Shore-to-ship power

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wbcsd

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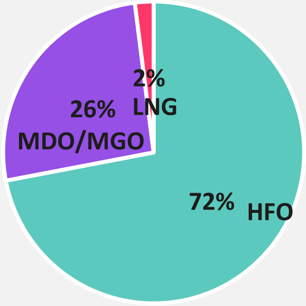
1. Background

Shipping is fueled by fossil fuels, and immediate availability of lower carbon fuels is limited

Energy consumption in shipping

- Energy consumption in shipping is almost exclusively fossil fuel based, with heavy fuel oil (HFO) and marine diesel oil/marine gas oil (MDO/MGO) responsible for the largest shares.
- Energy consumption in the sector is dominated by international shipping.
- Energy is consumed for propulsion, as well as to generate electricity for onboard use.

Share of fuel consumption by global shipping fleet (2015)[1]



Possible solutions to decarbonize

- Efficiency improvements have been achieved through slow steaming (operating ships at lower speeds) and the introduction of the Energy Efficiency Design Index (EEDI), which sets a minimum energy efficiency level for new ships.
- Fuel shifts:
  - Biofuels can reduce CO_2 emissions from shipping, depending on the feedstock type and processing.
  - Shore-to-ship power allows ships to turn off engines and connect to the electricity grid while in port. The emission reduction depends on the carbon intensity of the electricity grid; in the EU, there is a saving of 40% of CO_2 emissions while in port (see page 7).
  - LNG fueled ships can abate emissions by up to 21% compared to current marine fuels on a well-to-wake basis (including supply chain and fugitive emissions). The difference could be as low as 5%, depending on the engine technology and reference fuel.[2]
  - Synthetic fuels: hydrogen, ammonia and methanol produced with renewable energy are being considered as potential solutions.
  - Electric propulsion: electric ship technologies are emerging for short distance voyages. Hybrid ships are also emerging, with electric propulsion used for zero emissions operations in ports.[3]

Source: [1] ICCT, 2017: *Greenhouse gas emissions from global shipping, 2013-2015*. [2] thinkstep, 2019: *Life Cycle GHG Emissions Study on the Use of LNG as Marine Fuel*; [3] Stena Line, 2018: *Stena Line launches 'battery power' initiative*.

1. Background

Electricity generation on ships is CO_2 intensive and likely to grow under a BAU scenario

Current electricity generation and associated CO_2 emissions	• On-board electricity generation using auxiliary engines emits about 700gCO_2/kWh.[1] • Shipping emissions in ports account for 18 MtCO_2, or approximately 2% of total shipping emissions.[1] • Direct CO_2 emissions from shipping in 2015 were 932 MtCO_2 or about 3% of global energy-related CO_2 emissions.[2]
Evolutions forecast in a business-as-usual scenario	• The International Transport Forum estimates that shipping emissions in ports will grow fourfold by 2050, with emissions reaching about 70 MtCO_2.[1]
Obstacles to decarbonizing this application	• Limited financial incentives – energy taxes that apply to fossil fuel consumption e.g. for road transport, don't apply to fuels for international shipping, coverage of carbon pricing on shipping emissions is limited, and only some ports' fees are differentiated based on environmental criteria including shore to ship power. • Current regulations focus on reducing air pollution and noise, rather than GHGs from shipping. • Retrofitting vessels with the capability to use shore-to-ship power might require modifications in a dry dock, which means the vessel cannot be utilized over the installation period. • Split incentives between charter and ship-owning in the maritime charter market, where the ship owner provides the vessel, but fuel costs are borne by the charterer.

Sources: [1] ITF, 2014: *Shipping emissions in ports*; [2] ICCT, 2017: *Greenhouse gas emissions from global shipping, 2013-2015*.

