ECOFYS

sustainable energy for everyone

Potential for Shore Side Electricity in Europe

FINAL REPORT

Potential for Shore Side Electricity in Europe

FINAL REPORT

By: Rob Winkel, Ulf Weddige, Doris Johnsen, Vincent Hoen, Georgios Papaefthymiou
Date: 7 January 2015

Project number: TRANL14441

Reviewers: Maarten Cuijpers,
Erik Klaassen

Disclaimer

The information and views set out in this report are those of the authors and not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein.

Executive Summary

In view of the expected growth of the sector, the emissions from waterborne transport are a key concern for the Commission.

When at berth, ships typically use the auxiliary engines of the ship to generate electrical power for communications, lighting, ventilation and other on-board equipment. Boilers (using conventional fuels) are also used, for instance for hot water supply and heating and for avoiding the heavy fuels from getting solid. The use of the auxiliary engines causes greenhouse gas emissions and air pollution in the port areas, which are often located in or near cities. Air pollution in cities is a key concern for the European Commissions as it leads to negative health and environmental effects.

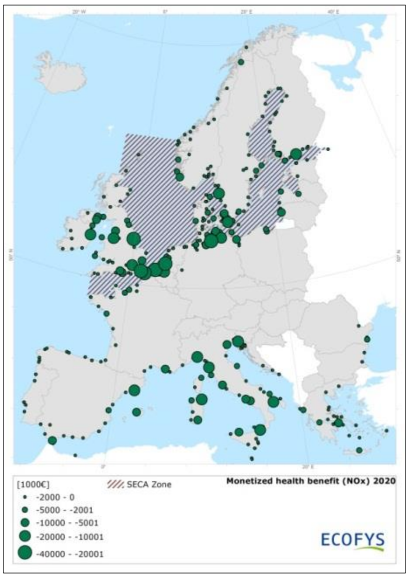
Shore Side Electricity (SSE) is an option for reducing the unwanted environmental impact of ships at berths, i.e. greenhouse gas emissions, air quality emissions and noise pollution of ships using their auxiliary engines. This report aims to quantify the economic and environmental potential for SSE in European ports, as well as providing insight into the barriers for implementation and formulating recommendations on policy action that the Commission could take to accelerate the implementation of SSE in European harbours.

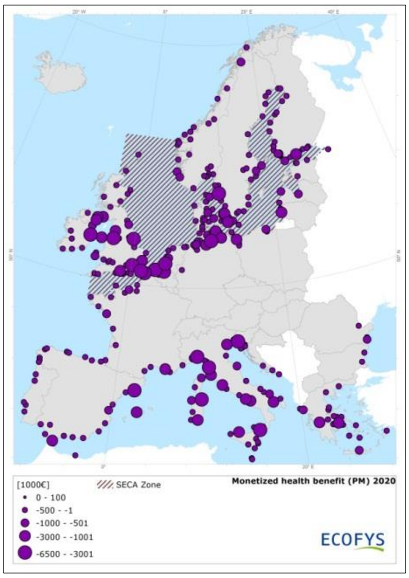
Environmental and economic potential of SSE

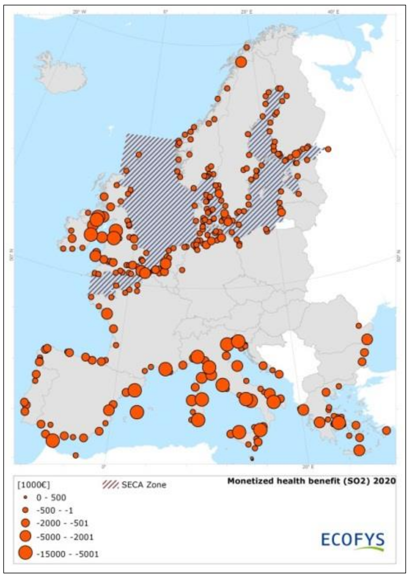
If all seagoing and inland ships in European harbours would use SSE by 2020 for covering their energy demand at berth, they would consume 3,543 GWh annually, which is approximately 0.1% to the electricity consumption in Europe as a whole in 2012. Furthermore, SSE offers the potential to mitigate 800,000 tons of CO_2 emissions. The maximum potential energy demand breakdown per ship type is provided in the table below:

Ship type	Annual electricity consumption (GWh)
Sea - Cruise ships	1,334
Sea - Oil tankers	760
Sea - Containers, including reefers	579
Sea- Bulk	448
Sea- RoRo	116
Sea - General cargo	105
Inland - Cargo	127
Inland - Passenger	74
TOTAL	**3,543**

In the figure below, the monetized health benefit in total for each port if the potential of SSE would be exploited is shown. The maps visualize a high health benefit by using SSE especially in the main ports of the Netherlands, Belgium, Germany, Italy and UK.







The business case for SSE is most attractive for ships that have a high electricity demand per berthing. High energy consumption in ports and low peak power demand would further improve the business case. The business case for SSE is found to be most attractive for cruise ships, container ships and RoRo.

Barriers

Inland shipping

Substantial technical problems don't exist for SSE in inland shipping. From the electricity network infrastructure, no major implications are expected, since the demand for inland SSE in EU is deemed low. On the distribution grid level further investigation on specific cases would be necessary to give a final assessment of possible problems, especially for areas with weak grids. Concerning the connection, a voltage standard is currently in place, but no standard connector type.

The acceptance of SSE in inland shipping is limited, even though the benefits of emission and vibration reduction are clear. Compared to maritime shipping, inland ships spend much more time in waiting areas. Thus, the main activities for SSE in inland shipping should lie in waiting areas and not in berthing areas. River cruisers have higher power and electricity demand and thus provide a better business case for SSE and better prospects for market development.

Maritime

Because the use of SSE is still relatively new, ports do not have experience with it. Today's incentives often do not cover all costs and do not offer equal support to all. One obstacle is the tax on the electricity for SSE, because it competes with the use of fuels which are not taxed.

Stakeholders indicated insecurities about the ownership of the SSE utilities and the business case for the use of SSE compared to current practices. The economical barrier is an important identified barrier, since the underutilisation of the SSE connection does not favour the overall business case. While very high investments need to be done from both the shore and ship sides, the challenge still remains that that the investors do not necessary benefit economically from SSE and the social and environmental benefits are difficult to quantify. Additionally, the impact depends much on the exact location of the ports, in particular their distance to residential areas.

The release of ISO standard IEC/ISO/IEEE 80005-1:2012 was an important step to overcome technical, practical and economical barriers. From the technical view point, there are only minor issues. Even for the 50/60 Hz obstacle, which is still widely discussed, there are technical solutions in place (converter) that allow the ports to support both systems if needed. Stakeholders are still sceptical about grid stability when the power demand grows through SSE.

