On Shore Power Supply and LNG

Cruise ships
> 200 m
10–20 MVA

Tankers
> 200 m
3-11 MVA

Container/reefer
> 200 m
3–6 MVA

Bulk/cargo/container/Ro-Ro
< 100 m
300 KVA–3 MVA

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1. What is OPS
2. Regulatory aspects
3. Port Environment
4. Costs
5. Implementation
6. Role of LNG
7. Current installations
1.1 What is OPS

Onshore power supply (OPS) is one of the strategies recommended by the several organizations to reduce the environmental impact of seagoing vessels in ports.

**OPS replaces auxiliary engines at berth**
When berthed, ships require electricity to support activities like loading, unloading, heating and lighting and other onboard activities. Today, this power is generally provided by auxiliary engines that emit carbon dioxide (CO₂) and air pollutants, affecting local air quality and ultimately the health of both port workers and nearby residents. The same holds for noise nuisance.

As an alternative to onboard power generation, vessels can be hooked up to an onshore power supply, i.e. connected to the local electricity grid. In this way ships’ operations can proceed uninterrupted, while eliminating negative side-effects.
1.2 What is OPS

Ports nowadays are not normally equipped to supply vessels with electricity from the dockside, nor are vessels usually equipped to receive power in this way.

Around the world, though, many activities in this direction are now underway and interest in the technology is rapidly growing, spurred on by tougher environmental legislation, greater focus on emissions in ports from shipping, and, more recently, rising fuel prices.

Cost-effective implementation of the technology requires collaboration among a wide range of stakeholders at an early stage, when planning new quays and ordering new vessels, for example.
1.3 Power generation

While OPS eliminates onboard emissions at berth, consideration needs to be given to the emissions associated with power generation as such, as the source of this power will have a major influence on the overall emissions reduction achieved. In particular, if renewable energy is used, near-zero emissions of all kinds of air pollutants can be achieved. Studies suggest that the average carbon dioxide emissions from the EU energy mix are around 50% lower than emissions from diesel engines. While coal-fired power plants emit more CO₂, though, they have lower emissions of nitrogen oxides, particulate matter and sulphur oxides, compared with those associated with burning marine diesel fuel with a 0.1 sulphur content.

In addition, stationary power plants are typically located some distance from densely populated areas, whereas dockside shipping emissions will often occur close to city centers as a consequence of a port’s typical location. Human exposure to air pollutants therefore also needs to be considered.
1.4 Power, voltage and frequency

When designing an OPS system, many parameters need to be considered. Terminals equipped with OPS have to take into account the variations in **power, voltage and frequency levels** in different parts of the world.

The low-voltage systems (typically 400-480 V) that have been applied earlier required numerous connection cables, while today's high-voltage systems (6.6 -11 kV) are easier to handle. The difference in electrical frequency between the North American continent/parts of Japan and the rest of the world is also a factor that needs to be allowed for.

In addition, the frequency and voltage of onboard electrical systems may differ among vessel’s sizes and categories. There are many open technical issues on interoperability, varying electrical frequencies and the power requirements at berth for different ship types.
1.5 Electrical world map: households and commerce
1.6 Electrical world map: households and commerce
Besides OPS, there are several other techniques available for limiting the emissions of ships at berth, the impact of which may differ widely, though, from both an environmental and health perspective. OPS, for example, reduces emissions of air pollutants, CO₂, noise and vibration, while most other techniques fail to reduce CO₂ or noise. It should be noted, however, that onboard techniques can be applied in any port, whereas the availability of OPS is limited to some ports only.

**Shoreside techniques**

There are several other shoreside emission reduction or treatment options available to ships at berth. For implementation of these techniques, except the baghouse system, the receiving vessel requires adaptation. The baghouse system can be used on virtually all visiting ships. A baghouse (BH, B/H), bag filter (BF) or fabric filter (FF) is an air pollution control device that removes particulates out of air or gas released from commercial processes or combustion for electricity generation.
1.8 Other options to reduce emissions: LNG / CNG

**Shoreside electricity production (off-grid shore power)**
One option for shoreside power is to use generators installed on the quayside. If these are mobile, it will permit more flexible deployment of the system. Although in some senses similar to OPS, this system will not eliminate the local emissions of power generation. Generator performance in this respect can be improved by burning relatively clean fuels like Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG).

**Onshore steam production**
To limit air pollutant emissions due to the use of fuel boilers while in port, steam can be provided by electrically powered onshore steam boilers.
1.9 Other options to reduce emissions: bi-fuel engines

**Onshore gas supply**

To limit quayside emissions from auxiliary engines, ships can in principle be fitted with bi-fuel engines so that when docked they can use natural gas provided by an onshore fuel system. Natural gas causes lower emissions of CO\(_2\) and air pollutants than standard marine fuels. Quayside supply of gas will mean less extensive redesigning or refitting of vessels, as the need for storage tanks is eliminated. As stated, though, this option means adapting the ship's engines for use of gaseous fuels (dual fuel capability). Such systems are currently being developed and tested, but are not yet commercially operational.

**Engine techniques**

Engine emissions can also be reduced by fitting or retrofitting engines based on enhanced combustion techniques, ranging from water injection into the cylinder to exhaust gas recirculation. The various combustion techniques target specific emissions.
1.10 Other options to reduce emissions: exhaust gas treatment

**Cleaner fuels**
Emissions from auxiliary engines and turbines can be reduced by burning cleaner fuels, ranging from conventional fuels with a lower sulphur content to fuels unconventional to shipping, like LNG. This option is limited to certain ferries and RoRo ships and LNG supply vessels, however.

**Exhaust gas treatment**
An alternative to emission prevention is emissions reduction using onboard exhaust gas treatment systems.

*Selective catalytic reduction (SCR)*
SCR limits NO\(_x\) emissions by injecting urea/ammonia into the exhaust gases and feeding them through a catalyst. The process converts NO\(_x\) into nitrogen and water.

*Particulate Matter filters*
Emissions of particulate matter (PM) can be reduced by means of a particulate filter. In this case the exhaust gases are fed through a ceramic-coated filter that traps the particles. Once saturated, the filter must be cleaned by burning or mechanically, depending on the type of filter. Particulate filters can only be used in combination with very low fuel sulphur levels (10 ppm).
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2.1 Regulatory Framework

Standards aren’t the same as Regulations and following a standard doesn’t guarantee that we are within the relevant Laws. In fact standards rarely cite the law as legislation could change within the lifetime of the standard.

The Governments often draws on Standards when putting together legislation or guidance documents. Standards are used to establish the technical detail, allowing the legislation to concentrate on long term policy objectives – for example product safety, or environmental protection.