2. Description of shore-to-ship power

Overview

Description of the new solution concept	• Ships typically use auxiliary engines to generate electricity for use onboard. • With shore-to-ship power, ships can shut down these engines while berthed and plug into an onshore power source. A ship's power load is transferred to the shore-side power supply without disruption to onboard services. • While floating/mobile LNG solutions* also exist to generate power for berthed ships, this business case focuses on electricity-based shore-to-ship power. • Technology is known under various names, including cold ironing, onshore power supply, alternative maritime supply.
Rationale for developing this solution	• Port areas are often located in or near cities, which aggravates the air pollution concern. Shore-to-ship power reduces the local environmental impact of ships at berths, including air pollution (SOx, NOx, particulate matter - PM), noise pollution and vibration.** • Shutting down ship engines saves running hours and consequently reduces maintenance costs. • CO_2 emissions can be avoided, depending on the underlying electricity mix. • More mature than other fuel shift options for shipping available today. • Shore-side electricity connections are also used to charge batteries on full electric vessels and hybrid ships; this might increase the utilization rate of the shore-side facility.
Assessment of technology readiness status	• Shore-to-ship power is an already mature technology – the US Navy has decades of experience with shore-to-ship power[1] – and the number of berths and ships with shore-to-ship capabilities is increasing. • Currently used for many types of ships: cruise, ferries, tankers, container, reefer, fishing vessels and tugs. • International IEC/ISO/IEEE standards exist to ensure on-board system compatibility.

*Floating/mobile solutions to shore-to-ship power consist of a LNG based electricity generation system situated on a barge or in a shipping container that provides electricity to a ship.

**Depending on the ship, shore-to-ship power does not always reduce *all* environmental impacts at port. Oil-fired boilers (or auxiliary boilers) are used in some ships (commonly, ocean-going ones) to generate steam while at port, which is used for heating purposes around the ship. This cannot be displaced by shore-to-ship power, but could be displaced by connecting to the district heating grid, where available.[2]

Sources: [1] US EPA, 2017: *Shore Power Technology Assessment at U.S. Ports*; [2] Celsius Smart Cities: *District heating for ships in harbour*.

2. Description of shore-to-ship power

Port-side solutions need to be customized depending on the vessel segment

Shore-to-ship power at ports needs to be designed to accommodate characteristics of each vessel segment (e.g. cruise ships, ferries, cargo ships), which can differ substantially:

- Voltage: Ships' voltage levels can range from low (400V-690V) to high (6.6 or 11kV) voltage. A transformer is needed either on each ship or on the port side to match the different voltage levels and to ensure galvanic isolation between ships that are connected simultaneously at a shore power facility.
- Frequency: the majority of ships operate with 60 Hz, with some at 50 Hz, while onshore power frequency varies depending on countries. European countries, for example, operate at 50 Hz. A frequency converter is needed to match the onshore power frequency to the onboard power system frequency, and it is one of the biggest cost drivers in a shore power facility.
- Power demand: depends on vessel type. Up to 3 MVA for ferry/RORO, 7.5 MVA for container ships and 20 MVA for cruise vessels. Berths need to have the appropriate infrastructure to meet the maximum power demand. Shore-to-ship power may not be suitable in regions that do not have stable electricity grids.

For information on standards, refer to:
ISO/IEC/IEEE 80005-1:2012 Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirements
ISO/IEC/IEEE 80005-2:2016 Utility connections in port -- Part 2: High and low voltage shore connection systems -- Data communication for monitoring and control
ISO/IEC/IEEE 80005-3:2014 Utility connections in port -- Part 3: Low Voltage Shore Connection (LVSC) Systems -- General requirements

Source: Ecofys, 2014: *Potential for shore side electricity in Europe*.

3. GHG reduction potential of shore-to-ship power

GHG emissions assessment of current and new solution

- The emissions avoided depend on the fuel used. Electricity generation using the auxiliary engines on ships emit about:*
  - 690gCO_2/kWh for marine gas oil.
  - 722gCO_2/kWh for heavy fuel oil.
- The emissions avoided also depend on the electricity grid emissions factor:
  - With the EU emission grid factor of 390gCO_2/kWh, there is a CO_2 saving of about 300gCO_2/kWh or 40%.
  - All emissions could be abated if electricity is generated using renewables.

