Onshore Power Supply for Cruise Vessels

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Assessment of opportunities and limitations for connecting cruise vessels to shore power


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ONSHORE POWER SUPPLY FOR CRUISE VESSELS

Assessment of opportunities and limitations for connecting cruise vessels to shore power

Bergen og Omland Havnevesen

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Objective: The Bergen Port (BOH, Bergen og Omland Havn) has engaged DNV GL to undertake an assessment of opportunities and limitations for connecting cruise vessels to power from shore for the GCP ports, and to outline a business plan for GCP's further work on onshore power supply.

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1 EXECUTIVE SUMMARY

Green Cruise Port (GCP) is working to reduce pollution from cruise activities in ports in the North and Baltic Sea region. Bergen Port (Bergen og Omland Havnevesen) has engaged DNV GL to undertake an assessment of opportunities and limitations for connecting cruise vessels to power from shore on behalf of GCP. This study comprises the business cases for establishing onshore power supply (OPS) for cruise vessels. Five project port partners of the Green Cruise Port (GCP) are used as basis for the business cases. The selected ports are Bergen, Hamburg, Rostock, Tallinn and Helsinki.

There exist clear opportunities for development of OPS for cruise ports and vessels, but there are also barriers related to high costs stemming from electricity prices or grid investments. The ports face total electricity charges that includes taxes, levies, and charges related to the promotion of renewable energy, and in total this reduce the possibility for viable business cases for OPS. The investment costs for establishing OPS are very dependent on the grid connection cost which varies with existing available grid capacity. Grid investments are stepwise in nature, and one step up to facilitate OPS can be prohibitively expensive. The use of a LNG-power-barge, can be an alternative in cases where high investment costs for grid connection is the main barrier. A LNG barge is also possible to move and increased utilization of the investment can be obtained through alternative use.

Grid charges are structured in a variety of ways with fixed and variable elements, based on capacity and electricity consumption. Several ports face a high total electricity charge, largely driven by high grid tariffs and tax levels. Authorities appreciate the benefits of OPS, such as less noise and air pollution. GCP can inform governments and local authorities on how to reduce barriers to OPS based on the findings of this report.

The business cases for establishing OPS with a shore to grid solution and a LNG solution at the five different ports, are presented in the table below. In the analysis, it is assumed that ship owner's willingness to pay for shore power is EUR 115 per MWh. In comparison, the price of MGO based on today's bunker price is EUR 125 per MWh, after adjusted for power efficiency. It should be noted that in addition to this assumption it has been necessary to apply a line of assumptions to calculate the business cases. The assumptions are based on the information available at the time of writing the report. Changes in the underlying assumptions will influence the business case results.

Table 1-1. Business case analysis for establishing OPS with a shore to grid solution and a LNG-power-barge solution with a sales electricity price of EUR 115 per MWh

	Bergen		Hamburg		Rostock		Tallinn		Helsinki	
2017 prices, MEUR	**Grid**	**LGN-barge**	**Grid**	**LGN-barge**	**Grid**	**LGN-barge**	**Grid**	**LGN-barge**	**Grid**	**LGN-barge**
Annual utilization of OPS infrastructure	1,730 hrs		570 hrs		1,040 hrs		1,530 hrs		510 hrs	
Interest and loan repayments	-11.2	-16.2	-11.0	-16.2	-25.6	-16.2	-16.8	-16.2	-13.0	-16.2
Operation & maintenance	-1.6	-1.6	-0.5	-0.5	-1.0	-1.0	-2.2	-2.2	-0.7	-0.7
Purchase of electricity/LNG	-14.9	-14.6	-15.1	-4.7	-19.5	-8.5	-19.7	-12.6	-9.3	-4.2
Sale of electricity	21.8	21.8	7.2	7.2	13.1	13.1	19.4	19.4	6.5	6.5
Total	**-5.9**	**-10.6**	**-19.4**	**-14.3**	**-33.1**	**-12.7**	**-19.2**	**-11.6**	**-16.5**	**-14.7**
Min. investment support	**5.9**	**10.6**	**19.4**	**14.3**	**33.1**	**12.7**	**19.2**	**11.6**	**16.5**	**14.7**

1) Port of Bergen has today a capacity fee reduction of 90 percent. The business case assumes a capacity fee reduction of 50 percent throughout the calculation period.

The analysis shows that all ports have a substantial need for investment support to cover the running costs for OPS, both in the shore to grid and LNG-power-barge case. Investment costs and total electricity price are the main cost elements of the business case. In Bergen Port the total electricity charges are relatively low due to reduced, interruptible grid tariffs and a low tax level. In ports where the investment costs and total electricity charges are high, such as in the Port of Rostock, the business case shows that a LNG-power-barge is likely a better alternative.

The required investment costs for OPS receival solution for a ship is relatively modest. The business case analysis shows that the profitability of an OPS solution is highly dependent on the hours of lay time in ports. For the ship owner shifting to OPS can be a profitable investment if OPS is provided in enough ports, depending on the cost of electricity.

Table 1-2. Operational business case Viking Star and The World with a sales price of electricity of EUR 115 per MWh

2017 prices, MEUR	**Viking Star**	**The World**
Total annual lay time in the five the five GCP ports [2)]	571 hrs	138 hrs
Interest and loan repayments	-0.5	-0.5
Operation and maintenance	-	-
Energy costs	0.6	0.2
Total	0.1	-0.3
Real rate of return	3 %	<0 %

2) Annual lay time is based on actual lay time in 2016. Total lay time is not adjusted for connection/disconnection time.

2 INTRODUCTION

Air and noise pollution is in general a problem in cities, and Green Cruise Port (GCP) is working to reduce pollution from cruise activities in ports in the North and Baltic Sea. Bergen Port (Bergen og Omland Havnevesen) has engaged DNV GL to undertake an assessment of opportunities and limitations for connecting cruise vessels to power from shore on behalf of GCP, and to outline a business plan for GCP's further work on onshore power supply.

This report assesses the business case for establishing shore power solutions in five selected GCP ports; Bergen, Hamburg, Rostock, Tallinn and Helsinki. The business case looks at the cost and benefits for vessel operator and ports related to establishment of onshore power supply. An overview of investment and operational costs for both a shore to grid solution and a LNG-Power-Barge solution is included. Total electricity costs, which includes the price of electricity, grid tariffs and national taxes and levies, is an important element of the operational cost. This report includes an overview of total electricity charges in the selected ports. The need for a coordinated initiative among several ports to provide sufficient incentive for ship owners to shift to shore power supply is also address in the report along with the effects of increased capacity utilization of the shore power infrastructure.

2.1 Background

Ships are among the most efficient type of transport for large volumes or numbers of passengers over longer distances, as well as a comfortable way of traveling to sightsee various locations. The cruise industry has been growing the last decades and there has been increasing focus on limiting the environmental footprint of cruise activities. When a vessel is alongside in a port, it does not need to run the main machinery, but the vessel still needs power for heating, lighting, general power supply, auxiliaries etc. This power is normally supplied by the vessels' auxiliary machinery and generators which normally runs on diesel, and thus produce emissions and noise. European cruise ports are often located in cities and densely populated areas that have challenges related to local air pollution.

Onshore power, for vessels while in ports, is one possible technology to avoid air and noise pollution from cruise vessels in cities. The first large scale onshore power systems in commercial ports were installed in Gothenburg (Sweden) in 2000 and for cruise ships in Janeau (Alaska) in 2001. DNV GL sees a growing application of onshore power supply, and this development has been supported by developments in technology and associated standards. Hamburg is a great example; In recent years, it has been established a shore to grid power solution at the Altona cruise terminal and a LNG-power-barge solution is supplying cruise vessels with shore power in HafenCity. On 18 September 2017, the German Senate indicated that a shore to grid power system is also to be established in HafenCity.

Internationally different terms are used for what is called onshore power supply (OPS) in this report, including cold ironing, alternative maritime power, shore-side electricity and high voltage shore connection systems. All these terms are principally referring to the same activity as OPS. In this report, there is not made any distinction between the different terms.

Green Cruise Port (GCP) is a joint project of several port authorities from around the Baltic Sea and the neighbouring North Sea, that are working together with other main cruise stakeholders to make the region more sustainable and better connected from a cruise tourism perspective. The GCP embraces 20 partners, incl. associated organisations, which represent port authorities, cruise lines, a maritime research institute and a governmental body. This study is part of the GCP efforts in preparing sustainable development of the cruise industry in the region.

2.2 Abbreviation list

Abbreviation	
Adj.	Adjusted
Av.	Average
CMS	Cable management system
GCP	Green Cruise Port
hrs	Hours
LNG	Liquefied natural gas
LV	Low voltage
MGP	Marine gas oil
MV	Medium voltage
OPS	Onshore power supply
Sales price of electricity	The port's sales price of electricity, i.e. the price of electricity that the cruise operators are subject to.
Total electricity charges	The purchasing price of electricity that the port is subject to. Includes the price of electricity, grid tariffs and national taxes and levies.

3 METHODOLOGY

The purpose of this study is to assess what the opportunities and limitations for connecting cruise vessels to power form shore in ports in the North and Baltic Sea region, and based on this propose next steps for GCP further work on onshore power supply.

The study will be looking at opportunities and limitations from both the cruise vessels and ports perspective, by constructing simplified business cases for these two parts of the OPS value chain. Cruise ship have large power consumption, and the study is focused on high voltage (above 6kV) onshore power supply systems.

To get a complete overview of all element that will impact the specific business case for a particular ship or port, further studies are required. The business case calculations and analysis are based on the current situation in five selected GCP ports; Bergen, Hamburg, Rostock, Tallinn, and Helsinki. These five business cases and additional supporting documentation is used to illustrate the opportunities and limitations for connecting cruise vessels to shore power.

The assessment requires input on cruise traffic and port calls, and DNV GL's strong experience in AIS assessment is applied as a basis for this input with further support by port-logs. The costs of OPS systems on-board vessels are established by cost data from public sources and input from port authorities and suppliers of OPS equipment. The costs on the port side is derived in a similar manner. The main case is based on power supplied from the grid and compared with cases for power supply from a LNG-power-barge system.

The business case for establishing onshore power supply depends on several elements, including future vessel traffic, technology cost and developments as well as the regulatory framework related to the use of shore power and alternative fuels. It is outside the scope for this study to provide scenarios for these developments. Assumptions applied in the report are based on current known technology and costs. To reflect the effect of increase in utilization of onshore power and changes in total electricity charges, sensitivity analysis' are included in section 8.

4 GENERAL ON ONSHORE POWER SUPPLY

4.1 System and technology description

This section gives a general system and technology description for OPS for ships. The description of the shore to grid solution is based on the DNV GL report *ReCharge Analysis of charging- and shore power infrastructure in Norwegian ports* /D53/. The description of the LNG-power-barge solution is based on public information and information from suppliers.

4.1.1 Shore to grid solution

To power vessels at berth, additional infrastructure onshore (port side) and on board ships is required as electrical power available from onshore grids is not adapted to vessels' requirements in terms of voltage, frequency and earthing. Furthermore, safety features need to be integrated, all of which are standardized as per the mentioned standards. In section 4.1.2., a short description of current shore connection standards is included.

Onshore power infrastructure (port side facility)

Transformer station: An electrical substation is required to convert voltage and frequency of the electrical grid to those required by vessels and specified by relevant standards, including electrical protection equipment. Upstream and downstream medium voltage (MV) cable connections from the grid to the power conversion system, and from the conversion system to the connection point on the vessel are also required.

Frequency converter: One major component of the charging- and shore power system is the frequency converter (FC). As per the shore connection standards a FC needs to be supplied where the shore grid frequency deviates from the ship-board frequency. Most ships today operate with an on-board grid frequency of 60hz. Most European shore grids, including Norway, Finland, Estonia and Germany, have a frequency of 50hz, hence conversion is in many cases needed. A FC is one of the most expensive components in an onshore power system.

Cable management system: A cable management system (CMS) ensures safe handling of cables during connection and disconnection procedures. The position of the CMS is also defined in the IEC standard: for all vessel types, other than container ships, the CMS needs to be installed onshore. Container ships are required to have on board cable reels due to space constraints on the berth. Another key area to consider is choice of sockets, plug and connectors. The ship–based CMS consist of electrical connectors (up to 12kV), flexible cables, a slipring, an optical fiber accumulator, a motor reducer, a cable drum, an electrical control panel, a retractable hydraulic cable guide and an alarm system that monitors the cable for tension and drift. A second alternative is similar to the ship-based version, where the CMS fits inside a standard cargo container and stored on board the ship, either after or forward of the accommodation block. As the system is entirely modular, the container can be moved per vessel or loading requirement's. For both systems, a pit that is installed into the quay is designed to occupy minimum amount of space, locations are spread out per vessel types at the quay.

On board ship infrastructure

Connection panel and control system. On board installations include a MV connection switchgear to manage power and ground connections, step-down transformer to the vessels voltage(s) level(s) as required; a receiving control panel will include the adaption of the existing MV or LV (low voltage) switchboard to receive shore power and synchronization through the control device. If required, a power management system is installed on board the vessel to manage shore connection and disconnection operation.

On board transformer. Where applicable (ship voltage different from shore connection voltage), an onboard transformer is needed to adapt the high voltage supply to the ship's main switchboard voltage. This transformer is preferably located near the main switchboard in a dedicated room.

4.1.2 LNG-power-barge

A LNG-Power-barge supplies electricity to ships and local grids through burning regasified LNG. The barge is not connected to the local power grid and thereby an independent power producer. This means that it can be operated independent from the local grid and it has the flexibility to customize power output, frequency and voltage level to provide electricity to different customers. The barge itself is classified as a seagoing barge and can be self-propelled.

The system can be divided into three main components;

- LNG Power Barge (Storage, Regasification, Generators)
- Electrical onshore distribution system
- On-board connection panel and control system

In the following a short description of the different components are given. An illustration of a LNG-power-barge solution is included below.

Figure 4-1. LNG-power-barge in the Port of Hamburg. Source: Hybrid Energy Port, 2017

LNG Power Barge

Even though the technology itself is new there exist several conceptual designs from different companies based on same principals. They all combine storage, regasification and generators on one and the same barge. Storage can either be a permanent tank that are refilled by trucks or bunker ships, or tanks that are removed and refilled elsewhere. The regasification unit transforms the liquefied natural gas into natural gas at atmospheric pressure. The power producing unit is normally design with a number of independent gas engines, to be able to scale both the power and energy output to meet demand.

The barge can through its generators produce voltage at a small to medium level (230 v to 11 kV), at a frequency of 50 or 60 Hertz. Most barges can be designed to provide power to more than one cruise ship at the time i.e. capacity above 14 MW. The operation is relatively silent compared to a diesel engine. It can produce power and/or heat with an efficiency close to 40 and 46% respectively.

The technical description of the first LNG barge to be put in operation, “Hummel”, is given in the table below.

Table 4-1 Technical description of the LNG-Power-Barge "Hummel". Source: Becker Marine Systems, 2017.

Elements	Technical description
Barge dimension	76 x 11,4 x 2,5 m
Storage capacity	2 x 15 t LNG Container
Power plant	5(or 7) x 1,5 MW
Efficiency	39,7 % (power) and 45,4% (heat)
Operation noise	60 dBA/10 m
Voltage	11/10 kV
Frequency	60/50 Hz
Other specifications	Not self-propelled

Infrastructure on shore/ Cable management system

The power barge can either supply power to cruise ships directly or through an onshore distribution system at the port. This port infrastructure consists of a shore junction box, cable channel and a cable handling unit. A medium voltage (MV) cable connection from the power barge to the connection point on the vessel is required.

On board connection panel and control system

On-board equipment follows the same standard as for an OPS solution supplied by the grid, cf. section 4.1.

4.2 Shore connection standards

To ensure a standardized, quality assured, safe and effective way for ships to connect to shore power, shore grids standards have been developed. The international standardization organizations IEC, ISO and IEEE have collaborated in developing a standard for both high voltage (HV) shore connection systems (IEC/IEEE DIS 80005-1) and low voltage (LV) shore connection systems (IEC/PAS 80005-3). The low voltage standard is, however, still pending final approval. The standardization organizations has also published a standard for data communication for monitoring and control of high- and low voltage shore connection (IEC/IEEE DIS 80005-2) /D21/.

The HV standard covers applications where the power requirement is exceeding 1000KVA and the LV standard covers power requirements below or equal to 1000KVA. By standardizing the shore connection systems, ships can call at multiple ports without the need of adjustments to their installed systems. In addition to the before mentioned benefits of efficiency and safety, a standardized way of connecting allow for more utilization for the installed connection systems on board and in port, potentially improving the overall business case and return of investment. The standards set requirements to the design, installation and testing of the following HV and LV shore connection systems and components:

- Shore distribution systems
- Shore-to-ship connection and interface equipment
- Transformers/reactors
- Semiconductor/rotating convertors
- Ship distribution systems

- Control, monitoring, interlocking and power management systems

However, the standard does not include practical elements such as the placement of the plug connection on the ship. As there is no standard connection point for ships, mobile facilities in port is necessary. Mobile facilities are more expensive to establish and operate than a fixed facility, increasing the OPS investment costs.

5 INTERNATIONAL DEVELOPMENTS AND REGULATIONS

Most of the cruise vessels operating in the GCP ports also operate internationally. Cruise companies' willingness to invest in and make use of OPS is thereby affected by international regulations, trends and technological development. Ships mainly operating in other countries than the GCP ports, regulations and incentives in these ports will determine if the cruise owners will invest in OPS. This section gives a short overview of the regulatory framework and main trends internationally and at EU-level.

OPS has been used in ships at berth for a long time, especially in military vessels which typically spend a long time at berth. An increasing focus on reducing emissions in general has led to an increased focus on reducing emissions from ships, including from cruise vessels. Through the last 15 years there have been several initiatives for establishing high voltage OPS in ports so that vessels with a large need for energy such as cruise ships can use OPS while at berth. While low-voltage OPS installations for ferries and smaller ships are not unusual to see, there is currently only one high-voltage OPS installation for cruise ships in Europe, opened in 2015 and located in Hamburg. In the USA and Canada there are several ports with OPS infrastructure for cruise ships, both on the East Cost - and West Coast.

In the manufacturing industry, there have been a positive development where suppliers collaborate in delivering berth systems and cabling systems that ensures a safe transmission of electricity, being OPS or batteries in hybrid/electrical-ferries. ABB, GE, Cavotec, Siemens, Wärtsila Sam Electronics, Terasaki, Patton & Coke and Schneider Electric all have information on their webpage and brochures covering OPS. Several suppliers offer components for both high voltage and low voltage OPS systems. This indicates that the market is becoming more and more mature and the solutions provided is no longer a limitation.

5.1 International policy and regulations

There are no international policies in place that directly enforce OPS. Most direct legal regulations are national. However, there are several international and regional initiatives to reduce the emission from vessels. Below, a short description of the most important initiatives is included.

The MARPOL-convention and IMO

Internationally, the most important framework for regulation of emissions from vessels is the MARPOL-convention. The MARPOL- conventions objective is the prevention of pollution of the marine environment by ships from operational or accidental cause. The first MARPOL-convention was signed and adopted by the International Maritime Organisation (IMO) in 1973. IMO is a United Nations specialized agency responsible for the safety and security of shipping and the prevention of marine pollution by ships.

In the MARPOL Convention in 2011 the parties of IMO adopted a revised form of the Annex VI "Regulations for the Prevention of Air Pollution from Ships". The Annex includes threshold requirements of sulphur and NOx-emissions from fuels used in ships which contribute to technology development towards more energy efficient shipping, where OPS is gaining an increasing focus.

In October 2016, IMO approved the designation of the Baltic Sea and the North Sea as an emission control area for nitrogen oxides (NECA). This decision means that NOx emissions in the area are to be reduced by 80 per cent from the present level. The regulation will be applicable to new ships built after 1

January 2021 when sailing in the North and Baltic Sea and other NECAs. To comply with this regulation ships must have catalyst converters installed or use LNG as fuel.

World Ports Climate Initiative

The World Ports Climate Initiative (WPCI), was established by the International Association of Ports and Harbors (IAPH) and launched in 2008 as a mechanism for assisting the ports to combat climate change. In 2009 the WPCI started an initiative promotion OPS in order to reduce local air pollution and greenhouse gas emissions in ports. In this relation, a working group on Onshore Power Supply (OPS) was established. The working group has since 2010 administered a web page to promote OPS. The webpage includes information and news about OPS, in addition to a simplified cost calculator. The cost calculator compares the annual cost of using OPS with the cost of using traditional auxiliary engines. Some of the ports participating in IAPH have also developed guidelines for establishment of OPS.

Other initiatives

California is the area that is the most advanced when it comes to promoting OPS through the use of regulation. According to the “Airborne Toxic Control Measure for Auxiliary Diesel Engines Operated on Ocean-Going Vessels At-Berth in a California Port” regulations, adopted by the California Air Resource Board in 2007, all vessels visiting Californian ports must either 1) turn off auxiliary engines and connect the vessel to some other source of power, most likely grid-based shore power; or 2) use alternative control technology that achieve equivalent emission reductions /D22/.

There are also different bilateral and regional initiatives to reduce emission from maritime sector that also are considering OPS. An example is the Pacific Ports Clean Air Collaborative, an initiative initiated by the port of Los Angeles and the Port of Shanghai in 2006.

5.2 EU regulations and incentives

The European Commission published in 2006 a non-binding recommendation on shore-side electricity for ships at berth in Community ports (2006/339/EC), where the Member States recommended to establish instruments and regulations to promote the use of OPS.

The 2012 Sulphur Directive[1] regulates the use of fuels by stipulating that the Member States must ensure that marine fuels are not used within their territory if their sulphur content exceeds a certain level. The directive limits the sulphur content to a maximum of 0.10 per cent. It is however possible to use fuels with a higher sulphur contents if an appropriate exhaust cleaning systems is in place, for example scrubbers.

During the 2011 revision of the EU Directive on energy and electricity taxation[2], the introduction of a tax exemption for electricity provided to seagoing vessels through OPS systems was under discussion. A proposal amending the Directive included amongst other things, an exemption from energy taxation for shore-side electricity provided to ships while at berth. The proposal was not adopted.

In the 2014 Clean Power Transport Directive /D02/, EU requires all trans-European core ports to provide LNG refuelling points from 2025 as a substitute to oil. The directive also requires the ports to provide shore-side electricity. An exception if given if it can be proven that there is no demand for shore-side electricity or the costs can be proven disproportionate to the benefits. The directive clearly indicates that OPS is seen as an important way forward to reduce emissions from transport. The directive also requires

[1] Directive 2012/33/EU of the European Parliament and of the Council amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels.

[2] Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity

the EU member states to report on the development and use of OPS. With the exception of Bergen Port, all ports included in the business case are included in the trans-European core ports.

The above-mentioned regulations and incentives clearly shows that EU sees OPS as an important measure to achieve the goal of reduce emission in the transport sector. No dedicated instrument to support the development of OPS is introduced, but falls under the EU instrument Connecting Europe Facility (CEF) for Transport. CEF for Transport is the funding instrument to realise European transport infrastructure policy. The instrument aims at supporting investments in building new transport infrastructure in Europe or rehabilitating and upgrading existing infrastructure /D15/. CEF Transport supports amongst other innovation in the transport system that reduce the environmental impact of transport, enhance energy efficiency and increase safety. The total budget for CEF Transport is €24.05 billion for the period 2014-2020. A horizontal priority of the Connecting Europe Facility (CEF) is the "Motorways of the Sea (MoS)" program. The program aims to promote green, viable, attractive and efficient sea-based transport links integrated in the entire transport chain. Maritime link based projects and projects of wider benefit are given priority in the selection process. The project should include at least two EU ports (two core ones or one core and one comprehensive) from two different Member States, one maritime operator and ideally hinterland transport operators. The project proponents may apply for up to 30% co-financing. Facilities for shore side electricity is amongst the infrastructure that are subject to co-financing, given that the facility is open to all users.