In a case like OPS, compliance with the ISO Standards will often mean we’re compliant with the relevant International legislation, although there are usually ways of being compliant with legislation without using a standard.
2.2 Regulatory Framework

**EU Regulations**
EU Directive 2005/333 emission fuel sulfur marine vessels berthed in ports, related to the MARPOL Convention - VI of the IMO

EU Recommendation EC 2006/339 Shore side electricity. It is a technical recommendation of 2006 to supply ships at berth in EU ports, electricity from land.

**International standards**
IEC 2012 6092 Electricity 9AS ships
Standard ISO 2009, revised in 2012 on the electrical installation in ships to supply high voltage electricity from land

ISO 2013 - TC -008 Ship & Marine Technologies
Business plan several ISO standards and their relationship with the IMO.
Shore Power Supply also call him "cold ironing"

IEEE P-1713 Electrical connections shore to shop

**Sector organizations**
2005 ESPO Position Paper on Recommendation 2006/339 for the supply of electricity from shore to ships at berth in EU ports.
2010 WPCI shore power supply
World Ports Climate Initiative is an initiative of the IAPH - International Association of Ports and Harbours, Ports Committee and Environment
2.3 OPS Standardization

In July 2012 the first international standard for OPS systems, called IEC/ISO/IEEE 80005-1 Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirements has been published.

This standard was jointly developed by the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO) and the Institute of Electrical and Electronics Engineers (IEEE).

This standard also refers to standard IEC 62613-1:2011 for the general requirements for plugs, sockets-outlets and ship couplers for high-voltage shore connection systems.
2.4 Key components of standardization

• Referring to both the application of international electrical standards already available and installation guidance.

• Design, installation and testing of high voltage OPS systems covered. Low voltage systems are not covered by the standard.

• The standard covers onshore as well as on board equipment and also addresses shore-to-ship connection and interface equipment.

• A high share of requirements are related to safety aspects like emergency shut downs.

• Definition of a nominal voltage of 6.6 or 11 kV.

• No definition of a specific frequency.

• Additional requirements are included for Ro-Ro passenger ships, cruise ships, container ships, tankers and LNG carriers.
2.5 Advantages of international standards

The international standard contributes to the harmonization of OPS equipment by avoiding differences in technical characteristics of systems, like voltages, power plug and socket design in such a way that OPS can be used more efficiently at different berths.

By use of the international standard safety of OPS systems should improve and ships with OPS equipment onboard should not face difficulties to connect to the terminals equipped with OPS.

This will expedite developments owing to lower costs and increased compatibility between shore side installations and onboard equipment. Furthermore, the standard extensively discusses safety facilities to be taken into account when designing an OPS system.
2.6 EU position on OPS

Taxation of energy products and electricity in the Union is governed by Council Directive 2003/96/EC (hereafter referred to as the ‘Energy Taxation Directive’)

The Commission recommendation 2006/339/EC on the promotion of shore-side electricity for use by ships at berth in Community ports

The Commission, may authorise any Member State to introduce further exemptions or reductions in the level of taxation for specific transport or environmental policies considerations

The EU authorities acknowledge that the measure constitutes state aid and that it favours owners of ships used for commercial shipping. They also claim that it should be neutral with respect to competition between ship owners or operators since it would be available to all ships at berth in concerned ports independently of their flag.
2.7 ESPO position on OPS

The European Sea Ports Organization (ESPO) represents the port authorities, port administrations and port associations of the seaports of the European Union. The organization acts as the representative body of all EU seaports.

ESPO welcomed the recommendation EC/2006/339 and fully endorsed the approach of the Commission which emphasizes the importance of leaving final decision making concerning shore side electricity to port authorities.

ESPO believes that the principles in relation to the promotion of shore side electricity as set out by the Commission Recommendation of May 2006 are still valid. ESPO also supports the Commission in its intentions to reduce tax disadvantages for shore side electricity. Finally, ESPO continues to favor the swift development of a global IMO standard for shore side electricity.
2.8 WPCI position on OPS

WPCI is an independent non-profit organization. Its position on OPS was first released in spring 2010 by the working group on Onshore Power Supply (OPS) established by the World Ports Climate Initiative (WPCI). In summer 2013 an update of the website was released.

The OPS technology is known by a variety of names: Alternative Maritime Power (AMP), Cold Ironing, Shoreside Electricity and Onshore Power Supply. The IEC/ISO/IEEE standard uses the term High Voltage Shore Connection (HVSC) systems.

WPCI supports OPS for seagoing vessels as a measure to improve air quality in ports and port cities and reduce emissions of air pollutants and noise and to a lesser extent carbon dioxide, by replacing onboard-generated power from diesel auxiliary engines with electricity generated onshore. The focus is on port authorities, terminal operators and shipping companies considering introduction or expansion of the technology.
MARPOL (shortened Marine Pollution) is one of IMO’s conventions that focus on preventing different forms of marine pollution including oil, noxious liquid substances, harmful substances, waste water, garbage and emissions of sulfur oxide and nitrogen oxide at sea. Mandatory limitations on NOx being released on the atmosphere are under MARPOL Annex VI Regulation 13. The regulation affects not only ships from signatory states but ships entering MARPOL signatory-members’ waters.
2.10 IMO MARPOL: SECA options for compliance and OPS

**Sulphur Emission Control Areas**

- Compliant fuel oil
- Equivalent compliance methods (regulation 4)
  - “Fitting, material, appliance or apparatus to be fitted in a ship or other procedures, alternative fuel oils, or compliance methods”
  - Exhaust gas cleaning systems (open/closed loop)
- Onshore power supply ("cold ironing")
  - IEC/ISO/IEEE standard expected to be published later this year refers to High Voltage Shore Connection System (HVSC)
- Bio-fuels
  - Operating challenges: fuel system compatibility, long term storage, biological contamination
- LNG
  - Operating challenges: on board storage, supply, crew qualifications
  - Dual fuel engines
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1.1 Ports emissions description and consequences

**NOX** include various nitrogen compounds like nitrogen dioxide (NO2) and nitric oxide (NO). These compounds play an important role in the atmospheric reactions that create harmful particulate matter, ground-level ozone (smog) and acid rain. Health impacts from NOX are that they cause respiratory problems such as asthma, emphysema and bronchitis, aggravates existing heart disease, and contributes to extended damage to lung tissues, and causes premature death.

**SOX** cause irritant effects by stimulating nerves in the lining of the nose and throat and the lung’s airways. This causes a reflex cough, irritation, and a feeling of chest tightness, which may lead to narrowing of the airways. This later effect is particularly likely to occur in people suffering from asthma and chronic lung disease, whose airways are often inflamed and easily irritated.

**VOC** Volatile Organic Compounds (VOC) is a greenhouse gas and contributes eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment.