Impact of EU-wide SSE implementation on the electricity grid

In general, the demand increase is not seen as problematic for the electricity grid, especially if we take into account that the SSE implementation is a medium- to long-term process which is aligned with the grid extension planning in the EU.
No severe obstacles are expected on the transmission level for the observed areas. The demand increase caused by SSE presents a rather minor impact, at least from the transmission grid perspective. SSE might even have positive effects for some coastal areas where RES are installed and generation and transmission are growing in future. To exclude all uncertainties on the distribution grid level, further investigation on the local level with advanced modelling needs to be performed.

Establishment of the carbon content of electricity provided

For most EU Member States SSE implementation would contribute to decreasing CO_2 emissions, since the carbon content of electricity from the grid is lower than of electricity produced on board of ships. In countries with high carbon content in their electricity supply, SSE leads to an increase of emissions. That does not mean that SSE should not be used in these countries, because a big advantage is that SSE moves the pollutants (emissions from ships) from densely populated areas to more remote regions where the large power plants are located and where emissions are less (because of legislation/cleaner fuels) and explicit damages such health impacts are less severe.

Policy recommendations

Inland shipping

- In order to successfully deploy SSE in inland shipping, a connector standard should be agreed upon for the whole EU. The Commission could play a role in facilitating the industry partners to agree upon a standard.
- Mandatory use of SSE in waiting areas for inland ships should be agreed upon, starting with river cruisers as their business case is likely to be the most profitable. The initiative lies here with the MS governments and ports.
- Financial tools to support the investments on board of ships might need to be provided to allow for investment on the ship side.

- There is some negative perception regarding SSE in the inland shipping sector. Public awareness-raising activities addressing local residents, ports and ship owners could be used as a tool to influence the public perception.

<u>Maritime</u>

- No international legislation is in place to support SSE in shipping. The mandatory policy that was introduced in California has shown that the implementation of SSE to support the maritime sector and reduce its environmental footprint is feasible and can help in solving air and noise pollution problems resulting from port operations. In Europe some ports have implemented SSE on their own account, without European or national policies driving them to do so. To further accelerate the uptake of SSE in European ports, the Commission could consider deploying mandatory requirements for European ports, as was suggested in the proposal for a binding directive on the deployment of alternative fuel infrastructure which was approved by the European Parliament in April 2014.
- Our analysis shows that activities which should be supported first should be related to Cruisers and Ferries. Implementing SSE successfully in a promising niche of the market is likely to have positive influence on the public perception by other stakeholders. Furthermore, the focus should lie in the beginning on harbours or areas in the port were impacts are most beneficial, like passenger waiting areas, ports close to residential areas, cruise ships and quays.
- The actors who are typically requested to invest on the shore side by current regulations are not the ones with the highest benefits from the reduction of the harmful emissions. This creates a difficult starting point for the development of SSE. Several stakeholders raised the point that an investigation should be conducted into who should pay for the infrastructure. These stakeholders also thought that ports need to be supported and that the EU should play a stimulating role in the deployment of SSE.
- The electricity that is used for SSE is currently taxed and covered by the EU-ETS, unlike the fuel that would have otherwise been used in the auxiliary engines. Tax exemptions on the electricity for SSE would create a level playing field and a better business case for SSE. The current possibility for Member States to include activities or installations (i.e. ships or ports) into the EU-ETS, according to Article 24 of Directive 2003/87/EC would partially solve the difference. None of the Member States has used this option so far.
- The commission could play a role in designing an institutional, interactive stakeholder engagement structure in which all stakeholders are involved, need to commit themselves to overall targets and be active members in established working groups on the local, national and European levels.

Table of contents

Tables

Figures

Glossary

AMP	Alternative Maritime Power
ANSI	American National Standards Institute
BDB	Bundesverband der Deutschen Binnenschifffahrt e.V. (Federation of German Inland Waterways Association)
CARB	California Air Resources Board
ECA	Emissions Control Areas
ECMFW	European Centre for Medium-Range Weather Forecasts
ECSA	The European Community Shipowners' Associations
EEDI	Energy Efficiency Design Index
EFIP	The European Federation of Inland Ports
ESPO	European Sea Ports Organisation
EV	Electric vehicles
GFC	Grid Frequency Converter
HELCOM	Helsinki Convention. Contracting Parties are Denmark, Estonia, the European Union, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden.
HFO	Heavy Fuel Oil
HV	High Voltage
HVSC	High Voltage Shore Connection
IMO	International Maritime Organization
LHV	Lower Heating Value
LoLo	Lift-On/Lift-Off or LOLO ships
LNG	Liquefied Natural Gas
LV	Low Voltage
MARPOL	International Convention for the Prevention of Pollution from Ships
MV	Medium Voltage
NECA	NO_x Emission Control Area
NUTS	*Nomenclature of Units for Territorial Statistics (*geocode standard for referencing the subdivisions of countries for statistical purposes)
OPS	Onshore Power Supply
QSE	Quay Side Electricity
PM	Particulate Matter
RES	Renewable Energy Sources
RoRo	Roll-on/roll-off (RORO or ro-ro) ships
SC	Shore Connection
SECA	Sulphur Emissions Control Area
SEEMPs	Ship Energy Efficiency Management Plans
SSE	Shore Side Electricity
WPCI	World Port Climate Initiative

Note
Several terms are used for the same system under study in this report: Cold Ironing, SSE, HVSC, OPS, AMP, QSE. In other languages for instance “walstroom” (Dutch) and “Stromtankstelle” (German) are used. This report uses the term SSE. In the tool that goes with this report the term OPS is used, since this tool is based on the WPCI OPS tool.

1 Introduction

1.1 Background

In 2010, shipping accounted for 15.3% of the EU's transport greenhouse gas emissions, which was more than aviation emissions (12.4%). Because – due to tremendous economies of scale - water carriage is very efficient, the emissions per tonne-km are relatively low. The Ricardo-AEA report (Ricardo-AEA, 2013) showed that ships arriving at or departing from EU ports emitted 180 million tonnes of CO_2 in 2010, which was 4% of the EU's total emissions.

The International Maritime Organization (IMO) has established the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plans (SEEMPs) in order to reduce the CO_2 emissions from new and existing ships (IMO).

In view of the expected growth of maritime and inland shipping, the emissions from waterborne transport are a key concern for the Commission. When at berth, ships typically use the auxiliary engines of the ship to generate electrical power for communications, lighting, ventilation and other on-board equipment. Boilers (using conventional fuels) are also used, for instance for hot water supply and heating and for avoiding the heavy fuels from getting solid. The use of the auxiliary engines causes greenhouse gas emissions and air pollution in the port areas, which are often located in or near cities. Air pollution in cities is a key concern for the European Commissions as it leads to negative health and environmental effects. In the White Paper the Commission has expressed the ambition to *"Internalise costs for local pollution and noise in ports"* (EU Commission SEC(2011), 2011).