*The emissions factor also depends on load and sizing of the engines.[1]

Source: [1] ITF, 2014: *Shipping emissions in ports*.

4. Cost assessment and sensitivity analysis

Investment costs	• The CAPEX costs of installing the electricity connection point for the port range from USD $300,000 to USD $4 million per berth. The port side costs depend on the maximum power demand, need for frequency conversion, the number of cables and the type of cable management system needed (including impact of cable trenches and ducting), and whether more than one ship can be connected to the facility simultaneously. Costs may be higher if a new high voltage substation is needed.[1] • Costs for shipside modifications can range from USD $100,000 to USD $1 million.[1]
Return on Investment (ROI)	• The ROI of shore-to-ship power is highly case specific; examples are illustrated in the following slides.
Sensitivity analysis	• The business case is sensitive to the following factors: - **Amount of electricity consumed:** the business case is best for ships that dock frequently and/or consume a lot of electricity while moored (e.g. cruise vessels docking every morning at a new port). For ports, the business case is optimized when there is a high utilization rate of shore-to-ship power connections. - **Fuel and electricity prices:** for ships, the ROI depends on the differential between the cost of electricity from shore-side power and the cost of self-generation (i.e. the oil price). For ports, the business case is sensitive to the fee they charge to ships (on top of the passed-on electricity cost) for use of shore-to-ship power facility. - **Port location and vessel types:** This determines the need for onshore or offshore transformers, frequency converters and maximum power demand requirements. In addition, vessel types determine whether retrofits require a dry dock period. These factors influence the shore-side and ship-side investment costs. - **Financial incentives for shore-to-ship power** such as tax reductions on electricity sold for this purpose, reduction on port fees, etc.

Source: [1] WPCI: *Onshore Power Supply Investments*.

4. Cost assessment and sensitivity analysis

DNV GL study on cruise vessels in the Baltic Sea

- DNV GL study[1] on the business case for establishing shore-to-ship power for cruise vessels calling at Bergen, Hamburg, Rostock, Tallinn and Helsinki.
- Key assumption: ship owner's willingness to pay for shore power is EUR €115/MWh; auto-generation price is EUR €125/MWh, average share of port calls using shore-to-ship power is 60%.

Port perspective:

- Electricity sales are only profitable in Bergen; other ports do not make a profit on electricity sales as the price that ship owners are willing to pay is lower than the price paid by ports.
- Even in Bergen, profits from sale of electricity does not cover investment and O&M costs (note that Bergen Port together with local utility have established a joint venture to provide shore power).

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**

Cruise vessel perspective:

- Higher rate of return on investment is achieved by increased utilization of shore-to-ship power (lay time).

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**

Port business case requires electricity prices that are lower than price that ships are willing to pay; high utilization rate is key for a strong shore-to-ship power business case.

Source: [1] DNV GL, 2018: *Assessment of opportunities and limitations for connecting cruise vessels to shore power*.

4. Cost assessment and sensitivity analysis

ABB business case tool of ferries vs cruise ships

2 ferries complete a return trip between 2 ports daily

Parameter	Value
Total cost vessel retrofit	EUR €600,000
Investment cost per terminal	EUR €1.2 million
Electricity price	EUR €70/MWh
Terminal electricity connection fee	EUR €0/MWh
Self generation price using marine gas oil (MGO)	EUR €118/MWh
Calls per year per ship at terminal	365
Hours at berth per ship per call	4

Case 1: Ship and terminal have the <u>same owner</u>:

- 8% internal rate of return (IRR) at 10 years
- Payback period 6.8 years

Case 2: Ship and terminal have <u>different owners</u>:

- Terminal charges EUR €35/MWh electricity connection fee;
- total price paid for electricity of EUR €105/MWh
- Ship owner has an 34% IRR at 10 years and payback period
- of 2.8 years
- Terminal Owner has 3% IRR at 10 years and payback period 8.8 years