**PM** Particulate matter (PM) emissions contribute premature death, irritating asthma, increased respiratory symptoms’ such as coughing and painful breathing, and they contribute to decreased lung functions.
3.1 EMAS: Environmental Management System

- Reference: ISO-14001
- Provide an overview of Environmental Management System work with ports.
- Explain the culture change, i.e. proactive movement toward improved ‘environmental stewardship’ and ‘sustainability’.
- Highlight Environmental Management Systems (EMAS) & how are they helping ports.
- Focus on Diesel and Greenhouse Gas emissions reduction.
3.2 What does Sustainability mean

• “The ability to meet today’s global economic, environmental and social needs without compromising the opportunity for future generations to meet theirs.”

• - Brundtland Commission
• 3 P’s - Profit/Prosperity, Planet, People
• 3 E’s – Economy, Environment, Equity
3.3 Environmental is critical for Sustainability

- EMAS vision for Environmental Stewardship – “where all parts of society actively take responsibility to improve environmental quality and achieve sustainable results.”
  - A value – a core value & a way to create business value
  - A behavior – doing more than just complying with the law

“Sustainability involves the simultaneous pursuit of economic prosperity, environmental quality and social responsibility...”
### 3.4 Top-10 environmental priorities of EU Ports (from ESPO – Ecoports)

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<tbody>
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<td>1</td>
<td>Port Development (water)</td>
<td>Garbage / Port waste</td>
<td>Noise</td>
<td>Air quality</td>
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<tr>
<td>2</td>
<td>Water quality</td>
<td>Dredging: operations</td>
<td>Air quality</td>
<td>Garbage / Port waste</td>
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<tr>
<td>3</td>
<td>Dredging disposal</td>
<td>Dredging disposal</td>
<td>Garbage / Port waste</td>
<td>Energy Consumption</td>
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<td>4</td>
<td>Dredging: operations</td>
<td>Dust</td>
<td>Dredging: operations</td>
<td>Noise</td>
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<tr>
<td>5</td>
<td>Dust</td>
<td>Noise</td>
<td>Dredging: disposal</td>
<td>Ship waste</td>
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<tr>
<td>6</td>
<td>Port Development (land)</td>
<td>Air quality</td>
<td>Relationship with local community</td>
<td>Relationship with local community</td>
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<tr>
<td>7</td>
<td>Contaminated land</td>
<td>Hazardous cargo</td>
<td>Energy consumption</td>
<td>Dredging: operations</td>
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<tr>
<td>8</td>
<td>Habitat loss / degradation</td>
<td>Bunkering</td>
<td>Dust</td>
<td>Dust</td>
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<tr>
<td>9</td>
<td>Traffic volume</td>
<td>Port Development (land)</td>
<td>Port Development (water)</td>
<td>Port development (land)</td>
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<tr>
<td>10</td>
<td>Industrial effluent</td>
<td>Ship discharge (bilge)</td>
<td>Port Development (land)</td>
<td>Water quality</td>
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### 3.5 Top-10 environmental priorities of EU Ports (from ESPO – Ecoports)

#### Table 2: The influence of port size on the environmental priorities

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<tr>
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<th>&lt; 1 million tonnes (24 ports)</th>
<th>1 - 10 million tonnes (47 ports)</th>
<th>10 - 25 million tonnes (23 ports)</th>
<th>&gt; 25 million tonnes (28 ports)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Garbage/ Port waste</td>
<td>Dredging: operations</td>
<td>Air quality</td>
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<td>Noise</td>
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<td>Port development (water)</td>
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<td>Dredging: disposal</td>
<td>Energy consumption</td>
<td>Noise</td>
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<td>Dredging: operations</td>
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<td>Energy Consumption</td>
<td>Dust</td>
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<td>8</td>
<td>Bunkering</td>
<td>Relationship with local community</td>
<td>Port development (land)</td>
<td>Conservation areas</td>
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<tr>
<td>9</td>
<td>Ship waste</td>
<td>Ship waste</td>
<td>Ship waste</td>
<td>Port development (water)</td>
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<tr>
<td>10</td>
<td>Cargo spillage (handling)</td>
<td>Port development (land)</td>
<td>Dredging: disposal</td>
<td>Climate change</td>
</tr>
</tbody>
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3.6 Top-10 environmental priorities of EU Ports (from ESPO – Ecoports)

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<tr>
<th>Position</th>
<th>Estuary (40 ports)</th>
<th>Engineered coastline (26 ports)</th>
<th>Embayment^2 (39 ports)</th>
<th>River (17 ports)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Conservation areas</td>
<td>Air quality</td>
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<td>Relationship with local community</td>
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<td>7</td>
<td>Air quality</td>
<td>Hazardous cargo (handling/storage)</td>
<td>Relationship with local community</td>
<td>Environmental risk assessment</td>
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While there is a limit to what port authorities have control over, they have more control than they think, e.g. can strengthen tenant lease and contract language, do tenant audit.

Can expand zones of influence and interest by getting more involved with coastal zone or watershed programs, or regional transportation planning.
3.8 Port environmental responsibilities

- What are progressive ports doing to become better environmental stewards?

- Developing Environmental Management Systems (EMASs) for existing & new facilities.

- Measuring and reporting on continuous improvement in environ. performance


- Communities want to know about more than economic impacts.
3.9 What is an Port EMAS

• A Port EMAS is a formal system for managing the environmental footprint of a Port.
  – Incorporates environmental considerations into day-to-day operations and strategic planning.
  – Provides a structured framework designed to achieve continual environmental improvement.
Since 1994, the vision of EcoPorts has been to create a level playing field on port EMAS in Europe through the sharing of knowledge and experience between port professionals. Serving the principle of "ports-helping-ports" EcoPorts brought together a network of port professionals from several European ports committed to exchange views and practices and to commonly work towards the improvement of the sector's environmental performance in line with the principles of voluntary self regulation. ECOPORTS works together with ESPO,

The World Ports Climate Initiative (WPCI) is dedicated fighting against climate change by initiating programs at the ports that reduce GHG emissions and improve air quality. Supported by IAPH the world’s leading marine ports' organization, the project ports and scroll ports are working together and implementing a wide range of actions to achieve these objectives.
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4.1 Costs in an OPS project

As the available examples and studies show, the required investments may vary considerably, depending on the local situation. In addition, cost calculations for RoRo terminals are different from those for container or bulk terminals. On the one hand RoRo ships have a high number of port calls and on the other, relatively low investment costs due to their low power requirements.

The need for a frequency converter is also associated with significant investments. The operational cost advantage of OPS depends on fuel and electricity prices and any tax on electrical power.
4.2 Investments Shoreside

Investments at quays close to a residential or industrial area, high-voltage power (6.6-11 kV) may often be available close at hand or within a few kilometers. In most ports there is access to electricity at different voltage levels. It is important, though, to be duly aware of issues of availability, because the costs of supplying high-voltage power can vary significantly if investment in transformer stations is required. OPS installations should be designed in accordance with the available standard. In assessing cost and system requirements the following cost items are generally found to be of greatest importance.