Shore Side Electricity (SSE) is an option to reduce emissions from the ships while in the port. When at berth, the ship is plugged into the electricity network instead of using the auxiliary engines. The Commission recognises the potential of SSE to contribute to the sustainable transport goals set out in the White Paper and states in the directive on the deployment of alternative fuels infrastructure: *"Shore-side electricity facilities can serve maritime and inland waterway transport as clean power supply, in particular in maritime and inland navigation ports where air quality or noise levels are poor"* (EU Proposal COM(2013)18, 2013). The directive on the deployment of alternative fuels infrastructure states that *"Member States shall ensure that the need for shore-side electricity supply for inland waterway vessels and sea-going ships in maritime and inland ports is assessed in their national policy frameworks. Such shore-side electricity supply shall be installed as a priority in ports of the TEN-T Core Network, and in other ports, by 31 December 2025, unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits".*

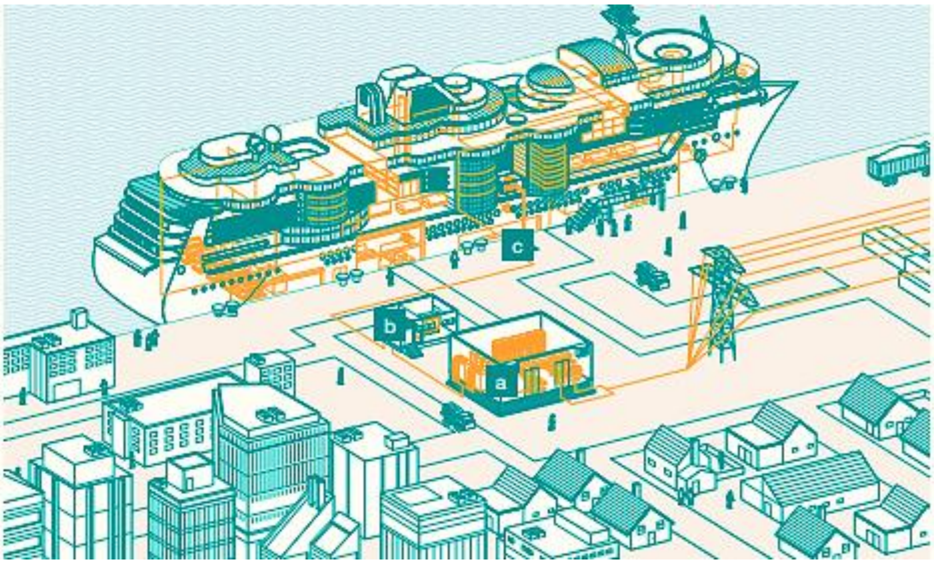


Figure 1: General overview of SSE, a=Transformer and switchgear, b=Converter, c=Connector (ABB, 2011)

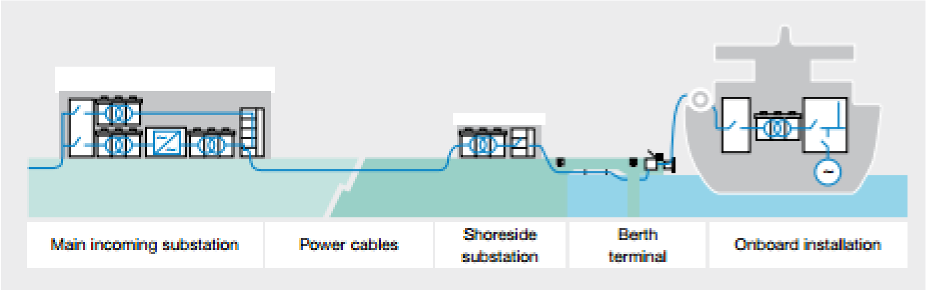


Figure 2: Overview of SSE connection (ABB, 2010)

The costs and benefits of SSE are dependent on regional characteristics: e.g. grid factor, electricity price, port size, grid conditions, vicinity to urban areas. Therefore a regional port scenario-based analysis is needed to understand how different characteristics influence the effectiveness of SSE. Also conditions vary for different seaports and inland ports, which are typically visited by different ship types (size, cargo, etc.). In Oslo SSE infrastructure was installed to power large cruise ships with a maximum power output of 4.5 MW. In Rotterdam 300 SSE connections were built for inland ships with a maximum power output of 25 kW per connection. Different power capacities will lead to different impacts on the business case for the SSE installations, on the size of the installations and for instance, on the impacts on the (local) power grid.

1.2 Shore Side Electricity: breaking through the deadlock of demand and supply

Although SSE is technically and physically available for more than a decade and the number of berths with SSE and ships with SSE capability is increasing, it will take some more time before SSE will become main stream.

For inland shipping there are many locations where berthed ships are already stimulated for using SSE or even prohibited from using onboard generators. Since the power requirements are limited (one ship has a power connection of about ten households), the impact on the regional and national grid is low. The investments for the infrastructure are relatively small and an unused connection is unfortunate, but not a significant financial risk.

Should the approach for inland ships be copied to sea ships and who should pay for that? These are just some of the questions that currently revolve around SSE. What is the best approach: should there be requirements first for SSE equipment onboard? For new ships only or also for existing? Should SSE be established first?

Will shipping lines decide to use SSE when there will be enough port connections for SSE?; should SSE infrastructure be stimulated in ships and ports at the same time? Should this be done for the whole of Europe or by starting with most attractive ports first?

Although there are barriers for the introduction of SSE, such as:

- Clarity on the business case;
- Limited grid capacity (e.g. in some in Eastern EU ports);
- Emission reductions (health effects and CO_2) that depend on the power plants that take over the power supply;
- High initial costs for retrofit, especially for powering the boilers for tankers;
- Problems with limited or unused SSE infrastructure.

The following opportunities should not be forgotten. The current SSE projects show that there can be a business case for all parties. The initial investment for ship owners and in ports is substantial, but they can be earned back from lower operating costs. Furthermore, huge benefits have been documented in terms of noise reduction, harmful emission reduction and CO_2 reduction. Less vibration makes life onboard inland water ships much more comfortable. Furthermore the additional SSE electricity demand creates opportunities for local balancing of electricity networks, especially in systems with supply overcapacity at the coastal areas due to the connection of renewable energy resources in the form of wind and solar energy. The next graph shows the potential renewable energy production from wind, especially in the North Sea and Baltic Sea. Places with higher wind speeds are of course better for the production of electricity. In the Mediterranean ports, solar energy typically has a huge potential.