In addition to these several countries have national funding pools. An example is Norway where government owned ENOVA is providing financial support related to the establishment of OPS in Norwegian ports. National funding pool differs however from country to country and are subject to changes.

6 CALCULATION PAPAMETERS

In this section, key input and assumptions to the business case analysis' are presented. A more detailed description of the port specific input is included in the Appendix to the report.

The Green Cruise Port project covers nine project partner ports and several associated organisations, shown in Figure 6-1. In cooperation with Bergen Port, five of the partner ports have been selected and analysed closer. This includes Bergen Port, Hamburg Port, Rostock Port, Tallinn Port and Helsinki Port.

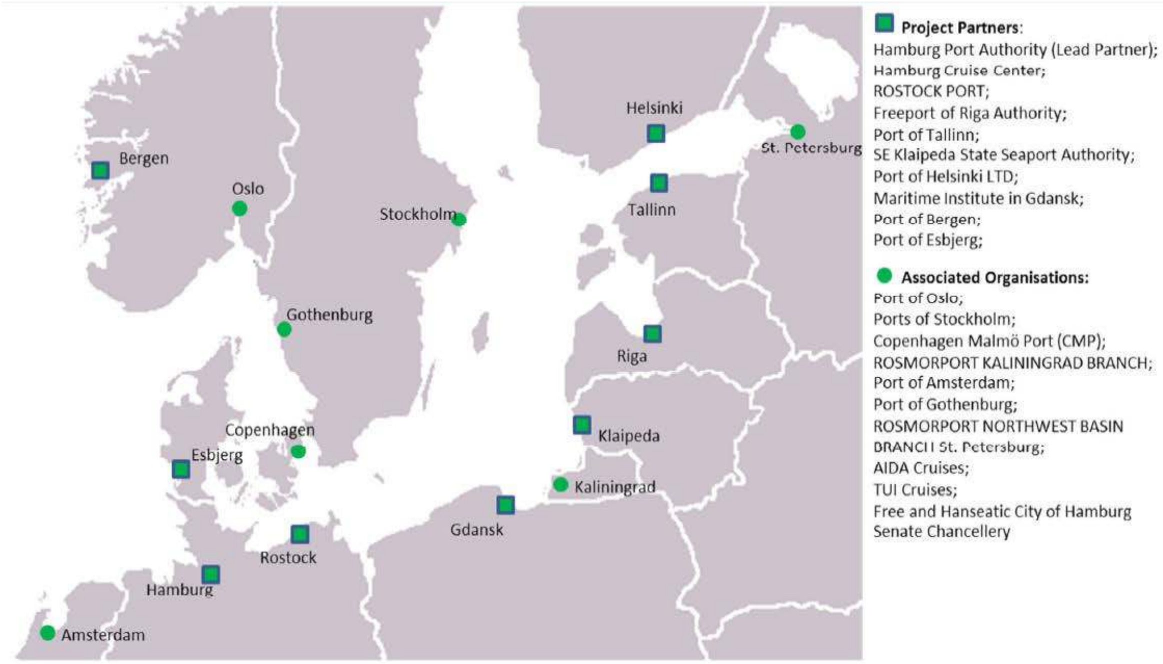

Figure 6-1. Scope and Partnership of the Green Cruise Port Project

6.1 General key assumptions

According to the 2012 EU Sulphur Directive[3], EU Member States have to ensure that ships in the Baltic, North Sea and the English Channel are using fuels with a sulphur content of no more than 0.10 percent as of 1 January 2015. This means that vessels operating in the GCP area must use MGO or LNG as fuel, unless they use cleaning technologies such as scrubbers. Conventional oil-based fuels are expected to remain the main fuel option for most vessels in the near future, and the study assumes that cruise vessels will use MGO while at berth. LNG technology is however seen as a good alternative to meet existing and upcoming emissions requirements and several shipping companies are already using LNG technology.

The construction period for establishing OPS is assumed to be one year. The construction period is set to 2018 for all ports and the shore power facility is assumed to be ready in 2019. The HafenCity area in Hamburg is under reconstruction until 2021. During this period the terminal will have limited capacity. To be able to compare the business case between the different ports the same calculation period for all ports is applied and full capacity at HafenCity is assumed throughout the calculation period.

The calculation period is set to 20 years from the OPS infrastructure is established. This is in line with the expected lifetime of the main on-board and shore side components. The calculation period is thus set to the years 2018 throughout 2037. The calculations assume that the investment costs are financed through a 20-year annuity with an annual interest rate of 2 percent per year. All figures are given in fixed 2017 prices. The expected increase in the general price level (inflation) is assumed to be 2 percent per year throughout the calculation period. As interest rates and inflation is assumed to be the same, the real interest rate is zero. Interest and loan repayments in fixed 2017 prices will thereby equal the investment cost. If the interest rate should be higher than the inflation over the calculation period, the real interest rate will be positive and the sum of interest and loan repayments in fixed 2017 prices will exceed the investment cost. Visa versa, if the interest rate should be lower than the inflation over the

[3] Directive 2012/33/EU of 21 November 2012 amending Council Directive 1999/32/EC as regards the sulphur content of marine fuels.

calculation period, the real cost of capital will be negative and the loan and repayments in a debt-finance business case will be lower than the total investment cost.

Loss of income due to installation of on-board OPS ship infrastructure is not included in the business case. This means that costs related to downtime while installing OPS equipment or reduction in the number of cabins as OPS equipment takes up space, is left out of the business case analysis.

6.2 Vessel traffic and port calls

The port business case' focuses on a specific port area. In Bergen the focus is on Skoltegrunnskaien (Skolten), in Hamburg the focus is on HafenCity area, in Rostock on the Warnemünde area, in Tallinn on the Old City Harbour area and in Helsinki the focus is on the Hernesaari area. The areas are chosen based on input from the respective port authorities.

The expected number of port calls and the average lay time over the calculation period is based on AIS data for 2016 and port logs and information from port authorities in the respective ports. It is assumed that the electrical connection to the ship will be fully automated and connection and disconnection will be limited to a total of 30 minutes on average. DNV GL has received feedback that with a fully automated system the connection and disconnection time could be reduced. On the other side, DNV GL has received feedback that due to technical problems, the actual connection time is significantly longer. With the increased number of OPS facilities DNV GL expects that the automated system will improve and that technical problems will be limited.

The number of port calls and average lay time is expected to stay the same throughout the calculation period. This assumption is related with substantial uncertainty as actual cruise traffic for the next 20 years is difficult to foresee. Changes in cruise traffic will affect the utilization of the OPS infrastructure and hence the business case. The effect of increase utilization of shore power on the port business case' is included in the sensitivity analysis in section 8 (scenario "100 % OPS share").

Per 2015, there were about 400 cruise ships operating globally and about 10 percent of these where assumed to accept shore power /D40/. With increased marine and costal tourism, along with new building requirements, the European Ships and Maritime Equipment Association estimates that there will be built six to eight new cruise vessels per year between 2015 and 2031 /D43/. The Cruise Lines International Association (CLIA) estimates that 33 new ocean cruise ships will be built in the period 2015-2020. Due to increased focus on emission reduction, opening of several new OPS installations is expected in the coming years and thereby also a gradual increase in the number of vessels adapted for shore power. Over the calculation period, it is assumed that 60 percent of the port calls use shore power while at berth. The effect of increase utilization of shore power is addressed in section 8.1

In Table 6-1 the applied assumptions and potential annual capacity utilization of the OPS infrastructure in the five ports is presented.

Table 6-1. Annual capacity utilization of OPS infrastructure

General assumptions	
Connection and disconnection time per ship	30 minutes
Average share of port call that use OPS	60 percent

Port specific assumptions	**Bergen – Skolten**	**Hamburg – HafenCity**	**Rostock – Warnemünde**	**Tallinn –Old City Harbour**	**Helsinki - Hernesaari**
Port calls per year	250	65	150	340	100
Port calls using OPS	150	39	90	144	60
Av. lay time per ship adj. for connection/disconnection	11.5 hrs	14.5 hrs	11.5 hrs	7.5 hrs	8.5 hrs
Total number of lay time	2,880 hrs	940 hrs	1,730 hrs	2,550 hrs	850 hrs
Annual capacity utilization of OPS infrastructure	**1,730 hrs**	**570 hrs**	**1,040 hrs**	**1,530 hrs**	**510 hrs**

6.3 Capacity demand and energy consumption

Installed capacity in cruise ships today varies typically between 6 and 18 MW, depending on size and on-board facilities. While at berth cruise ships only use part of the installed capacity. The capacity demand from cruise ships operating in the Nordic and Baltic Sea is normally also lower than the capacity demand for cruise operating in warmer areas air-conditioning is used to a much larger extent. A large part of the cruise vessels visiting the selected ports are also in the smaller range.

A case study of OPS in the Port of Helsinki from 2015 shows that ferries operating from Helsinki to Stockholm have an installed capacity of 4 MW and use on average a capacity demand of around 1.8 MW /D38/. Assuming that cruise vessels on average use around three times this capacity, this results in a capacity demand of around 5.5 MW. In the business case analysis, an average capacity demand of 5.5 MW is applied.

As the power efficiency of MGO is relatively low, a shift from MGO to onshore power supply will include an element of energy efficiency. An efficiency factor of 25 percent is assumed when calculating the energy consumption using MGO, i.e. it takes 250 gram MGO to generate 1 kWh of electricity. When calculating the energy consumption for the LNG-power-barge solution an efficiency factor of 39 percent is assumed. Table 6-2 gives an overview of calculated annual energy consumption using MGO and shore power.

Table 6-2. Annual energy consumption related to cruise ships use of energy at berth

General assumptions	
Average capacity demand per cruise vessel while at berth	5.5 MW

Annual energy consumption	**Bergen – Skolten**	**Hamburg – HafenCity**	**Rostock – Warnemünde**	**Tallinn – Old City Harbour**	**Helsinki - Hernesaari**
MGO (ton)					
Total	3,950	1,300	2,370	3,500	1,170
60 % capacity utilization	2,370	780	1,420	2,100	700
Electricity (MWh)					
Total	15,810	5,180	9,490	14,030	4,680
60 % capacity utilization	9,490	3,110	5,690	8,420	2,800
LNG (MWh)					
Total	40,550	13,290	23,720	25,060	11,690
60 % capacity utilization	24,330	7,980	14,230	21,040	7,010

6.4 Marine gasoil prices (MGO)

At the end of November 2017, the price of MGO was 14.1 USD/mmBTU or 475 EUR/mt /D62/. In the business case it is assumed that price of MGO remains at today's relatively low level throughout the calculation period. Figure 6-2 shows the price development of different gas and oil product since 1992 until today. The prices do not include supply to the ship.

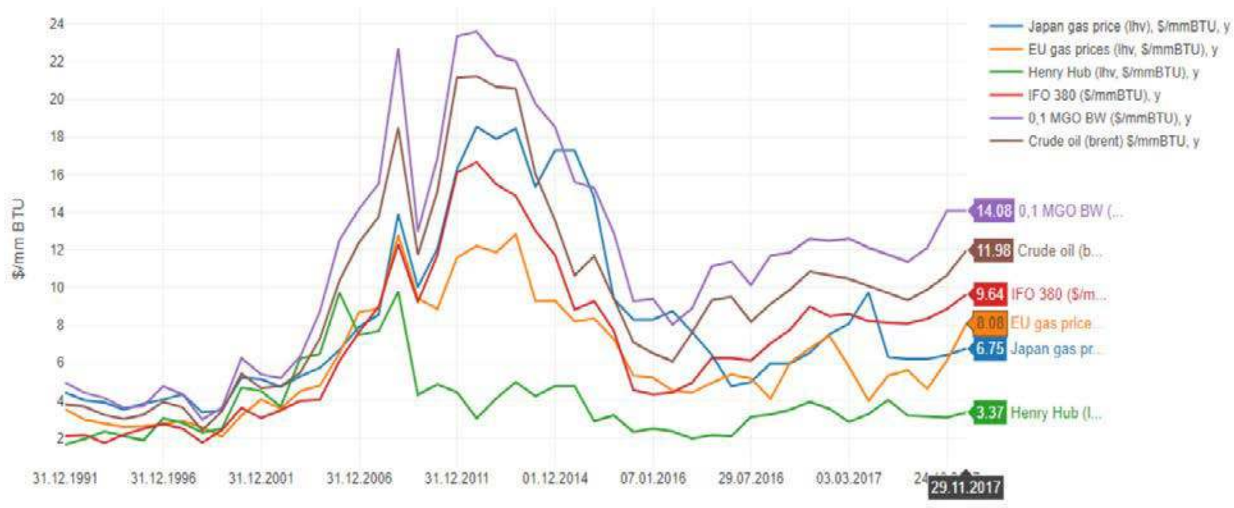

Figure 6-2. Price development oil and gas 1992 to 2017[4]. Source: DNV GL, 2017

The price of MGO is strongly correlated to the price of crude oil (Brent) and has in this period dropped from an all time high of over 23 USD/mmBTU to at around 14 USD/mmBTU today.

According to EIA in the USA[5] the price of crude oil is expected to stay at around 10 USD/mmBTU over the calculation period. Assuming that the premium of MGO above Brent remains stable the MGO price can also be expected to stay around 500 EUR/mt. Given an efficiency factor of 25 percent the price of MGO per MWh is EUR 125.

6.5 Total electricity charges (port’s purchasing price)

Total electricity charges reflect the ports purchasing price of electricity and includes the following three elements; the electricity price, grid tariffs and national taxes and levies (taxes). Figure 6-3 gives an overview of average total electricity charges for industrial consumers[6] in Europe in 2016. The figure shows that Germany is amongst the European countries with the highest total electricity charges, driven by a high tax level, while Finland is amongst the countries with the lowest total electricity charges. It should be notated that total electricity charges also varies within each country due to local differences in grid tariffs and variation in electricity prices in countries with several price areas such as Norway.

[4] Prices in the figures are yearly average prices until 2014. 2014 prices are the spot prices at the beginning of the month.

[5] U.S. Energy Information Administration

[6] Industrial consumers refer to consumers with an annual consumption of electricity between 2 000 and 20 000 MWh.

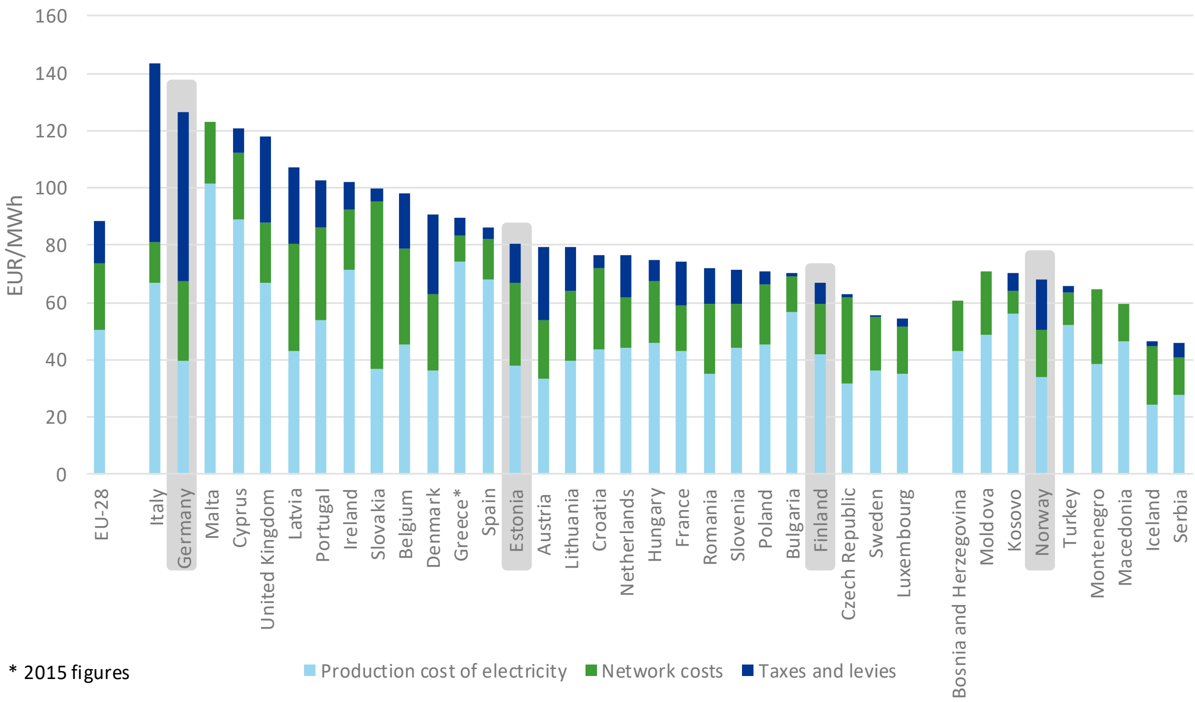

Figure 6-3. Electricity price for industrial consumers with electricity consumption from 2 000 MWh to 20 000 MWh, 2016. Source: Eurostat, 2017

While future grid tariffs and the level of taxes are hard to predict as these are dependent on local circumstances and national legislations, electricity price forecasts are widely used and some are also publicly available. The Norwegian TSO, Statnett, publishes long-term price forecasts /D45/. Electricity price forecast for Southern Norway, Germany and Finland based on Statnett's prognosis is shown in Figure 6-4. The price forecast for Estonia is based on an analysis conducted in 2014 by the Estonian TSO, Tallinn University of Technology and Ea Energy Analysis /D60/. The price forecasts show that for Norway, Germany and Finland the price of electricity is expected to increase from today's level to around EUR 45 per MWh in 2030 and then remain relatively stable until 2040. The electricity price in Estonia is already substantially higher than in the other countries and is expected to increase to around EUR 70 per MWh in 2030, and then increase slightly further until 2040.

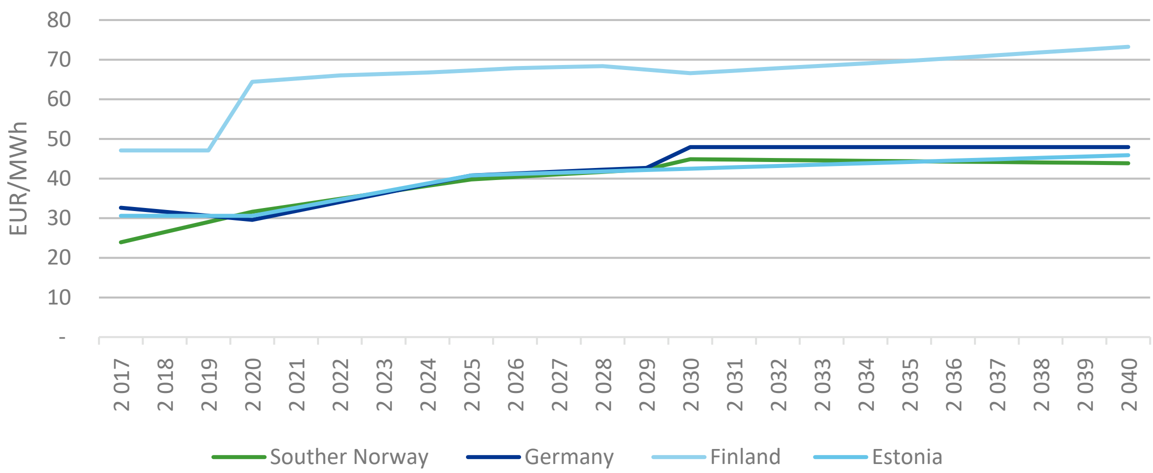

Figure 6-4. Long-term price forecast of power prices in Southern Norway, Finland, Estonia and Germany. Source: Statnett, 2016 and Elering et al., 2014. EUR/MWh

It is assumed that the electricity price will develop in line with the price forecasts above. Total electricity charges also depend on developments in grid tariffs and national taxes. It is expected that also these elements will develop, but it is related substantial uncertainty related to the development. The electricity price, grid tariffs and national taxes can go in opposite or the same direction, and the effect on the total electricity charges is uncertain. To illustrate the effect of a potential increase or drop in the total electricity charges relative to the price of MGO, sensitivity analysis' are included in section 8 (scenarios "Electricity price +20 percent" and "Electricity price -20 percent").

Figure 6-5 shows the total electricity charges in the different ports in 2019 and 2030, given the electricity price forecasts above and current grid tariffs and national tax levels.

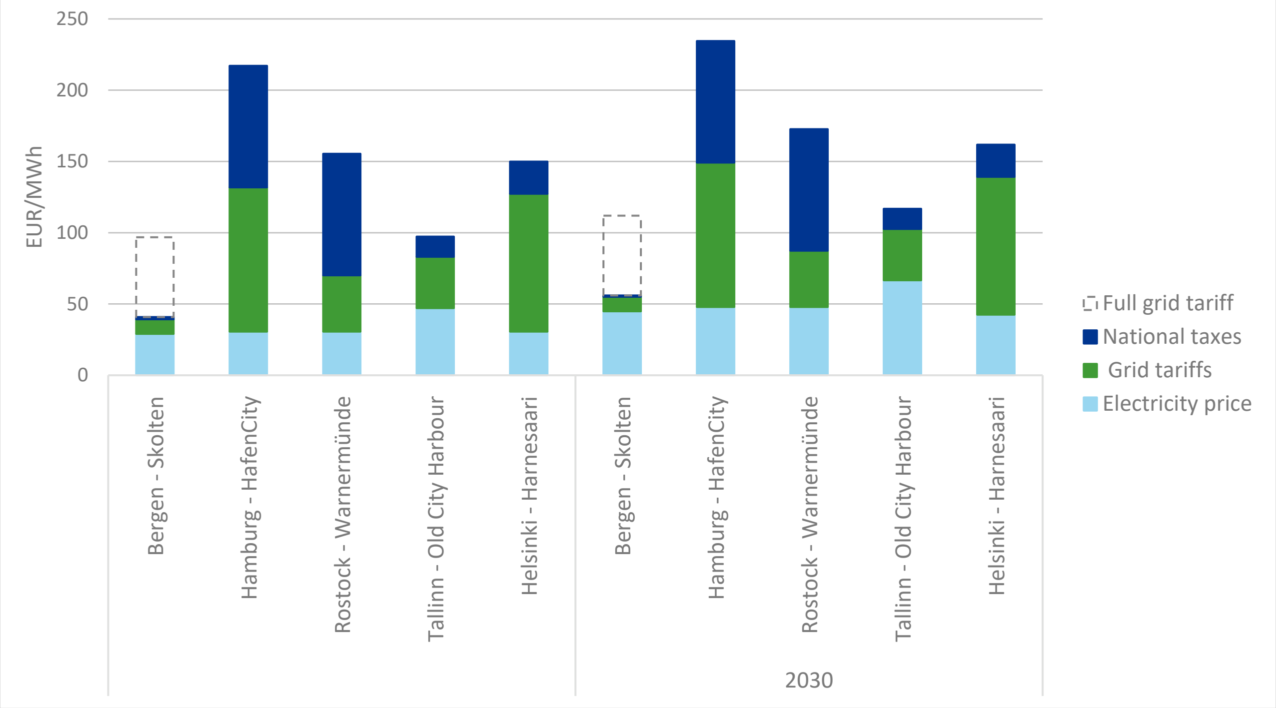

Figure 6-5. Total electricity charges (port purchase price of electricity)

The figure shows that total electricity prices in Bergen Port is substantially lower than in the other four ports. This can partly be explained by the low tax level related to the use of shore power[7], but is also a result of Bergen Port currently being subject to a so called flexible tariff. The flexible tariff allows the local grid company to cut the supply of electricity to the port in case of a constrained grid situation in Bergen City. In compensation, the port receives a 90 percent reduction in the capacity fee. The grey, broken lines indicates the effect on the electricity price of a full grid tariff charge in Bergen. The local grid owner, BKK Nett, has confirmed that they can offer Bergen Port a flexible consumption tariff also after the grid situation in the area is improved. The local grid operator has however communicated that after the grid situation is improved the capacity fee reduction will not remain at 90 percent. BKK Nett cannot say what the capacity fee reduction is likely to be in the future. In the business case a capacity fee reduction of 50 percent is applied.

