ports today. The auxiliary engines typically run on Heavy Fuel Oil (HFO), Marine Gas Oil (MGO) or Marine Diesel Oil (MDO). On average Stolt's fuel consumption in port is approximately 20% of their total consumption. Onshore power mitigates harmful emissions from auxiliary engines by connecting a ship to a more environmentally friendly, shore-based source of electrical power. An alternative is to run auxiliary engines either on gas (LNG or LPG) or extra low sulphur distillate fuels. However, in this case noise pollution will remain.

2.3.2 System

Large investments are generally required onboard as well as onshore in order to connect a ship to a source of electricity from the shore. The present study considers a fixed OPS system for the onshore infrastructure. For the onboard infrastructure both fixed and mobile systems are comparable.

Onshore infrastructure

Several suppliers provide turnkey solutions for the entire electrical system. This stretches from the receipt of power from the local grid, its adaptation to the ship's requirements, to the connection of shore power including the onboard system. The below figure provides an overview of the connection from the main substation to the ship.

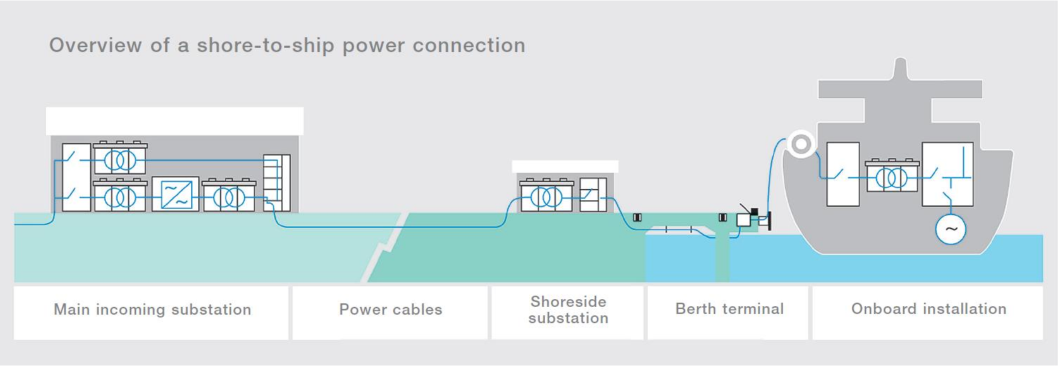


Figure 11 Overview of a shore-to-ship power connection

Typically, the onshore electrical infrastructure includes:

1. HV/MV distribution from main substation

   Distribution from the main substation to the shoreside substation with high voltage or medium voltage (HV or MV) power cables.

2. OPS Substation (including frequency converter)

   The OPS substation includes (step-down) transformers, frequency convertors and (step-up) transformers to match the grid supply to the vessel's onboard voltage and frequency level. The grid frequency in Europe is 50 Hz whilst the onboard power systems of most ships have a frequency of 60 Hz. For that reason, a frequency converter is installed in the OPS substation. In case a ship's power system operates at 50 Hz, the frequency convertor can be given a setting to supply at 50 Hz.

3. LV/HV distribution

   Most tankers operate at LV (440 V) and some newbuilds adopt HV connections. Generally connections between the substation and ships are based on MV or HV. The OPS can be designed to operate at both voltage levels. Depending on the ship's need either of the voltages can be set as nominal output voltage.

4. Cable Management System

   The cable management system allows for an efficient and safe connection between the onshore- and onboard power cables. It should be a flexible system which caters for vertical ship movements due to (un)loading cargo, movement due to local tide and other ship movements.

5. Shore connection box/plugs

   In several cases the onboard power cables are connected to the onshore cables by means of a shore connection box, refer also the below figure.

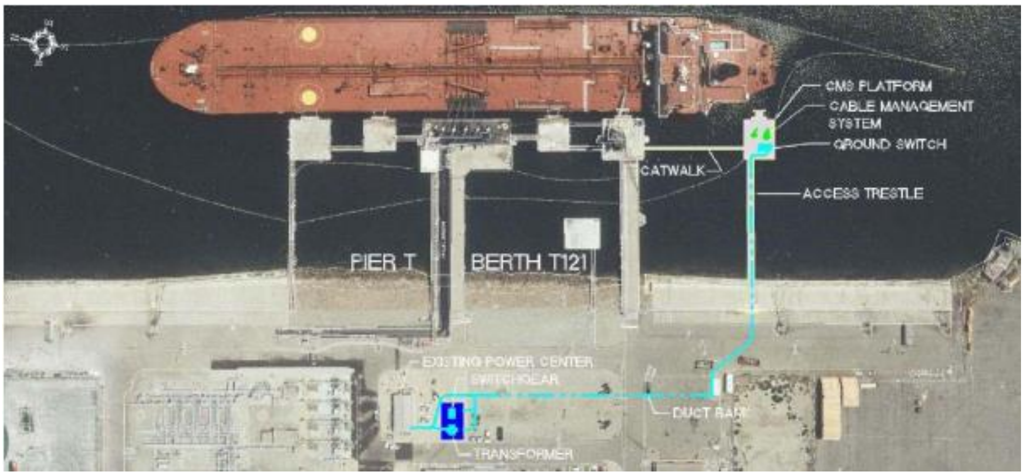


Figure 12 Overview of a shore-to-ship power connection with shore connection box

Onboard infrastructure

Typically, the onboard electrical infrastructure includes:

1. Cable connectors and shore-to-ship power panel

   The LV/HV shore power system is arranged with the on-board shore connection panel located outside the main switchboard room. For ships with on-board HV electrical distribution, the on-board HV shore connection panel is connected straight into the ship’s main HV distribution panel. For ships with on-board LV electrical distribution only, an additional on-board transformer to step down the voltage from HV to LV before it is connected into the on-board main LV distribution panel could be considered, refer also below figure.

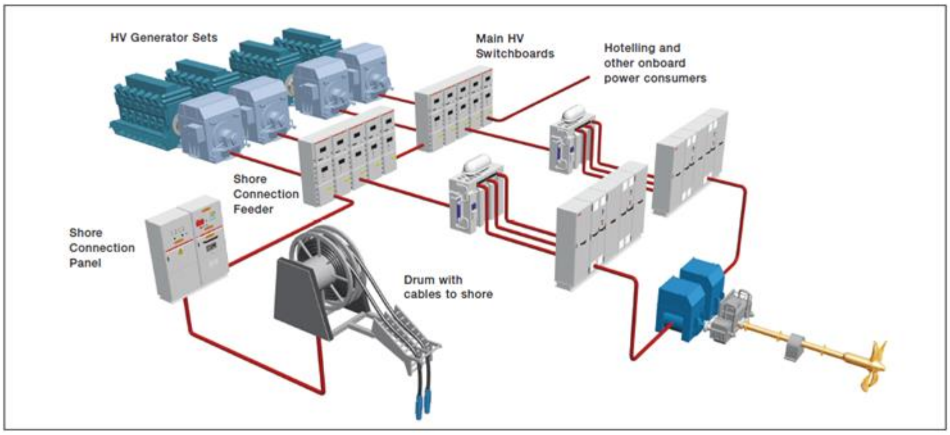


Figure 13 Overview of onboard cable connectors and shore-to-ship power panel

2.4 Project description

2.4.1 General

A number of OPS installations have been installed or are currently being planned around the globe. Up to present these are mainly realised at ferry, RoRo, cruise and container terminals.

A few OPS installations at liquid bulk/gas terminals have been realised which include amongst others:

- Port of Gothenburg has an OPS installation under construction for a tanker jetty with 3 berths[2]. It is expected that during Q1 2024 the first tanker will be connected.
- Port of Gävle has an existing OPS installation at a liquid bulk jetty, which is built by Actemium. Last November the first vessel (Tern Fors) connected to the installation[3]. This is the first port operating an explosion-proof OPS system in the world[4].
- The OPS installation at Port of Long Beach has been in operation since 2006[5]. The system can deliver up to 8MW at 6.6kV.
- Eemshaven's LNG terminal has two separate OPS installations to supply shore power to LNG FSRU's. The systems can deliver 16 MW respectively 24 MW at 6.6 kV.
- Schneider Electric and Igus developed a shore power solution for a LNG FSU for a terminal in Bahrain[6].

Vopak, Stolt Tankers and Port of Rotterdam are jointly studying the feasibility of developing an OPS system for liquid/chemical tankers in the Port of Rotterdam with the aim to develop a pilot OPS. DNV Maritime Advisory was hired late 2022 to prepare a technical feasibility study for the implementation of OPS at the Vopak Botlek terminal[7]. The objective of the DNV report was to carry out a feasibility study for development of a high voltage OPS for tankers. The study aimed at producing a showcase with the potential to accelerate development of an international standard on High Voltage OPS for tankers.

As mentioned, we have since been appointed to prepare a financial and economic analysis and a preliminary Environmental Impact Assessment initially for the Vopak Botlek terminal. Early on during the study it was decided to change the study location to the Vopak Vlaardingen terminal.

2.4.2 Vopak Vlaardingen

The proposed shore power project involves the construction and operation of a shore power system at berth 626 of the Vopak Vlaardingen terminal. The site location is shown in Figure 14.

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[2] Onshore Power supply for tankers. (portofgothenburg.com)

[3] GLOBAL: Terntank vessel uses shore power for unloading ops at Gävle Port - Bunkerspot - Independent Intelligence for the Global Bunker Industry

[4] Actemium delivers Onshore Power Supply in hazardous area (ATEX) - Actemium

[5] Riviera - News Content Hub - First tanker cold ironing facility is opened (rivieramm.com)

[6] Offshore chain for the floating storage unit | igus®

[7] Feasibility Assessment Study, High Voltage Shorepower Connection for Tankers, Report 2023-0466 Rev1, DNV AS Norway

Figure 14 Vopak Vlaardingen berth 626 (Source: Google Earth)

The terminal specialises in the handling and storage of vegetable oils and fats, oleochemicals, biodiesel and base oil. The terminal is situated in Vlaardingen, southeast of the city centre.

Further details such as the technical design of the system are presented in chapter 3.

3. Technical Aspects

3.1 Introduction

DNV Maritime Advisory had prepared a feasibility assessment study for the development of a high voltage shore power system at the Vopak Botlek terminal in June 2023. The study evaluated different technical concepts that could enable shore power for tankers and which could be acceptable concepts to arrive at a generally applicable solution. From a long list of 12 options, three options were selected and further detailed. The study recommended option H ('stern long range CMS crane') as the preferred option, refer below figure.

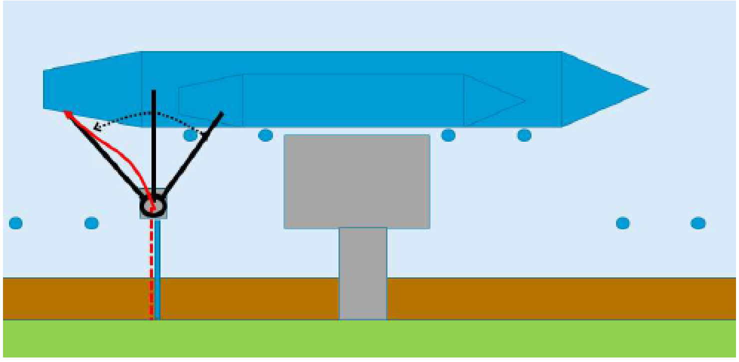

Figure 15 Illustration of scenario option H

The option considers a long reach Cable Management System (CMS) crane on top of a platform or monopile to bring the cable across to the most suitable area of the ship, as close as possible to the connection point on board assumed to be located at the stern. Figure 16 shows a potential solution for the proposed long reach CMS crane.

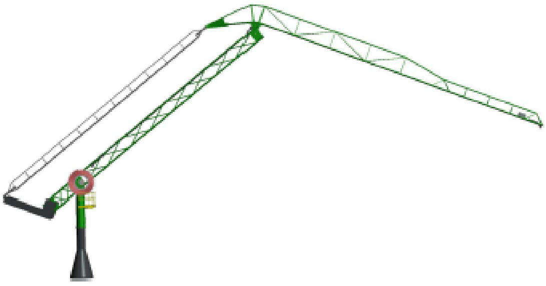

Figure 16 Potential solution for long-reach CMS crane (Credit: Eager.One)

From discussions with Vopak it is understood that the same technical option is proposed for berth 626 at Vopak Vlaardingen. In summary the technical solution considers the erection of a monopile in between the far eastern end of berth 626 and the shore with the installation of a long-reach CMS crane on top of the monopile. The location of the monopile and configuration of the long-reach CMS crane needs to be further studied in the next project stage, though as part of the current study a number of technical considerations have been included in the next paragraph. In addition, a new shoreside substation is required which is envisaged along the waterfront refer also Figure 17.

Typically, the shoreside electrical installation includes the following components:

- Outgoing feeder panel(s) in the HV switchgear of the distribution station of the local grid operator.
- HV cable connection between the distribution station of the local grid operator and a new shoreside OPS substation.
- Shoreside OPS substation comprising:
    - Incoming HV switchgear to connect to the local grid
    - Voltage transformers to transform incoming (grid) voltage to nominal input voltage level of frequency convertors
    - Frequency converter 50Hz – (50-60) Hz
    - Voltage transformers to transform frequency convertors outgoing voltage level to ship's required nominal voltage level
    - Electrical protection systems and comprehensive monitoring and control system
    - Cooling water system
    - Auxiliary transformer and battery backed UPS
- Cable Management System. This is the connection point where the ships actual connection is made. In order to make the connection between the OPS and the ship, a flexible plug-socket connection system is needed. The plugs are brought on board by the CMS crane and connected to the ship.

Figure 17 Indicative location shoreside substation and monopile at berth 626 (Source: Google Earth)

As there is insufficient power capacity at the terminal a new grid connection to the nearest Stedin medium voltage transformer station is required. The distance to the nearest station is approximately 1.6 km.

3.2 Design considerations

Late 2023 an update of the IEC/IEEE 80005 standard for the design, installation and testing of high-voltage shore connection (HVSC) systems was published (IEC/IEEE 80005-1:2019+AMD1:2022+AMD2:2023 CSV) which describes HVSC systems, onboard the ship and on shore, to supply the ship with electrical power from shore.

In addition, recently OCIMF published a preliminary guide to the design of OPS systems for tankers, terminals, and their interface[8]. The paper outlines recommendations for standardised OPS system requirements for voltage, frequency, and number of cables. It is suggested that the IEC/IEEE 8005 standard and OCIMF guidelines are used in the further design steps of the OPS system at Vopak Vlaardingen.

Additional site-specific design considerations are included in Appendix 3.

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[8] Onshore Power Supply Systems, Preliminary Design Recommendations for Tankers and Terminals, OCIMF 2023

4. Assumptions

This chapter summarises the key assumptions which impact the financial and economic analysis of both parties.

At the start of the assignment the following data was provided:

- Feasibility Assessment Study, High Voltage Shorepower Connection for Tankers, Report 2023-0466 Rev1, DNV AS Norway;
- AIS file with historic ship calls at berth 626;
- CAPEX estimates for the three system options;
- Shore power for liquid bulk vessels, Modelling of terminals and vessels for cost effectiveness of different shore power systems, September 2021, J.P.B. Willeijns

During the course of the study two workshops and several meetings were held to jointly refine the key assumptions impacting the financial and economic analysis.

4.1 Ship specifications and sizing of the OPS

Vopak and PoR provided an AIS file at the start of the assignment with all ship calls at berth 626 for the years 2018 to 2022. Based on our analysis and subsequent discussions with all parties it was decided to group the ship calls in five ship size classes.

Stolt provided the average and peak electricity demand during loading and discharging for each ship class. The respective model inputs are summarised in the table below. The electricity demand is specified in MW which is the amount of electricity the ship requires per unit of time.

	GT (min – max)	DWT (min – max)	Loading (in MW)		Discharging (in MW)	
			Average	Peak	Average	Peak
Class 1	0 – 5,000	0 – 7,500	0.2	0.3	0.5	0.6
Class 2	5,001 – 10,000	7,501 – 15,000	0.2	0.3	0.6	0.7
Class 3	10,001 – 15,000	15,001 – 25,000	0.6	0.7	1.2	1.3
Class 4	15,001 – 25,000	25,001 – 38,000	0.8	1.2	1.4	1.8
Class 5	> 25,001	> 38,001	0.8	1.0	1.6	2.1

Table 6 Ship power demand (Source: Stolt)

The model assumes based on discussions with Stolt the following split between average and peak demand whilst the ship is alongside (excluding connecting and disconnecting time):

- Average load: 75% of the net berthing time
- Peak load: 25% of the net berthing time

The sizing of the OPS is based on the electrical demand profile of the largest ship expected to connect to the system. It was agreed to adopt the Stolt Breland as maximum design ship. Based on this the required electrical power of the system was determined to be 2.5 MVA.

In addition, Stolt had provided the average ship fuel consumption which is kept constant for all classes: 217 gram of MGO fuel per kWh.

4.2 Number of calls

4.2.1 Berth 626

The number of historic calls per ship class were derived based on the AIS file provided by Vopak and PoR. The 2018 dataset was largely incomplete hence this year was omitted in the analysis. In 2020 and 2022 there was a drop in berth hours in comparison to 2019 and 2021. The 2020 drop is assumed to be related to the Covid pandemic whilst it is believed that the 2022 drop is due to the maintenance works undertaken at the berth. Based on this it was agreed to use the average of the 2019 – 2022 data as input values for the number of calls and berth hours. In addition it was agreed that the number of calls and berth hours would be kept constant during the model period. The below table summarises the model inputs.

			Number of calls per annum (#)		Average berthing time per call (hours)	
	GT (min – max)	DWT (min – max)	Loading	Discharging	Loading	Discharging
Class 1	0 – 5,000	0 – 7,500	33	16	16	10
Class 2	5,001 – 10,000	7,501 – 15,000	16	9	18	12
Class 3	10,001 – 15,000	15,001 – 25,000	8	10	15	29
Class 4	15,001 – 25,000	25,001 – 38,000	2	19	6	35
Class 5	> 25,001	> 38,001	1	14	7	36

Table 7 Historic calls berth 626 (Source: Vopak and PoR)

4.2.2 Stolt Breland

A separate analysis was conducted for the Stolt Breland ship. Based on the AIS dataset the Stolt Breland called berth 626 on average once per year between 2019 and 2022. The model inputs are summarised in the table below.