**Shoreside:**
- The costs of supplying high-voltage power
- Any need for transformers
- Switchboard and control panel
- The possible need for a frequency converter
- The length of underground cable conduits and canalization
Quayside investments

The cost of transporting electricity from a local grid to a port terminal range from US $ 300,000 to 4 million per berth, depending on port location, power demand, voltage and frequency and vessel type. A feasibility study for the Port of Rotterdam calculated € 4 million per berth, while at the Port of Gothenburg the figure was only a fraction of this (€ 255,000 for 2 berths), because of the already available high-voltage power supply, the lack of a need for a frequency converter and the limited power requirements of RoRo vessels.

At the Port of Long Beach estimated costs per berth vary significantly, depending on power requirements and berth location, ranging from US $ 1 to 4 million. Studies by the Port of Amsterdam and by the European Commission indicate that investments for cruise ships are likely to be around € 6 million per berth. The early Entec study commissioned by the European Commission reports costs at the lower end of the feasibility studies performed by others at a later stage.
4.4 Investments Onboard

Onboard:
• Electrical distribution system
• Switchboard and control panel
• Cable reel system (also possible on the quay, depending on design)
• Transformer (if not available on quay)

Power supply and frequency conversion as key factors
The two items with the greatest impact on OPS installation costs are frequency conversion and quayside supply of high-voltage power.

Compared with these costs, those of underground cabling and canalization are limited, as the available literature confirms. A feasibility study on OPS use at the Rotterdam Euromax terminal cites significantly different cost estimates from those available for the port of Gothenburg.
Shipside investments

Costs for shipside modifications can range from US $ 300,000 to 1-2 million, depending on vessel type and size and the need for an onboard transformer.

There is also a significant difference between retrofit and new-build projects, with the former sometimes costing up to 150 to 200 % of the latter.
4.6 Investments in installations

**OPS installed**

OPS is installed in more and more ports around the world. Most installations can be found along the North American East coast and Northern Europe, due to the strong environmental legislation, community pressure and social responsibility. In Asia, OPS is an upcoming technology to reduce local emissions.

In many cases already, local governments have contributed to investments. With its potential for significant cuts in air pollutant and CO$_2$ emissions, OPS is one of the options available for achieving sustainability targets.

There are also several examples of shippers and shipping lines expressing an interest in the application of OPS to achieve sustainability goals and improve working conditions. Implementation of OPS can be spurred by environmental regulations, pressure from communities, politicians and governments or stakeholder interest.
The environmental performance of ports is becoming increasingly important as a license to operate. The international regulations for seagoing vessels agreed by IMO in 2008 are a significant step forward, but it is broadly felt that additional measures are required to address local air quality concerns.

In several countries measures have already been taken to ban old trucks from sensitive areas and community acceptance of port expansion requires due attention from operators, including proactive behavior. Social responsibility is, in short, a prerequisite for future port development.

Figure C.33. The free space between the crane and the quayside is limited, approximately 1 meter.

Figure C.34. Cranes operate on fixed rails and require the full range of the quay.
4.8 Interest of Shippers

In recent years shippers have shown a growing interest in the environmental impact of the logistical chain.

The environmental burden embodied in consumer goods is being seen as increasingly important. In some countries regulations in this area are being developed and a sustainability goals through improvements to their product and logistical chains.

This kind of “greening” of supply chains may result from shippers participating in specific projects or may be part of green packages offered by the maritime industry. growing number of companies are pursuing

**Figure C35** Ro/Ro ramp used for unloading and loading vehicles onboard.

**Figure C36** Unloading and loading activity at a Ro/Ro terminal.
4.9 Environmental stewardship in Supply chains

Implementation of OPS will give a boost to the public image of project initiators, who will be associated with its positive environmental and health impacts. Thus, OPS serves not only the environment but also the image of companies and governments.

This is becoming ever more important as organizations are increasingly confronted with rising expectations from communities when it comes to bringing environmental stewardship to the community.
The **OPS Costs calculation tool** permits calculation of the overall costs of a project under study. It calculates operational and investment costs and provides a means of assessing the effects of optimizing parameters like berth occupancy, electricity supply costs, fuel costs and so on.

The **OPS Costs Calculator tool developed by WPCI** is at:

[http://www.ops.wpci.nl/_images/content_editor/_original/1375958658_opscalculationtoolversion05082013.xls](http://www.ops.wpci.nl/_images/content_editor/_original/1375958658_opscalculationtoolversion05082013.xls)
1. What is OPS
2. Regulatory aspects
3. Port Environment
4. Costs
5. Implementation
6. Role of LNG
7. Current installations
5.1 Initial analysis and Terminals selection

An analysis of the legal and policy context should be part of every research and implementation programme, because it may identify opportunities for local funding from an air quality perspective. Such analysis may also be necessary to obtain a good overview of future policies and their impact on the OPS project.

**Terminal selection**

Not all ports will be equally suitable for installing OPS and the particular local situation should therefore be carefully reviewed, from both the point of view of economic costs and environmental benefits.

**Terminal use and power consumption**

Another selection criteria is terminal utilization. The more the terminal is used and the more power is consumed, the greater the environmental benefits will be. Vessels frequently calling at the port, with long port stays and high power consumption patterns provide the greatest scope for emissions reduction.
5.2 Distance to local communities

As implementation of OPS will often involve significant investment, air quality modelling should be used to analyze whether and to what extent neighboring communities indeed stand to benefit. At the ports of Los Angeles and Long Beach there is no buffer zone between the local community and the port, and drastic control measures may therefore be needed in the form of OPS.

Similarly, at the Port of Rotterdam, OPS has been implemented at the Stena Line Terminal, which is close to the Hoek van Holland residential area. On the other hand, research has shown that installing OPS at the Euromax terminal at Maasvlakte 2 would not benefit local communities, as these are located outside the immediate region of air quality impacts. The greatest benefits are thus to be gained at terminals located close to built-up areas.
5.3 Cooperation with stakeholders

Create a working group with relevant parties
To build up a clear and comprehensive idea of the potential for OPS at a particular port requires input from many different parties. It is therefore advisable to set up a working group comprising experts and representatives from different stakeholder groups to discuss the issue and create a well-founded business case.

Stakeholders
The following stakeholders should be involved:
• the port authority
• the targeted shipping lines (frequent-callers)
• the terminal operator
• the local community
• suppliers of electricity and automation technology
• environmental engineers
• Ship owner
• Ship operator
5.4 Legal analysis

Legal analysis
The following section discusses policies of relevance for the use of OPS in the European Union and the United States.

No international requirements for OPS
There are presently no international requirements that would mandate or facilitate the use of OPS. However, National States are free to set standards for berthing vessels.