The Appendix includes a closer description of total electricity charges in each port and the different elements that constitute total charges.

[7] The use of OPS in Norway is subject to the minimum level of tax according to EU's tax directive, i.e. EUR 0.5 per MWh. Electricity consumers cost related to renewable support schemes in Norway is also relatively low and is expected to remain relatively low in the future.

6.6 Electricity price for sales to cruise ships

The price of electricity produced by ships' auxiliary engines based on MGO is assumed to be EUR 125 per MWh. A shift from using MGO to shore power while at berth requires the ship owners to invest in on-board OPS equipment on their cruise vessels. This involves a cost for the ship owners and it is assumed that the ship owners must be provided with an incentive to bear these costs. In the business cases, it is assumed that ship owners need a cost reduction of around 10 percent to accept shore power. Based on this, it is expected that shore power could be sold to ships at an average price of around EUR 115 per MWh in the five ports.

It may be that ship owners are willing to accept a higher sales price of electricity than assumed in the business cases. A desire to demonstrate environmental responsibility or offer increased comfort to its passenger in form of reduced noise and pollution while at berth could be reasons for increased willingness to pay for shore power. It is also likely that total electricity charges in different ports will affect ship owners willingness to pay for electricity. In ports with relatively low total electricity charges it can be expected that cruise vessels willingness to pay is lower than in ports that face higher total electricity charges.

6.7 Liquefied Natural Gas

The price of LNG is closely linked to the price of natural gas. In western Europe, the marginal cost of natural gas is set by LNG. However, most gas imported to continental Europe is supplied in pipelines from Russia and Norway.

The price of natural gas has dropped significantly in Europe the last decade. This drop can be explained by the build-up of a large global surplus, which has happened also in the other fossil fuel markets i.e. coal and oil. Many gas analysts believe that the surplus will continue into 2020-2025.

The main reason for the surplus is that gas consumption in Asia has grown far less than previously expected and a lot of new offers in the form of LNG, mainly from Australia and the United States, has come to the market. The shale gas revolution that has taken place in the US is one of the main driver behind the global surplus. The price of gas traded on exchanges in western Europe the next decades is expected to be closely linked to the short-term cost of LNG deliveries from the United States or Qatar. This is driven by Russia and Norway seeing LNG as competing against the piped supplies, and import growth is driven by a fall in the domestic gas production in central EU countries. The global LNG capacity is expected to increases by approximately 50 percent by 2019. Figure 6-6 shows the price forecast of the price of natural gas in nominal Euro per MWh.

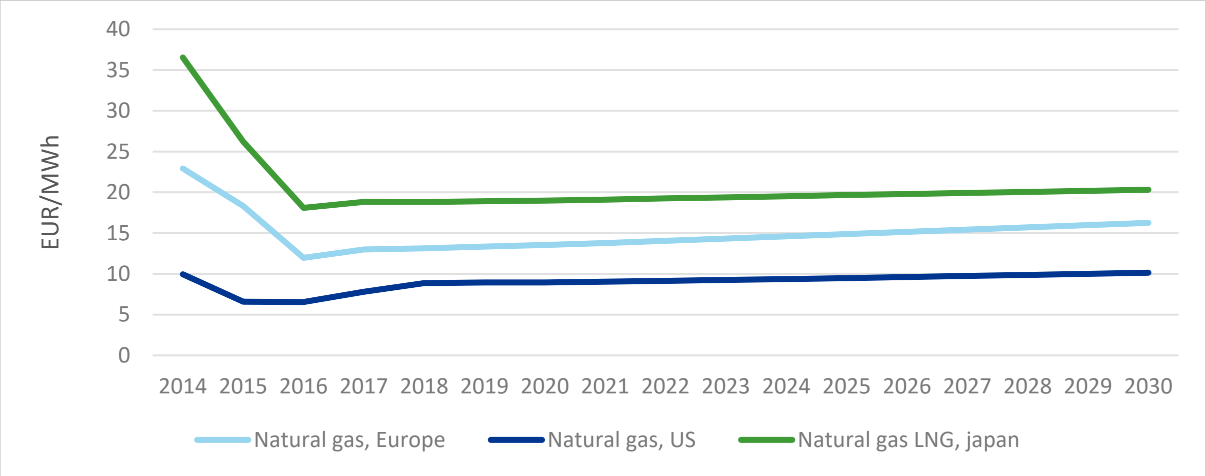

Figure 6-6. Long term price forecast of natural gas in Europe, Japan and the US. Source: World Bank Commodity Forecast Price Data, April 2017

The forecast of European natural gas and LNG spot prices shows that the price is not expected to exceed the 2014-prices within the next decade. The price of European natural gas is expected to be lower than the Japanese price, but significant higher than the US.

LNG in Europe competes with pipeline gas and therefore only the costs of distribution to ship have to be added to gas price. The distance to the nearest LNG source, e.g. LNG import terminal, influences distribution costs, as well as fees at the import terminal and national taxes related to the use of LNG /D67/. In the business cases, a LNG price of EUR 30 per MWh, equal to the price of LNG delivered in the Port of Hamburg is applied /D67/. This price includes a relatively high distribution cost as the LNG needs to be delivered from Rotterdam or Zeebrugge. In locations with a LNG source nearby such as in Rotterdam the price per MWh is lower.

6.8 Environmental effects

As this study looks at the operational business case for ports and ship owners in the form of a cash flow analysis, socio-economic aspects of OPS such as environmental effects of reduced emission are not included. Environmental effects are however the most important reason to switch to OPS and for EU and national regulators to provide instruments to incentivise such investments.

Energy used in cruise vessels is typically produced from MGO that causes emissions of greenhouse gases, local air pollution and noise. The use of OPS will reduce the level of pollution and noise in harbours.

The European Union Emissions Trading System (EU ETS) is a European scheme that regulates emission of greenhouse gases in all 28 EU member states and the EEE countries Iceland, Norway, and Liechtenstein. Currently the EU ETS covers more than 11,000 heavy energy-using installations (power stations and industrial plants) and airlines, covering around 45% of the EU's greenhouse gas emission. CO_2 emissions from cruise ships are not included in the EU ETS. A shift to shore power thus means that part of the cruise ships emissions will be covers by the EU ETS as power stations is covered by EU ETS. This means that cruise vessels' use of shore power will not create additional emissions.

Air pollution from cruise ships contribute to degraded air quality in the cities that the cruise ships visits. Reduced air quality due to emissions of particles, sulphure dioxide and NOx increases health risks. Cruise ships use of OPS while at berth will lead to reduced emissions and increased local air quality. Noise from engines can also be a nuisance and will also be avoided by using shore power from the grid.

An LNG-power-barge solution will also reduce emissions in port. According to Becker Marine a LNG-power-barge reduces NOx emissions by 80 percent and has no particulates or sulfur emissions /D63/.

The number of lay time for cruise vessels give an indication of potential societal benefits of OPS in the selected ports. The port with the highest number of lay time, i.e. Bergen cf. Table 6-3, is assumed to be the port which will have the largest environmental benefit of a shift to OPS.

Table 6-3 Expected average lay time and number of port calls in the five selected GCP ports based on AIS data from 2016

	Bergen – Skolten	Hamburg – HafenCity	Rostock – Warnemünde	Tallinn – Old City Harbour	Helsinki - Hernesaari
Annual capacity utilization of OPS infrastructure	1,730 hrs	570 hrs	1,040 hrs	1,080 hrs	510 hrs

If the shore power infrastructure also can be used by other vessels in periods when the utilization from cruise vessels is low, i.e. the winter season, this will increase the environmental effect. In case of a shore to grid connection, port authorities in the selected ports see very limited alternative use of the OPS infrastructure as the terminals are dedicated for cruise ship. A possibility is however to establish low-voltage connections as part of the high-voltage connection. A LNG-power-barge solution is in this case more flexible as it can be relocated and used for other ships or for electricity generation in the off-cruise season.

7 BUSINESS CASE ANALYSIS

In this section, the business case analysis from the port and cruise vessels perspective is presented. From the port perspective, both a stationary shore to grid solution and a LNG fuelled power barge solution is included.

7.1 Shore to grid solution

7.1.1 Shore to grid specific assumptions

7.1.1.1 Investment costs

Construction costs related to a shore to grid solution can be broken into two main elements; the grid connection and onshore distribution, illustrated in Figure 7-1. On-board installation is expected to be the same for a shore to grid connection and a LNG-power-barge solution.

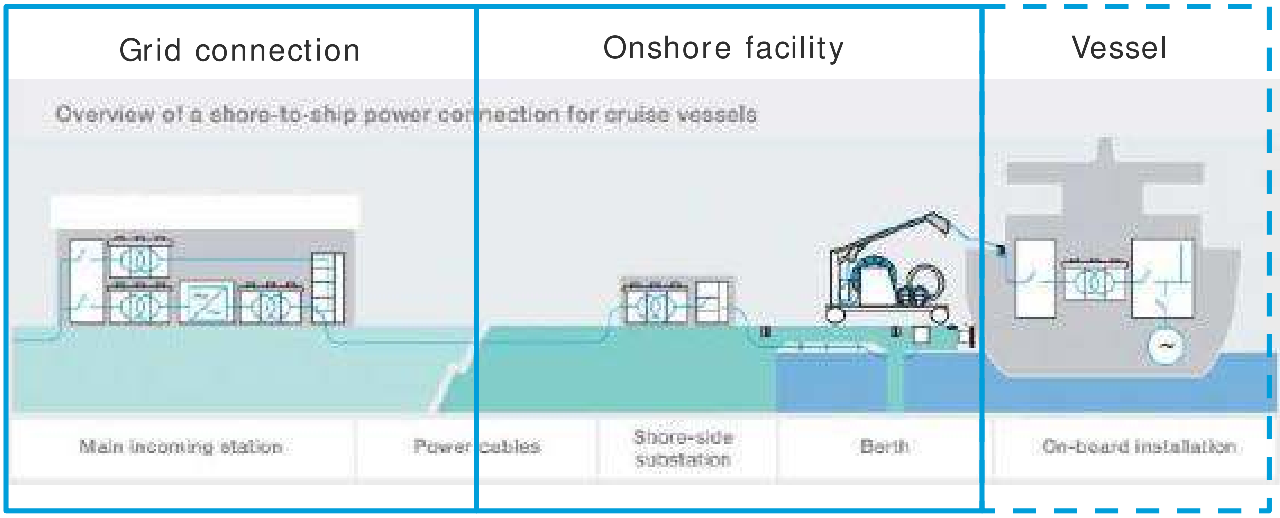

Figure 7-1. Overview of a shore-to-ship power connection. Source: ABB

Grid connection costs is port specific and varies between the ports depending on available gird capacity and the number of connection points. In the business case, it is assumed an average capacity demand of 5.5 MW per cruise ship. The capacity demand varies however between ships and seasons and can at times exceed the average expected capacity demand of 5.5 MW. To ensure some flexibility the business case allows for a maximum capacity demand of 7MW per cruise vessel. This is also the basis for the grid connection cost estimate[8].

To estimate the cost of the shore side facility, a general cost estimate based on input from suppliers is used. For Skolten and Warnemünde, port specific cost estimates from the Port of Bergen and the Port of Rostock respectively is applied have /D50/ /D52/. The number of connection points in each port and investments cost is presented in Table 7-1.

Table 7-1. Number of connection points and estimated grid connection costs and shore power installation costs

2017-prices, MEUR	**Bergen – Skolten**	**Hamburg – HafenCity**	**Rostock – Warnemünde**	**Tallinn – Old City Harbour**	**Helsinki - Hernesaari**
No. of connection point	3	2	3	3	2
Grid connection	1.1	0.5	5.6	6.0	3.0
Shore power installations	10.2	10.5	20.0	10.8	10.2
Transformer station (incl. housing)	1.4	1.3		1.0	1.0
Frequency converters	3.6	3.6		3.6	3.6
Cabling	2.0	3.2		3.0	3.0
Cable management systems	3.2	2.4		3.2	2.4
Total	**11.2**	**10.0**	**25.6**	**16.8**	**12.5**

The highest investment cost for establishing OPS are to be found in Rostock. The cost estimate is based on overall power output of three 12 MVA transformers /D52/. A breakdown of the cost components for the shore power installation is not provided. The investment cost in Tallinn is also relatively high, due to higher grid connection costs than the other ports. The investment costs of establishing in Bergen, Hamburg and Helsinki is expected to be significantly lower than in Rostock and Tallinn.

In a worst case scenario the OPS facility is simply not used. In that case, the entire investment cost will be lost. It is however considered realistic to assume that if OPS is established the facilities will be used.

7.1.1.2 Operational and maintenance costs

In addition to the cost of electricity there is expected some operational costs related to the handling and connection/disconnection of the OPS equipment in port. Due to the thickness and weight of the cables a crane and a purpose-built cable drum is necessary. Even with a fully automated system there is a need to plug the cables from the shore side to the cruise ship manually. It has been difficult to get a good estimate on the operational cost. In the business case, it is assumed an operational cost of EUR 500 per port call.

Experience with existing shore power facilities show that maintenance costs are low according /D68/. On average the maintenance cost can be assumed to be around EUR 1,500 per year the first 10 years. After 10 years the maintenance cost can raise due to some refurbishment (change of cable, motors) and the annual maintenance is assumed to be EUR 10,000 per year for the last 10 years. A prerequisite is that the mobile unit is stored in a dry space during the off season. If the equipment is stored in open space the maintenance cost will increase significantly.

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[8] The Appendix includes a closer description of the gird infrastructure and the port specific grid connection costs.

The cruise vessels maintenance cost related to the use of MGO is calculated based on running hours per auxiliary engine in use while at birth. The maintenance cost is assumed to be EUR 1.8 per hour per auxiliary engine. Operational cost related to the use of MGO is expected to be neglectable and is therefore not included in the business case.

7.1.2 Results

The net operating costs includes OPS investment costs, operation and maintenance costs, sales of electricity and total electricity charges. The table below gives a summary of the operational business case for the five ports.

Table 7-2. Operational business case for a shore to grid investment in selected GCP ports

2017 prices, MEUR	Bergen[1]	Hamburg	Rostock	Tallinn	Helsinki
Interest and loan repayments	-11.2	-11.0	-25.6	-16.8	-13.0
Operation & maintenance	-1.6	-0.5	-1.0	-2.2	-0.7
Purchase of electricity	-14.9	-15.1	-19.5	-19.7	-9.3
Sale of electricity	21.8	7.2	13.1	19.4	6.5
Total	**-5.9**	**-19.4**	**-33.1**	**-19.2**	**-16.5**

1 Port of Bergen has today a capacity fee reduction of 90 percent is applied. The business case assumes a capacity fee reduction of 50 percent throughout the calculation period.

For all ports establishment of OPS will require net public investment in the range of EUR 8.8 million to EUR 32.2 million. Only in Bergen port is the port's purchasing price of electricity (total electricity charges) lower than the cruise operators assumed willingness to pay for electricity (sales price of electricity of EUR 115 per MWh). In the other four ports the ports total electricity charges are higher than the income from the sale of electricity and the ports will therefore need investment support to cover both the financing of interest and repayments related to the OPS investment and the ongoing operating costs.

A cash flow analysis look as if there is sufficient cash to pay the ongoing cost. Cash flow analysis of the five port business cases show that for all ports a capital injection in year one is needed cover the ongoing costs. The table below summarize the cash flow analysis for the five ports.

Table 7-3. Cash flow analysis for a shore to grid investment in selected GCP ports

2017 prices, MEUR	Bergen	Hamburg	Rostock	Tallinn	Helsinki
Business case	**-5.9**	**-19.4**	**-33.1**	**-19.2**	**-16.5**
Extra liquidity requirements	5.9	19.4	33.1	19.2	16.5
Minimum investment support	**5.9**	**19.4**	**33.1**	**19.2**	**16.5**
Share of investment	53 %	176 %	129 %	115 %	127 %

7.2 LNG-Power-Barge solution

LNG-Power-Barges are floating power stations which produce electricity from regasified LNG. The power-barge is ideal for operation in remote locations and harbours, and is an environmental friendly alternative to the use of MGO.

The concept builds on integrating LNG storage, regasification facility and a power plant on one and the same barge. The LNG-power barge technology is new and there are only a few vessels in operation worldwide that use this technology. The first LNG-power Barge was put in operation at the Hamburg port in 2015.

In the business case, it is assumed that the port owns the LNG-power-barge. As the power barge solution is a stand-alone solution this means that the port will not be subject to any grid connection costs or grid tariff. Alternatively, a third party can own and operate the power-barge and the port can purchase electricity from the power-barge and sell to cruise vessels.

In addition to supplying OPS to cruise vessels, the power barge can be used to provide power to the local electricity and/or heat company during the winter season or during other times when the power barge is not used for shore power. In this business case, it is only assumed that the power barge is used for OPS. In contrast to an OPS to grid solution the LNG-power-barge solution can easily be moved. It is therefore likely to assume that the barge will have an alternative use that will increase the utilization of the barge.

7.2.1 LNG-Power-Barge specific assumptions

7.2.1.1 Investment costs

The investment cost for a LNG-power-barge can be broken into two main components; the power barge and onshore distribution. Onshore distribution cost includes cable laying and management system. The investment cost related to the onshore distribution infrastructure varies depending on where the power-barge is located. In the business case, it is assumed that the distance between the power barge and cruise ship (i.e. the length of the onshore distribution system) are less than 100 meter. If that isn't the case, the investment costs will increase due to the need of more civil work and cabling. It is also a possibility to connect the power-barge directly to the cruise ship. This will reduce the cost of onshore distribution.

LNG Power Barge

The barge designed is relative flexible with the possibility to vary both power output, voltage and frequency to meet customer demand. Depending on design i.e. number of gas turbines, the power barge can be costumed to deliver power output in the range of 4 -35 MW and charge up to three cruise ships at the same time. In the business case, it is assumed a LNG-power-barge will that can supply two cruise ship at the same time.

The barge can either be self-propelled or not. The investment cost is lower in a not self-propelled construction, but the operational cost is higher due to the need for transportation when it's relocating. In our analyses, it is assumed that the barge is self-propelled.

The power barge follows international OPS standards, cf. section 4.1.2, which enables cruises ships to connect to the local grid at one port and from a LNG barge at another.

The technology itself is new, with only a few barges in operation worldwide, and the only publicly available prices are based on pilot projects. This makes it difficult to estimate a new build price for an LNG Barge solution. The price used in our analysis is based on input from Hybrid Port Energy and Becker Marine related to the LNG power barge "Hummel" /D64/.

Port facility and equipment / Cable management system

Depending on the quay design, different electrical shore distribution system can be optimal. In these analyses it is assumed that the port facility equipment consists of high voltage connectors, shore junction box and a flexible interlink to connect cables to the cruiser. The cost of these component is based on input for different suppliers.

Total investment cost

A summary of the investment costs related to a LNG-power-barge solution with the possibility of three connection points is shown in Table 7-4.

Table 7-4. Investment cost for a LNG-power-barge solution

2017-prices, MEUR	LNG-power-barge
No. of connection point	3
LNG-power-barge	13.0
Shore power installations	2.1
Cabling	1.2
Cable management systems	2.0
Total	**16.2**

7.2.1.2 Operational and maintenance cost

The cost of cable handling at port is expected to be the same for the LNG-power-barge as for a shore to grid solution, assumed to be 500 EUR per port call.

Operation and maintenance cost related to the use of the power barge is influenced by the type and number of engines installed on the Barge. In the report it is assumed a annual operation and maintenance cost estimated of EUR 0.25 million.

To calculate the energy cost of a LNG-power-barge solution an efficiency factor of 39 percent is assumed.

7.2.2 Results

In Table 7-5 the operational business case for a LNG-power-barge investment in the five GCP ports is presented. Net operating costs includes interest and loan related to the LNG-power-barge and onshore distribution investments, operation and maintenance costs, sales of electricity and purchasing of LNG.

Table 7-5. Operational business case for LNG-power-barge investment in selected GCP ports

2017 prices, MEUR	Bergen	Hamburg	Rostock	Tallinn	Helsinki
Loan repayments	-16.2	-16.2	-16.2	-16.2	-16.2
Operation & maintenance	-1.6	-0.5	-1.0	-2.2	-0.7
Purchase of LNG	-14.6	-4.7	-8.5	-12.6	-4.2
Sale of electricity	21.8	7.2	13.1	19.4	6.5
Total	**-10.6**	**-14.3**	**-12.7**	**-11.6**	**-14.7**
Min. investment support	**10.6**	**14.3**	**12.7**	**11.6**	**14.7**

For all ports establishment of OPS will require net public investment in the range of EUR 10 to 15 million. In contrast to the shore to grid solution, with a LNG-power-barge all port earn a profit on the sale of electricity that contributes to financing interest and loan repayments related to the investment and operational cost. However, in the case of Bergen Port and Helsinki Port the investment cost for a LNG-power-barge solution is higher than a shore to grid solution. The business case for a shore to grid solution is therefore a better for these two ports. In Hamburg, Rostock and Tallinn the shore to grid investment costs are higher for a shore to grid solution than the LNG-barge alternative. This, together with high total electricity charges, contributes to the LNG-barge being a better alternative. As a LNG-power-barge solution is more flexible and can be easily moved, this is also likely to increase the utilization of the power barge and also the potential profit related to the sale of electricity from the power barge.

7.3 Business case from cruise vessels' perspective

A shift from using MGO to OPS while at berth requires the ship owners to invest in on-board OPS equipment on their cruise vessels. This is assumed to involve an additional cost for the ship owner and it is therefore assumed that the ship owner must be provided with an incentive in form of reduced operational cost to be willing to switch to shore power. It may however be the case that ship owners are willing to switch to OPS for other reasons than economic reasons for example to show environmental responsibility or provide increase comfort for its passenger in the form of reduced noise and pollution.

In the business case, it is however assumed that the increased investment cost of adapting the ship for OPS must be compensated by reduced operational cost, i.e. reduced energy cost while at berth.

7.3.1 Cruise vessels traffic

As the benefit from ships owners is assumed to come from reduced energy costs while at berth, a certain number of lay time in ports with OPS is required to cover the on-board equipment cost.