	Number of calls per annum (#)		Average berthing time per call (hours)	
Ship	Loading	Discharging	Loading	Discharging
Stolt Breland	0	1	NA	41

Table 8 Historic calls Stolt Breland (Source: Vopak and PoR)

4.3 Bunker price development and alternative fuels

Bunker price developments of current fuels and alternative fuels have an important impact on the shipping lines' willingness to pay for onshore power.

At present most ships use oil-based fuels however to reduce their environmental impact, several shipping lines have adopted non-oil fuels, such as LNG. This is feasible for newer ships with appropriate specifications.

It is likely that in the future shipping lines will expand their fuel mix with biofuels, methanol, LPG, ammonia and hydrogen amongst others.

Both the pricing for these newer fuel types and the uptake of alternative fuels is very uncertain. Due to this uncertainty and to reduce the number of scenarios it was agreed to only consider conventional oil-based fuels in the financial and economic analysis.

Based on discussions with Stolt it is understood that their ships use both MGO and VLSFO in the Port of Rotterdam and whilst at berth the auxiliary engines run on MGO only. The analysis also considers potential manoeuvring of the ship near the berth using a battery. At present the ships use MGO for this activity, therefore this study focuses on MGO fuel only.

The MGO bunker price forecast for the model period has been taken from Oxford Economics. This is referred to as the base MGO fuel price scenario. It was agreed to introduce a low and high MGO fuel price scenario which is respectively 20% lower and 20% higher than the base price forecast scenario. A bunker price starting value of USD 900 per MT as extracted from the online bunker index[9] is used as a starting value in the model. The MGO bunker price forecast as shown in Figure 18 incorporates the forecast scenario of Oxford Economics.

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[9] Bunker Prices Worldwide - BUNKER INDEX

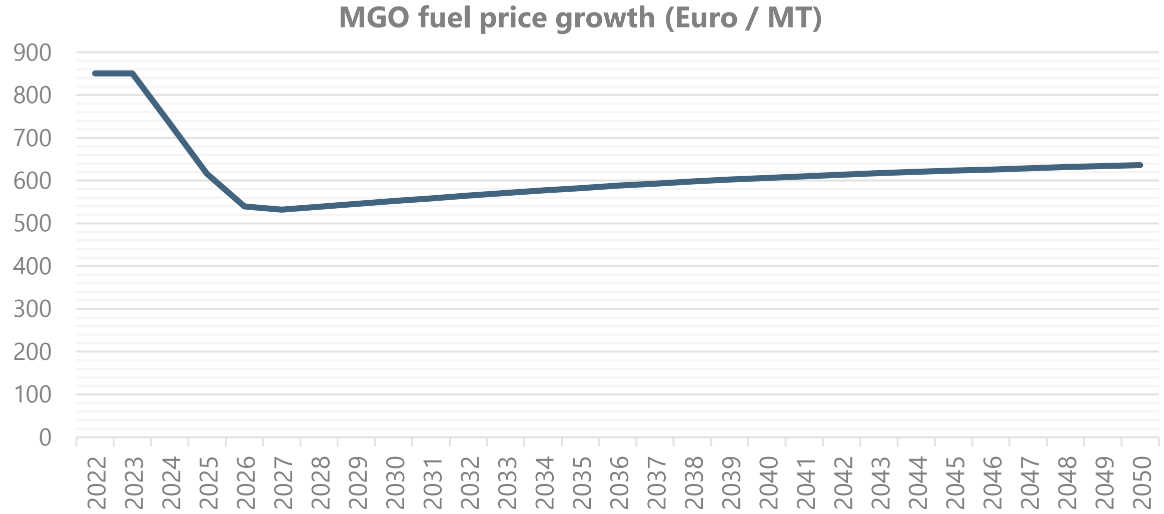


Figure 18 MGO bunker price forecast (real) – base fuel price scenario (Source: Oxford Economics, retrieved 25 October 2023)

Potential impact of the introduction of alternative fuels is assumed to be captured with the price variation scenarios for MGO fuel. It is expected that in the foreseeable future, cost of electricity intake for ships whilst at berth is less than the cost for auxiliary engines to use alternative fuels hence is likely to positively impact the utilisation of the OPS.

4.4 Share of renewable electricity and electricity price

The model incorporates a forecast of the share of electricity in the Dutch national grid generated from renewable sources. The forecast is developed from a synthesis of historic information and data available for specific future years based on internet search. The forecast follows a linear growth and extends up to the year 2050, remaining steady thereafter. The assumption underpinning this forecast is that by 2050 all electricity production will be generated from renewable energy sources. The forecast is used in order to estimate the additional emissions related to gas-fired power plants and their impact on the applicable emission savings at berth. It should be noted that at present the Dutch electricity grid is becoming overloaded which stems from the rate at which the Netherlands is shifting away from gas to more sustainable forms of energy. This may impact availability of electricity at the nearby distribution station and it is suggested to discuss this with the local grid manager Stedin during the next project phase.

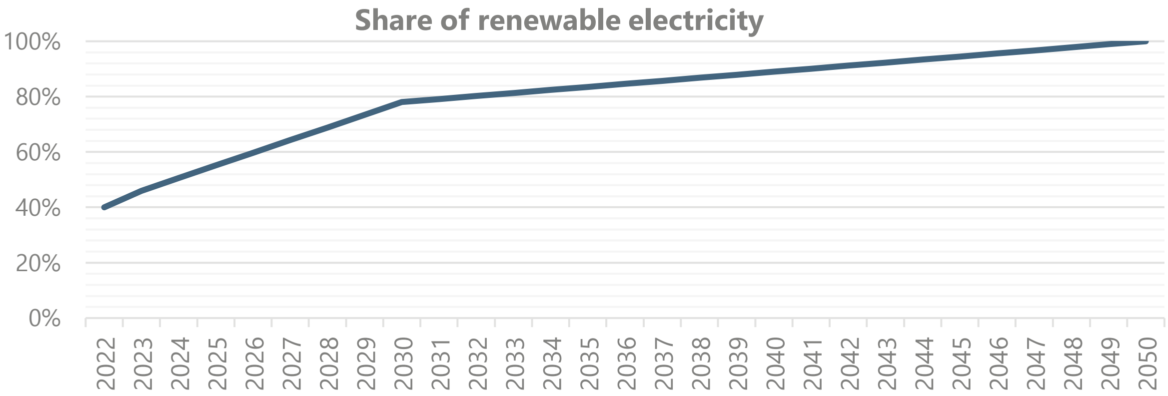
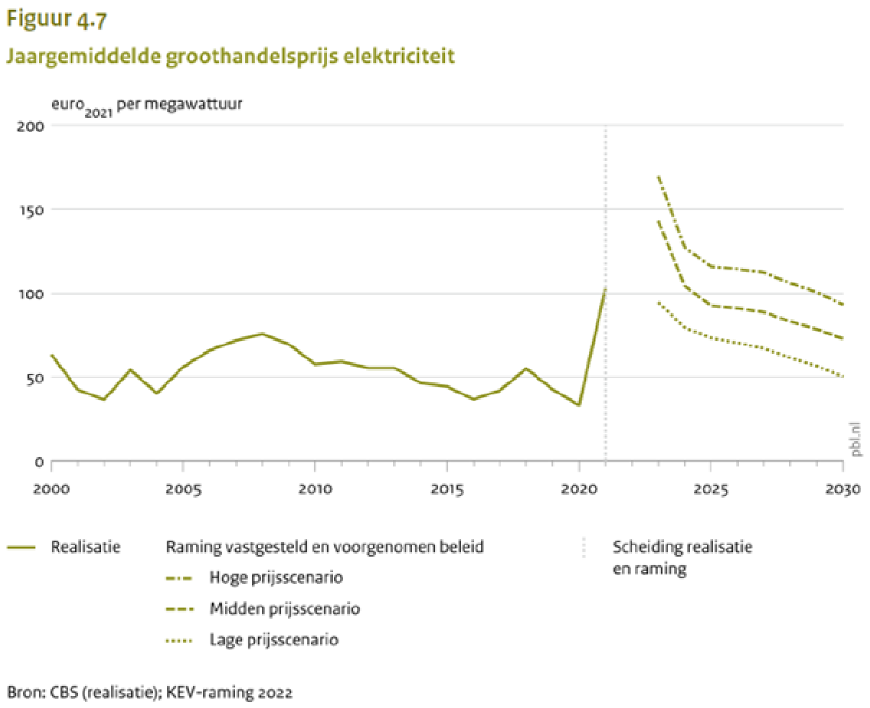


Figure 19 Share of renewable electricity (Sources: www.cbs.nl, www.iea.org, www.klimaatakkoord.nl, retrieved 1 December 2024)

The electricity price used in the model has been sourced from the forecast prepared by the Planbureau voor de Leefomgeving (PBL)[10].

The PBL report was prepared in 2022 shortly after the Ukraine war broke out which had led to a threefold increase in the average electricity price in the Netherlands from 2020 to 2021. In the Netherlands the electricity price is largely linked to the gas price hence the witnessed sharp increase in gas prices led to this steep increase in average electricity price. In their report PBL had developed three electricity price scenarios based on fuel and CO_2 price development figures from the European Commission.

Due to the large uncertainty involved regarding forecasting of electricity prices their three scenarios stop in 2030. For the present analysis it was agreed to use the forecast from PBL till 2030 and for the remainder model period to use the 2030 prices for the three scenarios as estimated by PBL.


Figuur 4.7
Jaargemiddelde groothandelsprijs elektriciteit

Bron: CBS (realisatie); KEV-raming 2022

Figure 20 Yearly average electricity price forecast large consumers (Source: Klimaat- en Energieverkenning 2022, PBL)

In addition, a green electricity surcharge of Euro 5 per MWh is applied in the model for all three scenarios. The Dutch Government agreed late 2021 to reduce the tax onshore power electricity close to nil for an initial period of 6 years. It has been agreed to build the functionality into the model to include a potential reversing of this policy and simulate a higher selling price. However, for clarity purposes, the financial and economic analysis as presented in this report assume no tax to be applicable.

4.5 Connecting and disconnecting time

Based on previous experience and discussions with Stolt it has been assumed that the connection process after ship arrival, and disconnection process before ship departure takes 1 hour each i.e. total assumed time per call that the ship continues to use its auxiliary engine whilst at berth is 2 hrs. The

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[10] Klimaat- en Energieverkenning 2022, Planbureau voor de Leefomgeving, 2022

average berthing time per call as shown in Table 7 has been reduced with the same duration to arrive at the total number of hours each ship is using shore power.

4.6 Emission output

The amount of emissions from ships in the port area is closely related to the age of the ship's engine and the type of fuel the ship uses. To reduce their environmental impact, shipping lines apply several strategies such as equipping ships with scrubbers (emission cleaning technology) to remove pollutants from the ship's exhaust.

As per paragraph 4.3 the current analysis assumes MGO fuel consumption only. The below table summarises the MGO GHG emission factors for emissions CO_2, NO_x, SO_x and PM10. This has been based on a report prepared by Marin in 2019[11] which aimed to determine the emissions to air of seagoing ships.

Pollutant	**Emissions per kg MGO**
CO_2	3,172.6 g
NO_x	26.3 g
SO_x	2.0 g
PM10	0.8 g

Table 9 Emissions per kg MGO (Source: emissieregistratie.nl)

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[11] Sea Shipping Emissions 2017: Netherlands Continental Shelf, 12 Mile Zone and Port Areas (emissieregistratie.nl)

5. Business case analysis Vopak

5.1 Introduction

Vopak are willing to invest in the shoreside electrical installation and bear the related project implementation risk. Vopak may opt to involve one or more partners at a later date to realise the OPS which would result in a different cost and risk profile for Vopak though for the current study it is assumed that Vopak would develop and operate the OPS.

As such Vopak would bear the complete CAPEX and OPEX of the shoreside electrical installation at their Vlaardingen terminal. Vopak would also take on the offtake risk i.e. the system's utilisation although they would seek to conclude minimum offtake guarantees with their customers to limit their exposure.

Vopak proposes to offload the electricity intake price risk to the shipping line, in line with current practice for the intake of bunker fuels.

To recover their investment and operational cost Vopak proposes to charge the users a fixed 'infrastructure fee' which is added to the electricity intake price as charged by the electricity provider. This 'infrastructure fee' is the minimum fee per kWh it must charge to the users to meet its target project return and is further described below.

In addition to the key assumptions summarised in chapter 4, key inputs for Vopak's business case are:

- CAPEX
- OPEX
- Uptake of shore power calls

5.2 Capital expenditure

5.2.1 Upfront

Large investments are required onboard as well as onshore in order to connect a ship to a source of electricity from the shore-side. As stated above it is assumed that the onshore investments i.e. the shoreside electrical installation are borne by Vopak. As per paragraph 3.1 the main components of the shoreside electrical installation include:

- Outgoing feeder panel(s) in the HV switchgear of the distribution station of the local grid operator;
- HV cable connection between the distribution station of the local grid operator and a new shoreside OPS substation;
- Shoreside OPS substation;
- Cable Management System.

A CAPEX estimate for the shoreside OPS substation, CMS and related works was provided at the start of the assignment which considered the three shortlisted technical options as per DNV's feasibility assessment study:

- Scenario 1 - Midships reel on platform (option A);

- Scenario 2 - Midships CMS crane on platform (option B);
- Scenario 3 - Stern long range CMS crane (option H).

In the course of the study a fourth scenario was added which is a variant of Scenario 3 with the option to also charge a ship with an onboard battery. The Scenario 3 CAPEX was inflated with 10% to cover the assumed slightly higher power output capacity of the OPS.

The CAPEX estimate of the Shoreside OPS substation assumes that the installation will be designed with a rated power of 2.5 MVA (refer also paragraph 4.1) and adopts a single frequency of 60 Hz with a 6.6 kV HV connection.

Vopak provided a CAPEX estimate of Euro 1 million for the HV cable connection between the distribution station and the shoreside OPS substation including the outgoing feeder panel(s) in the distribution station. Similarly for the variant of Scenario 3 the CAPEX for the connection with the local grid was inflated with 10%.

The below table includes a breakdown of the onshore investments for the four scenarios:

Nr	**Description**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 3 + battery**
1	Connection to local distribution station (both feeder panels and HV cable connection to the shore-side substation)	1,000,000	1,000,000	1,000,000	1,100,000
2	Project hours, external engineering, shore power cabling and equipment at the terminal	1,645,500	1,700,500	1,750,500	1,925,550
3	Jetty civil modifications at the terminal	15,000	15,000	85,000	93,500
4	CMS system	775,000	1,550,000	1,185,000	1,303,500
5	Other costs and contingency	873,650	1,122,650	1,049,150	1,154,065
	Total	**~ 4,310,000**	**~ 5,390,000**	**~ 5,070,000**	**~ 5,577,000**

Table 10 CAPEX estimate onshore investments (in Euro) (Source: PoR and Vopak)

The financial and economic analysis only evaluates scenarios with onshore investment 'Scenario 3' and 'Scenario 3 + battery'.

5.2.2 Reinvestments

In consultation with Vopak it has been assumed that the replacement of the CMS crane will take place after 15 years of operations. For the remaining components the replacement duration is estimated to exceed 20 years and therefore these re-investment costs are not being considered in the model.

5.3 Operating expenditure

Maintenance costs of the system components have been estimated at an average of 2% of the upfront investment per year.

Stedin is responsible for the grid infrastructure and grid management in Vlaardingen and own the nearby distribution station. In addition to the capital expenditure for the connection between the station and the shore-side substation, Stedin charges various transportation costs which are included in the model. In the first year of operation the total Stedin cost amounts to approx. Euro 184k. This increases as consumption goes up and is indexed with inflation.

5.4 Nitrogen space monetisation

Implementation of shore power projects will lead to increased nitrogen space ("stikstofruimte") to allow terminals located in densely populated areas and/or near Natura 2000 areas to continue to grow. During the assignment discussions were held with all stakeholders if the increased nitrogen space at and in the vicinity of the Vlaardingen terminal could be monetised in Vopak's business case.

In 2021 Minister Schouten (Ministry of Agriculture, Nature and Food Quality) indicated in response to questions from the Parliament that permit holders don't own their nitrogen deposition allowances hence these don't have a value for the permit holder[12].

However, if local nitrogen deposition levels reduce the Government could subsidise the reduction in deposition through a 'deposition bank'. This method has been successfully applied by several Provinces.

It is jointly concluded that for the Vopak Vlaardingen terminal the nitrogen space value to be applied in the model is nil. However, the functionality has been included in the model to allow this to be included in the business case in the next project phases if required.

5.5 Uptake of shore power calls

During the workshops various scenarios for the uptake of shore power calls at the terminal were discussed. Reference was made to the Port of Rotterdam Authority white paper which includes four global scenarios for the years leading up to 2050[13]. The scenarios are: Connected deep green, Protective markets, Regional well-being and Wake-up call.

The white paper does not include specific scenarios for uptake of shore power calls in the Port of Rotterdam. As an example the Connected deep green scenario assumes a global commitment to targets for combating climate change. The scenario assumes that as a result of the commitments global carbon neutrality is reached by 2050. This would imply a steep uptake of shore power calls.

The EU has adopted a law which requires that from 2030 onwards container and passenger ships (including cruise ships) must connect to shore power in the main EU ports[14]. It is expected that a similar law will be drafted for other ship types including liquid tankers, albeit at a later moment in time. In defining the overall 'Base' scenario it has been assumed that shore power for tankers becomes obligatory in 2041, refer also paragraph 7.2.1.

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[12] Kamervragen (Aanhangsel) 2020-2021, nr. 2309 | Overheid.nl > Officiële bekendmakingen (officielebekendmakingen.nl)

[13] white-paper-future-scenarios-2050_0.pdf (portofrotterdam.com)

[14] FuelEU maritime initiative: Council adopts new law to decarbonise the maritime sector - Consilium (europa.eu)

Based on the discussions during the workshops the following 'Vopak' uptake scenarios were developed:

- Low scenario – 50% uptake in 2037
- Base scenario – 50% uptake in 2035
- High scenario – 50% uptake in 2033
- Optimistic scenario: 50% uptake in 2031 and 100% uptake in 2035
- Vopak High scenario: 50% uptake in 2027

For clarity purposes it should be noted that these scenarios have not been discussed with end customers and/or other shipping lines besides Stolt. The willingness of other shipping lines to convert their ships needs to be further investigated in the next project stage and based on these discussions the scenarios can be refined.