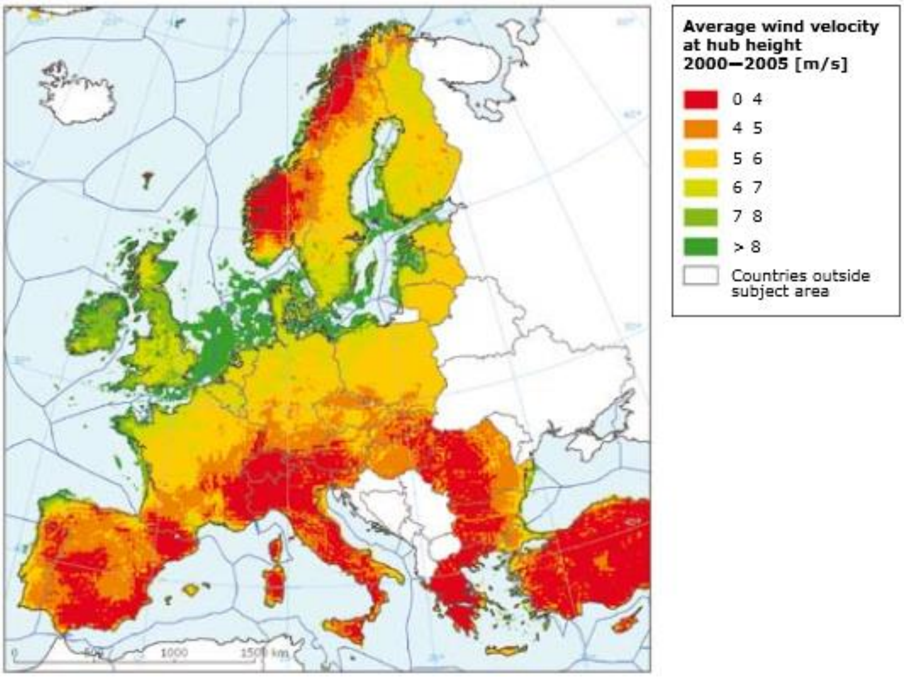


Figure 3: ECMFW wind field data after correction for mountains and local roughness [EEA, 2008]

1.3 Scope and objective of this report

This report aims in supporting the Commission in understanding the cost effectiveness, environmental benefits and grid impacts of SSE, and to effectively accelerate its deployment and use in EU ports. By analysing the value chain of SSE and understanding the costs, benefits and business cases for all stakeholders in the value chain, effective policies can be made to stimulate rollout in EU ports and tackle the "chicken-and-egg" problem of demand for and supply of SSE.

The scope of this report is commercial shipping, including e.g. container/reefer shipping, dry bulk shipping, tankers, roll on – roll off (RoRo) cargo and ferries, general cargo and cruise ships. Fishing boats and recreational shipping and therefore marinas are outside of the scope.

The WPCI, who have been promoting SSE for some time, presented all relevant themes of SSE in a graphical manner (see graph below). Examples of the issues included in the graph are environmental, legislation, leadership and relevant stakeholders. All of these themes, except the local citizens, are part of this report.

Figure 4: Important themes in relation to SSE including and specific issues [WPCI]

1.4 Structure of this report

To reach the objective of this project we have chosen a hybrid approach of both data collection and stakeholder interviews. This way all quantitative and valuable qualitative data can be collected and merged to build up an overall picture of the current status, potentials and appropriate instruments to deploy the use of SSE in European ports.

This report consists of four important chapters:

- Market potential for Shore Side Electricity – defining the demand;
- Barriers for Shore Side Electricity in ports – shaping the supply;
- Policy analysis and comparative assessment of policy recommendations;
- "Setting the course" - Recommendations for deployments of SSE in EU ports.

Market potential for Shore Side Electricity – defining the demand (chapter 2)

The objective of this chapter is to investigate the current state which plays SSE in EU ports, the (theoretical) potential of SSE in EU ports and its economic, social and environmental benefits and costs in a range of typical EU ports scenarios.

To get to a profound estimation of the SSE market potential this chapter is divided into three subtasks:

1. Top down demand calculation of SSE in Europe;
2. Cost-benefit analysis for SSE in seven port scenarios;
3. Mapping the potential in European ports.

Technical status quo side paper was prepared for the interims report which is placed in the annex as Annex 1: Technical Status Quo.

Together with insights in available technology, costs and benefits of SSE, we set the first building block towards the main objective of this project: determine the potential and possible measures to promote SSE in EU ports.

Barriers for Shore Side Electricity in ports – shaping the supply (chapter 3)
This chapter is mainly based on the results of the stakeholder interviews.
The objective of this task is to assess:

- Economic barriers that prevent an EU-wide implementation of shore side electricity in the EU before 2020;
- Impact of EU-wide implementation on the electricity grid;
- Identify good practices in the EU;
- Potential for using alternative means to the general grid e.g. mobile power barges in seaports.

In this chapter we focus both on seaports and inland waterway ports and identify technical, economic and social barriers to setting up the supply side for SSE in Europe ports.

Policy analysis and comparative assessment of policy recommendations (chapter 4)
To provide the European Commission with recommendations to carve out the course towards deployment of SSE in Europe in this chapter the following assessments will be conducted.

1. Assessment of existing policies in the EU Member States embedded in European legislations and punctual, related international activities.
2. Assessment of lessons learnt from of the Californian regulation, which is identified as one that led to a considerable development of SSE infrastructure and use.

Both investigations build the political related angle which will be combined with the technical and grid related angles as well as the barrier assessment to enable Ecofys to create the final recommendations for deployment of SSE in Europe.

"Setting the course" - Recommendations for deployments of SSE in EU ports (chapter 5)
In this chapter we conclude the results of all different assessments:

- Market potential assessment including technical, economical and electricity grid assessment;
- Barrier assessment;
- Policy assessment.

Ecofys focuses on how to make the transition towards shore side electricity in EU ports in order to disclose the identified potential. The goal of this task is to come up with a clear set of recommendations and possible measures on how the deployment of SSE in Europe's port can be stimulated.

2 Market potential for Shore Side Electricity - defining the demand

To assess the market potential of SSE in EU ports we estimate the electricity demand of SSE today and assess the potential demand by 2020 using the number of ships reaching each port, the average hoteling time and the average electricity consumption per ship type/size. A two-step approach is followed in order to map all EU ports: we conduct a detailed analysis for 7 port types which represent the cargo/passenger handling in Europe, and then we project the results to all EU ports based on the type of traffic each port handles (in this respect, each port is represented as a mixture of the 7 port types). The methodology allows the estimation of the energy demand as well as the port infrastructure requirements. The theoretical maximum potential of SSE is estimated as the electricity needed to replace fully the fossil fuel consumption of ships in EU ports in 2020. Based on the detailed mapping of the theoretical potential, we further analyse the economic, social and environmental benefits and costs of SSE and assess the health benefits of lower air pollution in monetary terms.