AIS data from 2016 shows that over 40 percent of the cruise vessels that visit one or more of the five selected GCP ports have a total lay time of under 100 hours, while almost 90 percent have a lay time of under 200 hours. The majority of the cruise ships visits two or more of the five GCP ports, cf. Figure 7-2.

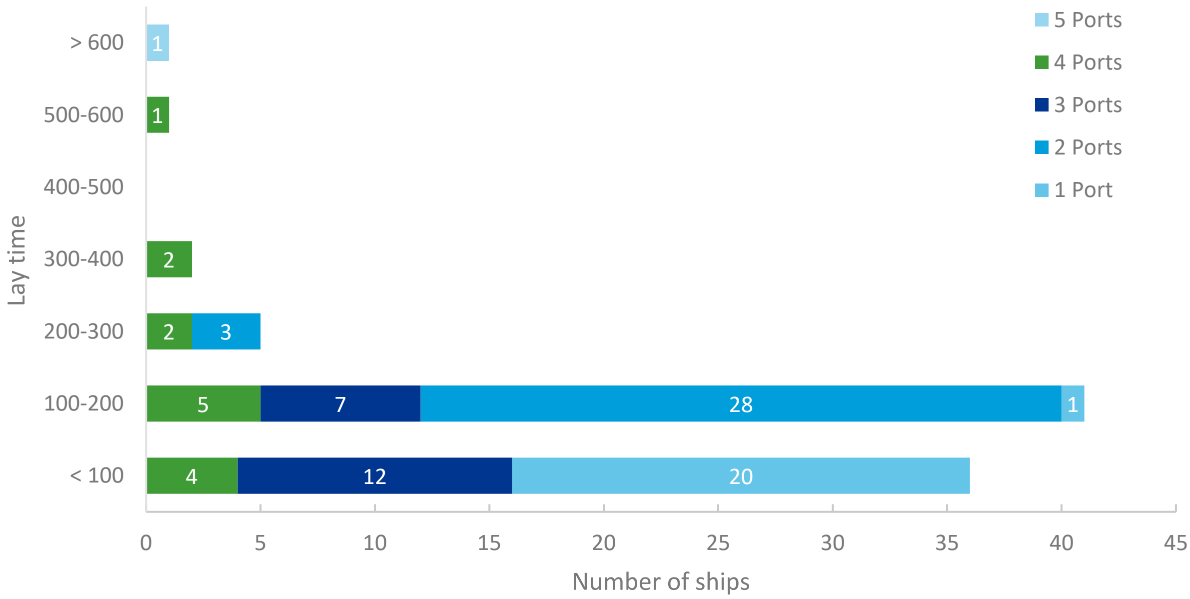

Figure 7-2. Number of cruise vessels in 2016 that visits one or more of the five selected GCP ports and their total laytime in the port(s). Source: DNV GL, 2017

To illustrate the business case of switching from MGO to OPS from the ship owner's perspective the business case analysis is conducted for two different cruise vessels operating in the North and Baltic Sea; Viking Star and The World.

Both Viking Star and The World operates internationally.

Figure 7-3 gives an overview of the 2016 route for the two cruise vessels. The size of the bobbles illustrates the lay time in each port.

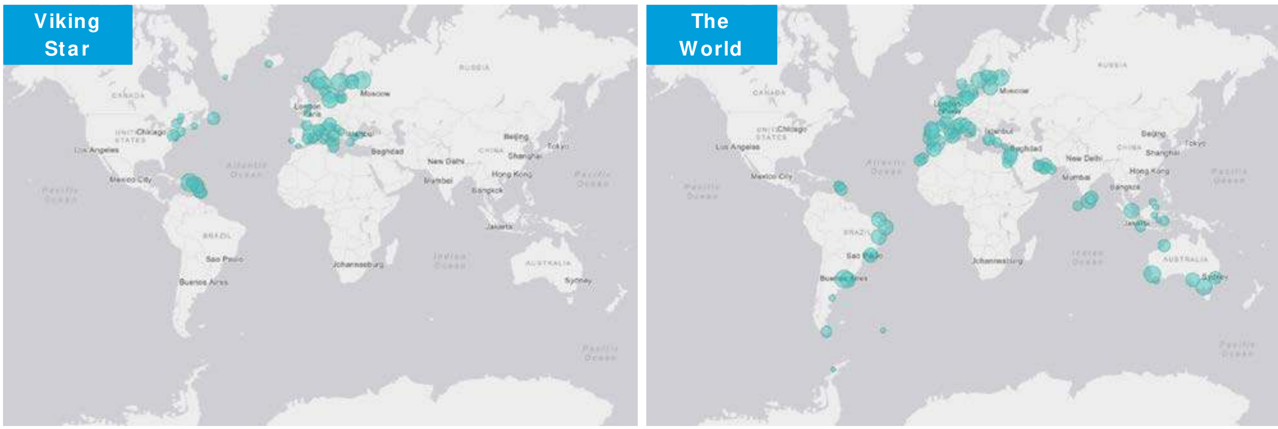

Figure 7-3. Overview of port calls Viking Star and The World, 2016

While Viking Star spends a large share of its time in ports in the North and Baltic sea, it also operates in North America and in the Caribbean. Viking Star has a relatively high number of total lay time in the five selected GCP ports, 617 hours in 2016. The World covers a larger part of the world and operates in South America, Asia, Australia and the Middle East, in addition to Europe. It follows that the cruise vessel has a significantly lower number of total lay time in the selected GCP ports, 138 hours in 2016.

Table 7-6. Vessel traffic Viking Star and The World 2016

Vessel traffic 2016	Viking Star	The World
Total lay time	3,781	3,335
Total lay time for selected GCP ports	617	138
Share of total	16 %	4 %
Average lay time in selected GCP ports	20 hrs	23 hrs

7.3.2 Cruise vessel specific assumptions

The study looks exclusively at the five ports and the business case is based on a joint analysis of these. If OPS is available also in other ports, and the cost of using OPS is lower than the cost of MGO, this will strengthen the business case of switching to OPS. In the five GCP ports it is assumed that the cruise vessels purchasing price for electricity is EUR 100 per MWh throughout the business case.

In the business case it is solely looked at the OPS investment cost. Potential loss of income due to downtime during installation of OPS equipment or loss of cabins because of OPS equipment is taking up cabin space is not included in the business case.

7.3.2.1 Energy- and electricity consumption

Based on the total lay time in the five selected GCP ports in 2016 the Viking Star’s total energy consumption while at berth is estimated to 999 mt MGO, while The World’s energy consumption is estimated to 474 mt MGO. The corresponding annual electricity consumption would be 4 GWh for Viking Star and 1 GWh for The World. Table 7-7 shows the annual lay time in each of the five ports and the corresponding MGO and electricity consumption. In the business case, it is assumed that the cruise vessels energy consumption remains at the 2016 throughout the calculation period.

Table 7-7 Annual lay time 2016, energy- and electricity consumption in the five GCP ports, Source: DNV GL AS

	VIKING STAR			THE WORLD		
2017-prices, MEUR	Annual lay time (hours)[1)]	Annual MGO consumption (ton)	Annual electricity consumption (MWh)	Annual lay time (hours)	Annual MGO consumption (ton)	Annual electricity consumption (MWh)
Bergen	351	480	1,930	-	-	-
Hamburg	-	-	-	68	90	370
Rostock	94	130	520	-	-	-
Tallinn	75	100	410	38	50	210
Helsinki	51	70	280	32	40	180
Total	**571**	**780**	**3 140**	**138**	**180**	**760**

1) Annual lay time is not adjusted for connection/disconnection time.

7.3.2.2 Investment, operation and maintenance costs

The investment cost for the cruise vessel is estimated to EUR 0.5 million. See section 3.1.1 for a description of the necessary on-board ship infrastructure. A general cost estimate based on input from suppliers of OPS equipment is applied to estimate the on-board installation costs.

The on-board OPS system is integrated into the full electrical system on-board. It is therefore assumed that the OPS system will not involve any additional operation and maintenance cost.

7.3.3 Results

Net operating costs includes interest and loan related to the on-board OPS installation and cost saving related to the use of energy. In Table 7-8 the operational business case for OPS given the Viking Star and The World vessel traffic in 2016 is presented.

Table 7-8 Operational business case Viking Star and The World with an electricity price of EUR 115 per MWh

2017 prices, MEUR	Viking Star	The World
Interest and loan repayments	-0.5	-0.5
Operation and maintenance	-	-
Energy costs	0.6	0.2
Total	0.1	-0.3
Real rate of return	3 %	<0 %

The results of the operational business case show that the profitability for the ship owner depends on a sufficient number of lay time in ports that provide OPS at a cheaper price than MGO.

The table below shows the necessary number of total lay time in ports for the investment to generate a positive return on the investment. If ship owner has a required real rate of return of the investment of 6 and 10 percent, the cruise vessels must have a total lay time of 790 and 1,065 hours per year respectively over the 20 year calculation period.

Table 7-9. Number of lay time (hours) for given rates of return

2017 prices, MEUR	Real rate of return 6%	Real rate of return 8%	Real rate of return 10 %
Interest and loan repayments Investment cost	-0.5	-0.5	-0.5
Operation and maintenance	-	-	-
Energy costs	0.9	1.0	1.2
Total	**0.4**	**0.5**	**0.7**
Lay time (hours)	**790**	**925**	**1,065**

8 SENSITIVITY ANALYSIS

To assess the effect of a change in assumptions applied in the base case scenario, three sensitivity analyses are included in this section. In the sensitivity analysis, only one factor is changed at a time, all other factors are held constant.

8.1 Increased utilization of OPS infrastructure

In the base case scenario a utilization of the OPS infrastructure corresponding to an average of 60 percent of the port calls is assumed. To reflect the effect of an increased utilization of the infrastructure it is in this case assumed that all ports calls use shore power. In the table below the result from the sensitivity analysis is presented.

Table 8-1. Sensitivity analysis 100 percent OPS share

2017 prices, MEUR	Bergen	Hamburg	Rostock	Tallinn	Helsinki
Interest and loan repayments	-11.2	-11.0	-25.6	-16.8	-13.0
Operation & maintenance	-2.6	-0.8	-1.6	-3.5	-1.1
Purchase of LNG	-20.4	-21.7	-32.2	-32.8	-12.0
Sale of electricity	36.4	11.9	21.8	32.3	10.8
Total	**2.1**	**-21.5**	**-37.6**	**-20.8**	**-15.3**

For the port of Bergen, which has a low electricity price and thereby earn a profit on the sale of electricity, an increase in the utilization of shore power will provide a positive business case. In the ports where total electricity charges, i.e. the ports purchasing price of electricity, is higher than the assumed sales price of EUR 115 per MWh, an increase in the utilization of the OPS infrastructure weakens the business case. The reason is that the ports have to cover the loss related to the additional number of hours.

8.2 Increase or decrease in total electricity charges

In this analysis, an effect of a 20 percent increase or decrease in total electricity charges compared to the MGO price is analysed. Total electricity charges consist of three elements; the electricity price, grid tariffs or tax level. An increase or decrease in total electricity charges could be a result of changes in one or several of these elements. The results are presented in Table 8-2 and Table 8-3.

Table 8-2. Sensitivity analysis 20 percent decrease in electricity price relative

2017 prices, MEUR	Bergen	Hamburg	Rostock	Tallinn	Helsinki
Interest and loan repayments	-11.2	-11.0	-25.6	-16.8	-13.0
Operation & maintenance	-1.6	-0.5	-1.0	-2.2	-0.7
Purchase of LNG	-11.9	-12.0	-15.6	-15.8	-7.4
Sale of electricity	21.8	7.2	13.1	19.4	6.5
Total	**-2.9**	**-16.4**	**29.2**	**-15.3**	**-14.7**

Table 8-3. Sensitivity analysis 20 percent increase in electricity price relative

2017 prices, MEUR	Bergen	Hamburg	Rostock	Tallinn	Helsinki
Interest and loan repayments	-11.2	-11.0	-25.6	-16.8	-13.0
Operation & maintenance	-1.6	-0.5	-1.0	-2.2	-0.7
Purchase of LNG	-17.9	-18.1	-23.5	-23.6	-11.1
Sale of electricity	21.8	7.2	13.1	19.4	6.5
Total	**-8.9**	**-22.4**	**-37.0**	**-23.2**	**-18.4**

The results show that a decrease in the electricity price of 20 percent strengthen the business cases as electricity becomes relatively cheaper compared to MGO. A 20 percent decrease in the electricity price is however not enough to provide a positive business case for a shore to grid connection in any of the ports.

A 20 increase in the electricity price weakens the business cases as the price difference between electricity and MGO becomes smaller.

8.3 Port business case for establishing OPS with a 50 percent reduction of the capacity fees and reduced taxes

In this analysis, the effect of beneficial grid tariffs and taxes is assessed. Figure 8-1 illustrates the effect on total electricity charges if all the five GCP ports are given a 50 percent discount on the capacity fee, are charged the minimum level of electricity tax (EUR 0.5 per MWh) and is exempted from national renewable energy fees. Total electricity charges given full grid tariffs and the current tax level is illustrated in the broken lines.

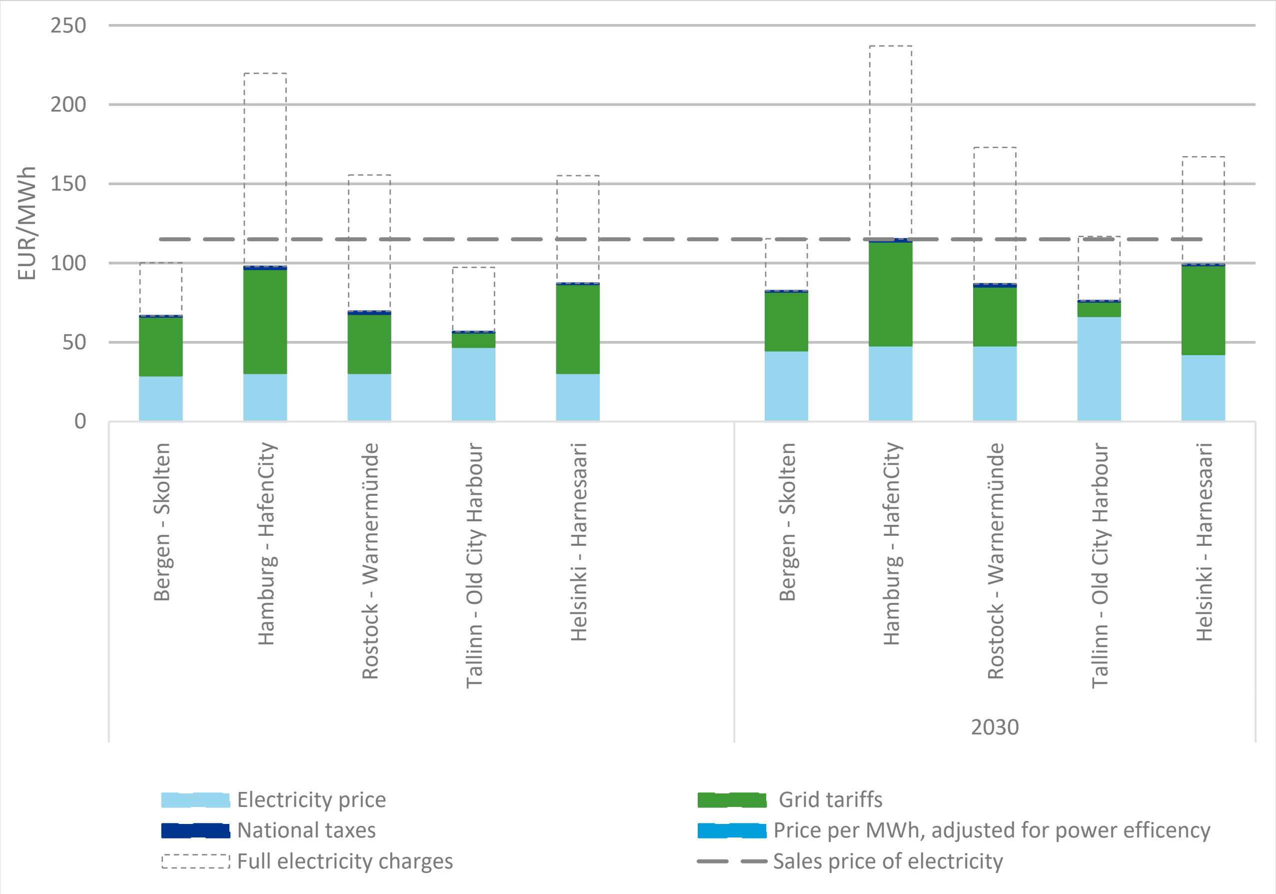

Figure 8-1. Total electricity charges in selected GCP ports subject to reduced grid tariffs and taxes, and price of MGO and LNG adjusted for power efficiency, 2019 and 2030. 2017-prices, EUR/MWh.

With 50 percent reduction of the capacity fee[9] and reduced taxes, total electricity charges fall below the cruise operators assumed willingness to pay for electricity for all ports.

The table below gives a summary of the cash flow analysis for the five ports, given the current grid tariffs and taxes level, cf. 7 and the reduced purchasing price scenario. For Bergen Port these two scenarios are the same as it is assumed that Bergen in the future will have a capacity fee reduction of 50 percent. For Bergen Port the business case with a full grid tariff is there included.

[9] Tallinn Port only subject to a consumption fee. A 50 percent reduction in the consumption fee is therefore assumed for Tallinn Port.

Table 8-4. Operational business case, base case and reduced capacity fee and taxes

2017 prices, MEUR	Bergen		Hamburg		Rostock		Tallinn		Helsinki	
	Base case	**Full tariff**	**Base case**	**Red. price**	**Base case**	**Red. price**	**Base case**	**Red. price**	**Base case**	**Red. price**
Interest and loan repayments	-11.2	-11.2	-11.0	-11.0	-25.6	-25.6	-16.8	-16.8	-13.0	-13.0
Operation & maintenance	-1.6	-1.6	-0.5	-0.5	-1.0	-1.0	-2.2	-2.2	-0.7	-0.7
Purchase of electricity	-14.9	-21.1	-15.1	-1.3	-19.5	-9.2	-19.7	-14.4	-9.3	-5.4
Sale of electricity	21.8	19.0	7.2	6.2	13.1	11.4	19.4	16.8	6.5	5.6
Total	**-5.9**	**-14.9**	**-19.4**	**-.6.6**	**-33.1**	**-24.4**	**-19.2**	**-16.4**	**-16.5**	**-13.5**
Min. investment support	**5.9**	**14.9**	**19.4**	**6.6**	**33.1**	**24.4**	**19.2**	**16.4**	**16.5**	**13.5**
Share of investment	53 %	133 %	177 %	60 %	127 %	95 %	115 %	98 %	128 %	104 %

The scenario with reduced total electricity charges shows even though the need for investment support is reduced significantly there is still a substantial need for public funding for the port to pay its ongoing costs related to a shore to grid OPS investment.

8.4 Other uncertainties

To construct a business case analysis a line of assumption has been applied. There is substantial uncertainty related to several of these assumption, including:

The number of ships arriving and using shore power: The business cases are based on vessel traffic in 2016 and it is assumed that the number of port calls and average lay time remains constant throughout the calculation period. The development in vessel traffic is uncertain. An increase in the number of port calls or lay time that use shore power will increase the utilization of the OPS facility. The sensitivity analysis in section 8.1 is included to reflect the effect of an increase in the utilization of shore power.

Investment costs: The investment costs are based on input from suppliers, port authorities and grid companies. The investment costs reflect the current situation and could change with time. Grid connection costs are for example highly dependent on available grid capacity which change over time depending on local demand and the need for grid reinforcement.

Fuel prices: There is substantial uncertainty related to the development of fuel prices. An increase or decrease in the price of MGO and LNG will affect the business case results. The sensitivity analysis in section 8.1 is included to reflect the effect of an increase or decrease in the price difference between total electricity charges and the price of MGO.

Other forms of energy: There are other forms of energy than shore power that can replace fuel oil such as LNG burned directly on the boat, liquid biogas, hydrogen, methanol and ethanol. In the shorter-term LNG and methanol are possible substitutes for shore power, while hydrogen may be a competitive alternative in the longer term. Alternative forms of energy contribute to uncertainty related to the period over which the investment in shore power can be amortised.

10 KEY ISSUES FOR A BUSINESS PLAN FOR OPS

The Green Cruise Port (GCP) is a project consisting of port authorities from around the Baltic Sea and neighbouring North Sea. GCP shall work to make the Baltic Sea Region more innovative, more sustainable and better connected, from perspective of cruise tourism. The promotion of low emission solutions, including OPS, is well aligned with the GCP ambitions.

Based on the findings in this report, there are some key elements that are relevant to follow up in GCP as to see barriers to OPS being lowered and opportunities being captured. OPS for cruise ships can be supported and more likely be achieved through a combined set of measures for ships, ports, regulators and incentive providers. To see a large-scale development and application of OPS for cruise vessels the business cases for vessels and port operators need to be positive. This can be supported by avoiding OPS carrying cost of other policy initiatives and by allowing the cruise industry to be remunerated for the contribution to positive externalities such as reduced pollution and noise.

<u>Recommendation for continued effort on OPS for cruise vessels and ports:</u>

1. **Cooperation and coordination between ports and ship owners**

   To facilitate the development and use of shore power there is a need for cooperation and coordination between ports and ship owners to ensure that the best solutions are promoted. GCP partnerships and arenas such as the Green Port Day arranged by GCP in Bergen in November 2017, facilitate discussion and sharing of experience that is valuable in the work to promote OPS a solution for cruise vessels. GCP should continue its efforts in this regard.

2. **Work for development of a legal framework that promote the use of OPS**

   In the 2014 Clean Power Transport Directive /D02/, EU requires all trans-European core ports to provide shore-side electricity, and the directive clearly indicates that OPS is considered an important way forward to reduce emissions from transport. GCP should work to highlight the benefits of OPS to contribute to the develop of legal frameworks that promote OPS at a national and EU level. An example in this regard is the EU Tax Directive that allows for a minimum tax on electricity of EUR 0.5 per MWh for business use. Norway and Sweden have already implemented a minimum tax on electricity related to the use of OPS. GCP should work to influence national authorities in other countries to do the same. As long as OPS is creating societal benefits in the form of reduced pollution, it seems less logical that its implementation is hampered by taxation.

3. **Have the use of onshore power exempted from renewable obligation cost**

   The purpose of support schemes for promotion of renewable electricity is to support a transition to more use of renewables and less use of fossil fuels. These schemes are usually financed through additional charges on the use of electricity. OPS is another way to reduce fossil fuels, and through electrification it opens for use of renewable energy from sources such as wind, solar and hydro power. High national taxes or obligation payments due to renewable priority schemes makes electricity more expensive, and likely more expensive than the use of MGO. GCP should work to have OPS exempted from renewable obligation fees/charges.

4. **Work to settle unclear issues**

   The interviews with ports and the discussion during the Green Port Day conference arranged by the GCP showed that there are certain elements related to the onshore power supply standard that may be misunderstood, such as the requirement related to the size of the transformer. These are elements that could increase the total investments costs for establishing OPS. GCP should work to clarify questions and uncertainties with respect to standards and OPS solutions.