An S-curve growth profile was assumed for all scenarios, refer Figure 21 below.

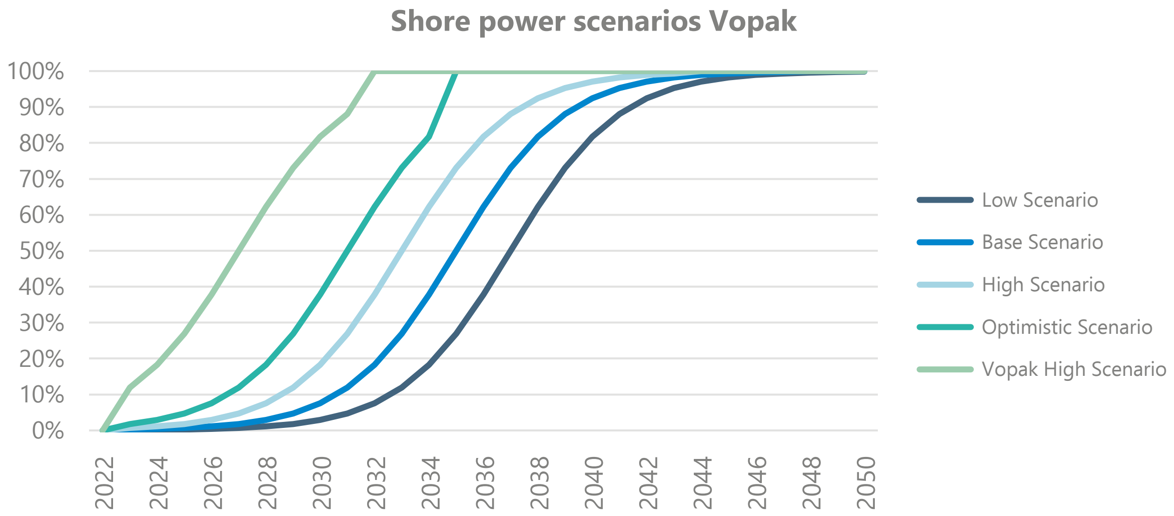

Figure 21 Shore power uptake scenarios Vopak expressed in % of calls

The model allows the user to select one of the five uptake scenarios and provides resulting number of calls per ship class and activity during the model period. As per Figure 21 the 'high' uptake scenario approximately matches the resulting average of the five scenarios.

The below figure shows the results for the high uptake scenario.

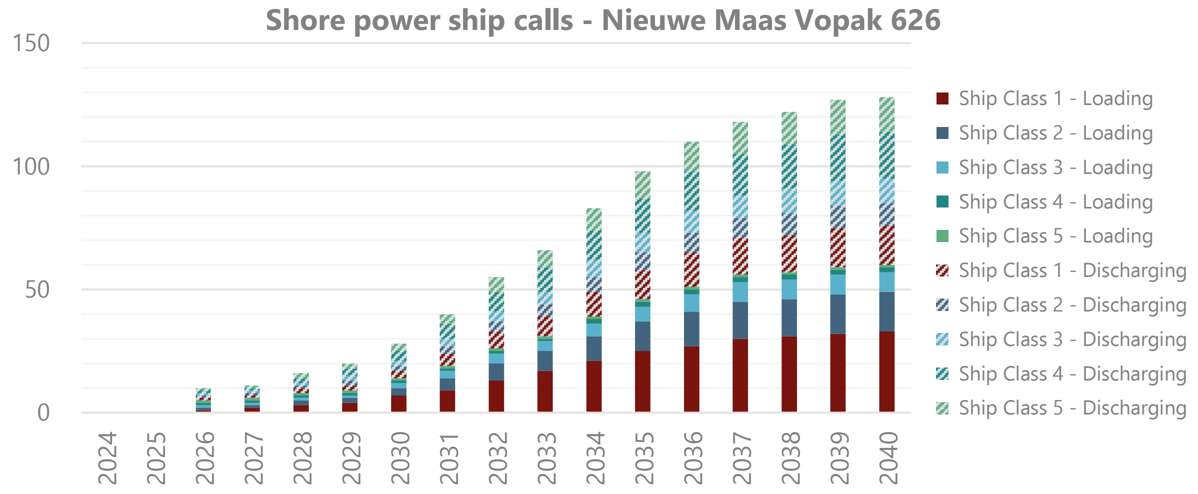

Figure 22 Shore power ship calls berth 626 – high uptake scenario

5.6 Results Vopak

Based on the selected settings in the cockpit the model calculates Vopak's 'infrastructure fee'. Vopak's 'infrastructure fee' is the minimum fee per kWh it must charge to the users to meet its target project IRR of 6.5% over a 15 year operational period.

The below figure shows Vopak's cash flow for the high uptake scenario.

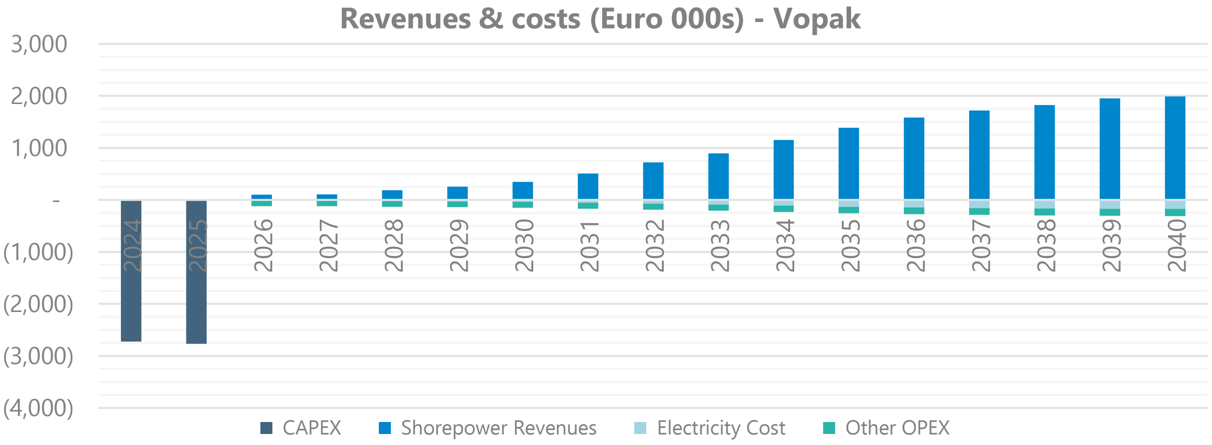

Figure 23 Vopak cash flow – high uptake scenario

Depending on the selected uptake scenario Vopak's required 'infrastructure fee' in 2026 varies between Euro 0.41 and 1.36 per kWh and increases in line with inflation. For the high uptake scenario the 'infrastructure fee' in 2026 is Euro 0.73 per kWh, which is broken down as follows:

- ~ Euro 0.56 per kWh for Vopak's CAPEX and OPEX
- ~ Euro 0.17 per kWh for the Stedin transportation cost

5.7 Observations

The below summarises the main observations regarding Vopak's business case:

- relatively large CAPEX and OPEX;
- the assumed number of ship calls appears low with a berth occupancy for berth 626 of around 34%;
- the required 'infrastructure fee' varies substantially based on the selected uptake scenario;
- the Stedin transportation cost make up a large portion of the required 'infrastructure fee';
- the assumed gentle S-curve uptake during the model period results in a low uptake during the initial years of operation and as a result negatively impacts the 'infrastructure fee';
- the assumed project duration of 15 years is relatively short.

6. Business case analysis Stolt

6.1 Introduction

Stolt are willing to invest in the conversion of the Stolt Breland to receive shore power and as such would bear the complete CAPEX and OPEX of the onboard investment. In addition Stolt recently placed an order for six newbuild tankers which will also be equipped with a shore power connection[15].

Stolt would also assume the offtake risk and in discussion with their clients would seek to maximise deployment of the Stolt Breland (and the six newbuild tankers) to terminals equipped with an OPS.

Stolt is used to fluctuating bunker prices though less familiar with the electricity intake price dynamics. They suggest to discuss the electricity price risk on a case by case basis both with the terminal and their customer to agree on a risk breakdown.

For the current analysis the electricity price risk is included in Stolt's business case and offset against the fuel cost savings.

In addition to the key assumptions summarised in chapter 4, the key inputs for Stolt's business case are:

- CAPEX
- OPEX variations
- ETS savings
- Uptake of shore power calls

6.2 Capital expenditure

6.2.1 Upfront

A CAPEX estimate for the Stolt Breland's electrical installation was provided at the start of the assignment in line with the shore-side investments. The CAPEX estimates consider the three shortlisted technical options as per DNV's feasibility assessment study, i.e. Scenario 1 – Midships reel on platform, Scenario 2 – Midships CMS crane on platform and Scenario 3 – Stern long range CMS crane, refer below table.

During the course of the study a fourth scenario was added which is a variant of Scenario 3 with the option to also charge a ship with an onboard battery.

The below table includes a breakdown of the onboard investments for the four scenarios:

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[15] Riviera - News Content Hub - Stolt Tankers to add at least six chemical tanker newbuilds to fleet (rivieramm.com)

Nr	Description	Scenario 1	Scenario 2	Scenario 3	Scenario 3 + battery
1	Shore power equipment on the ship	2,500,000	2,500,000	1,500,000	2,500,000
2	Contingency	750,000	750,000	450,000	450,000
	Total	**3,250,000**	**3,250,000**	**1,950,000**	**2,950,000**

Table 11 CAPEX estimate onboard investment Stolt Breland (in Euro) (Source: PoR and Stolt)

The financial and economic analysis only evaluates scenarios with onboard investment ‘Scenario 3’ and ‘Scenario 3 + battery’.

6.2.2 Reinvestments

Following average technical lifetimes have been assumed in the model:

- Shore power equipment on the ship:	15 years
- Battery:	10 years

For all components it has been assumed that the replacement cost is equal to the indexed CAPEX of the respective component.

6.3 Operating savings and additional expenditure

Due to a reduction of running hours of the ship’s auxiliary engine, the engine requires less maintenance which directly translates into maintenance cost savings. An estimate of the Stolt’s engine maintenance cost savings excluding labour cost of Euro 0.0026 per kWh was provided. Total engine maintenance cost savings including labour were assessed at Euro 0.0031 per kWh.

6.4 ETS

The EU Emissions Trading System (ETS)[16] is a carbon emission trading scheme set up to combat climate change. The scheme has recently been extended to cover maritime transport emissions as well. From 2024 onwards the scheme includes carbon emissions from all large ships (> 5,000 GT) entering EU ports, regardless of their flag.

The new regulation covers:

- 50% of the carbon emissions from voyages starting or ending outside of the EU;
- 100% of the carbon emissions resulting from a trip between two EU ports and while ships are staying within EU ports.

To ensure a smooth transition, shipping companies only have to pay carbon levies for a portion of their emissions during an initial phase:

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[16] EU Emissions Trading System (EU ETS) - European Commission (europa.eu)

- 2025: for 40% of their emissions reported in 2024;
- 2026: for 70% of their emissions reported in 2025;
- 2027 onwards: for 100% of their reported emissions.

During the past two years the maximum traded carbon price was approx. Euro 100 per tonne, refer also Figure 24.

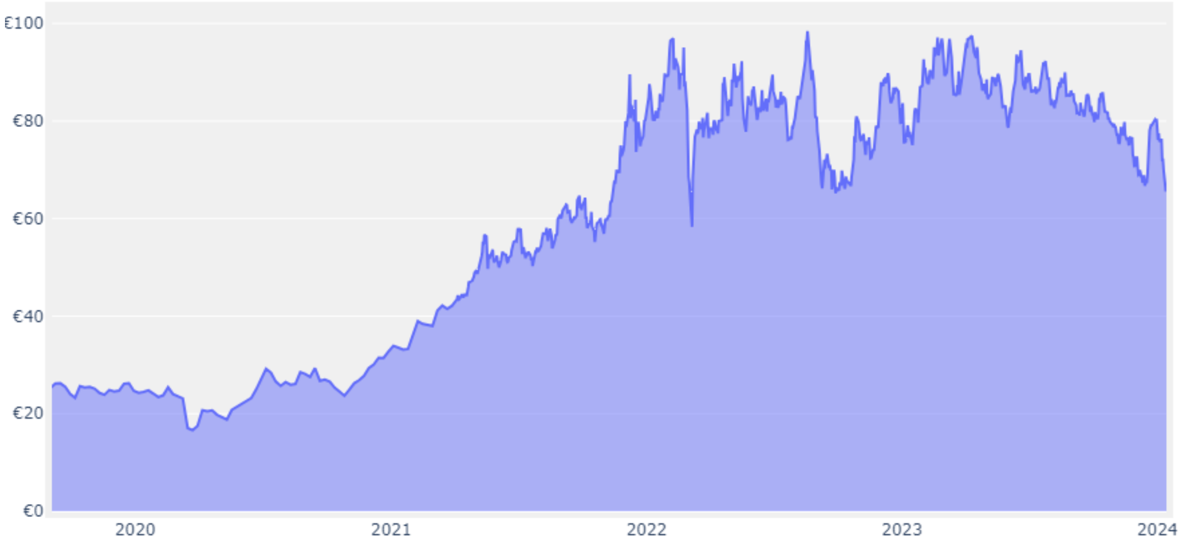

Figure 24 Daily European Union Emission Trading System (EU-ETS) carbon pricing from 2020 to January 2024 (Source: https://sandbag.be/carbon-price-viewer/)

Industry observers point out that carbon prices will not stay at this price level in the future and forecast higher prices[17]. Effectively the system is designed such that if society runs behind on the carbon emission reduction targets, the price will increase. Based on the discussions during the workshops the following ETS carbon price scenarios were developed;

- Low scenario – Euro 100 per tonne until 2026, linear growth to reach Euro 200 per tonne in 2040;
- Base scenario – Euro 100 per tonne until 2026, linear growth to reach Euro 250 per tonne in 2040;
- High scenario – Euro 100 per tonne until 2026, linear growth to reach Euro 300 per tonne in 2040.

In case a longer model period is selected the trend is extended in all scenarios after 2040.

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[17] Recent articles on this topic include: *Carbon markets forecast to weather short-term price dips* (Energy Monitor, 1 June 2023) and *The price of carbon emissions in the EU may reach €400/t by 2040 – forecast* (GMK Center, 6 October 2023). The opinions of market participants differ, but the general expectation is a strong rise of carbon prices in the second half of the current decade and thereafter.

6.5 Port dues discount

As per the Port of Rotterdam's tariff book[18], seagoing ships which achieve a score of 31 points or more as the Environmental Ship Index (ESI)[19] are eligible to apply for a discount of 10% on their port dues for the first 20 calls during any given quarter. In addition as per the current tariff book amongst others tankers holding a Green Award certificate are eligible for a 15% discount on their port dues.

The Port of Rotterdam and the Municipality are discussing options to further incentivise the use of shore power in the port which potentially could include an additional discount or replacement mechanism for the present incentives.

It was jointly decided that the model would include the functionality to simulate a potential discount per call though that in the financial and economic analysis it would be assumed that this is nil.

6.6 Carbon intensity indicator

The Carbon Intensity Indicator (CII) is a measure of how efficiently a ship transports goods or passengers and is given in grams of CO_2 emitted per cargo-carrying capacity and nautical mile. Based on this the ship is given an annual rating ranging from A to E, whereby the rating thresholds will become increasingly stringent towards 2030. For ships that achieve a D rating for three consecutive years or an E rating in a single year, a corrective action plan needs to be developed. Reference is also made to a recent ECSA workshop presentation from Fuel EU Maritime[20].

Based on discussions with Stolt it is understood that roughly 20% of their fleet has either a rating of D or E. Although the CII enforces the awareness of sustainable shipping in the sector, it has no direct financial impact at the moment. Ships with a too low rating will have to propose an improvement plan to enhance their score and subsequently implement the same. It is suggested that in the worst case ships could be taken out of service by the IMO, but it is unclear whether this will be the intended approach and such measures will actually be enforced. Given the uncertainty about how the regulation will be implemented exactly, it was jointly concluded that CII has no financial or economic impact on the Stolt Breland's proposed ship conversion. However it might be the case that in future a higher CII rating may result in financial benefits.

6.7 Uptake of shore power calls Stolt Breland

Similarly as for the Vlaardingen terminal, during the workshops various scenarios for the uptake of shore power calls for the Stolt Breland were discussed.

Based on the discussions during the workshops the following 'Stolt Breland' uptake scenarios were developed (in addition to the Stolt Breland calls at Vopak Vlaardingen, refer also paragraph 4.2.2);

- Low scenario – one additional terminal every 5 years;
- Base scenario – one additional terminal every 2 years;
- High scenario – one additional terminal every year.

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[18] Havenbedrijf Rotterdam NV - Algemene voorwaarden inclusief haventarieven 2023 (portofrotterdam.com)

[19] ESI Portal (environmentalshipindex.org)

[20] European Commission, Directorate General for Mobility and Transport, Unit D.1 Maritime Transport and Logistics, FuelEU Maritime, ECSA Workshop 16 January 2024

For all additional terminals it is assumed that the shore power offtake per year per terminal is identical to the Stolt's Breland offtake at the Vopak Vlaardingen terminal.