2.1 Top-down demand calculation of SSE in Europe

To assess the potential for SSE in EU ports a top-down approach is first used. Hulskotte & van der Gon (Hulskotte & van der Gon, 2010) have analysed the typical fuel consumption of different ships types (oil tankers, chemicals and other tankers, bulk carriers, containers, general cargo, ferries and RoRo, reefers and other) at berth. Based on fuel consumption measurements on board 89 ships in the harbour of Rotterdam they have developed formulas that provide a proxy for the hourly fuel consumption (kg fuel/hr) for these ship types as a function of the size of the ship. Also they provide average berthing times for different ship types (see Table 1).

Table 1: Hulskotte & van der Gon (2010) – fuel consumption and average ship size

Type of ship	Fuel consumption at berth (kg fuel/1000 Gt hr)	Average berthing time (hrs)	Average ship size (Gt) (2005 figures)
Oil tanker	19.3	28	46,135
Chemicals and other tankers	17.5	24	7,940
Bulk carrier	2.4	52	52,430
Container	5.0	21	28,855
General Cargo	5.4	25	3,458
Ferries and RoRo	6.9	24	26,171
Cruise	9.2	28	83,650

Currently in the segment RoRo, container and cruise ships are currently employing some SSE. They consume a large part (up to 45%) of the fuel in their auxiliary power generators (Hulskotte & van der

Gon, 2010). Since the consumption is also high per ship, SSE – which replaces the electricity production onboard via the auxiliary power generators - has great benefits for these ships.

Boilers also play an important role, especially for tankers. However, because of three reasons, boilers will not be converted to SSE soon. The harmful emission benefit is lower: the emissions from burning fuel in boilers are cleaner than from the combustion engines (less NO_x and PM_{10}) and furthermore, changing the installations from fuel fired to electric boilers is less efficient (additional heating equipment onboard that is only used in ports) and very expensive. These reasons were confirmed in the stakeholder interviews.

The world's fishing fleets are responsible for circa 1.2% of total global fuel consumption (Damalas, 2012). They mainly consume fuel while fishing/steaming. Only a small amount is for the refrigeration plant, while fishing. There are examples like New Bedford, USA, where 42 SSE connections are being installed for medium to large-sized fishing vessels, aiming for a reduction of 3,000 tonnes CO_2, but for this study it is considered as unproblematic. The SSE infrastructure used here has similar capacity as the ones for inland ships. Therefore the results from inland shipping can be translated to the fishing sector. Tugs, dredgers, other types of service ships are not considered because of the expected small impact for SSE.

2.1.1 Maritime Shipping

Our approach is to calculate how many ships it takes to transport the amount of goods to and from the EU harbours as given in Eurostat data and shipping sector growth studies for 2020 (e.g. Benchmarking Strategic Options for European Shipping and for the European Maritime Transport System in the Horizon 2008-2018, 2010). We assume ships always use their maximum capacity and we take a representative ship type for that specific class (e.g. sea container ship Panamax = 3,000 TEU).

Based on the data on how many ships of which type will reach the ports, we estimate the expected electricity consumption for European ports for 2020 based on the following parameters:

- Number of Ships (of different type-size for 7 different port types);
- Average hoteling time (h);
- Average electricity consumption per ship type/size (MWh/hr).

In particular, we use the average berthing time per ship type (e.g. 21 hours for containers) and combine it with the typical fuel consumption at berth (5.0 kg fuel / 1,000 Gt hr for container ships) to calculate the total fuel consumption of ships of a specific cargo type in EU ports.

Table 2: Hulskotte & van der Gon (2010) – fuel consumption at berth

Type of ship	Fuel consumption at berth (kg fuel/1000 Gt hr)	Average berthing time (hrs)	% fuel for electricity generation	Kg fuel /1000 Gt/ berth
Oil tankers	19.3	28	18%	97
Chemicals and other tankers	17.5	24	15%	63
Bulk carriers	2.4	52	64%	80
Containers (including reefers)	5.0	21	45%	47
General Cargo	5.4	25	66%	89
Ferries and RoRo	6.9	24	50%	83
Cruise	9.2	28	75%	193

The respective average electricity consumption per ship type is further estimated from the number in the last column taking into account an efficiency of 45% of the auxiliary engines that are used while berthing (Ecofys 2010, biofuels in shipping). Taking into account the number, type and size of ships and their average hoteling time, the electricity consumption of a large part of the fleet can be estimated. We compared the berthing time and calls (IHS Fairplay, 2011). The final output is the amount of electricity needed if all ships visiting EU ports would use SSE in 2020.Only for the most important categories we have information on the throughput for European ports in total and the right values for 2020. The result in terms of GWh is presented in the next table.

Table 3: Calculation of total GWh consumption at berth

Type of ship	Transport in 2020 (Gt)	Average ship Gt	Number of berths	Annual Fuel consumption for electricity (tonnes)	Annual GWh
Oil tankers	1,400 m tonnes	46,135	30,346	135,800	760
Bulk carriers	1,000 m tonnes	52,430	19,073	80,000	448
Containers (including reefers)	2,200 m tonnes	28,855	76,243	103,400	579
General Cargo	211 m tonnes	3,458	61,018	18,779	105
RoRo	250 m tonnes	26,171	9,553	20,750	116
Cruise		83,650	16,119	260,232	1334
			Total	**618,961**	**3,343**

Ships that have a high electricity demand overall and per berth are the first ones for which SSE will be beneficial, assuming there is a business case. High energy consumption in ports and low peak power demand would further improve the business case. Based on the previous list and the next one we are able to rank several ship types.

Table 4: Summery power demand on-board for vessel circulating in European ports (Ericsson & Fazlagic, 2008)

Vessel type	Average power demand (kW)	Peak power demand (kW)	Peak power demand for 95% of vessels (MW)
Container vessels (total)	800	2000	4
RoRo- and vehicle vessels	1500	2000	1.8
Oil and product tankers	1400	2700	2.5
Cruise ships (< 200 m)	4100	7300	6.7
Cruise ships (< 200 m)	7500	11000	9.5

Table 5: Ranking of ship types for SSE

Type of ship	Peak Power demand per ship	Relative number of ships (global)	MWh/a per ship (relative)	Relative average energy requirement per ship per connection power
Cruise	7-10 MW	525	2540	254-363
RoRo	2 MW	793	146	73
Container (including reefers)	4 MW	4928	117	29
Oil tanker	4 MW	7568	100	25

From the table above, we conclude that Cruise, RoRo and Containerships show the best business case for shore side electricity (high energy demand/low power requirements).