Thus, the CARB has set regulations for ships docking at Californian ports. The use of shoreside power is one of the solutions and ships equipped to receive such power will be able use it. A comparable case is the exclusion of single-hull tankers by EU and US governments during the nineties, before the IMO agreement.
5.5 Legal analysis : EU Policy

2025 Mandatory Shore Power in EU
The European Union approved the Directive 2014/94/EU Clean Power for Transport on the deployment of Alternative Fuel Infrastructures in 2014. This Directive obliges Member States to implement alternative infrastructure networks such as shore-side power technology by December 2025.

Therefore, the provision of shore power at EU ports will become a mandatory requirement by 2025. Under this Directive, Member States shall ensure:

• Shore-side electricity supply for waterborne vessels is installed in ports provided that it is cost-effective and has environmental benefits.

• Shore-side electricity supply shall comply with the technical specifications by 31 December: relevant EN standard, to be adopted by 2014, and, pending the publication of this standard, with the technical specifications of the IEC/ISO/IEEE 80005-1 standard.
In the coming years, fuel quality guidelines are set to become stricter. With the introduction of a maximum of 0.1 % S for fuel used at berth in the European Union and California, running auxiliary engines at berth will become more expensive, as use of HFO will no longer be possible. Within the 24 nautical mile regulatory zone off the California coastline, fuel requirements are in force for ocean-going vessels with respect to their main (propulsion) diesel engines, auxiliary diesel engines and auxiliary boilers when operating. This is the calendar for emissions reduction in the US.

<table>
<thead>
<tr>
<th>Date</th>
<th>Reduced Onboard Power Generation Option</th>
<th>Equivalent Emissions Reduction Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 1, 2010</td>
<td>Shore-power equipped ships must use shore power if available at berth</td>
<td>10% emission reduction</td>
</tr>
<tr>
<td>Jan. 1, 2012</td>
<td>Shore-power equipped ships must use shore power if available at berth</td>
<td>25% emission reduction</td>
</tr>
<tr>
<td>Jan. 1, 2014</td>
<td>50% shore-power visits and power reduction*</td>
<td>50% emission reduction</td>
</tr>
<tr>
<td>Jan. 1, 2017</td>
<td>70% shore-power visits and power reduction*</td>
<td>70% emission reduction</td>
</tr>
<tr>
<td>Jan 1., 2020</td>
<td>80% shore-power visits and power reduction*</td>
<td>80% emission reduction</td>
</tr>
</tbody>
</table>

*in addition, shore-power-equipped ships must use shore power if available at berth
5.7 OPS Feasibility Studies

Implementation of OPS requires input of plenty of detailed local data from the various stakeholders mentioned above and careful planning and study.

There are many examples of feasibility studies being undertaken prior to implementation of an OPS project. Examples include those carried out at the ports of Los Angeles, Long Beach, Rotterdam and Amsterdam.

The cost calculation tool contains all the relevant cost items and data needed to develop a feasibility study. It should be borne in mind that it is impossible to quantify all the benefits accruing from OPS. For example the value of improved working conditions on-board and at terminals. These effects should be taken into due account, however.

The following two issues should always be carefully analysed, as these will generally have the greatest impact on the feasibility of an OPS project:
- costs of local power supply
- distribution of vessel types and frequency of calls
WPCI offers a simple calculation tool that helps develop a feeling for the costs and benefits of OPS. The tool is filled out with characteristic data, but can be readily adapted to the local situation by changing the cost figures and data on the number of ships and their fuel consumption.

The tool can be used for two main specific goals: - to calculate the annual costs and benefits of OPS - to calculate the annual emission reduction. In addition, the tool permits estimation of the effects of different parameters on costs and emissions, thus providing insight into cost effectiveness.

In the cost effectiveness calculation, costs are balanced against the total amount of air pollutants prevented. Figures for the relative harmfulness of air pollutants have been taken from a study by AEA technology, Because of their more damaging nature, SO₂ and PM have been assigned a higher weighting factor. The calculation algorithm is as follows: pollution units (tonnes) = 1* NOₓ (tonne) + 2,2 * SO₂ (tonne) + 12.8 * PM (tonne). The cost effectiveness is expressed in € per pollution unit).
5.9 OPS Equipment's and solutions

**Systems not always interoperable**
The required equipment and solutions may differ from case to case. At the moment systems across the world are not interoperable, differing in their voltage and frequency as well as structural design. This is due to the lack of standardization and the difference in system frequencies between the North American continent/parts of Japan (60 Hz) and the rest of the world (50 Hz).

In addition, voltage levels differ among ports. Generally speaking, the first-generation OPS systems operate on low voltages. More recently, high voltage has become the standard, because of its easier operation in view of the limited amount of cabling required. For certain classes of vessel, however, matching voltage and frequency does exist. The cruise terminals in Juneau, Vancouver, Seattle and soon in Los Angeles all offer 11 kV and 6.6 kV to cruise ships.
Electrical frequencies also differ among vessel categories and sizes. Ocean-going vessels calling at European ports tend to have more 60 Hz electrical systems onboard, while smaller vessels have 50 Hz systems. The latter are primarily smaller vessels not sailing to other continents. It will thus depend on the particular local situation whether or not a frequency converter and/or an onboard transformer are needed. As stated earlier, these two items will affect the overall costs of an OPS system.

<table>
<thead>
<tr>
<th>Vessel type</th>
<th>50 Hz</th>
<th>60 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container vessels (&lt; 140 m)</td>
<td>63 %</td>
<td>37 %</td>
</tr>
<tr>
<td>Container vessels (&gt; 140 m)</td>
<td>6 %</td>
<td>94 %</td>
</tr>
<tr>
<td>Container vessels (total)</td>
<td>26 %</td>
<td>74 %</td>
</tr>
<tr>
<td>RoRo- and vehicle vessels</td>
<td>30 %</td>
<td>70 %</td>
</tr>
<tr>
<td>Oil and product tankers</td>
<td>20 %</td>
<td>80 %</td>
</tr>
<tr>
<td>Cruise ships (&lt; 200 m)</td>
<td>36 %</td>
<td>64 %</td>
</tr>
<tr>
<td>Cruise ships (&gt; 200 m)</td>
<td>-</td>
<td>100 %</td>
</tr>
<tr>
<td>Cruise ships (total)</td>
<td>17 %</td>
<td>83 %</td>
</tr>
</tbody>
</table>

Source: Shore side electricity, A feasibility study and a technical solution for an on-shore electrical infrastructure to supply vessels with electric power while in port, Chalmers University
5.11 OPS Power requirements at berth

For an idea of the kind of power required for an OPS system, the power requirements of various vessel types and sizes are presented below. The figures cited for smaller vessels are representative for ships operating in European waters, but may also apply to other regions. Power requirements have a significant impact on the costs of an OPS system and it is therefore important to pursue energy reduction options and assess peak power demand in advance.