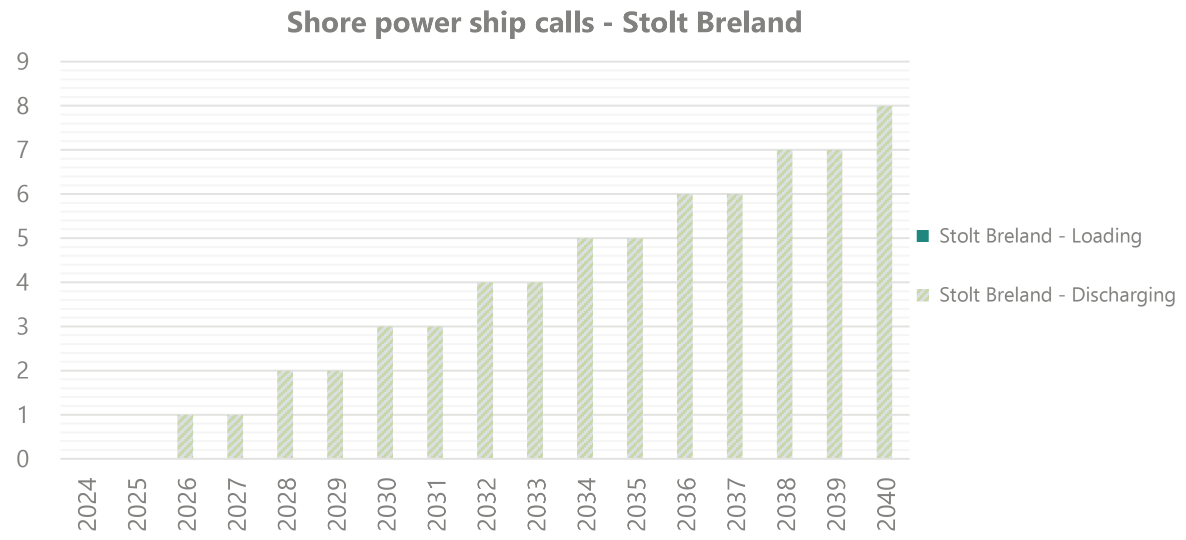

Figure 25 Shore power ship calls Stolt Breland – base uptake scenario

6.8 Results Stolt

Based on the selected settings in the cockpit the model calculates Stolt's 'willingness to pay'. Stolt's 'willingness to pay' is the fee per kWh they are willing to pay to receive shore power assuming identical cost as if the ship would use MGO to run its auxiliary engine whilst at berth. The cost comparison includes an expected project IRR of 8% for their investments.

The below figure shows Stolt's cash flow for the base uptake scenario.

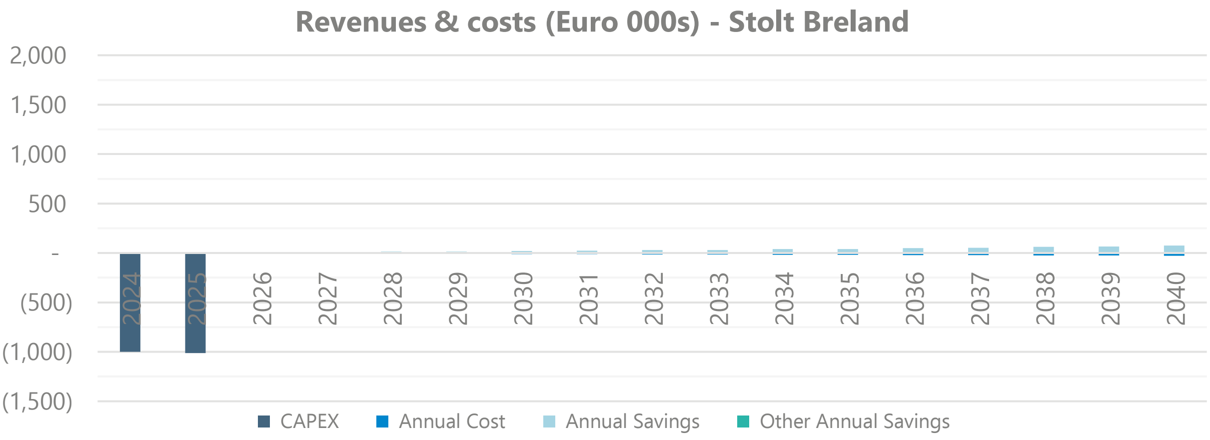

Figure 26 Stolt's cash flow – base uptake scenario

The ship conversion cost has a very high impact on Stolt's 'willingness to pay' due to the relatively modest uptake of shore power calls in all three scenarios.

Uptake scenario / Investment scenario	Scenario 3	Scenario 3 + battery
Low uptake scenario	Euro 1.76 / kWh	Euro 4.32 / kWh
Base uptake scenario	Euro 0.90 / kWh	Euro 2.36 / kWh
High uptake scenario	Euro 0.36 / kWh	Euro 1.15 / kWh

Table 12 Impact of Stolt Breland’s conversion cost on willingness to pay during first year of operations (2026)

In case the conversion cost is considered in the ‘willingness to pay’ calculation in all cases the ‘willingness to pay’ is negative.

Stolt’s total ‘willingness to pay’ excluding ship conversion cost for the first year of operations (2026) is Euro 0.15 per kWh which is broken down as follows:

- Electricity intake cost:	Euro (0.09) per kWh
- Green electricity surcharge:	Euro (0.0032) per kWh
- Engine maintenance savings:	Euro 0.0033 per kWh
- Fuel cost savings:	Euro 0.12 per kWh
- ETS savings:	Euro 0.12 per kWh

6.9 Observations

The below summarises the main observations regarding Stolt’s business case:

- relatively high CAPEX of the Stolt’s Breland’s conversion in comparison with installation of a shore power connection on a new build tanker;
- relatively low MGO fuel price forecast leads to a modest saving of electricity consumption costs (i.e. difference between electricity cost intake vs the MGO fuel cost);
- very low uptake of the Stolt Breland with one call per year initially increasing to eight calls per year at the end of the model period in the base uptake scenario;
- due to the low number of calls the electricity offtake is limited. As a result in all cases the ‘willingness to pay’ is negative should the ship conversion cost be considered in the Stolt Breland’s business case;
- the battery scenario worsens the business case as the additional benefits do not weigh up against the investment and operational cost.

7. Overall results of the financial analysis

7.1 Introduction

The objective of the financial analysis is to:

- Examine the financial feasibility of implementation of a shore power system at berth 626 at Vopak Vlaardingen Terminal and ship conversion of the Stolt Breland to receive shoreside electricity whilst berthed in Vlaardingen or other locations;
- Examine the relationship between the required 'infrastructure fee' and the 'willingness to pay' of Stolt;
- Assess the impact of variables (price of fuel, price of electricity, shore power uptake, ETS price, etc.) on the viability of the business cases for both Vopak and Stolt;
- Provide insights into mechanisms required to improve the viability of both business cases.

7.2 Definition and results of overall 'Base' scenario

7.2.1 Definition 'Base' scenario

As mentioned previously the model includes a number of key assumptions impacting the financial analysis of either or both business case(s).

A number of assumptions are fixed in the model whilst other assumptions include optionality to select alterative scenarios by the user.

The key assumptions which can be manually adjusted by the user in the cockpit are summarised in Table 13. Similarly Figure 27 shows an extract of the model cockpit with these model inputs. The table and figure also show the selected inputs for the 'Base' scenario.

	Description	**'Base' scenario**
General Model Inputs		
Shore power construction start year[21]	default year is 2024	2024
Operations duration	default period is 15 years. In the sensitivity analysis a longer period is also evaluated	15 years
Main Scenarios		
Grid connectivity	default entry 'No delay', in case the entry 'Delayed' is selected the model will assess the impact of a one year delay in start of operations	No delay
Shore power scenarios – Vopak Terminal	one can select one of five uptake scenarios as defined in paragraph 5.5	High
Shore power scenarios – Stolt Breland	one can select one of three uptake scenarios as defined in paragraph 6.7	Base
Shore-side investments	one can select one of four investment scenarios as defined in 5.2.1, as mentioned previously in the analysis only onshore investment 'Scenario 3' and 'Scenario 3 + battery' are considered	Scenario 3
Ship investments	one can select one of four investment scenarios as defined in 6.2.1, as mentioned previously in the analysis only ship investment 'Scenario 3' and 'Scenario 3 + battery' are considered	Scenario 3
Electricity intake price	one can select one of three electricity intake scenarios as defined in paragraph 4.4	Base
MGO fuel price	one can select one of three MGO fuel price scenarios as defined in paragraph 4.3	Base
ETS price scenario	one can select one of three ETS price scenarios as defined in paragraph 6.4	Base
Shore power (compulsory implementation)	Estimated year that shore power for tankers is obligated, default year is 2041. The entry only impacts the social cost benefit analysis as further described in chapter 8.	2041

Table 13 Model input by user and settings 'Base' scenario

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[21] The model includes a fixed two-year construction period before the start of operations

MODEL INPUTS

General Model Inputs

Model Reference Year	2023	Year
Shorepower Construction Start Year	2024	Year
Operations Duration	15	Years

Main Scenarios / Sensitivities

Grid Connectivity	No delay	
Shorepower Scenarios - Vopak Terminal	High	
Shorepower Scenarios - Stolt Breland	Base	
Shoreside Investments	Scenario 3	
Vessel Investments	Scenario 3	
Electricity Intake Price	Base	
MGO Fuel Price	Base	
ETS Price Scenarios	Base	
Shorepower - Compulsory Implementation	2041	Year

Figure 27 Extract model cockpit – Model Inputs

7.2.2 Results ‘Base’ scenario

The model cockpit includes a graph with Vopak’s ‘willingness to sell’ (i.e. their required ‘infrastructure fee’) and Stolt’s (and other liners’) ‘willingness to pay’ based on retrofitting a ship. As per paragraph 6.8 the conversion cost would lead to a negative ‘willingness to pay’ hence for the analysis of the above defined ‘Base’ scenario the ship conversion cost is ignored.

The below figure shows the evolution of Vopak’s ‘willingness to sell’ and Stolt’s ‘willingness to pay’ during the model period for the ‘Base’ scenario. As can be seen in the first year of operations the viability gap is around Euro 0.58 per kWh and reduces slightly during the model period.

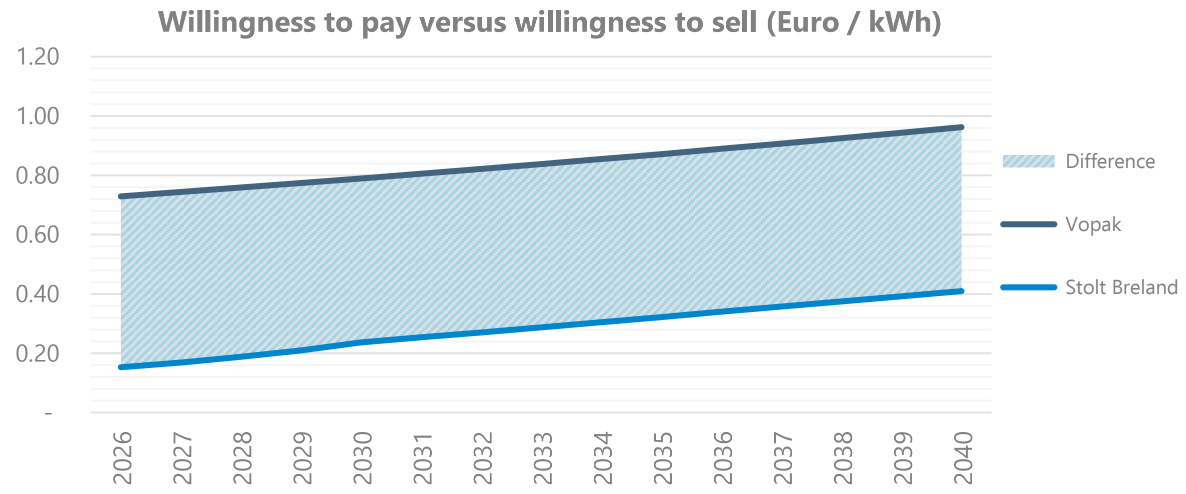


Figure 28 Willingness to pay vs Willingness to sell – 'Base' scenario

The same viability gap between 'willingness to sell' and 'willingness to pay' has also been expressed in a an average cost per shore power call, refer Figure 29.

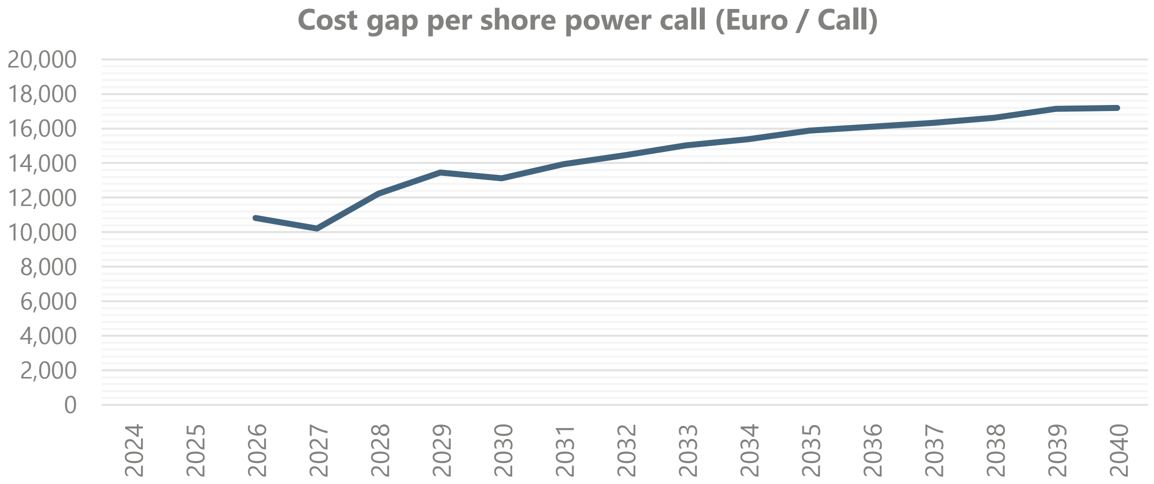


Figure 29 Gap expressed in additional cost per shore power call

As an additional refinement Vopak's 'infrastructure fee' and Stolt's 'willingness to pay' for the first operational year are plotted against typical costs of calling at the Port of Rotterdam. The analysis adopts the total power demand in kWh per ship class as per Table 6 and Table 7. For the port call costs we have used the estimated port dues for each ship class based on the current tariff book and included indicative costs for towage, pilotage and mooring/unmooring (referenced as 'Other Port Call Costs' in the figures below).

Figure 30 shows the average costs of a ship call whilst discharging, and Figure 31 shows the same costs for a ship loading. The large power demand when discharging for ship classes 3, 4 and 5 are clearly visible from Figure 30. For the larger ships the 'infrastructure fee' adds up to the combined estimated costs for port dues and marine services. In addition the significant share of the Stedin transportation costs is clearly visible which exceeds the 'willingness to pay' for all ships.

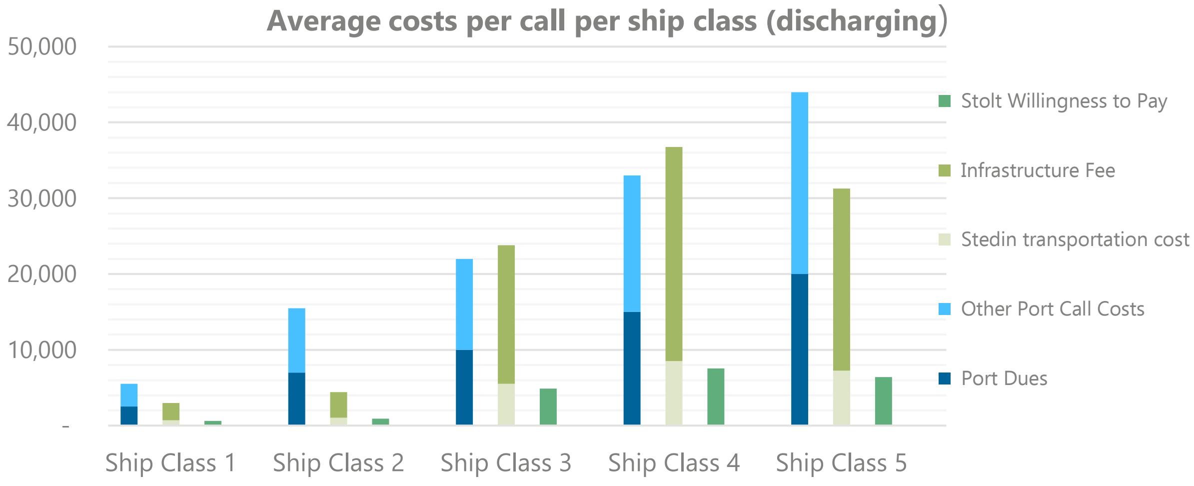


Figure 30 Average costs (in Euro) per call per ship class (discharging) in 2026

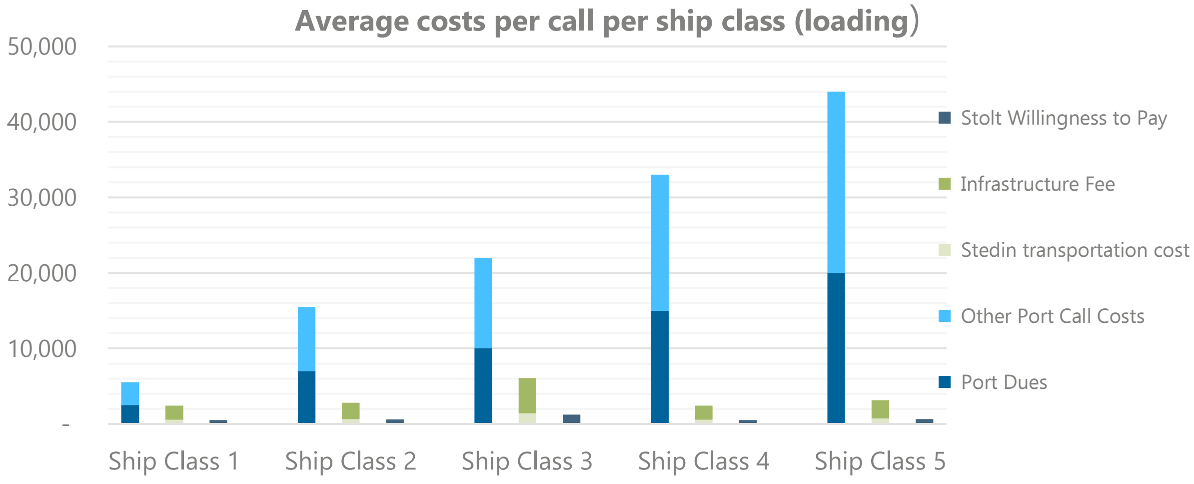


Figure 31 Average costs (in euro) per call per ship class (loading) in 2026

In Figure 32 the viability gap per volume handled over the jetty arrives at between 1.50 and 2 Euro / m^3 of product. This range of shore power costs per m^3 of product handled can be compared with trucking rates to put this in perspective of overall supply chain costs. Operating a tanker truck is roughly 2 Euro per km and a truck can carry roughly $20m^3$. This means that hinterland trucking cost is roughly Euro 0.1 per m^3 per km. The additional costs of using shore power translates to the equivalent of additional trucking of the product over roughly 15 to 20 km.