2.1.2 Inland Shipping

For inland passenger ships two main types can be distinguished: ships for day trips (about 2,000 in 2009 in Europe) and for river cruises (about 200 in 2009 in Europe). The first is often locally organised by local entrepreneurs and the second one is often run by internationally operating organisations. The total number of other inland ships was about 27,000 in 2009, of which 10,000 were dry bulk and container ships.

Concerning inland passenger ships, several stakeholders indicated in the interviews that river cruises might be potentially interesting for SSE implementation, see also (Ir. J.H.J. Hulskotte, 2008). The expected total demand in the EU from these ships when they all use SSE is 73.5 GWh: 1,500 kWh per ship per day, for 245 days (season from March to October), for 200 ships in 2020. Since the connection per ship is about 210 kW (Vree, 2008), which is relatively low, no barriers for grid connection are expected: for the total of 200 ships, the required power would be 42 MW if they were all connected at the same time.

For the other inland ships we calculate the potential as follows: 125% (growth to 2020) of 27,000 ships in 2010. Source: Medium and long term perspectives of IWT in the EU (CE Delft et.al., 2011).

We assume there will be one trip per week on average in which there is loading and unloading twice, therefore 6 hours per ship per week in the port. The expected total demand in the EU from these ships when they all use SSE is therefore 127 GWh: 75 kWh per ship per trip, for 50 trips per year, for 125% of 27,000 ships in 2010. If all other inland ships were connected at the same time, the power requirement would be 25kW*125%*27,000=844 MW.

The total electricity consumption in the EU in 2012 was 3,300,000 GWh (Eurostat Energy statistics, 2012). If all ships had SSE the potential for it in Europe, is 0.1% compared to the aforementioned figure. The contribution of inland shipping is 6% of that figure.

2.2 Analysis for SSE in seven port types

In the next step a bottom up approach is taken to zoom in on the economic, societal and environmental benefits of SSE in different port types. Energy demand at berth is highly dependent on the ship's type and cargo, therefore we will base the analysis on the types of goods that are most transported by sea and inland waterways. For each port type there will be a different number of calls per ship per year, hours at berth connected and number of ships. These port types are used as a base setup, assuming that these types of ports handle only one type of cargo. This will allow us to map existing European ports in the next phase by making combinations of these port types based on the types and amounts of cargo handled in each EU port.

2.2.1 Selection of port types

By the end of 2009 the total world fleet comprised 81,842 sea ships. Important categories of ships in terms of numbers are ferry/RoRo, container, general cargo (getting less important), bulk and tankers. In terms of weight, tankers, bulk and container ships are the most important. From interviews with the stakeholders, seven port types were selected that represent this important cargo/passenger handling in EU ports. These ports are considered to be average in terms of throughput. These port types could have been located in one port; however that is not the case. The following port types will be further worked out:

- Liquid bulk port (60,000,000 tonnes annually ≈ Marseille);
- Container (including an average of 5% reefer) port (2,000,000 TEU annually ≈ Barcelona);
- Bulk port (25,000,000 tonnes annually ≈ Hamburg);
- Ferries and Roro port (557,000 tonnes annually ≈ Gothenburg);
- Cruise port (2,000,0000 passengers annually ≈ Venice);
- Inland container port (50,000 TEU annually ≈ Veghel, the Netherlands);
- Inland bulk port (800,000 tonnes annually ≈ Drachten, the Netherlands).

Some of these ports already have SSE, in which case, existing information is used. For others the SSE power and energy requirements are based on information from the interviews and calculation from either typical power connection or fuel use for electricity.

2.2.2 Liquid bulk port (Marseille)

For liquid bulk the example of the port of Marseille was chosen. The key parameters for the SSE potential analysis are shown in Table 6.

Table 6: Liquid bulk port - port analysis inputs (Hulskotte & van der Gon, 2009 ; Port of Gothenburg, 2012; Marseille port data, 2014)

	Value	Unit
General Information		
Throughput	56,200,000	tonne/yr
Quays / berths	8	
Berthings per year	1,218	
Power capacity requirement	3	MW
Estimated Energy information per berthing		
Fuel consumption	24,931	tonne fuel
Of which for electricity	4,487.64	tonne fuel
Electricity consumption	25.13	MWh
Estimated Energy information per year		
Fuel consumption	30.4	ktonne fuel / yr
Of which for electricity	5.5	ktonne fuel / yr
Electricity consumption	31	GWh / yr

The shore side investment per berth for a 7 MVA electricity connection is estimated to be € 1,725,000 (WPCI OPS Calculation Tool, 2013). In practice the costs will be dependent on many parameters including, the costs of supplying high-voltage power, need for transformers, need for a frequency converter, etc.

2.2.3 Container Port (Barcelona)

For containers, Barcelona was chosen as the example port. The key parameters for the SSE potential analysis are shown in Table 7.

In the analysis we consider that the container port deals with an average number of reefer containers. Reefer containers (40ft) need 4kW on average. Average number of reefers is 5% (5-10% for Maersk) (MAERSK, 2014).

Table 7: Container port - port analysis inputs (Hulskotte & van der Gon, 2009 ; Port of Gothenburg, 2012; Barcelona port data, 2014)

	Value	Unit
General information		
Throughput	1,720,383	TEU/yr
Quays / berths	8	
Berthings per year	656	
Power capacity requirement	2	MW
Estimated Energy information per berthing		
Fuel consumption	3,030	tonne fuel
Of which for electricity	1,363.40	tonne fuel
Electricity consumption	7.64	MWh
Estimated Energy information per year		
Fuel consumption	2.0	ktonne fuel / yr
Of which for electricity	0.9	ktonne fuel / yr
Electricity consumption	5	GWh / yr

The shore side investment per berth for a 7 MVA electricity connection is estimated to be € 1,725,000 (WPCI OPS Calculation Tool, 2013). In practice the costs will be dependent on many parameters including, the costs of supplying high-voltage power, for transformers, for a frequency converter, etc.

2.2.4 Bulk port (Hamburg)

For bulk, Hamburg was chosen as the example port. The key parameters for the SSE potential analysis are shown in the next table.