Cruise ship connected to shore-to-ship power

Parameter	Value
Total cost vessel retrofit	EUR €800,000
Investment cost at terminal	EUR €4 million
Electricity price	EUR €70/MWh
Terminal electricity connection fee	EUR €30/MWh
Self generation price using MGO	EUR €121/MWh
Calls per year at terminal	50
Hours at berth per ship per call	12

Ship owner:

- 13% IRR at 10 years
- Payback period 5.5 years

Terminal owner

- 1 ship connected to shore-to-ship power: -8% IRR at 10 years
- 2 ships connected: 1% IRR at 10 years, payback period of 9.4 years
- 3 ships connected: 8% IRR at 10 years, payback period of 6.7 years

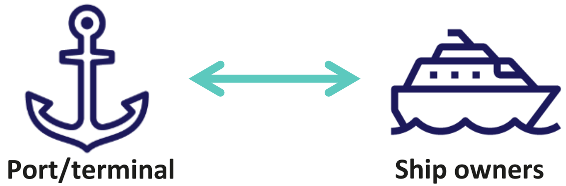
A high utilization rate is key for a strong shore-to-ship power business case

Source: ABB Business Case tool and personal communication.

5. New partnership opportunities

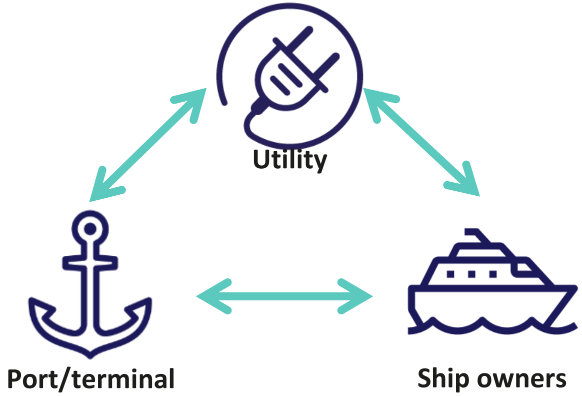
Cooperation between port/terminal and ship owners in a region or across a route:

- Installation of shore-to-ship power facilities can be coordinated to maximize utilization rates for both ports/terminals and ships.
- Business cases can be co-developed to ensure both sides receive positive ROI.



Cooperation between port/terminal, ship owners and a utility:

- Most port authorities/terminal operators are not permitted to sell electricity. Cooperation with utilities are needed for the following business models:
  - Ships pay the utility for electricity, ports/terminals charge ships an electricity connection fee.
  - Energy service company (ESCO model), where a utility or other third party makes the shore-side investment and ship owners pay a fee covering electricity cost and shore-side investment.



6. Shore-to-ship power SWOT analysis

Strengths

- Shore-to-ship power can reduce **emissions, noise and vibration** from ships at port.
- **Mature technology**, increasingly being built into new ships.
- **Enables ships to meet existing environmental regulations**, and regulations requiring the use of shore-to-ship power.
- **New revenue stream for ports/terminals and electricity utilities**.
- Can **reduce costs for shipping companies**, depending on the cost of electricity compared to fuel. Particularly relevant for ports where low-sulphur fuel regulations apply. Some ports reduce port fees for ships using shore-to-ship power.

Opportunities

- **New environmental regulations**. Global sulphur cap has increased the MGO price, improving the business case for shore-to-ship power; North Sea and Baltic Sea Emission Control Area begins in 2021.
- **Shipping industry is starting to move toward decarbonization**, with adoption of strategy which envisages 50% CO_2 reduction by 2050 compared to 2008.
- **EU policy** requires ports in the TEN-T network to install shore-to-ship power facilities by 2025 unless costs are disproportionate to benefits. Sweden, Germany and Denmark provide reduced tax rates on electricity consumed through shore-to-ship power and other EU countries may follow suit.
- **Emergence of electric or hybrid ships**, which require shore-to-ship power facilities at ports.

Weaknesses

- **Chicken and egg problem:** strong business case requires parallel investments at ports and ships to maximize utilization rates.
- **Environmental benefits are location specific:** CO_2 savings depend on the underlying power supply, and value of increasing air quality depends on the vicinity of the port to urban areas.
- **Principle-agent problem** due to split incentives between the charterer and the ship-owner.