<table>
<thead>
<tr>
<th>Vessel type</th>
<th>Average power demand (MW)</th>
<th>Peak power demand (MW)</th>
<th>Peak power demand for 95% of vessels (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container vessels (&lt;140m)</td>
<td>0.17</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Container vessels (&gt;140 m)</td>
<td>1.2</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Container vessels (total)</td>
<td>0.8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>RoRo- and vehicle vessels</td>
<td>1.5</td>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>Oil and product tankers</td>
<td>1.4</td>
<td>2.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Cruise ships (&lt;200 m)</td>
<td>4.1</td>
<td>7.3</td>
<td>6.7</td>
</tr>
<tr>
<td>Cruise ships (&gt;200 m)</td>
<td>7.5</td>
<td>11</td>
<td>9.5</td>
</tr>
<tr>
<td>Cruise ships (&gt;300 m)</td>
<td>10</td>
<td>20</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Partly based on: Shore side electricity, A feasibility study and a technical solution for an on-shore electrical infrastructure to supply vessels with electric power while in port, Chalmers University.
The success of shoreside power depends on the attitudes of parties on the land side as well as ship-owners. Several ship-owners have already invested in OPS technology on board their vessels. These include NYK Line, Evergreen, Princess Cruise and Holland America Line, China Shipping, Evergreen, MOL, Stena Line, Wagenborg, TransAtlantic, SOL, TransLumni, ICL, and Cobelfret.

**Container terminals need more connection points**
For vessels like tankers, cruisers and Ro-Ro vessels that commonly berth at the same dock and do not use cranes, shoreside connection is easier. At container terminals, where vessels do not always dock at the same position, there is a need for more connection points. At container terminals the area at the quay is restricted by rails, which makes quayside space more limited.
## 5.13 OPS and Diesel Electricity on shore: EU average prices 2015

<table>
<thead>
<tr>
<th>Electrical Grid</th>
<th>€ / kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Nuclear</td>
<td></td>
</tr>
<tr>
<td>New safety</td>
<td>0.50</td>
</tr>
<tr>
<td>Current</td>
<td>0.20</td>
</tr>
<tr>
<td>Old plants</td>
<td>0.02</td>
</tr>
<tr>
<td>2 Coal</td>
<td>0.20</td>
</tr>
<tr>
<td>Diesel - Vessel</td>
<td>0.17</td>
</tr>
<tr>
<td>3 Gasoil</td>
<td>0.10</td>
</tr>
<tr>
<td>4 Wind</td>
<td>0.10</td>
</tr>
<tr>
<td>5 Solar</td>
<td>North EU</td>
</tr>
<tr>
<td>South EU</td>
<td>0.10</td>
</tr>
<tr>
<td>6 Propane gas</td>
<td>0.08</td>
</tr>
<tr>
<td>7 LNG</td>
<td>0.05</td>
</tr>
<tr>
<td>8 Water</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*Final Price to ship owner depend on type of electrical tariff and tax cuts applied*
1. What is OPS
2. Regulatory aspects
3. Port Environment
4. Costs
5. Implementation
6. Role of LNG
7. Current installations
6.1 Ship owners environmental compliance strategies

There are a number of different strategies that can be applied to comply with the new emission regulations. In this report, mainly three strategies are studied:

• Continue using Heavy Fuel Oil (HFO) but add a scrubber to decrease sulphur emissions;
• Use Marine Gas Oil (MGO) as fuel;
• Use LNG or use a dual fueled engine (LNG inside the SECA only).

Which strategy, if any, that will come to dominate, is largely dependent on economic aspects such as investment costs as well as operational costs and then above all the future fuel prices.

Another, extremely important, factor for a potential shift to LNG use is the LNG availability which is linked to the LNG demand. A high availability paves the way for a high LNG demand, whereas a high LNG demand is vital to ensure a high availability.
6.2 LNG as marine fuel

Due to its low temperature, LNG has to be stored in cryogenic tanks, which require much more space than traditional fuel oil tanks. This may reduce the cargo capacity, depending on type of vessel, type of fuel tank and potential of adequate location of the LNG tanks on-board.

LNG is assumed to be available at competitive cost but the future price level is highly uncertain. Hence the price will be varied in the cost analysis (see below). The LNG fueled gas engines have been proven to be reliable and it is a low-sulphur fuel. Exhaust gas emissions such as SOX, NOx and PM are negligible.

LNG can also be used in dual fuel (DF) engines which have the advantage of being able to run on either liquid fuel oils or gaseous fuel. The idea is to use LNG inside SECA and another fuel outside the SECA. The dual fuel engines can be either four stroke Otto engines or two stroke diesel engines. For the four stroke engine, the working principle is based on the Otto Cycle when operating on natural gas and the Diesel Cycle is the basis for operation on fuel oils.
6.3 LNG price forecast

The LNG price forecast has been based on a forecast published by the UK Department for Energy and Climate Change (DECC). The LNG price forecast developed can be seen (together with the HFO and MGO forecasts) in Table 2 below. Three scenarios are used with LNG prices 6.5 €/GJ (300 €/tonne), 8.7 €/GJ (400 €/tonne) and 10.9 €/GJ (500 €/tonne), respectively. Also, a fourth scenario called the High80 is used, with an LNG price of 14.5 €/GJ is used (80 % of the MGO price).

Figure 10. Forecasted fuel prices at LNG hub in the different scenarios, from Appendix A
6.4 Pros & Cons of LNG for ship owners

There are a number of other factors related to economy that should be taken into account when making a comparative analysis of the compliance strategies (apart from availability, safety which are discussed elsewhere in this report). For example, bunkering LNG may take longer time than bunkering fuel oils. This could in many cases lead to loss of profitable time at sea. If this will be the case and how much time that is lost is however hard to quantify since it is case specific and dependent on how the ship is operated, bunkering capacity of the terminal (including bunker barges) and many other factors.

Another drawback with LNG is e.g. the need for extra education of the staff concerning fuel handling and use. This has been included in the investment analysis (see Appendix A for further details). Also, the potential requirement for special licenses for handling LNG may inflict some costs, as may environmental investigations preceding the granting of permissions to handle LNG in ports (example of a cost that will be transferred to the LNG end customers).
6.5 Maritime LNG supply chain

This chapter illustrates the maritime LNG supply chain, which is imperative for the availability of LNG as a marine bunker fuel. The different alternatives for the downstream LNG supply chain are illustrated and different bunkering solutions are reviewed from operational, logistics and regulatory perspectives. Critical parameters that determine bunkering solutions and suitable terminal equipment and facilities for different terminals that provide LNG bunkering are investigated and illustrated by three port cases. These cases are more in detailed analyzed in Appendix F. Finally, critical port criteria for LNG bunkering are described in the last section. The up-stream infrastructure and related facilities, refer to Figure below.
When LNG is used as a fuel for shipping, the supply chain is extended with several steps after the LNG import terminal.