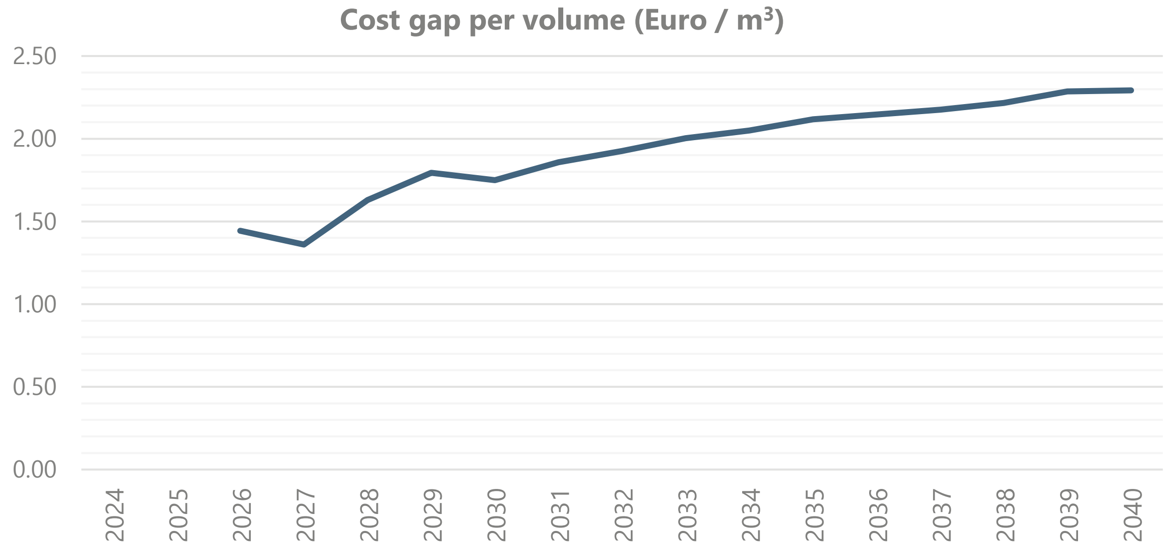


Figure 32 Gap expressed in additional handling cost per m^3 of product handled

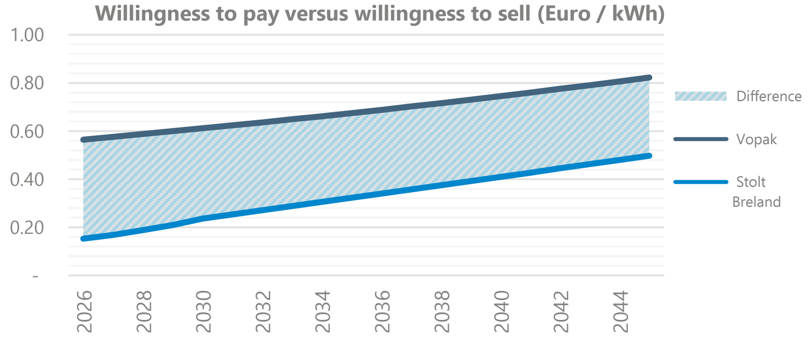
7.3 Sensitivity analysis

The objective of the sensitivity analysis is to assess whether certain variations in the input parameters can potentially narrow the viability gap between the two business cases. Furthermore, it demonstrates what impact can a certain change make on the two business cases. It should be noted however that the investment decision of Vopak not only depends on Stolt's willingness to pay but also on other shipping lines calling at Vopak Vlaardingen and the end customers.

A number of sensitivity scenarios have been selected, focusing on altering key parameters for either the Vopak (sensitivity scenarios 1 to 7) or the Stolt business case (sensitivity scenarios 8 and 9). The table below summarises the selected sensitivity scenarios and presents for each scenario the evolution of the viability gap and main observations.

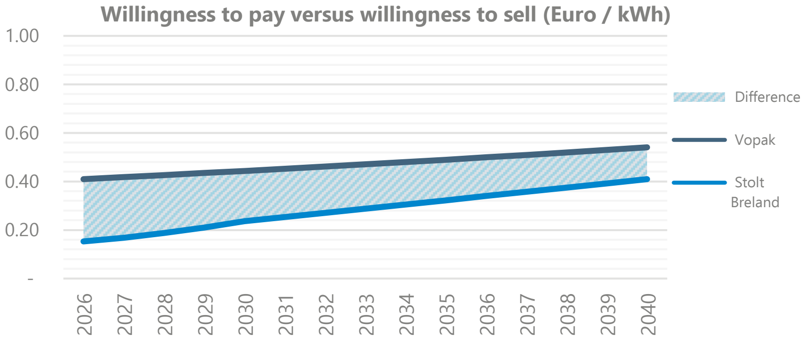
Sensitivity Scenario 1 – 20 years of operations & shore power becomes obligatory in 2050

- The gap reduces with approx. 29% compared to the 'Base' scenario to around Euro 0.41 / kWh
- The gap reduces over the years as a result of the extended operational period reaching Euro 0.32 / kWh at the end of operations.



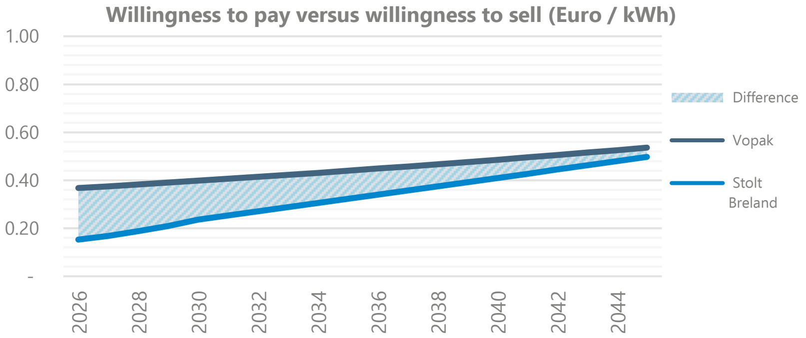
Sensitivity Scenario 2 – 15 years of operations & Vopak High uptake scenario

- The gap reduces with approx. 56% compared to the 'Base' scenario to around Euro 0.26 / kWh at the start of operations
- During the model period the gap steadily reduces, reaching approx. Euro 0.13 / kWh at the end of operations



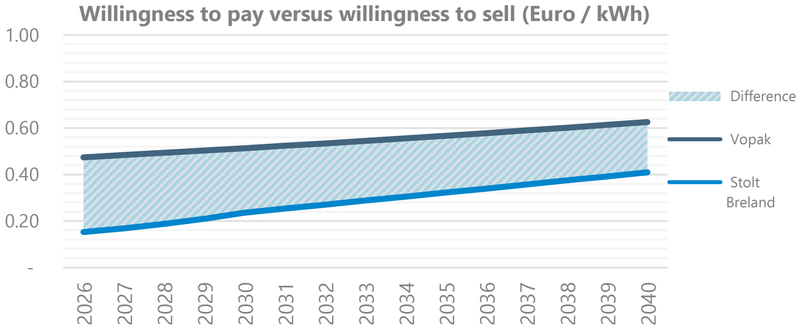
Sensitivity Scenario 3 – 20 years of operations & Vopak High uptake scenario & shore power becomes obligatory in 2050

- The gap reduces with approx. 63% compared to the 'Base' scenario to around Euro 0.21 / kWh at the start of operations
- During the extended operational period the gap steadily reduces reaching Euro 0.04 / kWh at the end of operations



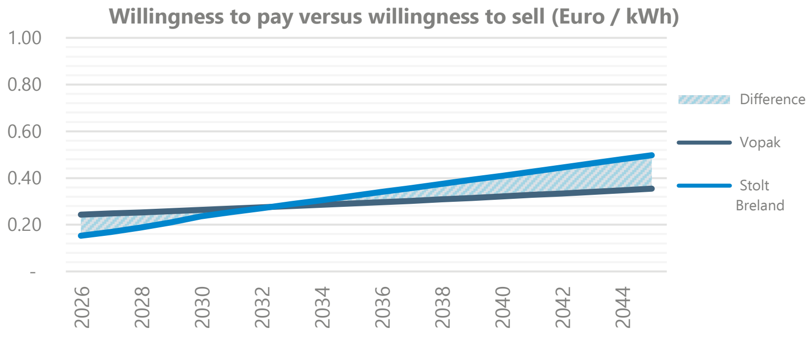
Sensitivity Scenario 4 – CAPEX subsidy of Euro 3 million shoreside electrical installation

- The gap reduces with approx. 45% compared to the 'Base' scenario to around Euro 0.32 / kWh at the start of operations
- During the operational period the gap steadily reduces to Euro 0.22 / kWh at the end of operations



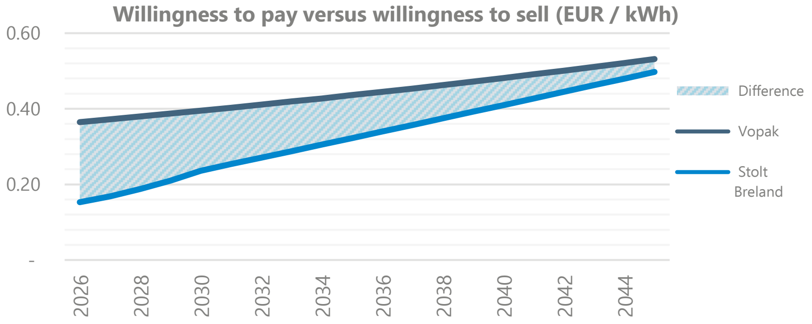
Sensitivity Scenario 5 – 20 years of operations & high uptake scenario & shore power becomes obligatory in 2050, CAPEX subsidy of 70%, no Stedin costs

- The gap is minimal, decreased by approx. 84% compared to the 'Base' scenario to around Euro 0.09 / kWh at the start of operations
- The gap fully closes in 2032. Thereafter the willingness to pay of Stolt increases constantly, being approx. 29% higher of willingness to sell of Vopak at the end of operations



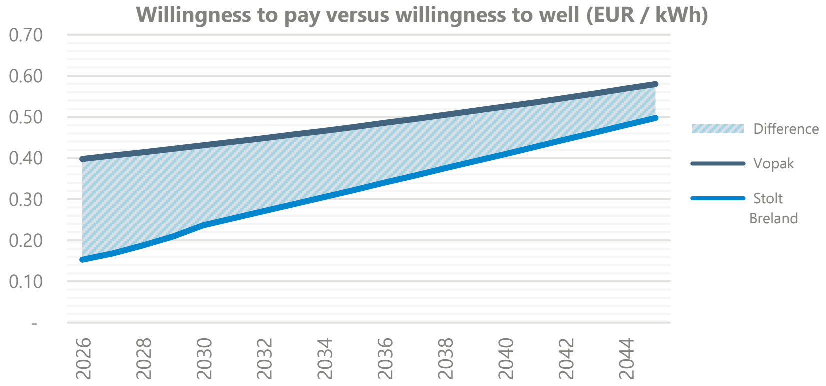
Sensitivity Scenario 6 – 20 years of operations & low uptake scenario & shore power becomes obligatory in 2050, CAPEX subsidy of 70%, no Stedin costs

- The gap decreased by approx. 63% compared to the 'Base' scenario to around Euro 0.21 / kWh at the start of operations
- During the operational period the gap steadily reduces and almost closes at the end of operations to Euro 0.03 / kWh



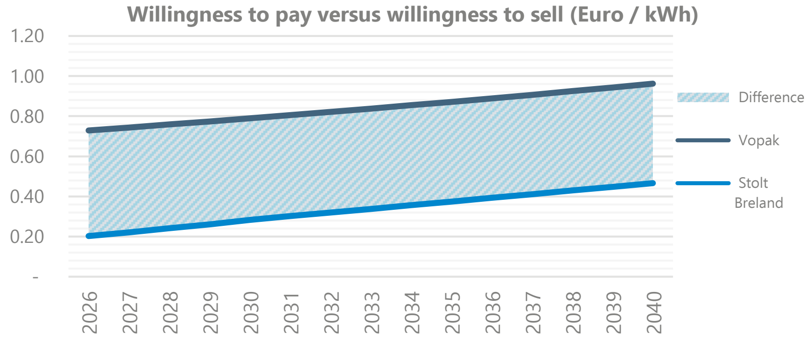
Sensitivity Scenario 7 – 20 years of operations & high uptake scenario & shore power becomes obligatory in 2050, CAPEX subsidy of 70%

- The gap decreased by approx. 57% compared to the 'Base' scenario to around Euro 0.25 / kWh at the start of operations
- During the operational period the gap steadily reduces and almost closes at the end of operations to Euro 0.08 / kWh



Sensitivity Scenario 8 – Low electricity price scenario & High MGO fuel price scenario

- The gap increases with approx. 9% compared to the 'Base' scenario to around Euro 0.53 / kWh at the start of operations
- It is observed that the gap remains steady after the first 5 years of operations



Sensitivity Scenario 9 – High ETS scenario

- The High ETS scenario has minimal impact in reducing the gap
- The increased ETS price slightly reduces the gap over the operational period, compared to the 'Base' scenario

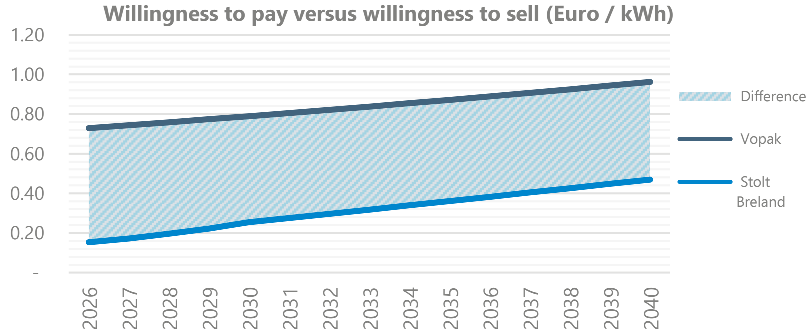


Table 14 Overview sensitivity scenarios

7.4 Subsidy schemes

The viability gap can be (partially) bridged by subsidies. There are two subsidy schemes that cover shore power projects:

- the Alternative Fuels Infrastructure Facility within the Connecting Europe Facility (CEF-AFIF);
- a subsidy scheme specifically aimed at shore power for maritime ships administered by the Dutch Enterprise Agency (RVO): "Tijdelijke subsidieregeling walstroom zeeschepen"

Both subsidy schemes have expired and are currently not available. However, they may be renewed or extended in the future.

Alternative Fuels Infrastructure Facility

Under AFIF 30% of the investment cost (exclusive of VAT) of OPS infrastructure in Trans-European Transport Network (TEN-T) ports could be subsidised. Onboard equipment was not eligible. The grants were awarded in a competitive procedure in response to calls for proposals. Both public and private parties were eligible. A total budget of Euro 1.5 billion was available for all types of facilities.

The most recent call had five submission deadlines, the last of which was in November 2023. No new calls are currently envisaged.

Tijdelijke subsidieregeling walstroom zeeschepen

This scheme was specifically aimed at shore power installations for maritime ships. Up to 35% of the investment cost of the onshore electrical installation could potentially be subsidised, with a maximum of Euro 5 million per project.

The grants were awarded in a competitive procedure. The scheme was available in 2022 and 2023. There were four cut-off dates for the submission of proposals, last of which was in September 2023.

The total budget amounted to Euro 31 million. Of this budget Euro 7.6 million is unspent and will be awarded in an extension of the scheme in 2024. In addition, the Government has made available an additional budget of Euro 40 million from the Climate Fund[22]. However, no tenders have yet been issued.

Under the 2022-2023 scheme grants were awarded based on three criteria:

1. the number of hectares of nitrogen-sensitive and nitrogen-overloaded Natura 2000 areas in a 25 km radius around the project site;
2. the number of inhabitants within a radius of 25 km around the project site;
3. the calculated average nitrogen deposition reduction in mol/ha/year/Euro of subsidy in nitrogen-sensitive and nitrogen-overloaded Natura 2000 areas within a radius of 25 km around the project site.

With respect to the third criterion a minimal threshold was defined, equal to a nitrogen deposition reduction of at least 0.03 mol/ha/year/million Euro of subsidy. If this threshold is also applied in the future scheme, the Vopak OPS project would not be eligible for any subsidy (see Aerius results in Appendix 2, paragraph 2.3).

Other subsidies

Other stakeholders such as Provinces or the Port Authority may also provide grants or subsidies. As an example it is understood that DFDS has obtained a subsidy from the Province of South Holland to implement a shore power system at their terminal which is located next to the Vopak Vlaardingen terminal. Sensitivity Scenario 7 as included in paragraph 7.3 assumes a 70% CAPEX subsidy for the shoreside electrical installation and a longer operational period of 20 years. This scenario results in a gap of approx. Euro 0.25 per kWh at start of operations and the gap steadily reduces to approx. Euro 0.08 per kWh at the end of the operational period.

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[22] Kabinet wil scheepvaart en havens verder verduurzamen | evofenedex

8. Social cost benefit analysis

8.1 Introduction and general assumptions

In a social cost-benefit analysis (SCBA) the project is considered from the perspective of society as a whole. The scope is therefore wider than that of the business case analyses presented in earlier chapters. In the business case analysis, the focus is on the *expenditures* and *revenues* for the investor/operator. The SCBA, on the other hand considers *costs* and *benefits* for all members of society in the Netherlands or even the world.

The business cases of Vopak and Stolt have been studied and presented separately, although based on the same common assumptions. The same approach has been followed for the SCBA. The Vopak and Stolt projects constitute separate investments, respectively onshore and onboard. There is a small overlap of benefits since the Stolt Breland ship also calls the Vopak Vlaardingen terminal and will use its OPS. However, the share of Stolt Breland's calls in the total number of shore power calls at the Vopak terminal is small and hence also the overlap. For practical purposes the SCBA of the joint project can be obtained by simply adding the SCBAs of the two separate projects.

8.1.1 Costs and benefits

The business case and social cost-benefit analyses overlap. Several costs and benefits appear in both analyses:

- project investment costs;
- project operating and maintenance costs;
- ship benefits (fuel and maintenance cost savings).