Threats

- **Other technologies are emerging to meet environmental regulations** such as LNG systems and exhaust gas scrubbers.
- **Electricity costs** (incl. taxation) may be higher than the cost of self-generation. In some jurisdictions, this is driven by energy taxation which applies to electricity, but not to consumption of shipping fuels.
- **Limited alignment** on port regulations/incentives holds back adoption offshore-to-ship power and might cause “carbon leakage” to unregulated ports.

7. Success factors

High utilization rates

Strong business case requires shore-to-ship power facilities on both port and ship side to be utilized frequently.

Alignment of policies, regulations and port incentives for shore-to-ship power

Needed to stimulate wider adoption and help overcome barriers such as chicken-and-egg problem.

Shore-side electricity price lower than cost of self-generation

Positive ROI for ships requires total cost of electricity (incl. connection fee) to be lower than self-generation; for ports/terminals, a sufficiently large gap between self-generation cost and electricity price is needed to be able to apply connection fee

Local power supply able to meet power needs of berthed vessels

Power supply at ports must be able to meet power demand of berthed vessels; certain ships (e.g. cruise ships) are very energy intensive. The electricity grid also needs to be stable.

Cooperation between port/terminal and ship operators

Helps to overcome the chicken-and-egg problem. Cooperation with other stakeholders such as utilities also needed when ports authority/terminal operator cannot directly sell electricity.

8. Shore-to-ship power: Case studies (1/3)

Ferry operator

Stena Line Hoek van Holland (Netherlands)	
Context	• Ferry terminal located in Hoek van Holland, adjacent to a residential area • Stena Line sought to mitigate negative impact on local community and environment and reduce fuel consumption • Stena Line owns the ferry and the terminal
Project description & objectives	• ABB delivered a shore-to-ship power project to simultaneously power two vessels from the local grid while berthed in port • Operation started in 2012
Main technical data	• ABB delivered turnkey shore-to-ship power installation including design, engineering, project management, installation and commissioning • Based on six MVA static frequency converter to adapt power from grid frequency (50 Hz) to 60 Hz ship frequency • Modifications were made on two roll-on/roll-off passenger (ROPAX) vessels and two roll-on/roll-off (RORO) vessels • Ship connection is automated, without assistance from shore personnel • Process does not interrupt onboard power

Source: ABB, 2012: *Turnkey shore-to-ship power connection at Stena Line B.V. ferry terminal in Hoek van Holland, the Netherlands*.

8. Shore-to-ship power: Case studies (2/3)

Ferry terminal

Port of Helsinki (Finland)	
Context	• Katajanokka Harbour in the Port of Helsinki is located near a residential area where noise and emissions regulations apply • 2 Viking Line ferries operate between Helsinki and Stockholm; in 2012/2013, each vessel stayed in the Katajanokka Harbour over 7 hours/day
Project description & objectives	• One shore-to-ship power connection in Katajanokka Harbour for Viking Line ferries • Port of Helsinki built the onshore side, Viking Line responsible for changes in vessels • Operation started in 2012
Main technical data	• 4 MW power, 400 V/50 Hz system with 12 cables • Investment costs of EUR €1.25 million for the port, with cost of cable handling device EUR €400,000
Benefits	• Fuel and electricity prices made it economically feasible for the vessels – shore-to-ship power in 2013 was 25% less expensive for the shipping company than use of auxiliary engines • For payback period of 6-8 years for the Port of Helsinki, an electricity connection fee of 2.5c/kWh must be charged • Emissions when using shore-to-ship power ranged from 1.3% to 15.6% of auxiliary engine emissions

Source: Port of Helsinki, 2015: Onshore power supply case study.