5. **Flexible discounted grid tariffs.**

As illustrated by the business case, Bergen Port has relatively low total electricity charges, influenced by lower grid tariffs. Bergen Port is subject to an interruptible supply tariff which allows the port to make use of electricity when there are no capacity constraints in the local grid. In case of capacity constrain, the local grid operator can disconnect Bergen Port. In compensation Bergen Port is currently given a 90 percent reduction in the capacity fee. The GCP port should work with national regulators and grid companies to explore similar flexible grid tariff solutions or other mechanisms which can contribute to reduce the cost of electricity for OPS.

6. **Work with national authorities to find instruments that provide investment support for OPS as to overcome barriers and initial threshold for OPS**

The investment costs for OPS in cruise ports are substantial. The environmental benefit of a OPS solution can however be very high, especially the local benefit in densely populated cities. GCP should work to highlight the environmental benefit of OPS and to have national authorities capture such positive externalities through instruments that provide investment support for OPS. Initial periods of support can help to drive technology developments as well as a wider application of OPS can support the business case for the ship operators.

7. **Promote the benefits of OPS to ship owners**

A switch from MGO to OPS give ship owners an opportunity to act to directly reduce emissions and in this show to their passengers and regulators that they support a long term sustainable cruise traffic development within the region. This makes it easier for authorities to promote further development of cruise industry, and it can be used as a marketing aspect to attract more cruise passengers. As OPS is about to be established in several ports, GCP should work with ship owners to illustrate the long term benefits of OPS in the relevant harbours.

8. **Work on bridging the development**

The establishment of OPS has higher costs in certain ports where there are grid capacity constraints or limitation to use of harbour. The use of LNG-barge to supply OPS is an alternative to stationary OPS solutions. Equally, working with suppliers to find flexible systems such as container based solutions or easy remodelling of ship power systems would help to reduce the barrier to make OPS being applied.

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APPENDIX A BUSINESS CASES

A1 Bergen Port

A2 Hamburg Port

A3 Rostock Port

A4 Tallinn Port

A5 Helsinki Port

Appendix A1 Bergen Port

The Port of Bergen is an intermunicipal company, owned by the counties Askøy, Austrheim, Bergen, Fedje, Fjell, Lindås, Meland, Os, Radøy, Sund and Øygarden, together with Hordaland county authority. The port is used by cruise vessels, oversea ferries, domestic ferries, cargo and leisure boats. Cruise vessels are located at Skoltegrunnskaien (Skolten) and in Jekteviken, cf. Figure. In Bergen Port the business case focus on the Skolten area which consists of three quays; Skolten North, Skolten South and Bontelabo 2.

Figure 1. Bergen cruise port. Source: Cruise Norway, 2017

In the Skolten area there is today one onshore power supply connection point. This is a low-voltage connection point (440V or 690V), used mainly to supply power for offshore ships. As this is a low-voltage connection point it not suitable for supplying OPS to cruise vessels. For cruise vessels to be OPS while in berth at Skolten it is necessary to establish a new high-voltage installation. According to Bergen Port, the existing low-voltage connections will be replaced if a high-voltage connection is established.

Skolten business case assumptions

In this section port specific business case assumptions are presented in this section. For key input and assumption relevant for all business cases cf. section 6.

Energy- and electricity consumption

In 2016, 71 cruise ships called at the three quays in the Skolten area (Skolten North, Skolten South and Bontelabo 2). The total number of port calls was 249 and the average lay time for cruise vessels were 12 hours. Based on input from Bergen Port, it is assumed that the number of port calls will remain stable at around 250 over the calculation period.

During the cruise season, all three quays in the Skolten area are in use. Assuming an average, individual capacity demand of 5.5 MW per vessel, the annual electricity consumption potential is estimated to 15.8 GWh in 2016. The corresponding annual MGO consumption is 3,950 mt. The annual energy consumption is based on 250 port calls a year and an average lay time of 12 hours. These assumptions are applied throughout the calculation period.

On average over the calculation period, it is assumed that 60 percent of the port calls will use OPS while at berth. This represent an annual electricity consumption of 9.5 GWh. The corresponding annual MGO consumption is 2,370 mt.

Table 1. Annual MGO and electricity consumption Bergen Port - Skolten

Assumptions	
Port Calls:	250 per year
Average Lay Time:	12 hours
Connection/Disconnection Time	30 minutes
Average capacity demand:	5.5 MW per ship
Share of OPS:	Average of 60 % over the calculation period

Consumption	**MGO**	**OPS**
Total annual energy consumption	3,950 mt	15,810 MWh
60 percent of annual energy consumption	2,370 mt	9,490 MWh

Without additional investments, it is not expected any alternative use of the OPS infrastructure in the off-cruise season. Bergen port has however informed that the port has plans to also establish new low-voltage connections points so that the high-voltage OPS connection for cruise vessels can be used for offshore and other vessels in the off-cruise season. This will increase the utilization of the OPS installation. In the business case, it is not assumed any alternative use of the OPS infrastructure in the off-cruise season.

Investment costs

Investment costs can be split into grid connection costs and shore power installations, including connection equipment on the quay. This section includes a description of the grid infrastructure in the Skolten area and the necessary investment to establish OPS at Skolten.

Grid connection

Transmission of electricity in Norway is officially divided into three network levels; the central grid, the regional grid and the distribution grid. The distribution grid is again divided into two levels; high voltage distribution level and low voltage distribution level. An overview of the grid infrastructure in the Bergen area is given in Figure 2. The grid connection point for the shore power facility will be at the high voltage level in the distribution grid.

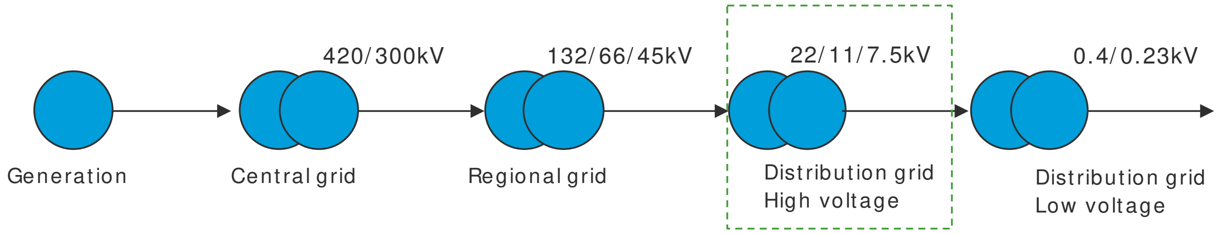

Figure 2. Grid infrastructure in the Bergen area (NO5) [10]

The calculated capacity for cruise ships is relatively high. The Bergen area has two exchange point with the central grid. The capacity need from cruise ships in Bergen Port is limited in the winter period when other load on the grid and the capacity demand is at its largest. The largest capacity need from cruise vessel will arise in the spring, summer and autumn period when the electricity production in the area is high. Since the cruise season coincide with the period when the electricity production in the areas is high, the capacity demand from OPS is not expected to be limited by the constraints in the regional or central grid.

Bergen city, including Bergen Port, is currently supplied by a 45 kV transmission line. Available capacity in the regional grid is sufficient for establishing OPS in Bergen Port. However, due to an increase in

[10] One 300 kV transmission line from Fana to Kollsnes is part of the regional grid, but is expected to be transferred to Statnett and part of the central grid during 2018.

capacity demand in the city area, driven by OPS among other things, the grid owner BKK Nett AS will replace the 45 kV transmission line with a new 132 kV line and new 132kV/11kV transformers. The upgrade of the transmission line is expected to be completed by 2025. The upgrade will increase the capacity in the city area.

If OPS for cruise vessels shall be established at Skolten, the incoming substation supplying the local area (Koengen substation) must be expanded as well as the local grid in to the Skolten area. The necessary investments include expanding the incoming substation with a 31.5 MVA transformer and the laying of new 11 kV high-voltage cables from the substation to the Skolten area. Bergen Port's investment costs related to the expansion of the substation is estimated to be in the range of EUR 0.8-1.0 million and the laying of cables is estimated to around EUR 0.2-0.3 million /D58/. Based on this information provided it is assumed in the business case a grid connection cost of EUR 1.1 million.

Shore power installations

Bergen Port has provided port specific information related to the cost of establishing OPS at Skolten and these estimates are applied in the business case. The cost estimate includes three connection points, one at each of the three quays at Skolten. Necessary equipment includes a new substation with transformers, frequency converters and cable culverts and cables.

Summary of construction costs

Table 2 summaries investment costs applied in the business case for establishing OPS three connection points at Skolten. The cost estimates do not include planning or contingencies.

Table 2. Investment cost three shore-to-ship connection points in Bergen Port - Skolten[11]

2017-prices, MEUR		
Grid connection	Expansion of substation and new 11 kV cables	1.1
Shore power installations	Transformer station (incl. housing)	10.2
	Frequency converters	1.4
	Cabling	3.6
	Cable management systems	2.0
Total investment costs		**11.2**

Total electricity charges

The cost of electricity can be split into three elements; price of electricity, grid tariffs and taxes and levies. This section gives a description of the elements that makes up the total electricity price in Bergen Port. The total charge will develop over the calculation period, depending on market developments and regulations. In the business case, it is assumed the electricity price will develop according to Statnett's long term price forecast. Grid tariffs and taxes and levies are held constant throughout the calculation period.

Electricity price

The price for electricity in Norway is mainly determined by supply and demand of electricity in the Nordic electricity market. Grid congestions (capacity constrains) also effect the electricity price. Norway is divided into five price areas to reflect grid congestions. Bergen Port lies in the West-Norway price area (NO5). Figure 3 shows the average monthly system price[12] and the spot price in the Bergen area from

[11] Investment costs originally given in NOK. An exchange rate of 9,0 have been applied.

[12] The system price is the unconstrained market reference price calculated without any congestion restrictions.

January 2013 to August 2017. The electricity price in Bergen follows the system price closely, but is in general a bit lower than the system price.

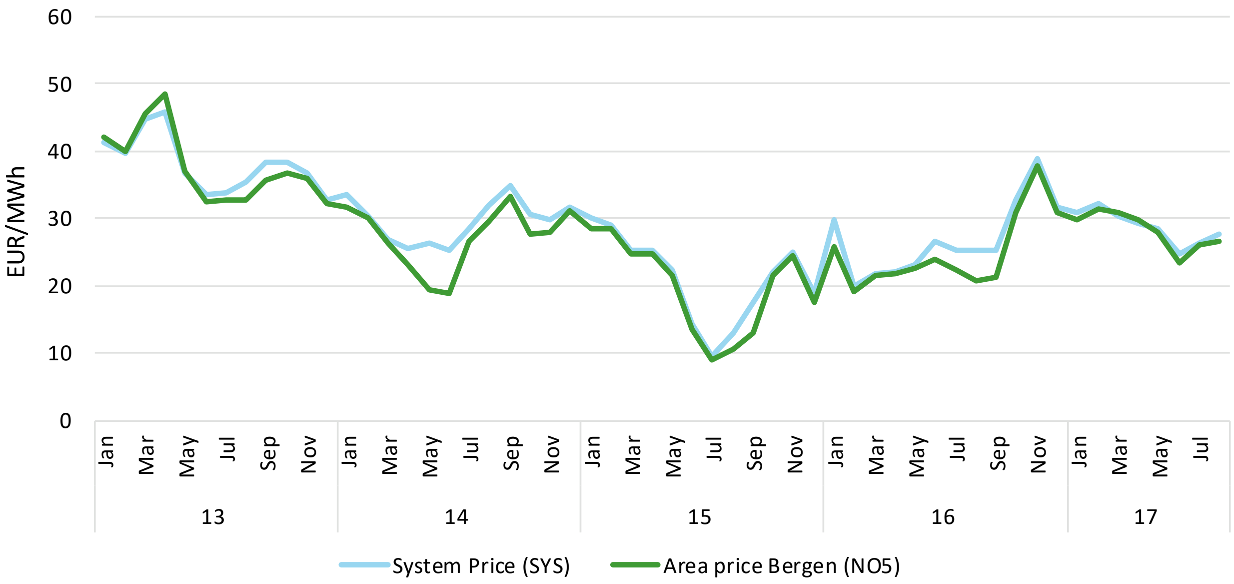

Figure 3. Average monthly system price (SYS) and spot price in the Bergen area (NO5), Jan-2013 to Aug-2017. Current prices, EUR/MWh. Source: Nordpool, 2017

The electricity price is lower in the summer months and higher in the winter months. The average price in the Bergen area in the cruise season (April to October) in the period 2013 to 2017 was EUR 23.45 per MWh, while the average price in the 2016 cruise season was EUR 23.35 MWh. The price level in 2016 is considered to best reflect the current price level. The average 2016 electricity price during the cruise season is therefore applied as a reference for the current price, together with Statnett's long-term price forecast for Norway to estimate the future electricity price, cf. section 6.5.

Grid tariffs

In Norway, like in other places in Europe, the maximum allowed revenue of the local grid owners (DSO) is regulated. However, the method in which a DSO calculates its tariffs is for a large part to be determined by the DSO – as long as the method is considered fair, transparent, and non-discriminatory, and the total revenue is not higher than what the regulator allows, the DSO is allowed to set its own tariffs. In practice, this means large differences are observed between DSOs with regards to how the grid tariff is calculated.

The local grid owner in the Bergen area is BKK Nett AS. BKK Nett uses several elements in its calculation of grid tariff. An overview of the current stated tariffs for connection at the nearby 11-22kV substation per 1 July 2017 is provided in the table below. As the cruise season is mainly in the summer period summer rates are applied in the business case.

Table 3. Grid tariffs, electricity consumption 11kV – 22kV substation[13]. Source: BKK Nett, 2017

2017-prices, EUR	Original fee		Flexible consumption fee	
Fixed fee (monthly)	-	EUR	-	EUR
Capacity fee (monthly)				
- summer	3.71	EUR/kW	0.37	EUR/kW
- winter	5.14	EUR/kW	0.51	EUR/kW
Consumption fee (per kWh)[14]				
- summer	0.0021	EUR/kWh	0.0021	EUR/kWh
- winter	0.0023	EUR/kWh	0.0023	EUR/kWh

Due to a constrained grid situation in the port area in Bergen, Bergen Port has today a grid tariff for flexible consumption. This means that the grid owner can cut the supply of electricity to the port if needed. In compensation, the port is given a 90 percent reduction in the capacity fee. The grid owner has confirmed that they can, under the current regulation, offer Bergen Port a grid tariff for flexible consumption also after the grid situation in the area is improved. They have however stated that the capacity fee reduction in the future will not be as high as it is now. In the business case, it is assumed that Bergen Port will only be charged 50 percent of the capacity fee throughout the calculation period.

Taxes and levies

In Norway, electricity consumption used for OPS is currently subject to the following taxes and levies:

- Electricity tax: A tax on the use of electricity. From 1 January 2016, commercial vessels are subject to the minimum tariff of 0.5 EUR/MWh[15].
- Renewable electricity fee: End users subject to electricity tax must contribute to the financing of the electricity certificate scheme. The electricity certificate scheme is a support scheme for development of new electricity based on renewable energy sources. All end must each year purchase a certain about of electricity certificates, corresponding to a specific percentage of their electricity consumption. The specific percentage is for 2017 set to 13.7 percent and will increase to around 19.5 percent in 2020, before it is reduced towards 2035. To calculate the electricity certificate cost SKM[16] spot and forward prices for electricity certificate and the annual quota obligation are applied.
- Enova fee: Non-household consumers are charged a fee of 89 EUR per year[17] that contributes to the financing of Enova. Enova is a state-owned enterprise with the objective to promote a shift to more environmentally friendly consumption and production, as well as development of energy and climate technology.

In the business case, it is assumed that the electricity tax and Enova fee remains at the current level throughout the calculation period. In line with the current political consensus it is assumed that no new renewable support scheme is introduced after 2021, when new renewable electricity production is no longer entitled to support under the elcertificate scheme.

[13] Summer is the period 1 April to 30 September and winter the period 1 October to 31 March.

[14] The consumption fee for connection to a salve station is connection specific. The current stated fee for a general connection to the 11kV-22kV network is therefore used.

[15] Minimum tariff according to Energy Tax Directive, set to 0,48 NOK/kWh.

[16] SKM – Svensk Kraftmäkling is the largest trader of electricity certificates. Forward prices are provided for the years until 2022. From 2023 and onwards we have assumed the certificate price to be equal to the 2022 forward price.

[17] The annual Enova fee for business consumers is 800 NOK/year. A NOK/EUR exchange rate of 9.0 is applied.

National and port specific regulations and incentives

The Norwegian parliament want to see policies that promote and facilitate an increase use of OPS in Norwegian ports /D23/. In line with this intention, the Government has introduced tax reductions and different instruments to promote the development and use of OPS:

- *Reduced tax on electricity.* From 1 January 2016 commercial vessels are subject to the minimum tariff of 0.5 EUR/MWh[18]. The general electricity tax in Norway is currently 18.1 EUR/MWh[19].
- *Enova investment support for establishment of OPS*. Government owned ENOVA[20] is providing financial support related to the establishment of OPS in Norwegian ports /D08/. Ports or other parties that want to establish OPS in Norwegian ports are eligible for support. Allocation of support is provided based on an application process. A precondition for support is that OPS is established according to the current OPS standards and must be operated for at least three years. The support is limited to 80 per cent of project costs. Enova also gives financial support to ships that invest in climate friendly solutions and which have their main share of operations in the Norwegian economic zone or call on a fixed basis in Norwegian ports. The support is limited to 30 percent of the additional cost of the climate friendly solution compared to traditional alternatives.
- *The NOx-fund.* The objective of the fund is to reduce NOx-emissions. The fund provides support to OPS related investments in ships and ports that gives an actual reduction in NOx-emissions. The support is granted according to reported reduction in NOx-emissions that can be allocated to the investment. The current support is approximately EUR 27 per kg reduced NOx (250 NOK/kg). The support is limited to 80 percent of the investment costs. Investments that are fully or partly financed with other forms of governmental support, for example from Enova, do not qualify for support from the NOx-fund.

In addition to the national incentives, Bergen Port gives an “Environmental discount” on port charges for vessels registered with the Environmental Ship Index (ESI), introduced by the World Ports Climate Initiative. The discount includes a 20 percent reduction on the port-charge for vessels that can document that they have an ESI score over 30 and a 50 percent reduction for vessels with an ESI score over 50. The discount is calculated based on charges payable after the deduction of any liner reductions. Environmental discount incentives given by the port strengthens the business case for the cruise vessels. At the same time, it increases the cost for the ports as it represents a loss in potential port charges.

Results

The operation of the OPS system can be financed by a public company taking a loan to cover the investment costs, after which income from the sale of electricity will contribute to finance the ongoing costs including interest and loan repayments. Alternatively, the company can receive public investment support to cover the necessary investment costs. A combination of public investment support and loan financing is also possible.

The calculations assume the investment costs are financed through a 20-year annuity with an annual interest rate of 2 percent per year. All figures are given in fixed 2017 prices. The expected increase in the general price level (inflation) is assumed to be 2 percent per year over the calculation period. As

[18] Minimum tariff according to Energy Tax Directive, set to 0,48 NOK/kWh.

[19] The general electricity tax for 2017 is 16,32 NOK/kWh. A NOK/EUR exchange rate of 9.0 is applied.

[20] Enova is financed partly by electricity levy and partly by state funding,

interest rates are the same as expected inflation, the real interest rate is zero percent and the cost of interest and repayments in 2017 prices will be the same as the actual investment cost. If the interest rate is higher than the inflation, this will give a positive real interest rate and the direct financed business case would have a better result than the debt-financed business case. Visa versa, if the interest rate is lower than the inflation the debt-finance business case would come better out as the real interest rate will be negative.

From 2019 the onshore power facility will be in operation. It is assumed that the port will not pay interest or instalments during the construction period. A presentation of the cash flow in the operational period is presented in the figure below.

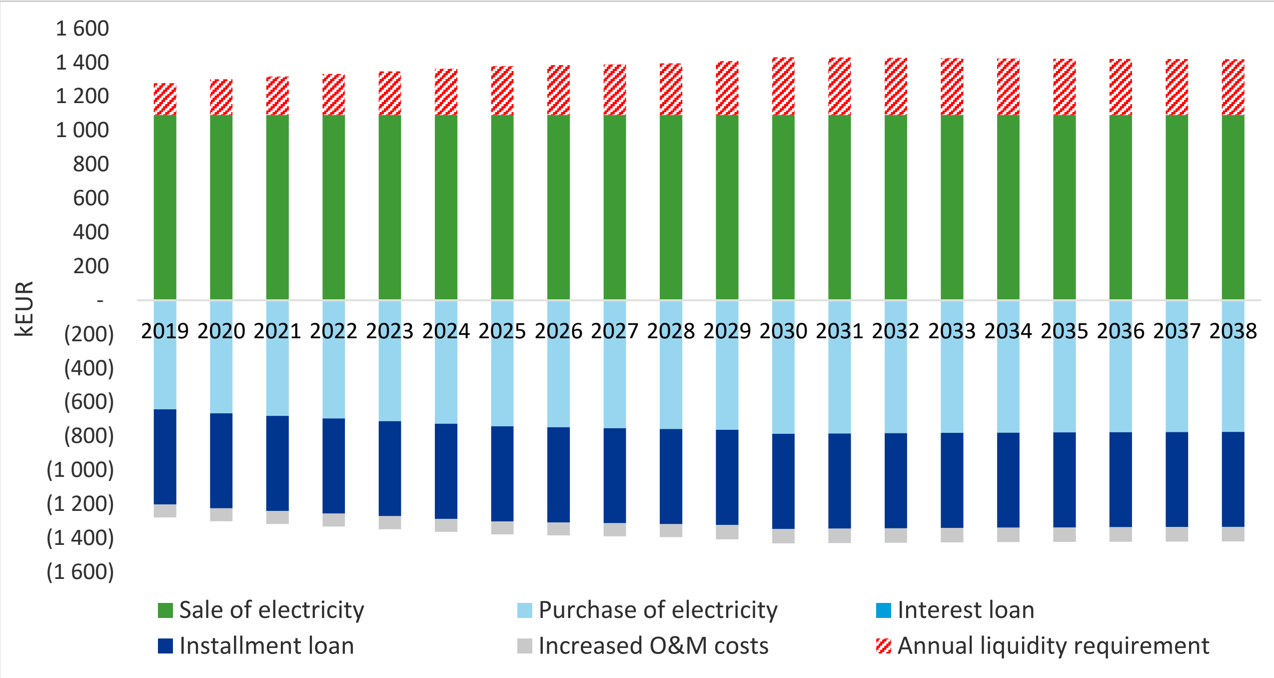

Figure 4. Cash flow analysis OPS in Bergen Port – Skolten. Operational period 2019 to 2038, kEUR 2017-prices.

The port's income potential through sale of electricity is calculated based on a sales price of electricity of EUR 115 per MWh. The port's cost of purchasing electricity (total electricity charges) is given by the light blue area, while the dark blue area shows the ports annual interest and loan repayment. The grey column illustrates the port's increased operation and maintenance related to the OPS facility. The red, hatched area indicates the port's annual need for liquidity to cover its ongoing costs.

As the cost of electricity in Bergen is lower than the cost of using MGO, cruise vessels are expected to be willing to accept an electricity price that is higher than the port's purchasing price, and the port will receive a profit from the sale of electricity. The profit will contribute to recover part of the cost of the OPS investment. The operational business case calculations for Bergen Port with a debt-financed investment is presented in Table 4.