The reason is that the investors and operators of the OPS and the ship owners/operators using the OPS are also members of society, and so are their shareholders, employees, and customers.

The emission benefits, on the other hand, are only considered in the social cost-benefit analysis. They consist of the positive effects on the environment and climate change from reduced emissions. They accrue to all members on society, but do not represent financial payments to investors and operators of the project.

Finally, there are financial impacts that are considered in the business case analysis but are excluded from the social cost-benefit analysis. This is the case for all subsidies and for all service fees (such as Vopak's shore power revenues). Subsidies and service fees are paid by one party and received by another. From the perspective of society the net effect equals zero.

8.1.2 Reference case and project case

In a social cost benefit analysis, the situation without project (reference case) is compared to the situation with project. The costs and benefits of the project derive from the differences between both situations. It is therefore important to forecast both the reference and project cases.

Both the reference and project cases are based on a set of common assumptions incorporated in the model. In fact, one can define several forecasts of the reference and project cases depending on the choices made regarding the common assumptions; in the SCBA the focus will be on the 'Base' scenario defined in Table 13 in paragraph 7.2.

On the cost side the difference between the reference and project cases is straightforward. In the project case the investments in respectively an OPS at berth 626 and shore power equipment on the Stolt Breland are carried out in the near future (in 2024-2025 in the 'Base' scenario), and subsequently maintained and operated. In the reference case these investments are not made in the near future but are postponed until the provision and use of shore power have become mandatory.

In the 'Base' scenario shore power is assumed to become mandatory in 2041. That year coincides with the end of the lifetime of (most of) the original investment in shore power in the project case. Hence, in the 'Base' scenario a new (re)investment would be needed both in the project and reference cases, so there is no difference between the two. The only difference between both cases concerns the investment in the near future, which is absent in the reference case and present in the project case. In the 'Base' scenario, only the initial investment therefore needs to be included on the cost side of the SCBA.

On the benefit side the key variable is the uptake of shore power calls. This variable determines all project benefits.

- In the project case the number of shore power calls is as defined in the business cases of Vopak and Stolt (see paragraphs 5.5 and 6.7). Various uptake scenarios have been defined, resulting in as many project case scenarios. As mentioned above, the focus will be on the 'Base' scenario;
- In the reference case there are no shore power calls until 2041, at which date the use of shore power is assumed to be mandatory and 100% of ships calling connect to shore power.

Consequently, from 2041 onwards there is no difference between the reference and project cases, and hence no costs or benefits. The reference and project cases coincide from that year onwards.

8.1.3 Estimation of emission reduction benefits

The project reduces the emissions of greenhouse gases and air pollutants caused by ships at berth because electricity generated by diesel-powered auxiliary engines is replaced with shore power largely generated by renewable sources. The emission factors of electricity generation are presented in paragraph 4.4.

Emissions of greenhouse gases and air pollutants cause damages to the environment and to health. Estimates on the social cost per ton of emissions are presented in the table below.

Pollutant	**Social costs in Euro per tonne**
Greenhouse gases (CO_2 equivalent)	167
NO_x	34,258
SO_x	65,882
PM10	79,402

Table 15 Social cost of emissions – unit values (Euro/tonne, 2023 price level)

The unit value of the cost of greenhouse gas emissions is obtained from the Economic Appraisal Vademecum 2021-2027 issued by the Directorate-General for Regional and Urban Policy[23]. The source values in 2016 price level are updated to 2023 price level using the evolution of the HICP for the Netherlands. The social cost of greenhouse gas emissions increases over time. The table above shows the 2023 value: Euro 167 per tonne of CO_2 equivalent. This value rises to Euro 319 per tonne in 2030 and Euro 670 per tonne in 2040.

The unit values of the social cost of the air pollutants are based on the central values proposed in CE Delft (2023)[24]. The source values in 2021 price level are updated to 2023 price level using the evolution of the Dutch CPI.

8.1.4 Present value

The result of the SCBA is expressed in the net present value, which is calculated as follows:

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+d)^t}$$

where : B_t = sum of project benefits in year t (in fixed prices of year 0)

K_t = project costs in year t (in fixed prices of year 0)

d = social discount rate

T = time horizon of the SCBA

All costs and benefits occurring during the time horizon of the SCBA are summed, with future costs and benefits given a lower weight the more distant into the future they occur. This weighting is done by dividing the costs and benefits t years into the future by (1+d) to the power of t, where d is the social discount rate. In this SCBA, year 0 equals 2023, year T is 2041, and the discount rate is 2.9% per annum[25].

The project has a positive socio-economic return if the NPV is positive.

The SCBA is prepared in constant price level (in this case price level 2023), which is customary for SCBAs.

8.2 Vopak

8.2.1 Specific assumptions

In the SCBA of the OPS at berth 626 of the Vopak Vlaardingen Terminal the following cost and benefits have been considered:

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[23] Inforegio - Economic Appraisal Vademecum 2021-2027 - General Principles and Sector Applications (europa.eu)

[24] Handboek Milieuprijzen 2023 - Methodische onderbouwing van kengetallen gebruikt voor waardering van emissies en milieu-impacts (CE Delft, February 2023)

[25] Discount rate prescribed for SCBAs in the Netherlands (https://www.rwseconomie.nl/discontovoet). The discount rate applicable for benefits that are dependent on the business cycle is used, since the number of vessel calls will be influenced by macro-economic conditions. The selected value of the discount rate is near the default value recommended by the Economic Appraisal Vademecum 2021-2027 issued by the Directorate-General for Regional and Urban Policy (3% per annum).

- costs shoreside electrical installation: outgoing feeder panels in distribution station, HV cable connection between distribution station and shoreside OPS substation, shoreside OPS substation and Cable Management System;
- OPS operating and maintenance costs: maintenance, electricity purchases, periodic grid connection costs;
- ship benefits: fuel and maintenance cost savings;
- emission reduction benefits.

Ship conversion costs are not considered. It is assumed that only ships that are already equipped for shore power make use of the OPS. This is reflected in the uptake scenarios (see paragraph 5.5). The project itself only concerns one berth and does not influence ship owners/operators to implement a shore power system. The latter decision is based on the opportunities to use shore power in the entire sailing area and is addressed in the Stolt SCBA.

The emission volume is estimated based on the ships' auxiliary engine specifications (see paragraph 4.6).

8.2.2 Results

The results of the SCBA in the base scenario are presented in the table below. The project has a clear positive net present value, with a Benefit-Cost Ratio (BCR) of 1.6, hence benefits exceed costs by 60%.

The positive result is largely due to the emission reduction benefits. These benefits accrue to the wider community (impact on health, environment and climate change) and not to the investors in the project.

	Present value 000s Euro
Ship Benefits	1,765
Emission Benefits	12,817
Project Investment Costs	(5,093)
Project O&M Costs	(4,010)
SCBA Net Present Value (S-NPV)	**5,274**
Benefit Cost Ratio (BCR)	**1.60**

Table 16 SCBA results of OPS Vopak

The results depend on the scenario assumptions. Particularly the uptake scenarios have a significant impact. In the low uptake scenario, the BCR falls slightly below 1 (0.95, corresponding to a negative net present value of approx. Euro 460k).

8.3 Stolt

8.3.1 Specific assumptions

In the SCBA of the conversion of the Stolt Breland the following cost and benefits have been considered;

- investment costs: ship conversion costs;
- operating and maintenance costs: purchase of electricity, switchboard maintenance;
- ship benefits: fuel and maintenance cost savings;

- emission reduction benefits.

The SCBA for the case of Stolt does not consider OPS investment and maintenance costs. The availability of OPS facilities in the ports called by the Stolt Breland is taken as a given. It is reflected in the assumption regarding the number of port calls where shore power is used (see paragraph 6.7). The SCBA of shore power from the terminal perspective is covered in the Vopak analysis above.

8.3.2 Results

The results of the SCBA in the 'Base' scenario are presented in the table below. The project has a positive net present value, with a Benefit-Cost Ratio (BCR) of 1.23. This implies that economic benefits outweigh economic costs, and that the threshold rate of economic return (2.9% per annum) is achieved.

The positive result is mostly due to the emission reduction benefits. These benefits accrue to the wider community (impact on health, environment and climate change) and not to the shipowner/operator. For the latter the balance is negative: ship benefits are substantially lower than shore power costs.

	Present value 000s Euro
Ship Benefits	295
Emission Benefits	2,167
Project Investment Costs	(1,868)
Project O&M Costs	(382)
Net Present Value (NPV)	**453**
Benefit Cost Ratio (BCR)	**1.23**

Table 17 SCBA results of Stolt Breland shore power

The results strongly depend on the scenario assumptions. Particularly the uptake scenarios have a significant impact. In the low uptake scenario, the BCR drops to 0.71 (negative NPV of Euro 570k). In the high uptake scenario the BCR rises to 2.17 (positive NPV of almost Euro 2.5 million).

9. Conclusions and recommendations

9.1 Conclusions

- The two business cases result in a substantial viability gap for all scenarios and further optimisation is required to reduce the same, refer the recommendations below;
- For the larger ships the 'infrastructure fee' adds up to the combined estimated costs for port dues and marine services;
- The viability gap is substantially reduced, with approx. 63% in comparison to the 'Base' scenario, if a longer model period of 20 years is assumed in combination with the Vopak High uptake scenario and an assumed deferred obligatory requirement to connect tankers;
- If a subsidy is provided of Euro 3 million for the onshore electrical installation, the viability gap is reduced with approx. 45% in comparison to the 'Base' scenario to around Euro 0.32 per kWh at the start of operations;
- The Stedin transportation cost make up a large portion of Vopak's required 'infrastructure fee' and exceeds the 'willingness to pay' for all ships;
- The assumed project duration of 15 years is relatively short, extending the period to 20 years reduces the viability gap with approx. 29%;
- In case a 70% subsidy is provided of approx. Euro 2.85 million (70% of the CAPEX for the onshore electrical installation) and a longer operational period is assumed, the gap at the start of operations is approx. Euro 0.25 per kWh and reduces to approx. Euro 0.08 at the end of the operational period;
- The Stolt Breland uptake scenarios result in a very small shore power offtake which results in all cases in a negative 'willingness to pay' should the ship conversion cost be considered in its business case in other words the investment costs cannot be recouped by the additional savings generated;
- The battery scenario worsens the Stolt Breland's business case as the additional benefits do not weigh up against the investment and operational cost;
- Based on the social cost benefit analysis it is concluded that Vopak's BCR is quite robust and exceeds 1 in all but the low uptake scenario;
- The Stolt BCR is less robust though also exceeds 1 in two out of three uptake scenarios;
- Based on the preliminary environmental impact conducted, it is concluded that the positive effects substantially outweigh the negative ones;
- Based on the AERIUS calculations it is concluded that the average nitrogen deposition reduction in Natura 2000 areas within a radius of 25 km around the project site is limited;
- Without a regulatory push the project is cumbersome to get invested as the viability gap without subsidies is quite large. Both Vopak and Stolt business cases would benefit from regulations to stimulate offtake.

9.2 Recommendations

In the next project phases it is suggested to:

9.2.1 Port of Rotterdam

- promote to extend the 'Tijdelijke subsidieregeling walstroom zeeschepen';
- initiate discussions with other potential subsidy providers such as the Province of South Holland;
- initiate discussions with Stedin to discuss the availability of electricity at the nearby distribution station in view of the current grid issues and the high impact of their transportation cost on the Vopak (and other shore power) business cases;
- further investigate the potential monetisation of the nitrogen space;
- internally discuss options to provide additional incentives to; shipping lines via the port's tariff book and operators via concession agreements.

9.2.2 Vopak

- undertake a value engineering exercise with a view to lower the CAPEX of the onshore investment;
- undertake a review if certain cost components of the onshore electrical infrastructure can be shared with other terminal development projects;
- initiate discussions with potential subsidy providers, refer also paragraph 7.4;
- initiate conversations with Stedin regarding the proposed HV cable connection to their distribution station and discuss potential optimisation of their standard tariff structure with a view to lower the transportation cost allocated to the pilot project;
- investigate options to increase the berth occupancy at berth 626 with a view to increase the shore power offtake. Alternatively investigate options to supply shore power to other nearby berths using the same OPS substation;
- investigate options to use the existing grid capacity at the terminal with a view to reduce the Stedin cost in the business case such that it is burdened only with the electricity intake price for each kWh consumed;
- the uptake of shore power calls at berth 626 is largely dependent on the willingness of both the shipping lines and end customers to use the OPS and assume both the electricity price risk and pay an additional 'infrastructure fee'. Recently Vopak sent a questionnaire to 23 shipping lines to gauge their interest to use shore power whilst berthed at Vopak Vlaardingen. It is understood that interest was limited. As a follow up it is suggested that interest from end customers is jointly verified together with Stolt as they control the products and indirectly the shipping lines;
- together with the end customers refine the assessment on the call duration and electricity offtake;
- investigate options for increase of uptake by charging for instance tugs and pilot boats;
- include marketing benefits of showcasing the first shore power connection for tankers in the ARA region in the internal decision making process;

- further investigate the potential monetisation of the nitrogen space;
- apply different 'infrastructure fee' tariffs for retrofits and newbuilds and per activity (loading/discharging). For newbuilds the onboard CAPEX is less hence the 'willingness to pay' is higher in comparison to retrofits;
- before proceeding with the implementation it is suggested to assess the potential disturbance to local flora and fauna;
- it is suggested that the IEC/IEEE 8005 standard and OCIMF guidelines are used in the further design steps of the OPS system at Vopak Vlaardingen.

9.2.3 Stolt

- Compared to conversion cost of for instance container ships the conversion cost of the Stolt Breland appears high. It is understood that the CAPEX estimate provided is based on an actual quote from a shipyard. A discussion with the shipyard could be initiated to discuss the relatively high conversion cost in comparison with conversion cost of other ships;
- initiate discussions with potential subsidy providers, although based on an initial screening there appear to be no subsidy options for ship conversions, refer also paragraph 7.4;
- review port uptake scenarios. The uptake of shore power calls for the Stolt Breland is largely dependent on the willingness of the end customers to use the shore power connection. As a follow up it is suggested that interest from end customers is jointly verified together with Vopak as they control the products and indirectly the deployment of the Stolt Breland at Vopak Vlaardingen and other terminals;
- investigate the possibility to maximise deployment of the Stolt Breland (and the six newbuilds) to terminals with a shore power connection;
- continue discussions with the PoR to investigate potential further discount of the Stolt Breland's port dues;
- continue to monitor the developments around the CII score as this may lead to a financial impact;
- further analyse the risk of electricity price volatility and bunker fuels and if required adjust model inputs to assess impact on the business case;
- include marketing benefits of showcasing the first shore power connection for tankers in the ARA region in the internal decision making process.

Appendix 1 Preliminary EIA

The aim of this preliminary environmental impact assessment (PEIA) is to undertake an initial screening of the environmental- and safety impact of the implementation of a shore power system at berth 626 of the Vopak Vlaardingen Terminal. For this initial screening existing environmental and safety data has been used. Where appropriate this preliminary assessment provides guidance on the detailed environmental and safety analysis that should be provided in the final assessment.

The Directive 2014/52/EU has been used as a basis for the initial screening. The detailed environmental assessment is anticipated to mainly focus on Natura 2000 areas, water bodies and densely populated regions in the vicinity of the terminal. Further a more detailed safety analysis is required before finalising the shore power system concept.

1.1 Project Main Features

The proposed shore power project involves the construction and operation of a shore power system at berth 626 of the Vopak Vlaardingen terminal. The site location is shown in Figure 33. The following paragraphs describe the technical-, environmental and safety aspects of the proposed shore power system.

Figure 33 Vopak Vlaardingen terminal

The terminal specialises in the handling and storage of vegetable oils and fats, oleochemicals, biodiesel and base oil and is situated in Vlaardingen southeast of the city centre. Distance from the berth to the nearest residential properties is around 600 m and the total population in Vlaardingen is approx. 75,000. Natura 2000 areas within a 25 km radius include Oude Maas, Haringvliet, Solleveld & Kapittelduinen, Oudeland van Strijen, Voornes Duin, Boezems Kinderdijk, Hollands Diep, Westduinpark & Wapendal, Voordelta, Krammer-Volkerak, Meijendel & Berkheide en Duinen Goeree & Kwade Hoek. The situation of Vopak Vlaardingen Terminal is shown in Figure 34.

Figure 34 Situation of Vopak Vlaardingen terminal; The flag icon shows the site location; The red circle shows the radius of 25 kilometer from the terminal. According to the EU Habitat directive (92/43/EEC) the green, yellow and blue shaded areas are protected Natura 2000 sites.

1.2 Environmental Aspects

1.2.1 General

The construction and operation of any shore power system produces certain impacts on the environment. Some of these impacts may be negative or adverse, while others may be positive or beneficial.

The major aspects of the shore power system at berth 626 of the Vopak Vlaardingen that are expected to impact the environment include the following:

- Temporary disturbance of the land surface during construction of the grid connection to Stedin’s medium voltage transformer station;
- Temporary disturbance of the riverbed during the construction of the monopile (or platform support piles);
- Temporary reduction in air quality during construction works of the grid connection, shoreside substation, monopile and CMS crane erection;

- Occupation of the land surface with permanent shoreside substation;
- Occupation of a small portion of riverbed with permanent monopile;
- During operations less warm ship engine room cooling water return flow into the Nieuwe Maas;
- During shore power operations substantial improvement in air quality as auxiliary engine is turned off which results in a decrease of local carbon (CO_2) and air pollution emissions (NO_x, PM10, SO_x);
- During operations reduction in underwater and above water noise;
- During operations reduction in odour and visible smoke plumes at and in vicinity of the berth;

The nature and significance of the environmental impacts expected to result from these aspects are discussed below.

1.2.2 Water quality

Construction

Floating plant may be used during construction works of the monopile and installation of the CMS crane. Such plant create heated cooling water flow in the water bodies. The cooling water is often polluted with chlorine dosage to prevent internal fouling of the vessel equipment. The heated cooling water with pollutants is considered negative for the water quality.

The construction that takes place on land is not expected to affect the water quality.

Operation

During operation of the shore power system the ship's auxiliary engine running hours are minimised which leads to a reduction of heated cooling water flow in the water bodies. Operation therefore has a positive impact on the water quality.