The different supply options from the LNG import terminal to the ship are illustrated in this Figure.
6.7 LNG Terminal

An intermediary LNG terminal can be used if the distance from the LNG import terminal plant to the end user is longer than what is economically feasible for a bunker vessel or truck to cover (approximately 40-100 nautical miles for a bunker vessel and 350-600 kilometers for a truck. Longer distances are possible for larger volumes). An intermediary terminal may also be needed if it is necessary to bunker at a fast rate and for local bunkering to consumers such as harbor tugs, fishing vessels or ferries.

An intermediary terminal can therefore vary considerably in size. In a full-scale application, the terminal in a large port could be as large as 100,000 m³, while an LNG terminal serving small fishing vessels or tugboats through a pipeline at a bunkering quay may have a capacity down to 50 m³.
6.8 LNG bunkering solutions

There are three types of bunkering solutions analyzed in this work are:
• 1. ship to ship, at quay or at sea;
• 2. tank truck to ship;
• 3. LNG intermediary terminal to ship via pipeline.

The possibility to use containerized solutions whereby the entire tank/container is replaceable is also briefly described. Many factors need to be taken into account when deciding on a suitable bunkering solution, for example distances, traffic intensity, volumes, frequency, safety and vicinity to other LNG bunkering ports or land-based demand.
6.9 Suitable LNG bunkering for vessel types

<table>
<thead>
<tr>
<th>Type of vessel / Type of bunkering</th>
<th>STS</th>
<th>TTS</th>
<th>ITPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RoPax / RoRo Vessels</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Tugboats (vessel occupied in port areas)</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Coastal Tankers / Bulk Carriers</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Container Feeder Vessel</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>LNG Feeder Vessels</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>LNG Bunker Vessels</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>LNG Tankers (140 000m³)</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Naval / Coast Guard Vessels</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Offshore Supply Vessels</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Smaller Passenger Vessels</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Larger Fishing Vessels</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>VLCC (Very Large Crude oil Carrier)</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

*Source: SSPA, FKAB, White Smoke, SMTF (2011).*

Ship to Ship Bunkering (STS) / Tank Truck to Ship Bunkering (TTS) / LNG Terminal to Ship via Pipeline (TPS)
6.10 Suitable LNG bunkering for vessel types

Suitable solutions for bunkering of vessels in port depend on many factors. In order to select the best solution for an individual port, the following critical parameters have been identified and described: the LNG bunkering volumes, physical limitations in port, logistic issues, types of vessels and shipping companies and safety issues.

<table>
<thead>
<tr>
<th>Port characteristics / type of bunkering</th>
<th>STS</th>
<th>TTS</th>
<th>ITPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large LNG volumes due to large vessels</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Large LNG volumes due to high frequency</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Significant physical limitations on water</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Significant physical limitations on land</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Many activities in port</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Short distance LNG Import terminal</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Large share of different vessel types</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>High safety requirements in port</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Matrix Abbreviations:**

1. Best suitable LNG bunkering solution.
2. Suitable LNG bunkering solution, though not the best.
3. Unsuitable LNG bunkering solution for a port with this characteristic.

Ship to Ship Bunkering (STS) / Tank Truck to Ship Bunkering (TTS) / LNG Terminal to Ship via Pipeline (TPS)
1. What is OPS
2. Regulatory aspects
3. Port Environment
4. Costs
5. Implementation
6. Role of LNG
7. Current installations
7.1 OPS in the Port of Goteborg (Sweden)

The first step for shore side power supply in Port of Göteborg (Sweden) was taken in 1989. The port converted a terminal to service Stena Lines passenger ferries to Kiel with a low-voltage, 400 V, shore-side power supply system, see Figure B3 and Figure B4. This service is run by the two combined passenger and Ro/Ro ferries Stena Scandinavica and Stena Germanica.

Stena Line has implemented shore-side connect the majority of the vessels in the Scandinavian enterprise. In total they invested about €10 million to adapt vessels. Stena Lines business in Port of Göteborg was the first to receive shore-side power supply. All was retrofitted to be able to receive shore power.
7.2 OPS in the Port of Stockholm (Sweden)

In 1985, Port of Stockholm (Sweden) inaugurated their first shore-side power supply facility for connection of bigger vessels. The connection is located in Stadsgården and connects ships that are operating to Aland Island - Viking Cinderella and Birger Jarl.

These ships are connected with a low voltage connection, 400 V/50 Hz. To be able to deliver sufficient amount of power to the vessels (2.5 MW), 9 cables need to be connected before the electricity generators onboard the vessel are shutdown. To make the connection as smooth at possible a custom made cable arrangement was made at land, see Figure B8 and Figure B9. The connection process takes approximately 5 min.
Port of Helsingborg (Sweden) is providing shore-side electricity to the ferries that stay at berth during night. The Scandlines ferries are connected via 400 V/50 Hz 2 x 250 A cables, which is sufficient for limited supply. Sundbussarna are connected with shore-side electricity 400 V/50 Hz 2 x 125 A. HHFerries are connected with 440 V/50 Hz.
7.4 OPS in the Port of Antwerp (Belgium)

In 2008, Port of Antwerp (Belgium) in cooperation with ICL Holding of Hamburg installed the world’s first 50/60 Hz shore-side electric supply system for the Independent Maritime Terminal (IMT) on Port of Antwerp.

The facility will typically enable up to three container vessels to connect to it for approximately three days within any one week while berthing. The on-shore supply facility is a high voltage, 6.6 kV, facility and uses Pulse Width Modulated (PWM) technology for conversation of the frequency from 50 Hz to 60 Hz. The on-shore power supply is able to provide a power of 800 kVA through one cable connected to the ships cable drum. The facility has not been taken in operation yet.

Figure B15: A barge with the transformer and a cable reel is moored at the stern of the container vessel. Nine heavy cables are hoisted into position using a crane.

Figure B16: The 9 cables are connected to the vessel connection box.
7.5 OPS in the Port of Lubeck (Germany)

In 2008, Port of Lübeck (Germany) successfully installed a shore-side electric supply system. The system grid at the port is 10 kV. A transformer rated 2.5 MVA is installed in a concrete substation on the harbor site for separating the harbor grid and the ship grid electrically and to lower the voltage to 6 kV, see Figure B12.

Another component of the shore-side connection is a smaller cabinet with a 6 kV/50 Hz outlet enabling power to be obtained from the berth via a cable supplied by the ship. (see Figs B13 and B14) After connection, an automation system installed on-shore can automatically initiate the start up of the shore side power supply system. The auxiliary engines of the on-board power supply can then be shut down.
In 2005, cooperation between Port of Long Beach and British Petroleum (BP) voluntarily started to work with a shore-side power supply project on Berth T121. The purpose of the project was that the two BP tankers, which traffic Port of Long Beach, should use shore-power whenever they called at the Port.