Table 4. Operational business case for OPS investment in Bergen Port

2017-prices, MEUR	
Instalments and interest (loan repayments)	-11.2
Operation and maintenance	-1.6
Purchase of electricity	-14.9
Sale of electricity	21.8
Total	**-5.9**
Minimum investment support	**5.9**

The alternative to finance the investment through a loan, is that the investment cost is financed directly. The advantage of this is that the risk that there will not be sufficient cash to pay the ongoing loan repayment for the OPS investment is eliminated. The result is the same as for a debt-financed investment since the interest rate and inflation is assumed to be the same throughout the calculation period.

To assess the effect of changes in some of the assumptions applied in the business case three sensitivity analyses are included in section 8.

Appendix A2 Hamburg Port

Hamburg Port Authority is responsible for development and maintenance of the port infrastructure in the Port of Hamburg. The port is the largest port in Germany and the leading foreign trade hub. Hamburg is also a major cruise destination. The port is one of Europe's largest ports of call for cruise passengers traveling the Atlantic, Norwegian and/or Baltic Seas. The port has three passenger terminals for cruise ships; Hamburg Cruise City Centre Altona (HCC-Altona), Hamburg Cruise City Centre (HCC-HafenCity) and Hamburg Cruise Center Steinwerder (HCC-Steinwerder).

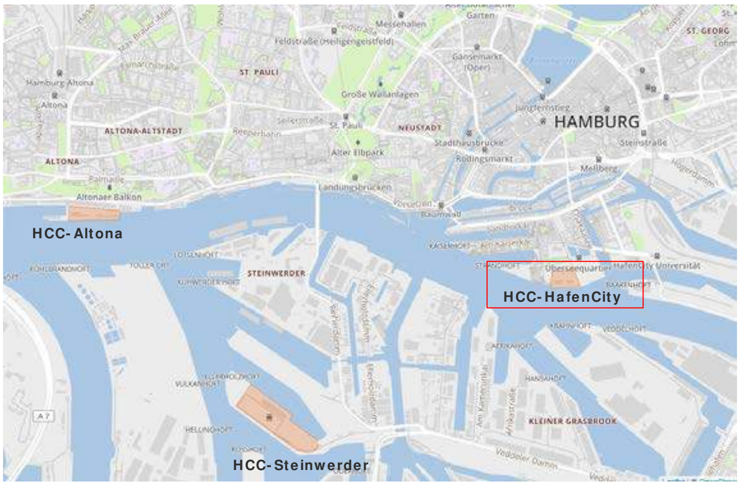

Figure 5. Overview of Hamburg Port

HCC-Altona, located west of Hamburg city and has a shore to grid OPS system in place. HaftenCity is located close to the city centre and has a LNG-power-barge solution in place that supply shore power to cruise vessels during summer. HCC-Steinwerder is located on the south side of Elbe, opposite of Hamburg city centre. Steinwerder was established as a temporary cruise terminal in June 2015 and is intended to be used only for 15 years.

As the HCC-Altona terminal already have an OPS system in place and HCC-Steinwerder is a temporary terminal, the business case focus' on the HafenCity terminal. On 18 September 2017 the German Senate indicated that an OPS system will be established in HafenCity /D59/.

HafenCity business case assumptions

In this section, port specific business case assumptions are presented. For key input and assumption relevant for all business cases cf. section 6.

Energy and electricity consumption

In 2016, 25 cruise ships called at the HafenCity terminal. The total number of terminal calls was 65 and the average lay time for cruise ships was 15 hours.

HafenCity terminal will be under reconstructed in the period 2017-2021. During this period, there will only be one berth available for cruise vessels. To be able to compare the business case for HafenCity with the other ports the same calculation period is applied and it is assumed full capacity during the whole period.

Assuming an average, individual capacity demand of 5.5 MW per vessel, the annual electricity consumption potential is estimated to 5.2 GWh in 2016. The estimated electricity consumption is based on 65 port calls a year and an average lay time of 15 hours. The corresponding annual energy consumption based on MGO is 1,300 mt. These assumptions are applied throughout the calculation period. As the terminal is a dedicated cruise terminal is it not expected any alternative use of the OPS infrastructure in the off-cruise season.

A gradual increase in the number of vessels adapted for OPS during the calculation period is expected. On average over the calculation period, it is assumed that 60 percent of the port calls will use OPS while at berth. This represent an annual electricity consumption of 3.1 GWh. The corresponding annual MGO consumption is 780 mt.

Table 5. Annual MGO and electricity consumption Hamburg Port - HafenCity

Assumptions	
Port Calls:	65
Average Lay Time:	15 hours
Average capacity demand:	5.5 MW per cruise vessel
Connection/Disconnection Time:	30 minutes
Share of OPS:	60 percent over the calculation period

Consumption	**MGO**	**OPS**
Annual energy consumption	1,300 mt	5,180 MWh
60 percent of annual energy consumption	780 mt	3,110 MWh

Investment costs

The investment costs break down into grid connection costs and shore power installations, including connection equipment on the quay. This section includes a description of the grid infrastructure in the HafenCity area and the necessary investment to establish OPS at HafenCity Terminal.

Grid connection

Transmission of electricity in Germany is officially divided into two network levels; the transmission grid and the distribution grid. The distribution grid is again divided into different voltage levels. The grid infrastructure setup is illustrated in the figure below.

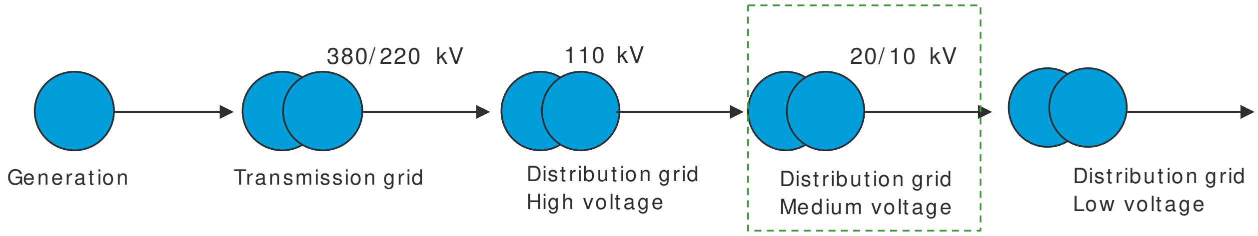

Figure 6. Grid infrastructure in the Hamburg area

A lot of infrastructure and both the cruise and cargo ports are located in the centre of Hamburg. The demand for electricity in the area is very high, with most of the supply covered by two nearby coal fired power plants. The local grid in Hamburg is designed to handle the high demand with a meshed grid with a total of 53 substations.

The local 10 kV transmission line, as well as 110 kV distribution grid, in Hamburg is owned and operated by "Stromnetz Hamburg GmbH". The port and surrounding area are supplied by the 110/10 kV substation "HafenCity". The substation was commissioned in June 2013 and was designed with a 30 MVA overcapacity to meet future demand from connection of an OPS facility at HafenCity cruise port. Assuming an electrical load per cruise ship of around 7 MW the installation of up to two OPS systems at HafenCity port is considered feasible.

The linear distance from the cruise ship terminal to the nearest connection point (110/10 kV substation HafenCity) is approximately 0.9 km. The cost of laying and installing cables is estimated to be 300 EUR/meter, considering the difficult soil conditions in the area (city area, surrounding water). Multiplying the distance with a factor of 1.5 for nonlinear routing gives an approximately cable distance of 1.5 km and a cable cost of EUR 0.45 million. An additional costs of EUR 50,000 related to planning and permit, results in a rough grid connection cost of EUR 0.5 million.

Shore power facility

For Hamburg Port, the general cost estimate for a shore power facility, which is based on input from suppliers is, applied.

Summary construction costs

Table 66 summaries the investment costs for establishing OPS at two quays at HafenCity terminal. The cost estimate of establishing OPS at HafenCity is around EUR 10 million. This is in line with our cost estimate. The cost estimates do not include planning or contingencies.

Table 6. Investment cost for two shore-to-ship power connection in Hamburg Port - HafenCity

2017-prices, MEUR		
Grid connection	Grid investment	0.5
Port facility and equipment	Transformer station (incl. housing)	1.3
	Frequency converter	3.6
	Cabling	3.2
	Cable management system	2.4
Total investment costs		**11.0**

Total electricity charges

This section gives a description of the different elements that constitute the electricity price in Hamburg Port. The price of electricity over the calculation period will however vary depending on market developments and regulations. The total charge will develop over the calculation period, depending on market developments and regulations. In the business case, it is assumed the electricity price will develop according to Statnett's long term price forecast. Grid tariffs and taxes and levies are held constant throughout the calculation period.

Price of electricity

Germany consist of only of one price area. This means that the spot price of electricity is the same throughout Germany. End consumers in Germany are free to choose their power supplier. Smaller end consumer normally purchase power from a power supplier, while larger end consumer often purchase power directly in the wholesale market. Figure 7 shows the production price of electricity in Germany from 2013 to 2016. The average price of electricity has in this period been reduced with over 40 percent, from EUR 60 per MWh in 2013 to EUR 42 per MWh in 2016.

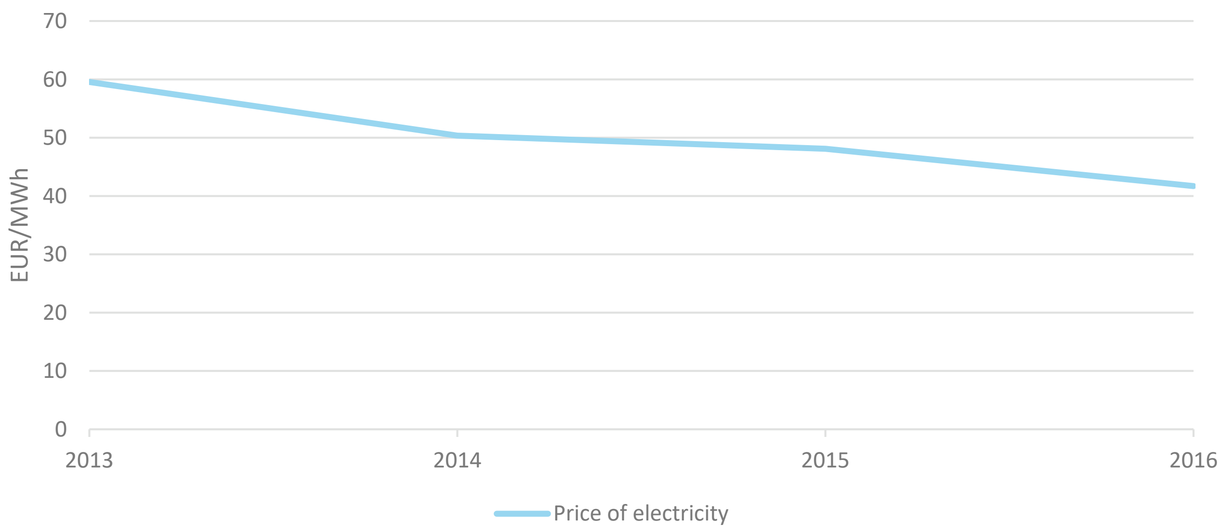

Figure 7. Average annual price of electricity for industrial consumers with electricity consumption 2 000 MWh to 20 000 MWh, Germany 2013-2016. Current prices, EUR/MWh. Source: Eurostat, 2017

According to Hamburg Port, the port purchase electricity from the local power company Stromnetz Hamburg GmbH and currently have a fixed price contract with a duration of two years. In the business case, the current spot price on electricity is used as a reference and Statnett's long-term price forecast for Germany to estimate the expected electricity price over the calculation period.

Grid tariffs

The maximum allowed revenue of the local grid owners in Germany is regulated, as is the case in many other places in Europe. In Germany, the regulator sets a revenue cap for a time period of five years for each grid operator. Based on the value set by the regulator, the grid operators determine their grid tariffs. An overview of the current annual tariff for electricity consumption at a voltage level of 10 kV is provided in table 7.

Table 7. Grid tariff, electricity consumption at 10 kV <2500h/a in Hamburg. Source: Stromnetz Hamburg, 2017

2017-prices, EUR		
Fixed fee (annual)	-	EUR
Capacity fee (annual)	23,360	EUR/MW
Consumption fee (annual)	27.40	EUR/MWh

Taxes and fees

In German, electricity consumption used for OPS is currently subject to the following taxes and levies:

- Electricity tax: A tax on the use of electricity. The tax is fixed by law and is EUR 20.5 per Mwh (2.05 Ct/kWh) for industry end consumer
- Renewable energy source fee (RES fee): All end users must contribute to the financing of the integration of renewable energy. The value for the RES fee will be changed year by year depending on the compensation of RES and is set by the ministry. In 2017 the RES fee is EUR 68.80 per MWh (6.88 Ct/kWh).
- Concession fee: Levy to municipality for the right of usage official road for laying and operation of power lines. The value is EUR 1.10 per MWh (0.11 Ct/kWh) for consumers with a demand of more than 30,000 kWh per year.

National or port specific regulations and incentives

There are no current national support schemes for OPS systems in Germany. However, within the "Diesel Gipfel" – a German governmental conference for fulfilment of the European limits for the emission of diesel engines – the ministry announced an upcoming support program for OPS pilot projects. It is possible to receive support for development of OPS from the so called "Umweltinnovationsprogramm (UIP)" from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUB).

According to the "General terms and conditions for Hamburg Port", Hamburg Port as of 1 January 2017 gives a port discount for ships that mostly use shore power while at berth. The discount rate is 15 percent of the port fee, limited to 2 000 EUR. As for Bergen, ships solely powered by LNG is given the same discount. The discount related to the use of LNG is however limited to 31 December 2018. Environmental discount incentives given by the port strengthens the business case for the cruise vessels. At the same time, it increases the cost for the ports as it represents a loss in potential port charges.

Results

The operation of the OPS system can be financed by a public company taking a loan to cover the investment costs, after which income from the sale of electricity will contribute to finance interest and repayments. Alternatively, the company can receive public investment support to cover the necessary investment costs. A combination of public investment support and loan financing is also possible.

The calculations assume the investment costs are financed through a 20-year annuity with an annual interest rate of 2 percent per year. All figures are given in fixed 2017 prices. The expected increase in the general price level (inflation) is assumed to be 2 percent per year over the calculation period. As interest rates are the same as expected inflation, the real interest rate is zero percent and the cost of interest and repayments in 2017 prices will be the same as the actual investment cost. If the interest rate is higher than the inflation, this will give a positive real interest rate and the direct financed business case would have a better result than the debt-financed business case. Visa versa, if the interest rate is lower than the inflation the debt-finance business case would come better out as the real interest rate will be negative.

From 2019 the onshore power facility will be in operation. It is assumed that the port will not pay interest or instalments during the construction period. A presentation of the cash flow in the operational period is presented in the figure below.

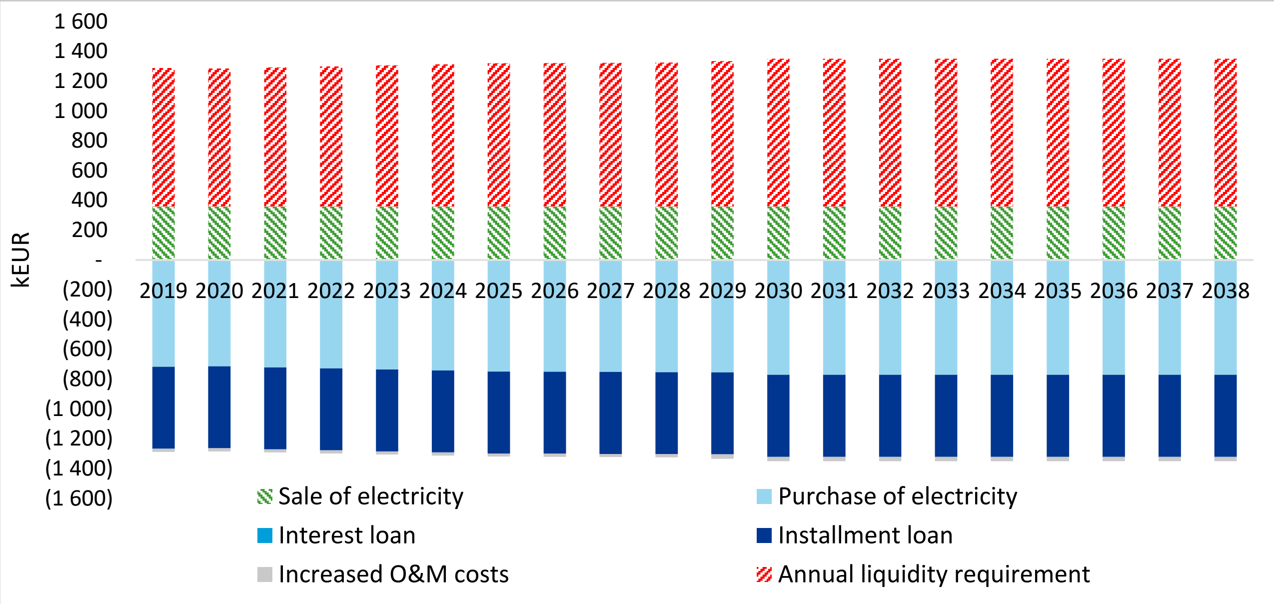

Figure 8. Cash flow analysis Hamburg Port – HafenCity. Operational period 2019 to 2038, kEUR 2017-prices

The port's income potential through sale of electricity is calculated based on a sales price of electricity of EUR 115 per MWh. The port's cost of purchasing electricity (total electricity charges) is given by the light blue area, while the dark blue area shows the ports annual interest and loan repayment. The grey column illustrates the port's increased operation and maintenance related to the OPS facility. The red, hatched area indicates the port's annual need for liquidity to cover its ongoing costs.

Cruise vessels are expected to be willing to accept an electricity price of EUR 115 per MWh. This is lower than the port's purchasing price for electricity, and the port will have a loss on the sales of electricity. This means that the port will need financial support to also its total electricity charges and the need for investment support increases. The operational business case calculations for Hamburg Port with a debt-financed investment is presented in Table 8.

Table 8. Business case analysis for OPS investment at Hamburg Port - HafenCity

2017 prices, MEUR	
Interest and loan repayments	-11.0
Operation and maintenance	-0.5
Purchase of electricity	-15.1
Income potential from sale of electricity	7.2
Total	**-19.4**
Minimum investment support	**19.4**

The alternative to finance the investment through a loan, is that the investment cost is financed directly. The advantage of this is that the risk that there will not be sufficient cash to pay the ongoing loan repayment for the OPS investment is eliminated. The result is the same as for a debt-financed investment, since the interest rate and inflation is assumed to be the same throughout the calculation period.

To assess the effect of changes in some of the assumptions applied in the business case three sensitivity analyses are included in section 8.

Appendix A3 Rostock Port

The Port of Rostock is owned by The Federal State of Mecklenburg-Western Pomerania and the Hanseatic City of Rostock. The cruise centre in Rostock Port is located north of Rostock city centre, in the district of Warnemünde, directly on the Baltic Sea cost. Warnemünde harbour is one of Europe's busiest cruise ports measured in number of passengers. The other harbours in Rostock port is located south of the city centre.

In the business case for Rostock the focused is on the Warnemünde area and the two quays designated for larger cruise vessels (P7 and P8), see the map below

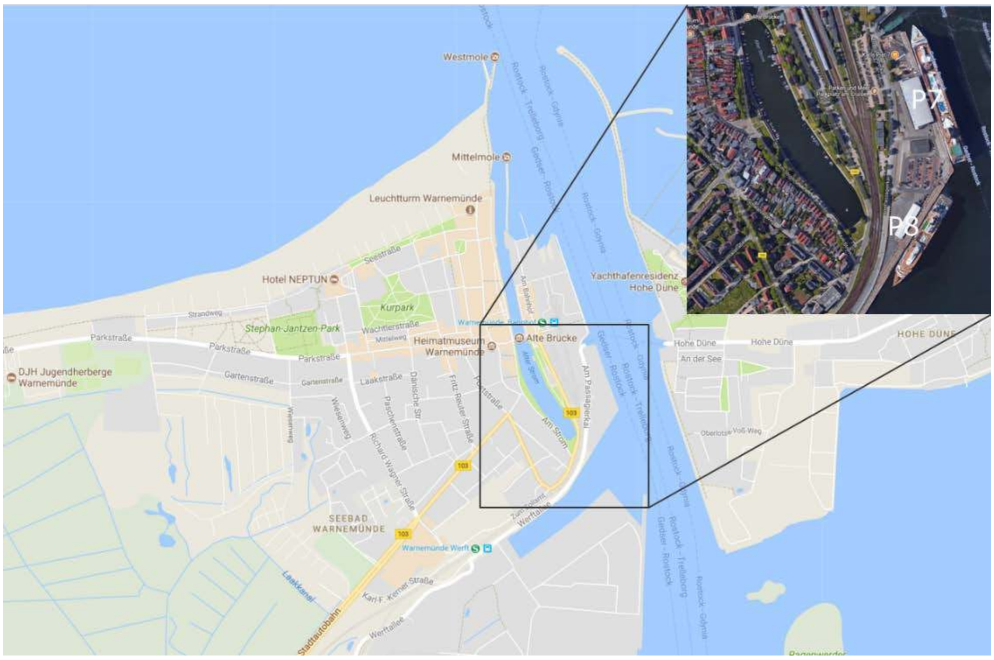

Figure 9. Overview of Rostock-Warnemünde.

Warnemünde business case assumptions

This section includes port specific business case assumption. For general input and assumption cf. section 6. This section gives a description of the grid infrastructure in the Warnemünde area and the necessary investment to establish OPS at Warnemünde Terminal.

Energy- and electricity consumption

In 2016, 31 cruise ships called at the Warnemünde Terminal. The total number of port calls was 150 and the average lay time for cruise vessels was 12 hours. In 2017, the number of call is expected to increase to 192 port calls by 38 vessels.

Warnemünde Terminal has three berths. Assuming an average, individual capacity demand of 5.5 MW per vessel, the annual electricity consumption potential is calculated to 9.5 GWh. It is assumed that there are 190 port calls a year, an average lay time of 12 hours. The corresponding annual energy consumption based on MGO is 2,370 mt. As the cruise terminals are dedicated for cruise vessels there is not expected any alternative use of the OPS infrastructure in the off-cruise season.

A gradual increase in the number of vessels adapted for OPS during the calculation period is expected. On average over the calculation period, it is assumed that 60 percent of the port calls will use OPS while at berth. This represent an annual electricity consumption of 5.7 GWh. The corresponding annual MGO consumption is 1,420 mt.

Table 9. Annual MGO and electricity consumption Rostock Port – Warnemünde

Assumptions	
Port Calls:	150
Average Lay Time:	12 hours
Connection/Disconnection Time	30 minutes
Average capacity demand:	5.5 MW
Share of OPS:	60 percent over the calculation period

Consumption	**MGO**	**OPS**
Annual energy consumption	2,370 mt	9,490 MWh
60 percent of annual energy consumption	1,420 mt	5,690 MWh

Investment costs

The investment costs break down into grid connection costs and shore power installations, including connection equipment on the quay. This section gives a description of the grid infrastructure in the Warnemünde area and the necessary investment to establish OPS for cruise vessels at Warnemünde Terminal.

Grid connection

Transmission of electricity in Germany is officially divided into two network levels; the transmission grid and the distribution grid. The distribution grid is again divided into different voltage levels; high voltage, medium voltage and low voltage. The grid infrastructure set-up is illustrated in the figure below.