1.2.3 Air quality

Construction

During construction works a temporary reduction in air quality is expected mainly due to the deployment of construction equipment. The reduction could be mitigated enforcing the deployment of for instance electric or hydrogen fuel propelled equipment in the construction contract.

Operation

During operation of the shore power system the ship's auxiliary engine running hours are minimised which leads to a reduction in both local carbon (CO_2) and air pollution emissions (NO_x, PM10, SO_x). The reduction of these emissions is linked to the number of ships connected to the system and their engine specifications. The main body of this report includes a detailed analysis of the emissions saved during the life of the system. As an example the below figure summarises the emissions saved per annum for the defined base scenario.

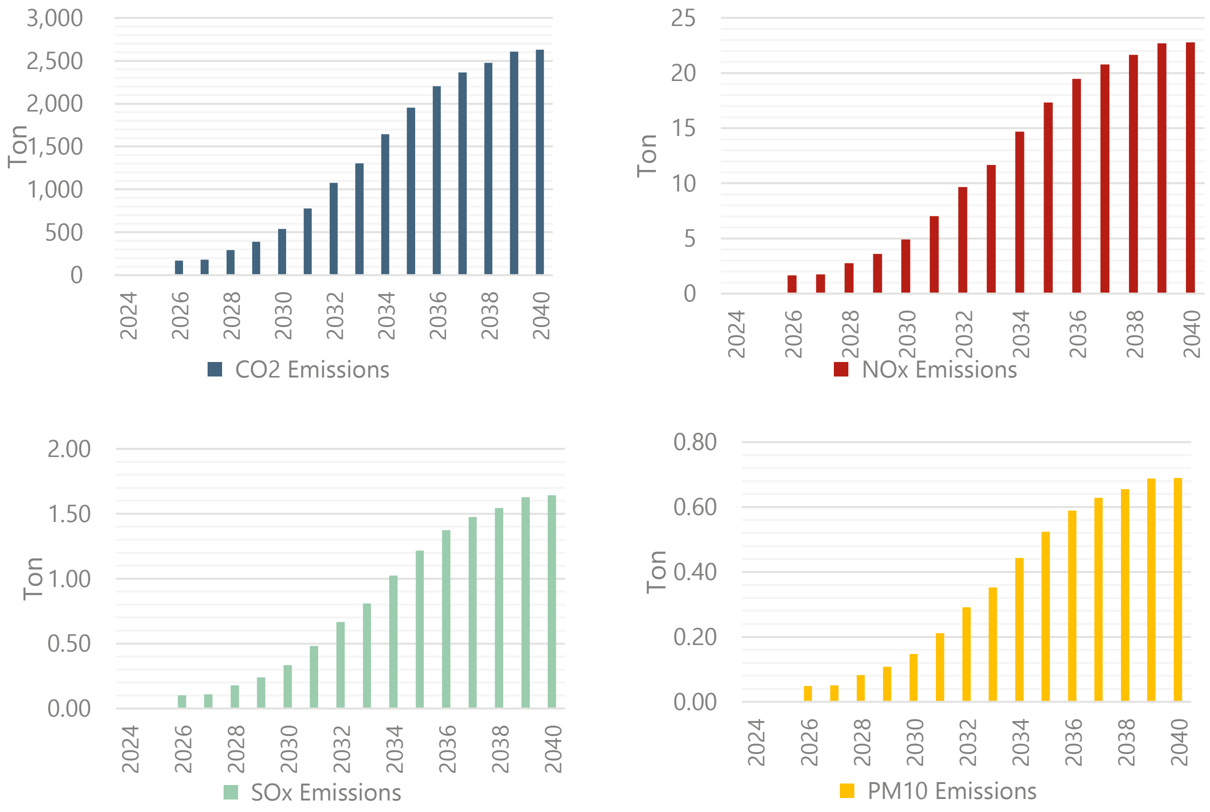

Figure 35 Emission savings for ‘Base’ scenario

Noise

Construction

During construction works a temporary increase in noise pollution is expected due to the deployment of construction equipment. The reduction could be mitigated enforcing the deployment of for instance electric or hydrogen fuel propelled equipment in the construction contract and/or install a prefabricated shoreside substation to reduce construction activities at the site.

Operation

During operation of the shore power system the ship’s auxiliary engine running hours are minimised which leads to a reduction in noise above and under water. The noise created by the ship’s engine rooms have a negative impact on marine life under water and a negative impact on the health of the ship's crew, port workers, and nearby residents. Royal Haskoning [26] estimates the noise reduction for immediate residents to be approximately 2 dB. DGMR[27] found a similar noise reduction due to the implementation of shore power for container ships in the Port of Amsterdam, namely 3 dB. These studies are not specifically done for tankers nor the Vopak Vlaardingen terminal.

To make a significant impact on noise emissions, the tanker’s cargo pumps must be powered by electricity as well. The impact of the noise emission depends on the distance between the ship and the

[26] Royal Haskoning, 2010. Haalbaarheidsstudie walstroom binnenvaart en zeevaart, Rotterdam: Royal Haskoning B.V.

[27] DGMR, 2010. Acoustic Investigation Ceres, Den Haag: DGMR Industrie, Verkeer en Milieu B.V.

residents and or crew and port workers. The planned location for the shore power system at berth 626 is in the centre of the terminal about a distance of some 650m from the nearest residential buildings.

1.2.4 Odour

Construction

During construction works a temporary increase in odour and smoke is expected due to the deployment of construction equipment. Marine diesel engine odour and smoke is a nuisance to workers on the terminal and nearby residents. The reduction could be mitigated enforcing the deployment of for instance electric or hydrogen fuel propelled equipment in the construction contract.

Operation

During operation of the shore power system the ship's auxiliary engine running hours are minimised which leads to a reduction of odour and smoke.

1.2.5 Flora and fauna

Construction

Construction activities have the potential to disrupt local flora and fauna, altering their habitat through processes such as ground excavation and noise generation. Including a temporary disturbance of the riverbed during the construction of the monopile. No information was available regarding the local flora and fauna on site and in the river hence it is suggested that this is further assessed by an ecologist during the next project phases. If there is disturbance of local flora and fauna due to construction works, appropriate measures should be taken. Potential actions include creating alternative habitat elsewhere, adjust working materials to create less disturbance or temporarily suspending activities during breeding seasons.

In order to mitigate a negative impact from increased nitrogen emissions resulting from construction activities it could be considered to enforce the deployment of for instance electric or hydrogen fuel propelled equipment in the construction contract.

Operation

While in operation, the shore power installation might take up space that serves as habitat for local flora and fauna. This involves using a permanent shoreside substation on the land surface and a small part of the riverbed with a permanent monopile. Should this be identified by the ecologist during the next project phases this could be mitigated by establishing alternative habitats elsewhere.

In order to calculate reduction in nitrogen emissions during operations, AERIUS calculations have been carried out refer also Appendix 2 for additional details. The decrease in nitrogen deposition for the years 2035 and 2040 are summarised below for ease of reference.

- Voornes Duin: 0.02 mol N/ha/year
- Meijendel & Berkheide: 0.02 mol N/ha/year
- Solleveld & Kapittelduinen: 0.02 mol N/ha/year
- Westduinpark & Wapendal: 0.02 mol N/ha/year
- Krammer-Volkerak: 0.01 mol N/ha/year

- Voordelta: 0.01 mol N/ha/year

1.2.6 Conclusion

The construction of a shore power system at Vopak Vlaardingen is likely to have a very limited negative temporary impact on the environment during the construction works. The limited temporary impact can be mitigated by the deployment of for instance electric of hydrogen fuel propelled equipment.

The operation of the shore power system is expected to substantially improve water and air quality, decrease noise and odours, decrease nitrogen deposition in sensitive nature areas within a 25 km radius and decrease other emissions such as CO_2, PM10 and SO_x hence positively impacting the ecology in those regions.

Potentially there could be a limited negative impact on the local ecology during operation due to the permanent presence of a shoreside substation on the land surface and river bed surface at the location of the monopile. Further investigation is necessary to determine the presence of sensitive local flora and fauna at the site and if required mitigating measures can be implemented. The below table summarises the main findings of the PEIA.

	Impact during construction	**Impact during operation**
Water quality	Limited negative impact, but possible to mitigate with electric or hydrogen fuel propelled equipment.	Substantial positive impact
Air quality	Limited negative impact, but possible to mitigate with electric or hydrogen fuel propelled equipment.	Substantial positive impact
Noise	Limited negative impact, but possible to mitigate with electric or hydrogen fuel propelled equipment.	Substantial positive impact
Odour	Limited negative impact, but possible to mitigate with electric or hydrogen fuel propelled equipment.	Substantial positive impact
Flora and fauna	Possible limited negative impact due to habitat disturbance of local flora and fauna, possible to mitigate with appropriate measures. The deposition of nitrogen in N2000 areas during construction is expected to be limited.	- (Limited) negative impact due to occupation of the land surface and the riverbed. - Positive impact due to a decrease in nitrogen deposition in N2000 areas.

Table 18 Main findings PEIA

Based on the qualitive research done in this preliminary environmental impact, it is concluded that the positive effects substantially outweigh the negative ones. Considering the positive as well as negative impacts during both construction and operation, it supports the installation of the onshore power system. Before proceeding with the implementation it is suggested to assess the potential disturbance to local flora and fauna.

1.3 Safety Aspects

1.3.1 Introduction

The operation of any shore power system induces certain safety impacts. Similarly, as for the environmental impacts some of these may be negative or adverse, while others may be positive or beneficial.

The current project considers implementation of a shore power system at the Vopak Vlaardingen terminal which specialises in the handling and storage of vegetable oils and fats, oleochemicals, biodiesel and base oil. The ambition however is to gradually develop standards that can be rolled out as word-wide standard for the implementation of shore power systems for tankers. As such although the Vopak Vlaardingen terminal does not handle or store hazardous products for the purpose of the current safety analysis it has been assumed that the berth and surrounding area is classified as an ATEX zone.

As referenced earlier, the feasibility assessment study for the development of a high voltage shore power system at the Vopak Botlek terminal as prepared by DNV Maritime Advisory includes amongst others a HAZID assessment (Chapter 5) and the Multi Criteria Analysis (Chapter 6) also considers safety aspects for the three shortlisted options.

Their report has been used as a basis for the initial screening and our analysis makes reference to the specific paragraphs of this report. We have structured our analysis in three parts;

- Within paragraph 1.3.2 we address the generic concepts of various waterfront layouts and potential solutions;
- Within paragraph 1.3.3 we summarise main comments and observations on the DNV report.

1.3.2 General

Essential safety requirements for shore power systems include:

- Comply with all safety requirements as applicable typically in the oil and chemicals world:
    - Based on interactions with one supplier it is understood that certified sockets & plugs (and the actual CMS) are not yet available in versions that allow operations in a classified zone today. Hence it is understood that at present the CMS and connections between shore supplied cable with plug(s) and vessel sockets are to operate in a non-classified area near the stern of the tanker. It is suggested that during further project stages additional suppliers are contacted to verify the same though for the purpose of this report it has been assumed that such certified sockets & plugs are not yet available in versions that allow operations in a classified zone.

  - For many tanker jetties a stern CMS solution lacks flexibility (e.g. ship's lengths and ship's orientation) and may result in substantial investment costs for the terminal operator. As such the industry is seeking cost effective solutions for explosion proof sockets, plugs and CMS.
  - Tankers from different flag states and class societies come with varying area classifications around the deck area, often extending beyond the tanker rail, specifically near the midships manifold, whilst many terminals have classified areas embedded in their operational permits that cover the jetty (central) deck area near the ships manifold, overlapping also part of the tanker deck area. Such established area classifications will not be easily amended, hence technical solutions are required for the safe implementation of shore power systems in hazardous areas, generally imposed around the loading arms and midships manifolds.
  - Cable management may be possible with manual handling for very small power supply requirements only. At higher loads and higher voltage levels (6.6 kV or 11 kV) heavy and multiple cables are required that cannot be man-handled between shore and tanker. The possibility for man-handling is depending on cable requirements. LV connections require higher current capacity cabling. Even at modest power rating the cabling is most likely already too big and heavy for man-handling.

    This will require a special (mechanically / hydraulically) operated extendable boom system to bridge the distance between the jetty (/shore) and ship in a safe and ergonomically acceptable manner.
  - It is recommended that the orientation of power cables between the shoreside substation and ship are verified based on a safety assessment of the mooring launch operations (for the vessel breast lines, and risks analysed for the potential effects of failing ("snapping") mooring lines).
- Comply with IEC/IEEE 80005-1:2019+AMD1:2022+AMD2:2023 CSV for HV shore power systems
- Comply with Dutch employment law in particular worker health and safety sections.

1.3.3 Summary of main comments on DNV report

General observations (Chapters 1 to 3)

- The DNV report was written on the basis of trying to develop a common standard for most, if not all tanker berths. However, due to the variation in tanker sizes (and their required power and voltage levels) a standardised approach has proven complex as berth layouts and power requirements vastly differ. A staged approach may be more sensible, and starting on a modest scale, as per selected example Vopak Vlaardingen terminal may be a better approach.
- The preference from a safety point tends to aim at making the CMS connect to the aft area of the tankers, so outside the ATEX safety zones as set by tanker class requirements and onshore safety permit requirements. However, this solution in many terminals will require a solution to bridge larger distances between ship connection sockets and berth structures, requiring a larger CMS (either a large and heavy crane or a smaller CMS with cable reel mounted on rail-track to bridge the variations of onboard sockets along the berthing line). This solution may also clash with the mooring line patterns for "breast-lines" (i.e. running perpendicular to the berthing line of the jetty), unless if there is a longer quay-type structure available.

- Cable & socket details (ref p.1) were not considered, but it is recommended to check with leading hardware suppliers what type of equipment is currently on the market or under development to support shore to tanker power supply configurations.
- In terms of general safety requirements, the following should (always) apply:
  - Sockets and plugs meeting hazardous area classifications, unless connections are made at aft of the vessels in an unclassified area
  - Cables stored on a reel and when connected to the tankers in such a configuration that the risk of mechanical damage is minimized. Regular inspection of cables and plus should be a standard terminal (and tanker) operational requirement embedded in terminal and vessel procedures.
  - Cables handling to establish connection to the tanker always in de-energized condition onshore and aboard the tanker, and resolution on the need for a bonding cable to prevent sparks. Energising and de-energising only respectively before and after start or completion of cargo transfer.
  - Cable handling with CMS support should make the handling of (heavy) cable bundles safe, practical and ergonomically justified for the vessel (and jetty) operators.
  - The CMS cable management should always have provisions for an Emergency Shutdown System (ESD) to de-energize the connection on both sides in case of emergency, such as drift-off of the tanker from its moorings, or in case of a fire. In addition, the CMS should have a built-in “weak-link” to prevent progressive (“domino”) damage in case the tanker breaks away from its moorings.
  - The tanker-based power generation system should have an installed UPS battery back-up system for essential services and an ability for a black-start as shore-based power supply systems can have (unplanned) outages. This may not happen frequently, but experience shows even in the Netherlands such outages can happen more than once per year. Such outages should also trigger an ESD on product transfers between tanker and shore.
  - In case of a connection in an ATEX zone and socket and plug connections are placed in a conditioned container (onboard) the supply of clean air or nitrogen should be guaranteed at all times when the system is life, if needed with back-up from pressurized bottle rack.

Reflections on DNV Hazid (Chapter 5)

Initial observations on the Hazid section:

- Hazid to be reviewed again once more info around available hardware is available that could potentially meet the hazardous area requirements;
- The hazard list (table 5.3 in DNV report) is not fully consistent with the hazards for the various options (e.g. 2.1A in fig 5.4);
- With risks as portrayed only option C would seem viable.
- Views on numbered recommendations:
  - 3: ESD and data communication cables on jetties are normally stored on reel and not protected against rain.

- 4: it is believed that bonding cable and de-energised systems both ends should eliminate such risk.
- 11: review codes for ship-shore interface for accepting bonding cables (note: within the Gas / LNG world traditionally the LNG carriers are isolated from the shore systems).
- 12: depends on cable size and practicality of creating such room. Feedback on socket / plug technology is needed before deciding if a separate box or room is needed.
- 15: a black-start capability of on-board power generation units is a must, as shore supplied power may experience short or longer outages.
- 16: automatic de-energising and built-in weak link in cable connection to prevent domino damage effect when tanker drifts away should suffice. Most oil & chemical jetties also do not have an automatic "dry-break" disconnect on their loading arms.
- 18: should be in protocols, similar to handling loading arms and gangways.

1.4 Summary of environmental and safety aspects

The below tables summarises the main environmental and safety impacts in the current and future (with shore power system) situation.