Table 8: Bulk port - port analysis inputs

	Value	Unit
General information		
Throughput	39,600,000	tonne/year
Quays / berths	199	
Berthings per year	1,531	
Power capacity requirement	2	MW
Estimated Energy information per berthing		
Fuel consumption	6,543	tonne fuel
Of which for electricity	4,187	tonne fuel
Electricity consumption	23.45	MWh
Estimated Energy information per year		
Fuel consumption	10.0	ktonne fuel / yr
Of which for electricity	6.4	ktonne fuel / yr
Electricity consumption	36	GWh / yr

The shore side investment per berth for a 2 MVA electricity connection is estimated to be € 425,000 (WPCI OPS Calculation Tool, 2013). In practice the costs will be dependent on many parameters including, the costs of supplying high-voltage power, for transformers, for a frequency converter, etc.

2.2.5 Ferries and RoRo port (Gothenburg)

For Ferries and RoRo, Gothenburg was chosen as the example port. The key parameters for the SSE potential analysis are shown in Table 9.

Table 9: RoRo and ferries Port – port analysis input

	Value	Unit
General information		
Throughput	557,000	tonne/year
Quays / berths	9	
Berthings per year	1,300	
Power capacity requirement	2	MW
Estimated Energy information per berthing		
Fuel consumption	4,334	tonne fuel
Of which for electricity	2,166.96	tonne fuel
Electricity consumption	12.13	MWh
Estimated Energy information per year		
Fuel consumption	5.6	ktonne fuel / yr
Of which for electricity	2.8	ktonne fuel / yr
Electricity consumption	16	GWh / yr

The shore side investment per berth for a 2 MVA electricity connection is estimated to be € 425,000 (WPCI OPS Calculation Tool, 2013). In practice the costs will be dependent on many parameters including, the costs of supplying high-voltage power, need for transformers, need for a frequency converter, etc.

2.2.6 Cruise Port (Venice)

For cruises, Venice was chosen as the example port. The key parameters for the SSE potential analysis are shown in Table 9.

Table 10: Cruise port - port analysis data

	Value	Unit
General information		
Throughput	1,998,960	passengers/yr
Quays / berths	6	
Berthings per year	548	
Power capacity requirement	12	MW
Estimated Energy information per berthing		
Fuel consumption	11,592	tonne fuel
Of which for electricity	8,694.00	tonne fuel
Electricity consumption	48.69	MWh
Estimated Energy information per year		
Fuel consumption	6.4	ktonne fuel / yr
Of which for electricity	4.8	ktonne fuel / yr
Electricity consumption	27	GWh / yr

The shore side investment per berth for a 12 MVA electricity connection is estimated to be € 3,725,000 (WPCI OPS Calculation Tool, 2013). In practice the costs will be dependent on many parameters including, the costs of supplying high-voltage power, need for transformers, need for a frequency converter, etc.

2.2.7 Inland container port

The calculation of the potential for the inland container terminal is done via the example of Veghel: the container throughput is 50,000 TEU annually. In Veghel three reach stackers are used to load/unload a maximum of two ships at a time. The typical number of moves for a reach stacker is 15 moves per hour.

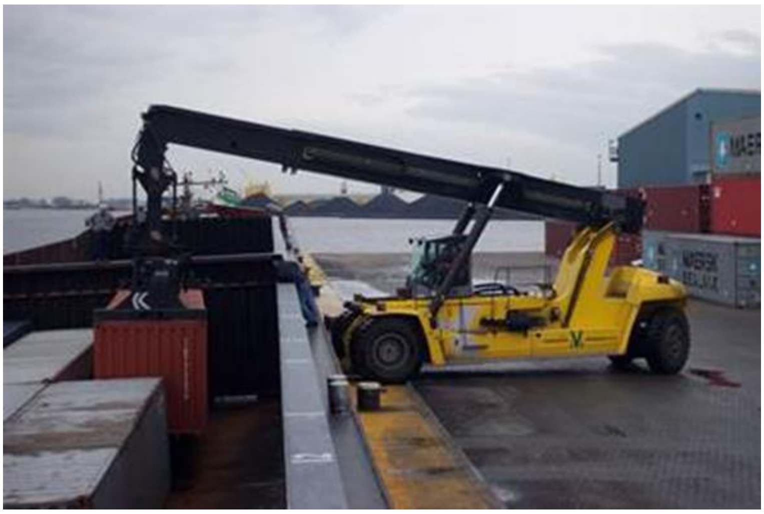


Figure 5: Loading and unloading of an inland water container ship with a reach stacker

In Veghel there are three reach stackers and 3,300 hours in total is needed to move 50,000 TEU. If they work at the same time, they are loading/unloading for about 1,100 hours.

Since inland container ships carry around 108 TEU max, at least about 462 ships (2-3 hours per ship) will be berthed. Consumed power for inland ship is typically half of the maximum connection power of 25 kW. The energy consumption and duration of the loading/unloading was verified via the interviews.

Table 11: Inland container port - port analysis inputs

Port type parameters	Value	Comment
Container throughput	50,000 TEU /year	Port data Veghel (2013)
Nr of ship port calls per year	462 berthings / year	Based on the average size of a container ship of 108 TEU
Number of quays	2 quays	Port data Veghel
Max SSE Power requirement in the port	50 kW	2*Typical max connection power
Typical berthing time	3 hours	Ecofys calculation
Typical fuel requirement per berthing	6.7 kg fuel *or* 37.5 kWh electricity	Ecofys calculation
Estimated annual fuel or electricity requirement	3 tonne fuel /yr *or* 17.3 MWh / yr	Ecofys calculation

Cost analysis:

- Investments shore side: € 20,000;
    - Nr. of quays: 2; Investment per quay: € 10,000. These type of connections (25kW) cost about € 10,000 per connection (Alphen, 2010).
- Investments ship side, cable system € 1,000 per ship;
- Fuel (gasoil) prices (€ 730/1,000 l, in 2014), the onboard electricity price is then (€ 0.16/kWh) (de Groot, 2010), excluding maintenance;
- Average EU electricity prices (€ 0.17/kWh – € 0.34/kWh);
- O&M costs (% of investment/year): only 6 minutes in order to connect the cable each time.

Extra information on the terminal in Veghel is available here:
http://www.inlandterminalveghel.eu/nl/inland-terminal-veghel/terminal/ontwikkelingen

2.2.8 Inland bulk port

The calculation of the potential for the inland bulk terminal is done via the example of ‘De Haven’, the bulk port of Drachten. The annual throughput is 800,000 tonnes, mainly raw minerals and construction material (Ewout Bückmann, 2008).