8. Shore-to-ship power: Case studies (3/3)

Container seaport

Port of Long Beach (United States)	
Context	• Port of Long Beach is the second-busiest container seaport in the US, adjacent to Los Angeles • Los Angeles-Long Beach area is the US' most polluted area, with ships the largest sources of NO_x and SO_2 in the area
Project description & objectives	• Collaboration between US Port of Long Beach and British Petroleum (BP) • Alaska Tanker Company (BP owned) equipped two of their vessels that regularly visit Long Beach to plug into the BP Terminal, which supplies local refineries with crude oil • As tankers generally carry highly flammable cargoes, safety was a key considering in the design of the system • First shore-to-ship power facility for tankers (other shore-to-ship power facilities at Long Beach can accommodate container and cruise vessels) • Operation started in 2008
Main technical data	• Transformer installed at the oil terminal berth used to transform the local voltage to 6.6 kV at 60 Hz. Ships receive 10 MVA through three cables, which are rolled out from the berth • Joint project cost USD $23.7 million: USD $17.5 million from the Port and USD $6.2 million from BP

Sources: WPCI: Long Beach; Port of Long Beach: Pier T Berth T121 BP Cold Ironing Project for Alaska Class Tankers; Schneider Electric, 2012: Shore Connection Technology.

9. Summary

Emissions and energy	• Shipping emissions in ports account for 18 $MtCO_2$, or approximately 2% of total shipping emissions. Shipping emissions in ports could grow fourfold by 2050, reaching around 70 $MtCO_2$. • Shipping is fuelled almost exclusively by fossil fuels.
Solution	• Shore-to-ship power allows vessels berthed in ports to shut down their auxiliary engines and connect to an onshore power source without disrupting onboard services. • The technology can be used for many types of ships e.g. ferries, tankers and container ships. • Port-side infrastructure needs to be customized to meet the specific voltage, frequency and power demand requirements of vessel segments using the technology.
Avoided GHG emissions and co-benefits	• GHG emission reductions can be significant, depending on the electricity generation mix. In Europe, GHG emissions can be reduced by about 40%. • Shore-to-ship power reduces the local environmental impact of ships at berths, including air pollution (SOx, NOx, PM), noise pollution and vibration.
Readiness status	• Shore-to-ship power is an already mature technology and the number of berths and ships with shore-to-ship capabilities is increasing.
Barriers	• Ship owners postpone investments in shore-to-ship technology until ports have upgraded their facilities; at the same time, ports only invest in such facilities if they can ensure a high use rate. • There are split incentives in the charter market, because the ship owner provides the vessel, but the charterer bears the fuel costs.
Success factors	• High utilization rate of shore-to-ship power facilities (at the port and by the ship). • Shore-side electricity price that is lower than the costs of self-generation. • Alignment of policies, regulations and port incentives for shore-to-ship power.

10. Key sources and references on Shore-to-ship power

- ABB Business Case tool and personal communication
- ABB, 2012: Turnkey shore-to-ship power connection at Stena Line B.V. ferry terminal in Hoek van Holland, the Netherlands
- Celsius Smart Cities: District heating for ships in harbour
- DNV GL, 2018: Assessment of opportunities and limitations for connection cruise vessels to shore power
- Ecofys, 2014: Potential for shore side electricity in Europe
- Global maritime energy efficiency partnerships: Shore power
- IMO, 2015: Third IMO GHG Study 2014
- ICCT, 2017: Greenhouse gas emissions from global shipping, 2013-2015
- ITF, 2014: Shipping emissions in ports
- ITF, 2018: Decarbonising Maritime Transport. Pathways to zero-carbon shipping by 2035
- Port of Helsinki, 2015: Onshore power supply case study
- Port of Long Beach: Pier T Berth T121 BP Cold Ironing Project for Alaska Class Tankers
- UN EPA, 2017: Shore Power Technology Assessment at U.S. Ports
- Schneider Electric, 2012: Shore Connection Technology
- Stena Line, 2018: Stena Line launches 'battery power' initiative
- thinkstep, 2019: Life Cycle GHG Emissions Study on the Use of LNG as Marine Fuel
- US EPA, 2017: Shore Power Technology Assessment at U.S. Ports
- WPCI: Onshore Power Supply Investment
- WPCI: Long Beach

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