Area of impact	Type of impact	Current situation – impact on area	Shore power – impact on area
Water bodies	Ships engine emissions (cooling water)	Ship engines running when alongside the berth create a heated cooling water return flow, often polluted with chlorine dosage to prevent internal fouling of the vessel equipment. Such cooling water return is generally considered negative for the environment	The aim of shore power is to minimise on board engine running hours and thus will lead to less warm cooling water return into the Nieuwe Maas.
	Risk of fuel spills	The fuel oil requirements for running onboard power generation when in port area is relatively modest, compared to the total vessel fuel demand for sea-voyages, and thus the impact on possible spills during tanker bunker operations is negligible.	No material improvement by introduction of shore-side power.
	Hydraulic oil spills		If the CMS is using mechanical means of cable handling, based on

			hydraulic power, then the impact of hydraulic oil leakages can be minimised by adopting bio-degradable hydraulic fluids to eliminate lasting damage to the environment.
	Product spills when loading or unloading a ship	Most terminals have detection and Emergency Shut-Down Systems (ESD) to automatically stop cargo transfer to minimise the spill size in case of malfunctioning transfer equipment or power failures (onshore or onboard). In some terminals even automatic dry-break couplers are integrated in the loading arms to prevent spills in case of tanker breaking out of its moorings, or in case of local fire (onboard or on the jetty).	With shore power it is expected that power outages are lower than in case of onboard power generation. However, such shore power black-outs can occur, and provisions onshore and onboard should be linked to a trip of the ESD, whilst also ensuring that the monitoring of vessel tank conditions and activation of essential valves is supported by a UPS system, supplemented with back-up power generation initiation on-board.
	Noise emissions	Ship engine rooms have a tendency to create underwater noise, which has a negative impact on marine life, and in some areas of critical migration of endangered species may even need to be kept to an absolute minimum level.	With the use of shore power running hours of ship-based engine room equipment will reduce, and thus noise emissions underwater will be less. The shore power equipment does not create underwater noise, except during the construction stage if an additional support structure is to be created with driven foundation piles in the waterbody.
N2000 area (onshore)	Vessel engine emissions (CO_2, NO_x, PM10, SO_x)		The aim of shore power is to minimise on board engine running hours and thus reduce air emissions proportionally. Shore power will usually not create emissions in N2000 areas, but of course the source of cable supplied power, away from the jetty (terminal), in itself is a potential air

			emission source, if coal or gas-fired power generation is involved.
	Risk of fuel spill	Bunkering of ships normally is done via bunker ships, and thus no risk for ground pollution. In some terminals bunker fuel is supplied from the terminal, across the jetty, with some risk of pollution of soils, but the percentage of fuel used in port compared to ship round trips is negligible hence introduction of shore power will not have a material impact.	A shore power system does not use hydrocarbons in a combustion process, hence soil pollution is not applicable. If the implementation of shore power leads to the installation of new oil-filled transformers in the terminal, then normal spill collection facilities will be the norm. On jetties often gas-filled transformers are used.
	Noise emissions		No onboard noise from HVSPS. The switching off of the ship's engine room power generation will reduce noise emissions from the terminal. On shore HVSPS electrical equipment is in enclosed containers/buildings. Dominant sound comes from outside located cooling fans which even for high power systems is minimal.
Densely populated region	Ship's engine emissions (CO_2, NO_x, PM10, SO_x)		The aim of shore power is to minimise on board engine running hours.
	Risk of fuel or hydraulic fluid spills	Negligible impact, as stated above.	No fuel spills from HVSPS, and when the CMS is using hydraulic operated equipment, using bio-degradable fluid will minimise the risk of lasting contamination.
	Product spills, fires or explosions	During product transfers there is a potential risk of leakage of product, fires and/or explosions, depending on the nature of the products being handled.	The introduction of shore power on a terminal will require integration of this new operating method for the terminal, and more specifically for the ship.

		Terminals and ships are equipped with detection systems to trigger ESD and also have fire-fighting equipment to combat incidents and minimise impacts to avoid escalation to for example loss of ship and/or a complete jetty.	Attention should focus on integration to ESD systems, but also on the capability of the ship to retain its essential safety features in case of power outage from the shore power system. This may involve adding uninterrupted battery back-end power supply (UPS) capacity and black-start capability for the ship to quickly restart its own onboard power generation. Synchronising shore power and ship generated power may also be an essential requirement for smooth operations and transitions between shore and onboard power supply.
	Noise emissions		No onboard noise from HVSPS On shore HVSPS electrical equipment is in enclosed containers/buildings. Dominant sound comes from outside located cooling fan's which even for high power systems is minimal. Stopping onboard power generation will reduce ship's noise emissions.
Terminal	Risk of onboard incidents and during operations		Onboard operation is unchanged provided adequate provisions are made to deal with (unplanned) shore power outages. The introduction of HV electrical equipment (at 6.6 or 11 kV) onboard vessels normally operating with lower voltage levels, will require a detailed analysis to generate a layout of equipment and safeguards around the HV elements, such as dedicated locked switch-room, and secured area for cable socket connections. In addition, adequate protection of HV

			cables against mechanical damage needs to be provided. Potential impact zones of snapping mooring lines should also be part of design checks for laying out the shore power system.
	Risk of fire or explosions during connection and disconnection of the shore power system		Connecting and disconnecting of shore power is to be operated with a de-energised system. However, the CMS contains several electrical components and equipment. When the equipment is placed in an ATEX classified area, ATEX certified execution acceptable to both the ships as on shore regulations shall be used to mitigate the risk of igniting flammable substances.
	The risks on the safety systems during the switch between the ship based power generation to shore power		Linking of ESD systems for new operating mode and analysis of consequences of black-outs caused by the shore power require a detailed analysis (cause & effect), to ensure adequate mitigating measures are in place. This could include ESD trip initiation widening, UPS expansion and back-start capabilities of onboard power generation, in combination with synchronizing capability to transfer back to shore power supply once the system is back on-line in a smooth manner.

Table 19 Overview of environmental and safety aspects

Appendix 2 Aerius Calculations

2.1 Introduction

Anyone wishing to undertake something that might release nitrogen into a Natura 2000 area needs a nature licence or other consent decree. AERIUS Calculator allows initiators to calculate the effect of projects on nitrogen deposition in Natura 2000 areas.

2.2 Model inputs

Using the AERIUS Calculator the nitrogen deposition saving for the base case Vopak uptake scenario was calculated in the years 2026, 2030, 2035 and 2040. The below table lists the following model input data; year, ship class, number of calls per year and average duration per call.

Year	Ship class	Calls per year	Average call duration in hours
2026	1; Oil tankers GT 3000-1999	2	11
	2; Oil tankers GT 5000-9999	2	13
	3; Oil tankers GT 10000-29999	2	20
	4; Oil tankers GT 10000-29999	2	18
	5; Oil tankers GT 30000-59999	2	20
2030	1; Oil tankers GT 3000-1999	5	12
	2; Oil tankers GT 5000-9999	3	14
	3; Oil tankers GT 10000-29999	2	20
	4; Oil tankers GT 10000-29999	3	23
	5; Oil tankers GT 30000-59999	3	24
2035	1; Oil tankers GT 3000-1999	25	12
	2; Oil tankers GT 5000-9999	13	14
	3; Oil tankers GT 10000-29999	9	21
	4; Oil tankers GT 10000-29999	11	31
	5; Oil tankers GT 30000-59999	8	30
2040	1; Oil tankers GT 3000-1999	46	12

	2; Oil tankers GT 5000-9999	24	14
	3; Oil tankers GT 10000-29999	18	21
	4; Oil tankers GT 10000-29999	20	30
	5; Oil tankers GT 30000-59999	14	32

Table 20 Model inputs for AERIUS calculations

The selected emission point was located at the stern of the ship, refer below figure.

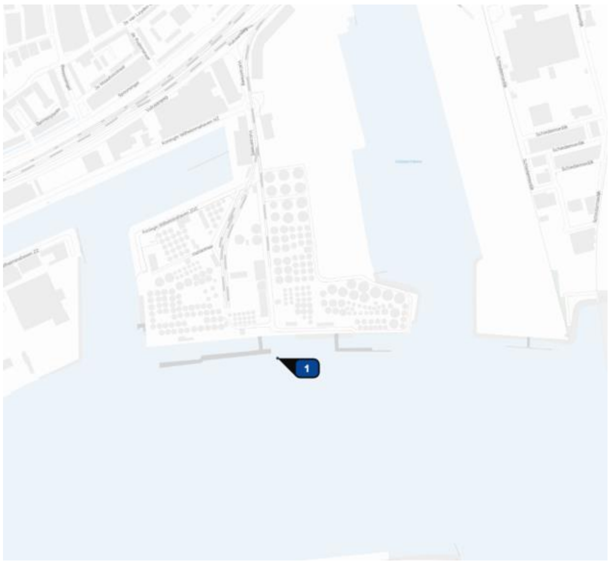

Figure 36 AERIUS emission point

Deposition points

The AERIUS model automatically determined 81 possible deposition points in nature areas within a 25 km radius from the emission point. Three deposition points near the emission point are added manually; 1) waterbody next to emission point, 2) jetty and 3) nearest residents.

Figure 37 AERIUS deposition output points

2.3 Results and conclusions

The below table shows the results from the AERIUS calculations.

	Scenario 1 (2026) – mol N/ha/year	**Scenario 2 (2030) – mol N/ha/year**	**Scenario 3 (2035) – mol N/ha/year**	**Scenario 4 (2040) – mol N/ha/year**
Assessment point 1 (waterbody next to emission point)	0.15	0.23	0.95	1.49
Assessment point 2 (quay)	0.20	0.31	1.27	2.00
Assessment point 3 (nearest residents)	0.04	0.06	0.21	0.34
N2000 area ‘Voornes Duin’	0	0	0.01	0.02

N2000 area ‘Meijendel & Berkheide’	0	0	0.01	0.02
N2000 area ‘Solleveld & Kapittelduinen’	0	0	0.01	0.02
N2000 area ‘Westduinpark & Wapendal’	0	0	0.01	0.02
N2000 area ‘Krammer Volkerak’	0	0	0.01	0.01
N2000 area ‘Duinen GOEREE & Kwade Hoek’	0	0	0.01	0.01
N2000 area ‘Voordelta'	0	0	0.01	0.01

Table 21 Overview of results from AERIUS calculations

As per the above expected maximum expected decrease in nitrogen deposition in sensitive nature areas is approximately 0.02 mol N/ha/year.

Appendix 3 Design considerations

Although initially berth 626 will be equipped with a shore power system it is suggested that the design process also considers future roll out of shore power at the berths which share the same access trestle i.e. berths 628, 629 and 631.

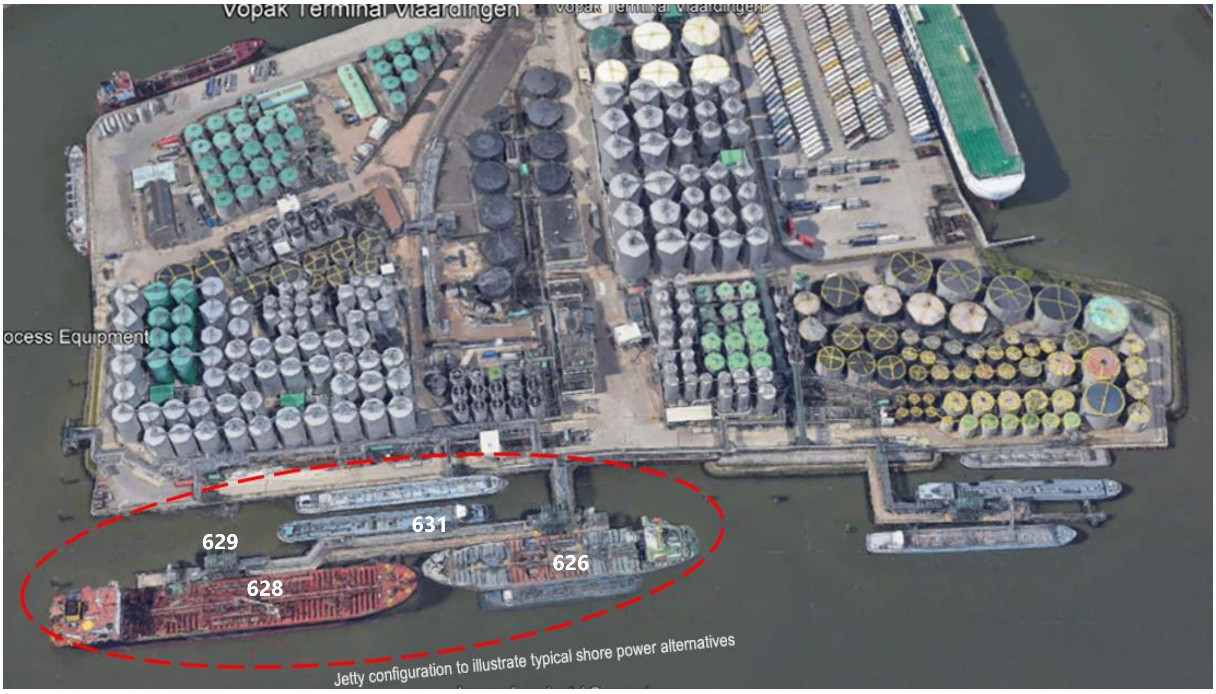

Figure 38 Berth numbering Vopak Vlaardingen

As indicated in the main body of the report it is understood that the same technical option H is proposed for berth 626 though it could be considered to opt for a mid-ship solution if the types of products handled do not attract fire / explosion risks and there is no ATEX zoning.

Assuming an aft solution is preferred we have included below potential configurations for;

- A solution with long-reach CMS cranes (refer Figure 39)
- A solution with small hydraulic cable support units running along rail tracks (refer Figure 40)

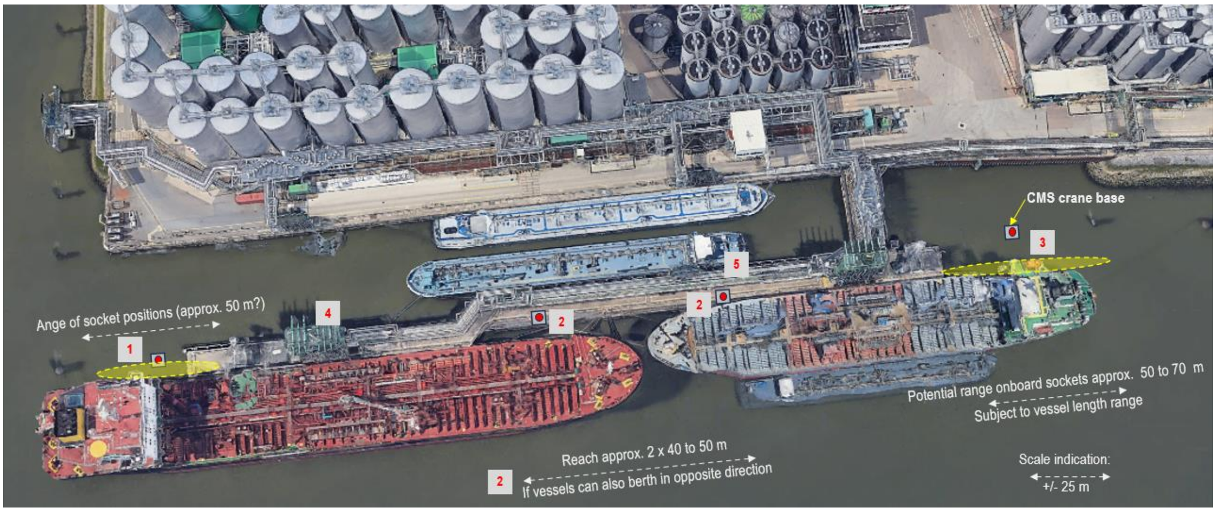

Figure 39 Potential configuration with long-reach CMS cranes as part of CMS

Remarks to be read in conjunction with Figure 39:

1. For shore power at positions 1 & 3 a reach of some 50 to 65 m may be required, subject to variation in Loa, and variations in (near midships) manifold positions & socket connection onboard ships visiting these two berths. This would translate to a boom with some 25 to 30 m outreach;
2. If the ships can also berth with opposite orientations potentially additional long reach cranes are required at position 2;
3. Ships on the inside berths 4 and 5 are expected to need supply at 400 V and require likely modest power demand;
4. Not sure if for connection points 1 to 3 a large boom type crane with a reach of some 30 m and supported on an extra platform is the ideal solution as the reach and size of the crane will be large and susceptible to wind. Operation of the crane would require a certified operator and very stable foundation (similar to the support of loading arms). The weight of power cable bundles may range between 50 and 100 kg per meter length, hence the crane will need to be very robust to prevent oscillation at the boom tip due to crane foundation movements. Another aspect to take into consideration is its maintenance and maintain its certification.
5. The CMS platform base at position certainly at berth 1 must be pretty close to the berthing line, in view of the berths behind the jetty and thus may be exposed to impacts at angular berthing.

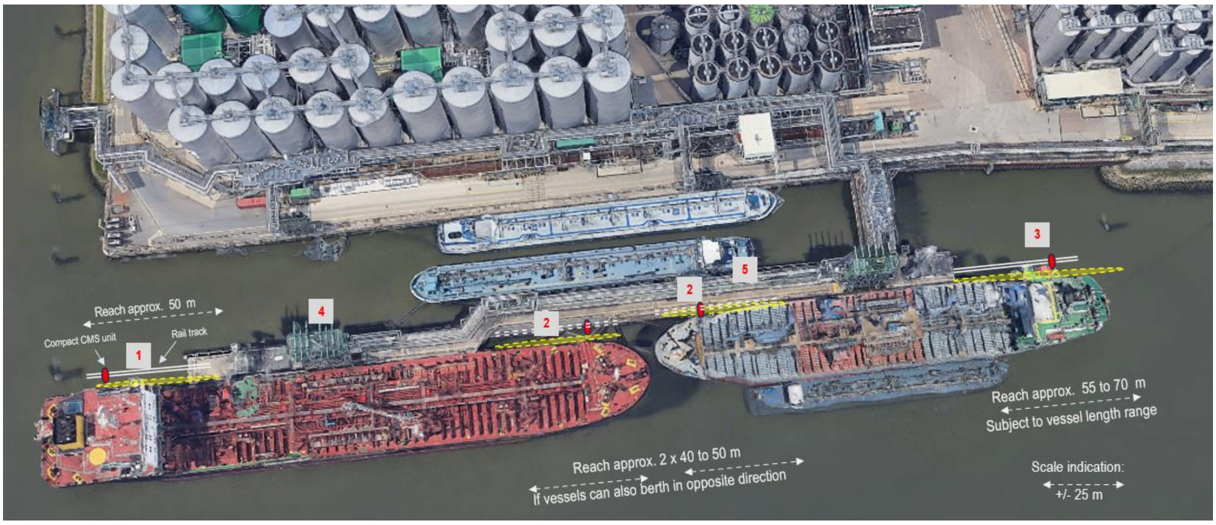

Figure 40 Potential configuration with small hydraulic cable support units running along rail tracks

Remarks to be read in conjunction with Figure 40:

1. For shore power at positions 1 & 3 a reach of some 50 to 65 m may be required, subject to variation in Loa and manifold & socket positions onboard of ships visiting these two berths. This could be a compact CMS unit with cable reel moving on rail-tracks;
2. If the ships can also berth with opposite orientations then two additional rail-tracks & CMS units may need to be installed for reach on positions 2;
3. Ships on the inside berths 4 and 5 are expected to need supply at 400 V and modest power demand;
4. A compact hydraulic CMS to bring cables to the correct elevation near ship rails will be easier to position and manoeuvre, with rail rack length and cables on reel to provide the necessary reach;
5. Piled rail-tracks to be placed a few meters behind the (compressed) berthing line to minimise risks of damage when ships berth at an angle, and location and elevation of rail track to be checked against mooring patterns with lines from the stern of the ships.

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