In 2008 the installation was finished and completed, but the testing stage took more time than expected, due to strict regulations for tanker vessels, so the official use of the shore-side power supply will be in year 2009. A transformer is used to step down the voltage from local power grid to 6.6 kV. The power transferred to the tankers is 10 MVA, and 3 cables are used for the power transfer [11]. The project can be seen in Figure B21.
7.7 OPS in the Port of Juneau (USA)

In June 2001, Port of Juneau (Alaska) in cooperation with Princess Cruise Lines installed the world’s first high voltage shore-side power system for cruise ships docked at the Port. The shore-side electric system consists of cables and a substation to transfer electricity from the port grid. A dual-voltage transformer is used to step down the voltage from local power grid to 6.6 kV or 11 kV to provide different classes of ships, see Figure B22. A custom made dock-side gantry cable system was made for easier connection of the vessels. Four cables are used for the electric connection, each consisting of three cores for each phase, see Figure B22 and Figure B24.
In 2005, Princess Cruise Lines in cooperation with Port of Seattle installed a high-voltage shore-side power supply to one berth at Terminal 30, in Port of Seattle. Two of Princess Cruise Line’s larger cruiser ships equipped with shore-power equipment was connected to the shore-side power supply.

The overall electrical specifications and designs are similar to Port of Juneau. Shore-side cables were stored within a cable trench at the edge of the berth. When a cruise ship is at berth, cables are hoisted to the ship-side by a gantry and connected to the on-board electric system, see Figure B25 and Figure B26.
In 1991, the Pohang Iron & Steel Company in Pittsburg established a shore-side electricity system to connect four dry bulk vessels at Port of Pittsburg. The vessels require a power supply of approximately 0.5 MW. The shore power is transmitted by two 440 V cables. After a ship docks the Port, two crewmembers pull the power cables on board and plug them into the onboard power system. This procedure takes approximately 20 minutes to complete.
### 7.10 Worldwide ports using OPS 2000 - 2014

<table>
<thead>
<tr>
<th>Year of introduction</th>
<th>Port name</th>
<th>Country</th>
<th>Capacity (MW)</th>
<th>Frequency (Hz)</th>
<th>Voltage (kV)</th>
<th>Ship types making use of OPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-2010</td>
<td>Gothenburg</td>
<td>Sweden</td>
<td>1.25-2.5</td>
<td>50 &amp; 60</td>
<td>6.6 &amp; 11</td>
<td>RoRo, ROPAX</td>
</tr>
<tr>
<td>2000</td>
<td>Zeebrugge</td>
<td>Belgium</td>
<td>1.25</td>
<td>50</td>
<td>6.6</td>
<td>RoRo</td>
</tr>
<tr>
<td>2001</td>
<td>Juneau</td>
<td>U.S.A.</td>
<td>7-9</td>
<td>60</td>
<td>6.6 &amp; 11</td>
<td>cruise</td>
</tr>
<tr>
<td>2004</td>
<td>Los Angeles</td>
<td>U.S.A.</td>
<td>7.5-60</td>
<td>60</td>
<td>6.6</td>
<td>container, cruise</td>
</tr>
<tr>
<td>2004</td>
<td>Piteå</td>
<td>Sweden</td>
<td>1.0</td>
<td>50</td>
<td>6</td>
<td>RoRå</td>
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<tr>
<td>2005-2006</td>
<td>Seattle</td>
<td>U.S.A.</td>
<td>12.8</td>
<td>60</td>
<td>6.6 &amp; 11</td>
<td>cruise</td>
</tr>
<tr>
<td>2006</td>
<td>Kemi</td>
<td>Finland</td>
<td></td>
<td>50</td>
<td>6.6</td>
<td>ROPAX</td>
</tr>
<tr>
<td>2006</td>
<td>Kotka</td>
<td>Finland</td>
<td></td>
<td>50</td>
<td>6.6</td>
<td>ROPAX</td>
</tr>
<tr>
<td>2006</td>
<td>Oulu</td>
<td>Finland</td>
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<td>50</td>
<td>6.6</td>
<td>ROPAX</td>
</tr>
<tr>
<td>2008</td>
<td>Antwerp</td>
<td>Belgium</td>
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<td>50 &amp; 60</td>
<td>6.6</td>
<td>container</td>
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<tr>
<td>2008</td>
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<td>50</td>
<td>6</td>
<td>ROPAX</td>
</tr>
<tr>
<td>2009</td>
<td>Vancouver</td>
<td>Canada</td>
<td>16</td>
<td>60</td>
<td>6.6 &amp; 11</td>
<td>cruise</td>
</tr>
<tr>
<td>2010</td>
<td>San Diego</td>
<td>U.S.A.</td>
<td>16</td>
<td>60</td>
<td>6.6 &amp; 11</td>
<td>cruise</td>
</tr>
<tr>
<td>2010</td>
<td>San Francisco</td>
<td>U.S.A.</td>
<td>16</td>
<td>60</td>
<td>6.6 &amp; 11</td>
<td>cruise</td>
</tr>
<tr>
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<td>Sweden</td>
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<td>50</td>
<td>11</td>
<td>ROPAX</td>
</tr>
<tr>
<td>2011</td>
<td>Long Beach</td>
<td>U.S.A.</td>
<td>16</td>
<td>60</td>
<td>6.6 &amp; 11</td>
<td>container</td>
</tr>
<tr>
<td>2011</td>
<td>Oslo</td>
<td>Norway</td>
<td>4.5</td>
<td>50</td>
<td>11</td>
<td>cruise</td>
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<tr>
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<td>Prince Rupert</td>
<td>Canada</td>
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<td>60</td>
<td>6.6</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Rotterdam</td>
<td>Netherlands</td>
<td>2.8</td>
<td>60</td>
<td>11</td>
<td>ROPAX</td>
</tr>
<tr>
<td>2012</td>
<td>Ystad</td>
<td>Sweden</td>
<td>6.25</td>
<td>50 &amp; 60</td>
<td>11</td>
<td>ROPAX</td>
</tr>
<tr>
<td>2013</td>
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<td>Sweden</td>
<td>3.5-4.6</td>
<td>50</td>
<td>11</td>
<td>ROPAX</td>
</tr>
<tr>
<td>2015</td>
<td>Hamburg</td>
<td>Germany</td>
<td>12</td>
<td>50 &amp; 60</td>
<td>6.6 &amp; 11</td>
<td>cruise</td>
</tr>
</tbody>
</table>
On Shore Power Supply and LNG

- Cruise ships: > 200 m, 10–20 MVA
- Tankers: > 200 m, 3–11 MVA
- Container/reefer: > 200 m, 3–6 MVA
- Bulk/cargo/container/Ro-Ro: < 100 m, 300 KVA–3 MVA

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