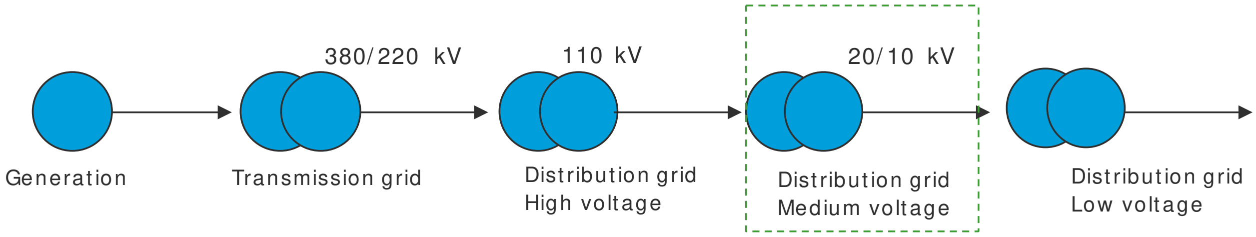

Figure 10. Grid infrastructure in the Rostock-area

The local 20 kV medium-voltage distribution grid in Warnemünde area is owned and operated by "Stadtwerke Rostock Netzgesellschaft GmbH". It is supplied upstream through a substation to a 110 kV high-voltage distribution grid which is operated by the distribution network operator "E.DIS AG". The 110/20 kV substation in Warnemünde has a total installed transformer capacity of 63 MVA, which allows a supply of 31.5 MVA in case of single contingency.

The electrical load for a cruise ship is assumed to be around 5.5 MW on average. Rostock city, including Warnemünde Port, is currently supplied by a 20 kV distribution grid. The common cable sizes in the 20kV grids of German cities are 150 mm² - 240 mm², which meets a transport capacity of around 10 MW till 14 MW. The local grid operator has confirmed that it is possible to supply the needed capacity of around 7 MW to establish one OPS by the existing grid. To establish OPS at more than one quay, it will be necessary to upgrade the distribution grid to increase the capacity in the port area. According to the Port of Rostock, the estimated investment cost of related to establishing three connection points is EUR 5.6 million and the cost for onshore distribution is estimated to EUR 20 million. A breakdown of these costs are not provided.

Shore power facility

For the Rostock Port the general cost estimated which based on input from suppliers is applied.

Summary of investment costs

The table below summaries the investment costs for establishing OPS at the two quays at Warnemünde.

Table 10. Construction cost of two shore-to-ship power connection points at Rostock port – Warnemünde

2017-prices, MEUR		
Grid connection	Grid investment	5.6
Port facility and equipment		20.0
Total investment costs		**25.6**

Total electricity charges

This section gives a description of the different elements that constitute the electricity price in Hamburg Port. The price of electricity over the calculation period will however vary depending on market developments and regulations. The total charge will develop over the calculation period, depending on market developments and regulations. In the business case, it is assumed the electricity price will develop according to Statnett's long term price forecast. Grid tariffs and taxes and levies are held constant throughout the calculation period.

Price of electricity

Germany consist of only of one price area. This means that the spot price of electricity is the same throughout Germany. The price of electricity is therefore the same in Rostock and Hamburg. The average price of electricity in the period 2007 to 2016 was EUR 71.56 per MWh, falling from above 80 EUR/MWh in 2008 to below 50 EUR/MWh in 2016, cf. section 6.2.1.2 for more detailed description of electricity prices in Germany. In the business case, the current spot price on electricity is applied as a reference point and used Statnett's long-term price forecast for Germany to estimate the electricity price over the calculation period.

Grid tariffs

In Germany, like many other countries in Europe, the maximum allowed revenue of the local grid owners is regulated. The regulator in Germany sets a revenue cap for a time period of five years for each grid operator. Based on the value set by the regulator, the grid operators determine their grid tariffs. The local grid operator in Rostock is Stadtwerke Rostock Netzgesellschaft GmbH.

An overview of the current stated tariff for power consumption at a voltage level of 20 kV is provided below.

Table 11. Grid tariff, power consumption at 20 kV <2500h/a (medium voltage). Source: Stadtwerke Rostock Netzgesellschaft GmbH, 2017

2017-prices, EUR		
Fixed fee (annual)	-	EUR
Capacity fee (annual)	2,530	EUR/MW
Consumption fee (annual)	34.80	EUR/MWh

Taxes and fees

In German, electricity consumption used for OPS is currently subject to the following taxes and levies:

- Electricity tax: A tax on the use of electricity. The tax is fixed by law and is EUR 20.5 per Mwh (2.05 Ct/kWh) for industry end consumer
- Renewable energy source fee (RES fee): All end users must contribute to the financing of the integration of renewable energy. The value for the RES fee will be changed year by year

depending on the compensation of RES and is set by the ministry. In 2017 the RES fee is EUR 68.80 per MWh (6.88 Ct/kWh).

- Concession fee: Levy to municipality for the right of usage official road for laying and operation of power lines. The value is EUR 1.10 per MWh (0.11 Ct/kWh) for consumers with a demand of more than 30,000 kWh per year.

National or port specific regulations and incentives

There are no current national support schemes existing for OPS systems in Germany. However, within the “Diesel Gipfel” – a German governmental conference for fulfilment of the European limits for the emission of diesel engines – the ministry announced an upcoming support program for OPS pilot projects.

Rostock port gives a discount on port charges for vessels registered with the Environmental Ship Index (ESI), introduced by the World Ports Climate Initiative. The discount includes a 5 percent reduction on the port-charge for vessels that can document that they have an ESI score over 40, a 7.5 percent discount for vessels with an ESI score over 50 and 10 percent discount for vessels with and ESI score over 60. Environmental discount incentives given by the port strengthens the business case for the cruise vessels. At the same time, it increases the cost for the ports as it represents a loss in potential port charges.

Results

The operation of the OPS system can be financed by a public company taking a loan to cover the investment costs, after which income from the sale of electricity will contribute to finance interest and repayments. Alternatively, the company can receive public investment support to cover the necessary investment costs. A combination of public investment support and loan financing is also possible.

The calculations assume the investment costs are financed through a 20-year annuity with an annual interest rate of 2 percent per year. All figures are given in fixed 2017 prices. The expected increase in the general price level (inflation) is assumed to be 2 percent per year over the calculation period. As interest rates are the same as expected inflation, the real interest rate is 0 percent and the cost of interest and repayments in 2017 prices will be the same as the actual investment cost. If the interest rate is higher than the inflation, this will give a positive real interest rate and the direct financed business case would have a better result than the debt-financed business case. Visa versa, if the interest rate is lower than the inflation the debt-finance business case would come better out as the real interest rate will be negative.

From 2019 the onshore power facility will be in operation. It is assumed that the port will not pay interest or instalments during the construction period. A presentation of the cash flow in the operational period is presented in figure below.

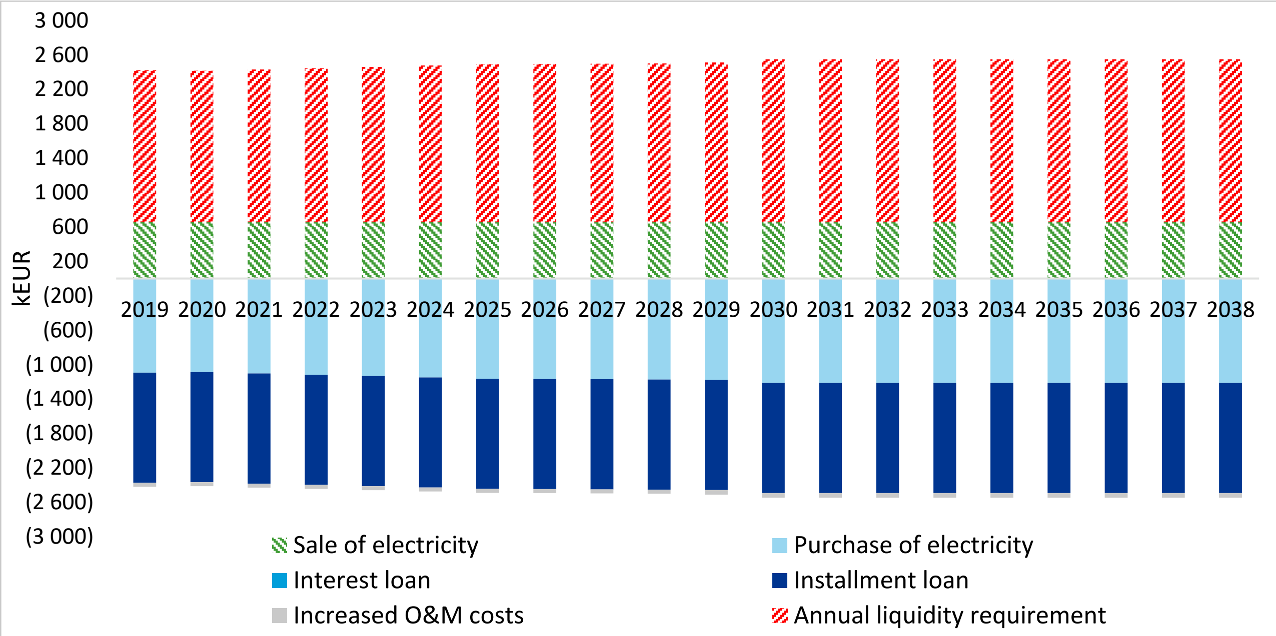

Figure 11. Cash flow analysis of base case scenario, Rostock Port – Warnermünde. Operational period 2019 to 2038, kEUR 2017-prices.

The port's income potential through sale of electricity is calculated based on a sales price of electricity of EUR 115 per MWh. The port's cost of purchasing electricity (total electricity charges) is given by the light blue area, while the dark blue area shows the ports annual interest and loan repayment. The grey column illustrates the port's increased operation and maintenance related to the OPS facility. The red, hatched area indicates the port's annual need for liquidity to cover its ongoing costs.

Cruise vessels are expected to be willing to accept an electricity price of EUR 115 per MWh. This is lower than the port's purchasing price for electricity, and the port will have a loss on the sales of electricity. This means that the port will need financial support to also its total electricity charges and the need for investment support increases. The operational business case calculations for the Port of Rostock with a debt-financed investment is presented in table 12.

Table 12. Business case analysis for OPS investment at Rostock Port - Warnemünde

2017 prices, MEUR	
Interest and loan repayments	-25.6
Operation and maintenance	-1.0
Purchase of electricity	-19.5
Income potential from sale of electricity	13.1
Total	**-33.1**
Minimum investment support	**33.1**

The alternative to finance the investment through a loan, is that the investment cost is financed directly. The advantage of this is that the risk that there will not be sufficient cash to pay the ongoing loan repayment related to the OPS investment is eliminated. The result is the same as a debt-financed investment, since the interest rate and inflation is assumed to be the same throughout the calculation period.

To assess the effect of changes in some of the assumptions applied in the business case three sensitivity analyses are included in section 8.

Appendix A4 Tallinn Port

The port of Tallinn is the biggest port on the shore of the Baltic sea in both cargo and passenger traffic. It consists of five harbours; Old City Harbour (inc. Old City Marina), Muuga Harbour, Paldiski South Harbour, Paljassaare Harbour and Saaremaa Harbour. The port is operated by the state-owned company Tallinn Port. The Port of Tallinn is used both by cruise ships, oversea ferries, domestic ferries, cargo and leisure boats. There are two harbours designed for cruise ships, the Old City Harbour and Saarema Harbour, with five and two quays respectively reserved for cruise ships. In the analysis, the focus is on the Old City Harbour, quays 24 ,25 ,26 and 27, as these can share the same OPS infrastructure.

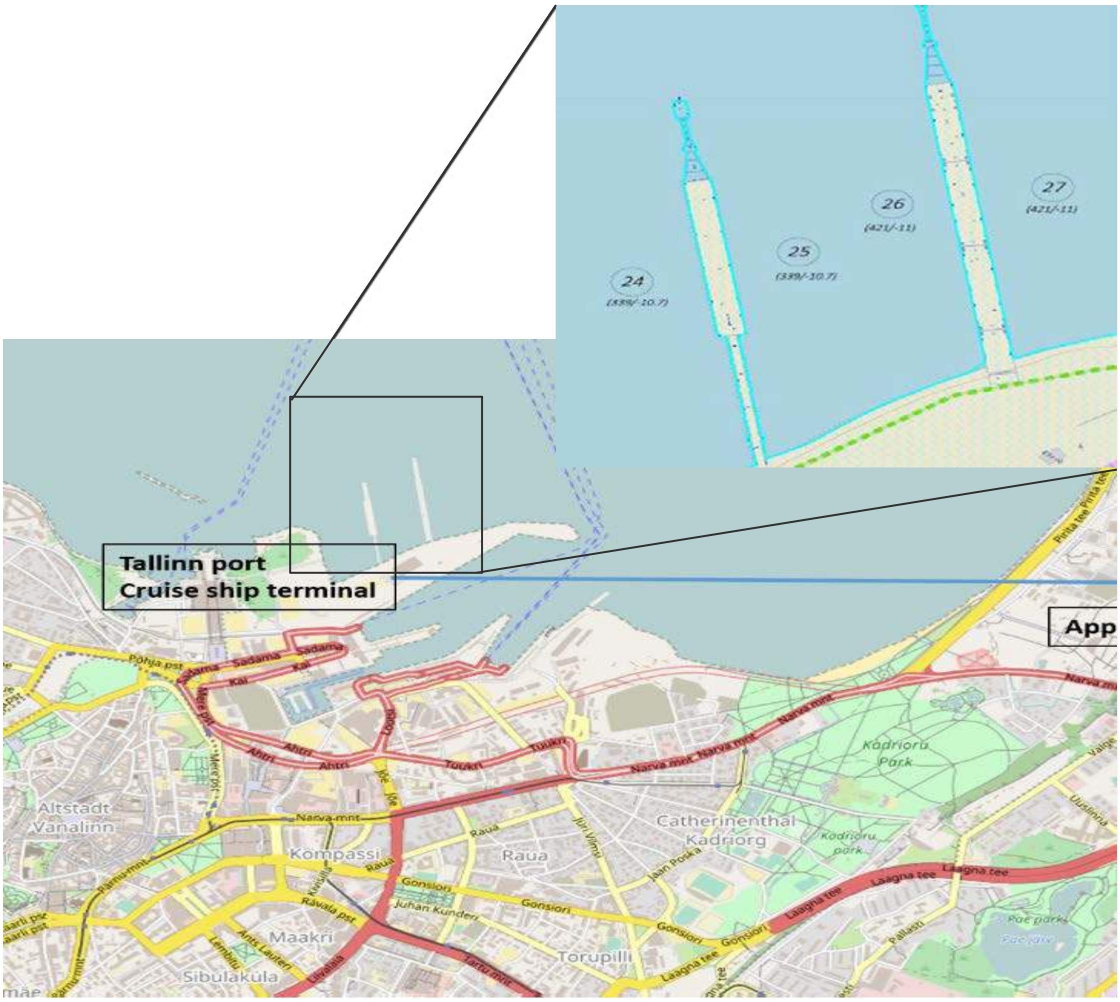

Figure 12. Overview of Old City Harbour, Tallinn port

Business case assumptions

This section includes port specific business case assumption. For key input and assumption cf. section 6.This section gives a description of the grid infrastructure in the area that supply the Old City harbour area and the necessary investment to establish OPS at The Old City harbour.

Energy and electricity consumption

In 2016, 62 cruise ships called at the Old City harbour while the total number of port calls was 271 and the average lay time for the ships was 8 hours. According to information from the Port of Tallinn the number of port calls in 2017 was 311 and is expected to increase to 335 in 2018. In the business case it is assumed on average 340 port calls per year over the calculation period.

During the cruise season, all four quays in the Old City harbour are in use. With an OPS share of 60 percent it is a likely case that OPS is only established at three of the four quays. Assuming an average, individual capacity demand of 7 MW per vessel, the annual electricity consumption potential is estimated to 9.9 GWh. It is assumed that is no alternative use of the OPS infrastructure in the off-cruise. These assumptions are applied throughout the calculation period. The corresponding annual energy consumption based on MGO is 2,480 mt.

Over the period, it is assumed that OPS will be use for 60 percent of the port calls. The share of OPS constitutes an annual electricity consumption of 5.9 GWh. Table 13 gives an overview of annual MGO and electricity demand.

Table 13. Annual MGO and electricity consumption, Tallinn – Old City harbour

Assumptions	
Port Calls:	340
Average Lay Time:	8 h
Connection/Disconnection Time	30 minutes
Average capacity demand:	5.5 MW
Share of OPS:	60 percent over the calculation period

Consumption	**MGO**	**OPS**
Annual energy consumption	3,500 mt	14,030 MWh
60 percent of annual energy consumption	2,100 mt	8,420 MWh

Investment costs

Investment costs break down into grid connection costs and shore power installations, including connection equipment on the quay. This section includes a description of the grid infrastructure in the Old City Harbour area and the necessary investment to establish OPS at Old City Harbour.

Grid connection

Transmission of electricity in Estonia is officially divided into two network levels; the transmission grid and the distribution grid. The distribution grid is again divided into two different voltage levels, shown in figure 13.

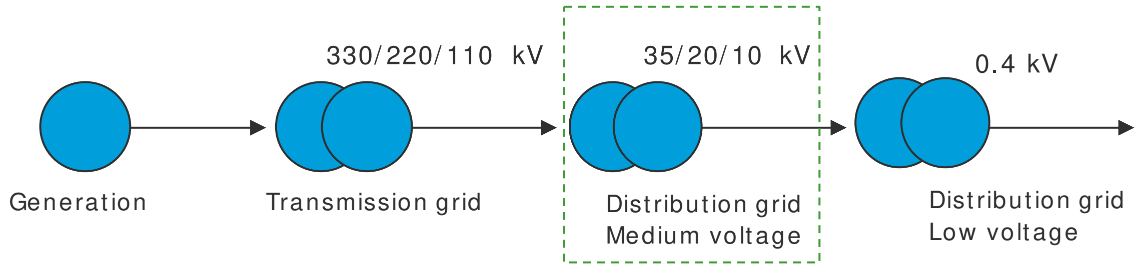

Figure 13. Grid infrastructure in Estonia

The transmission system operator (TSO) Elering AS is responsible for the high voltage transmission grid. TS Energia UÖ is one of around 27 distribution network operators (DNO) in Estonia and owns and operates the grid in Tallinn port. The company is a 100% subsidiary of the port of Tallinn. The port of Tallinn is currently supplied by a 6 kV and 10 kV distribution grid.

The grid capacity in Tallinn Port is limited and it is assumed that the existing 10 kV grid in the port is not sufficient to supply up to three cruise ships with electricity. Establishment of OPS in the port will therefore require substantial investments in the local grid through extending the current grid and building new lines to the 110kV transmission grid. According to the Port of Tallinn this is estimated to cost around EUR 5-7 million. In the business case, it is assumed a grid investment cost of EUR 6 million.

Shore power facility

For the shore power facility, the general cost estimated based on input from suppliers is applied.

Summary of construction costs

Table 14 summaries the investment costs for establishing OPS at the three quays at old city harbour.

Table 14. Construction cost three shore-to-ship connection points at Old City Harbour

2017-prices, MEUR		
Grid connection	Grid investment	6.0
Port facility and equipment	Transformer station (incl. housing)	1.0
	Frequency converter	3.6
	Cabling	3.0
	Cable management system	3.2
Total investment cost		**16.8**

Total electricity charges

This section gives a description of the different elements that constitute the electricity price in Bergen Port. The price of electricity will vary over the calculation period, depending on the market development and regulations. The total charge will develop over the calculation period, depending on market developments and regulations. In the business case, it is assumed the electricity price will develop according to the Estonia's TSO et al. long term price forecast. Grid tariffs and taxes and levies are held constant throughout the calculation period.

Electricity price

Estonia is part of the integrated electricity wholesale market of the Nordic countries (Nord Pool), The price of electricity in Estonia is mainly determined by the supply and demand of electricity in the Nordic electricity market.

Estonia consists of one price area which means that the price of electricity is the same in all of Estonia. Figure 14 shows the average monthly system price[21] and price in Estonia from January 2013 to August 2017. The electricity price in Estonia is in general higher than the system price.

[21] The system price is the unconstrained market reference price calculated without any congestion restrictions.

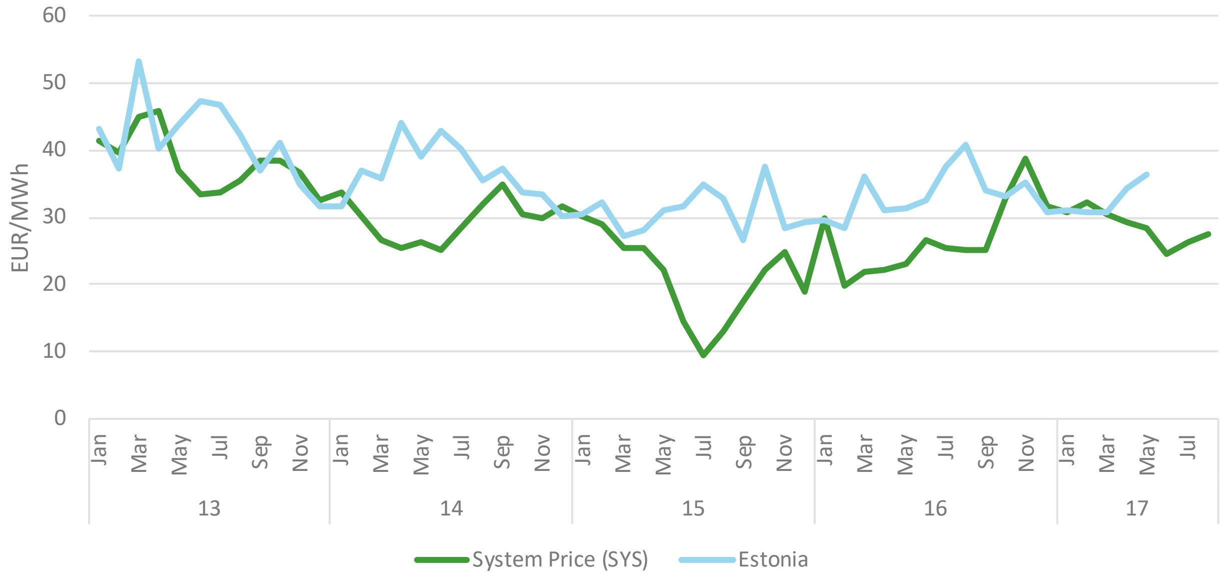

Figure 14. Average monthly system price (SYS) and spot price in Estonia, Jan-2013 to Aug-2017. Source: Nordpool, 2017

End users in Estonia are free to choose their power supplier. Smaller end users normally purchase power from a power supplier, while larger end users often purchase power directly in the wholesale market. The local grid operator, TS Energia UÖ, is a 100 percent owned subsidiary of Tallinn Port. For consumption of electricity the company currently charge a price of electricity of EUR 50.88 per MWh, this is slightly higher than the current spot price which is EUR 47 per MWh. In the business case, the current spot price on electricity is used as a reference and Elering et al. long-term price forecast for Estonia from 2014 to estimate the expected electricity price over the calculation period.

Grid tariffs

TS Energia UÖ currently main tariff related to network services is EUR 36.08 per MWh. The rate during the day rate and the night rate is both scientifically higher than the main tariff. An overview of the current stated tariffs for network services is provided below. In the business case, it is assumed that the port is charge grid tariffs according to the main rate.

Table 15. Grid tariff in Tallinn port. Source: TS Energia UÖ, 2017

2017-prices, EUR	
Grid tariff	
- Main tariff	36.08 EUR/MWh
- Day rate	69.18 EUR/MWh
- Night rate	47.08 EUR/MWh

Taxes and levies

In Estonia, electricity consumption used for OPS is subject to the following taxes and levies:

- Electricity tax: A tax on the use of electricity. Commercial vessels are subject an electricity tax of EUR 4.47 per MWh (0.447 ct/kWh).
- Renewable electricity fee: End users subject to electricity tax must contribute to the financing of the renewable energy sources. The subsidy for renewable energy sources is EUR 9.60 per MWh (0.96 Ct/kWh).

National or port specific regulations and incentives

There are no known ambitions to implement support schemes for OPS-systems in Estonian ports. However, there might be the chance to get funding from the national "atmosphere air protection programme".

Results

The operation of the OPS system can be financed by a public company taking a loan to cover the investment costs, after which income from the sale of electricity will contribute to finance interest and repayments. Alternatively, the company can receive public investment support to cover the necessary investment costs. A combination of public investment support and loan financing is also possible.

The calculations assume that the investment costs are financed through a 20-year annuity with an annual interest rate of 2 percent per year. All figures are given in fixed 2017 prices. The expected increase in the general price level (inflation) is assumed to be 2 percent per year over the calculation period. As interest rates are the same as expected inflation, the real interest rate is 0 percent and the cost of interest and repayments in 2017 prices will be the same as the actual investment cost. If the interest rate is higher than the inflation, this will give a positive real interest rate and the direct financed business case would have a better result than the debt-financed business case. Visa versa, if the interest rate is lower than the inflation the debt-finance business case would come better out as the real interest rate will be negative.

From 2019 the onshore power facility will be in operation. It is assumed that the port will not pay interest or instalments during the construction period. A presentation of the cash flow in the operational period is presented in figure below.

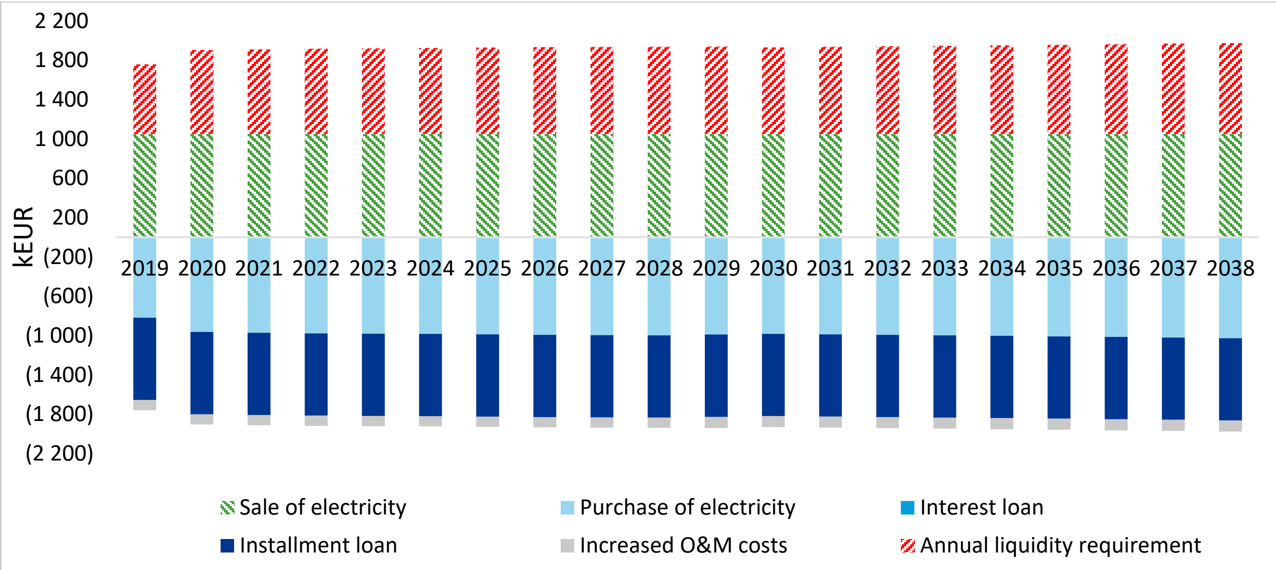

Figure 15. Cash flow analysis OPS investment Tallinn Port – Old City Harbour. Operational period 2019 to 2038, kEUR 2017-prices.

The port's income potential through sale of electricity is calculated based on a sales price of electricity of EUR 115 per MWh. The port's cost of purchasing electricity (total electricity charges) is given by the light blue area, while the dark blue area shows the ports annual interest and loan repayment. The grey column illustrates the port's increased operation and maintenance related to the OPS facility. The red, hatched area indicates the port's annual need for liquidity to cover its ongoing costs.

Cruise vessels are expected to be willing to accept an electricity price of EUR 115 per MWh. This is just below than the port's purchasing price for electricity, and the port will have a loss on the sales of electricity. This means that the port will need financial support to cover also its total electricity charges, and the need for total investment support increases. The operational business case calculations for Hamburg Port with a debt-financed investment is presented in Table 8. The operational business case calculations for Tallinn Port with a debt-financed investment is presented in below.

Table 16. Business case analysis for OPS investment in Tallinn Port - Old City Harbour

2017 prices, MEUR	
Instalments and interest (loan repayments)	-16.8
Operation and maintenance	-2.2
Purchase of electricity	-19.7
Sale of electricity	19.4
Total	**-19.2**
Minimum investment support	**19.2**

The alternative to finance the investment through a loan, is that the investment cost is financed directly. The advantage of this is that the risk that there will not be sufficient cash to pay the ongoing loan repayment related to the OPS investment is eliminated. The result is the same as a debt-financed investment, since the interest rate and inflation is assumed to be the same throughout the calculation period.

To assess the effect of changes in some of the assumptions applied in the business case three sensitivity analyses are included in section 8.

Appendix A5 Helsinki Port

The Port of Helsinki is Finland's main port and is owned by the City of Helsinki. The Port is used for both cruise ships, oversea ferries, domestic ferries, cargo and leisure boats. The port has three harbours that hosts international cruise ships; South Harbour & Katajanokka, West harbour and Hernesaari. The figure below shows an overview of cruise quays in Helsinki. The South Harbour & Katajanokka serves smaller international cruise ships and the Katajanokka harbour has since 2012 had one low-voltage onshore power supply connection that serves ferries operating from Helsinki to Stockholm.

According to the Port of Helsinki, Munkkisaari Quay (quay 1 and 2) located in the Hernesaari area and Valtameri Quay (quay 3) located in the West harbour area, are better suited for OPS with regards to grid infrastructure. In the business case, the focus is on Munkkisaari Quay in the Hernessari area.

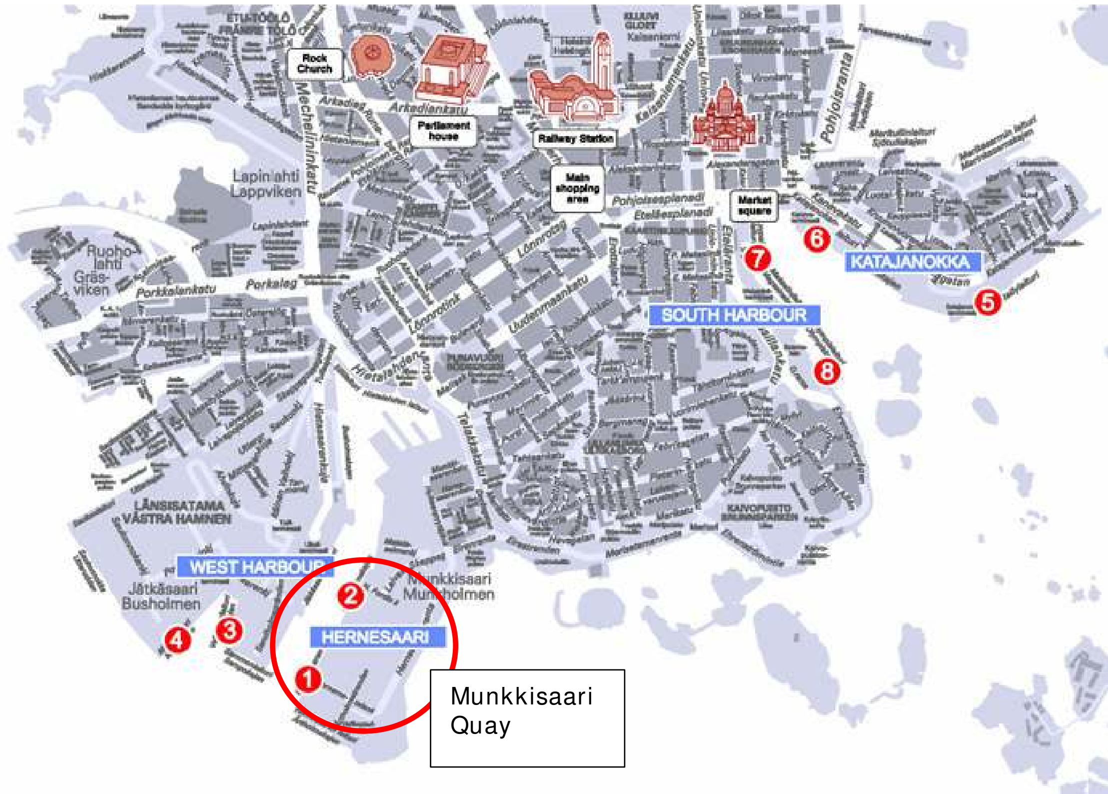

Figure 16. Map of Cruise Quays in Helsinki (Source: Port of Helsinki)

Hernesaari business case assumption

This section includes port specific business case assumption. For key input and assumption cf. section 5. This section gives a description of the grid infrastructure in the area that supply the Hernessari area and the necessary investment to establish OPS at Munkkisaari Quay.

Energy- and electricity consumption

In 2016, 24 cruise ships called at the Munkkisaari Quay. The total number of terminal calls was 98 and the average lay time for the cruise ships was 9 hours. In the business case, it is assumed that the number of port call will remain stable, at 100 throughout the calculation period and that the average lay time will be as in 2016.

Assuming an average, individual capacity demand of 5.5 MW per vessel, the annual electricity consumption potential is estimated to 4.7 GWh in 2016. It is assumed there is no alternative use of the

OPS infrastructure in the off-cruise season. These assumptions are applied throughout the calculation period. The corresponding annual energy consumption based on MGO is 1,170 mt.

A gradual increase in the number of vessels adapted for OPS during the calculation period is expected. Over the period, it is assumed that OPS will be use for 60 percent of the port calls. The share of OPS constitutes an annual electricity consumption of 2.8 GWh. The table below gives an overview of annual MGO and electricity demand.

Table 17. Annual MGO and electricity consumption Helsinki Port – Hernesaari

Assumptions	
Port Calls:	100
Average Lay Time:	9 h
Connection/Disconnection Time	30 minutes
Average capacity demand:	5.5 MW
Share of OPS:	60 percent over the calculation period

Consumption	**MGO**	**OPS**
Annual energy consumption	1,170 mt	4,680 MWh
60 percent of annual energy consumption	700 mt	2,800 MWh

Investment costs

Investment costs break down into grid connection costs and shore power installations, including connection equipment on the quay. This section includes a description of the grid infrastructure in the Hernessari area and the necessary investment to establish OPS at Munkkisaari Quay.

Grid connection

Transmission of electricity in Finland is officially divided into three network levels; the transmission grid, the regional network and distribution network. The distribution grid is again divided into two voltage levels; medium voltage and low voltage.

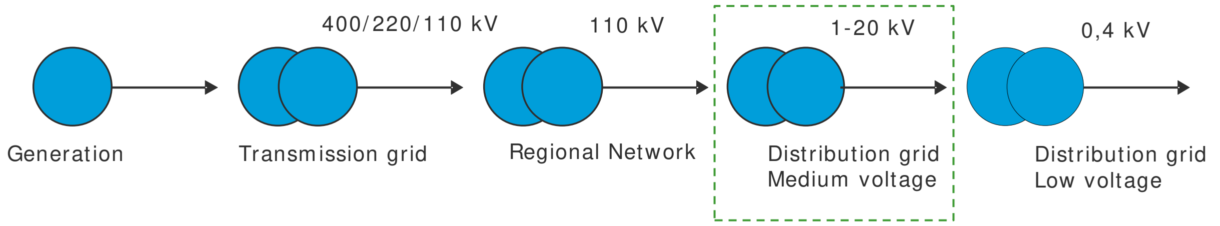

Figure 17. Electricity system in Finland

The local grid operator Helen Sähköverkko operates the grid infrastructure in the Hernesaari area. The area is currently supplied by a 10 kV distribution network. With the current grid set-up the network owner can supply the quay with a 10 MVA connection. For a higher capacity a connection to the high voltage 110 kV network is necessary. According to network operator, a connection of over 10 MVA has an estimated connection cost of EUR 3 million /D61/. The connection cost includes cabling and switching devices in the nearby substation Kamppi.

Shore power facility

For establishing shore power connection at Munkkisaari Quay the general cost estimated, based on input from suppliers, is applied.

Summary of construction costs

Table 18 summaries the investment costs for establishing two OPS connection points in the Hernesaari area.

Table 18. Construction cost for two shore-to-ship connection points in Helsinki Port - Hernesaari

2017-prices, MEUR		
Grid connection	Grid investment	3.0
Port facility and equipment	Transformer station (incl. housing)	1.0
	Frequency converter	3.6
	Cabling	3.0
	Cable management system	2.4
Total investment costs		**13.0**

Total electricity charges

This section gives a description of the different elements that constitute the electricity price in the port of Helsinki. The price of electricity will vary over the calculation period, depending on the market development and regulations. The total charge will develop over the calculation period, depending on market developments and regulations. In the business case, it is assumed the electricity price will develop according to Statnett's long term price forecast. Grid tariffs and taxes and levies are held constant throughout the calculation period.

Electricity price

The price of electricity in Finland is mainly determined by supply and demand in the Nordic, Baltic and Russian electricity markets. Grid congestions (capacity constrains) also effect the electricity price. Finland consists of one price area to reflect grid congestions. The table below shows the average monthly system price[22] and the average monthly spot price in the Finland from January 2013 to August 2017. The figure shows that the electricity price in Finland is in general higher than the system price.

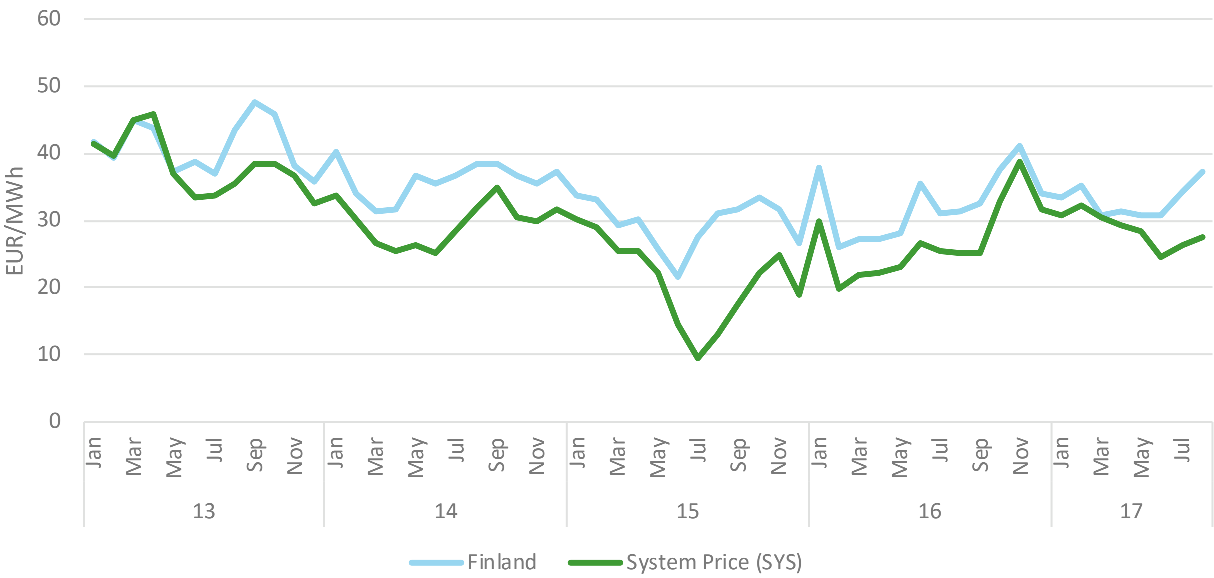

Figure 18. Average monthly system price (SYS) and spot price in Finland, Jan-2013 to Aug-2017. Source: Nordpool, 2017

In the business case the current spot price on electricity as a reference point and Statnett's long-term price forecast for Finland to estimate the electricity price over the calculation period are used

[22] The system price is the unconstrained market reference price calculated without any congestion restrictions.

Grid tariffs

In Finland, like many other countries in Europe, are the maximum allowed revenue of the local grid owners (DNO) regulated. The local grid operator in Helsinki is Helen Säkhöverkko and in the analysis their distribution tariffs per 1 July 2017 is used to calculate the grid connection costs.

An overview of the current stated tariff for power consumption at a medium-voltage level is provided below in 12.

Table 19. Grid tariff, power consumption at medium-voltage power distribution. Source: Helen Elnät AB

2017-prices, EUR		
Basic charge	175	EUR/month
Capacity fee	3.35	EUR/kW
Consumption fee (Summer season)	0.94	Ct/kWh

Taxes and fees

In Finland, electricity consumption used for OPS is currently subject to the following taxes and levies:

- Electricity Tax: Electricity tax is levied on all electric energy distributed to customers through the distribution network. The excise tax on electricity and strategic stockpile fee[23] are included in the electricity tax charge. The general electricity tax (tax class I) is currently EUR 22.53 per MWh (2.253 ct/kWh). Electricity consumption used for production purposes, data center services or professional greenhouse cultivation may register for a reduced rate of EUR 7.03 per MWh (0.703 ct/kWh). It is assume that the consumption of electricity for OPS is subject to the general electricity tax (tax class I).

National or port specific regulations and incentives

There are no known ambitions to implement support schemes for OPS-systems in Finnish ports.

Results

The operation of the OPS system can be financed by a public company taking a loan to cover the investment costs, after which income from the sale of electricity will contribute to finance interest and repayments. Alternatively, the company can receive public investment support to cover the necessary investment costs. A combination of public investment support and loan financing is also possible.

The calculations assume the investment costs are financed through a 20-year annuity with an annual interest rate of 2 percent per year. All figures are given in fixed 2017 prices. The expected increase in the general price level (inflation) is assumed to be 2 percent per year over the calculation period. As interest rates are the same as expected inflation, the real interest rate is 0 percent and the cost of interest and repayments in 2017 prices will be the same as the actual investment cost. If the interest rate is higher than the inflation, this will give a positive real interest rate and the direct financed business case would have a better result than the debt-financed business case. Visa versa, if the interest rate is lower than the inflation the debt-finance business case would come better out as the real interest rate will be negative.

From 2019 the onshore power facility will be in operation. It is assumed that the port will not pay interest or instalments during the construction period. A presentation of the cash flow in the operational period is presented in figure below.

[23] The stockpile fee is levied on liquid fuels, electricity, coal and natural gas to cover expenses as a result of complying with international stockpiling obligation.

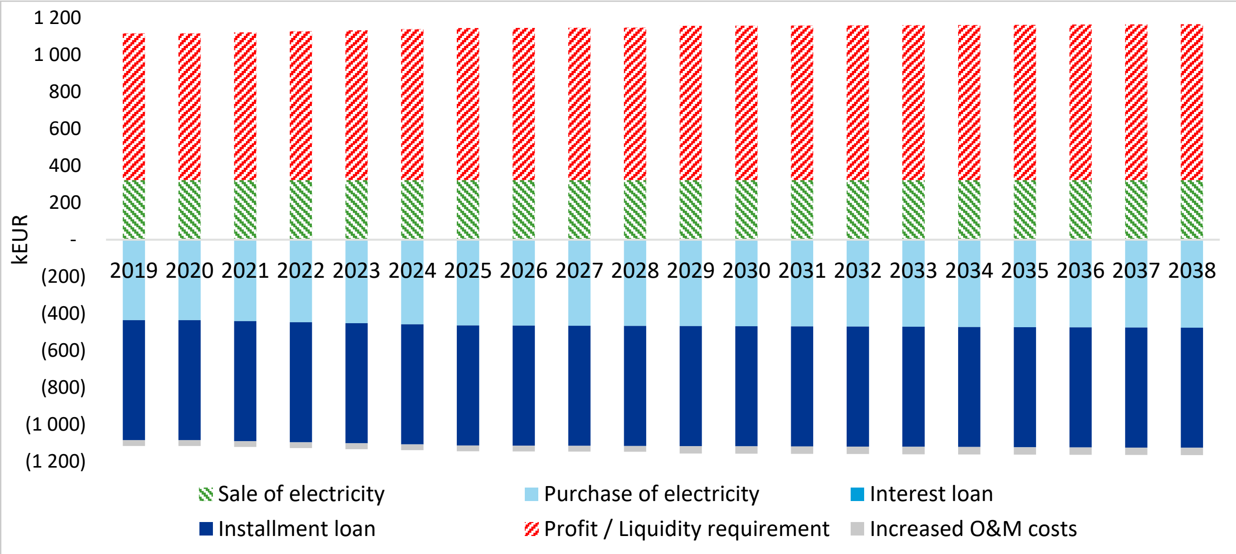

Figure 19. Cash flow analysis OPS investment Helsinki Port – Hernesaari. Operational period 2019 to 2038, kEUR 2017-prices.

The port's income potential through sale of electricity is calculated based on the price of MGO, and illustrated by the green, hatched area in the figure above. The port's cost of purchasing electricity is given by the light blue area, while the dark blue area shows the ports annual loan repayment (interest[24] and instalments). The grey column illustrates the port's increased operation and maintenance related to the OPS facility. The red, hatched area indicates the port's liquidity requirement, i.e. the port's annual shortfall.

Cruise vessels are expected to be willing to accept an electricity price of EUR 115 per MWh. This is lower than the port's purchasing price for electricity, and the port will have a loss on the sales of electricity. This means that the port will need financial support to also its total electricity charges and the need for investment support increases. A cash flow analysis with a debt-financed investment at Hernesaari is presented in the table below

Table 20. Business case for OPS investment in Helsinki Port - Hernesaari

2017-prices, MEUR	
Instalments and interest (loan repayments)	-13.0
Operation and maintenance	-0.7
Purchase of electricity	-9.3
Sale of electricity	6.5
Total	**-16.5**
Minimum investment support	**16.5**

The alternative to finance the investment through a loan, is that the investment cost is financed directly. The advantage of this is that the risk that there will not be sufficient cash to pay the ongoing loan repayment for the OPS investment is eliminated. The result is the same as a debt-financed investment, since the interest rate and inflation is assumed to be the same throughout the calculation period.

To assess the effect of changes in some of the assumptions applied in the business case three sensitivity analyses are included in section 8.

[24] As the nominal interest rate and the inflation is each 2 percent, the real interest rate is 0 percent and the loan repayments equals the actual investment cost of EUR 13.4 million

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