Table 12: Inland bulk port - port analysis inputs

Port type parameters	Value	Comment
bulk throughput	800,000 tonnes /year	Port data Drachten (2013)
Nr of ship port calls per year	800 berthings / year	Based on the size of a 1000 tonne ship, 67 meters long
Number of quays	1.2 km quay length	Port data Drachten
Power requirement	250 kW	10*Typical connection power
Typical berthing time	3 hours	Estimation Ecofys based on (Alphen, 2010)
Typical fuel requirement per berthing	6.7 kg fuel *or* 37.5 kWh electricity	Ecofys calculation
Estimated annual fuel or electricity requirement	5.4 tonne fuel /yr *or* 30 MWh / yr	Ecofys calculation

Cost analysis:

- Investments shore side: € 100,000;
    - Nr. of quays: 10; Investment per quay: € 10,000. These type of connections (25kW) cost about € 10,000 per connection (Alphen, 2010).
- Investments ship side, cable system € 1,000 per ship;
- Fuel (gasoil) prices (€ 730/1,000 l, in 2014), the onboard electricity price is then (€ 0.16/kWh);
- Average EU electricity prices (€ 0.17/kWh – € 0.34/kWh);
- O&M costs (% of investment/year): only 6 minutes in order to connect the cable each time.

2.3 Mapping the potential in European ports

Existing ports handle a mixture of goods, unlike the chosen port types which are assumed to only handle one type of cargo. Based on the information from the port types we are able to make combinations that match the cargo profile of European ports. Using the Eurostat statistics (e.g. Notteboom 2012) on the amounts and types of cargo handled in European ports for 2020 we estimate the following key parameters for the main sea and inland ports:

- The energy requirements for SSE: the yearly SSE energy demand for each port, which is a key indicator for estimating the average energy costs, and avoided emissions.
- Power requirements for SSE: the electricity grid infrastructure capacity necessary for hosting the respective ship traffic, which is a key indicator for understanding the possible impacts to the European grids.
- Greenhouse gas emission reduction based on the average European carbon content of electricity.
- Societal benefits (monetisation of health impacts).

Each of these elements will be worked out below. The economic costs and benefits depend largely on how often the ships can make use of SSE.

2.3.1 The energy requirements for SSE

The energy requirements in terms of annual electricity consumption (GWh/a) for seaports in 2010 and 2020 are estimated based on a detailed analysis of the traffic in each port. Source for the 2020 shipping growth scenario are Holland, Watlkiss, Pye, de Oliviera, & van Regemorter (Holland, Watlkiss, Pye, de Oliviera, & van Regemorter, 2005) and the European Cruise Council (European Cruise Council, 2012). Detailed results are presented in the next figure. The inland ports are not plotted because of their very low impact on the results (they potentially contribute to 6% of the total demand from SSE). As can be seen, similar geographical patterns appear between 2010 and 2020, with 2020 being

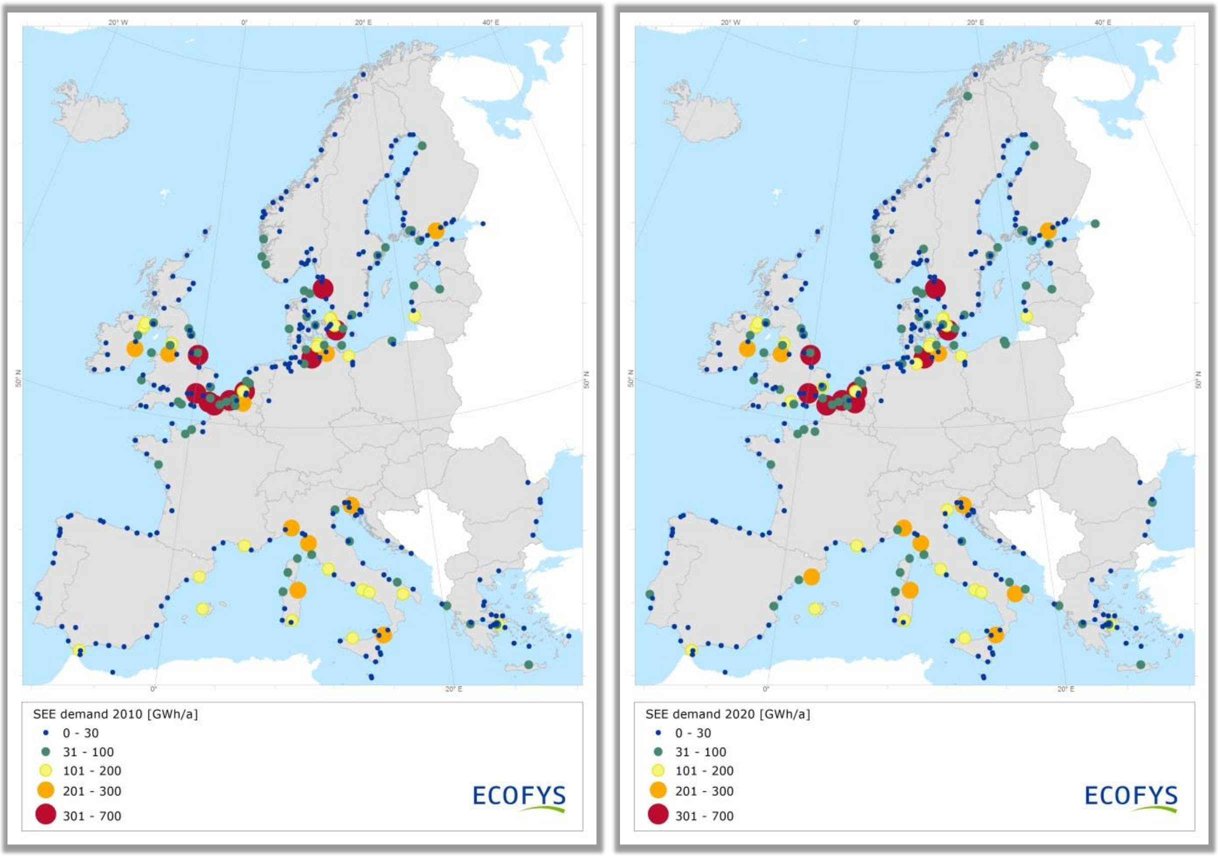


Figure 6: Estimated SSE yearly energy demand for each port in Europe for 2010 and 2020 (GWh/a)

2.3.2 Power requirements for SSE

The power SSE demand in terms of MW is presented in Figure 7. The figures are estimated with regard to different parameters, like type of ship, hoteling time, and calls in a year. Figures shown are the peak demand (max. MW), indicating the maximum number of places necessary to supply the maximum number of ships at the same time. The highest demand by far is in Rotterdam with 71.5 maximum MW, followed by Marseille with 25 maximum MW in 2010. In 2020 there is a growth compared to 2010, but the geographic proportion stay nearly the same. The areas presenting the highest demand increase due to SSE are the following: Rotterdam, Marseille, Antwerp, Bergen, Milford Haven and Le Havre; however, the increase in all cases is less than 5.5 MW at peak demand.

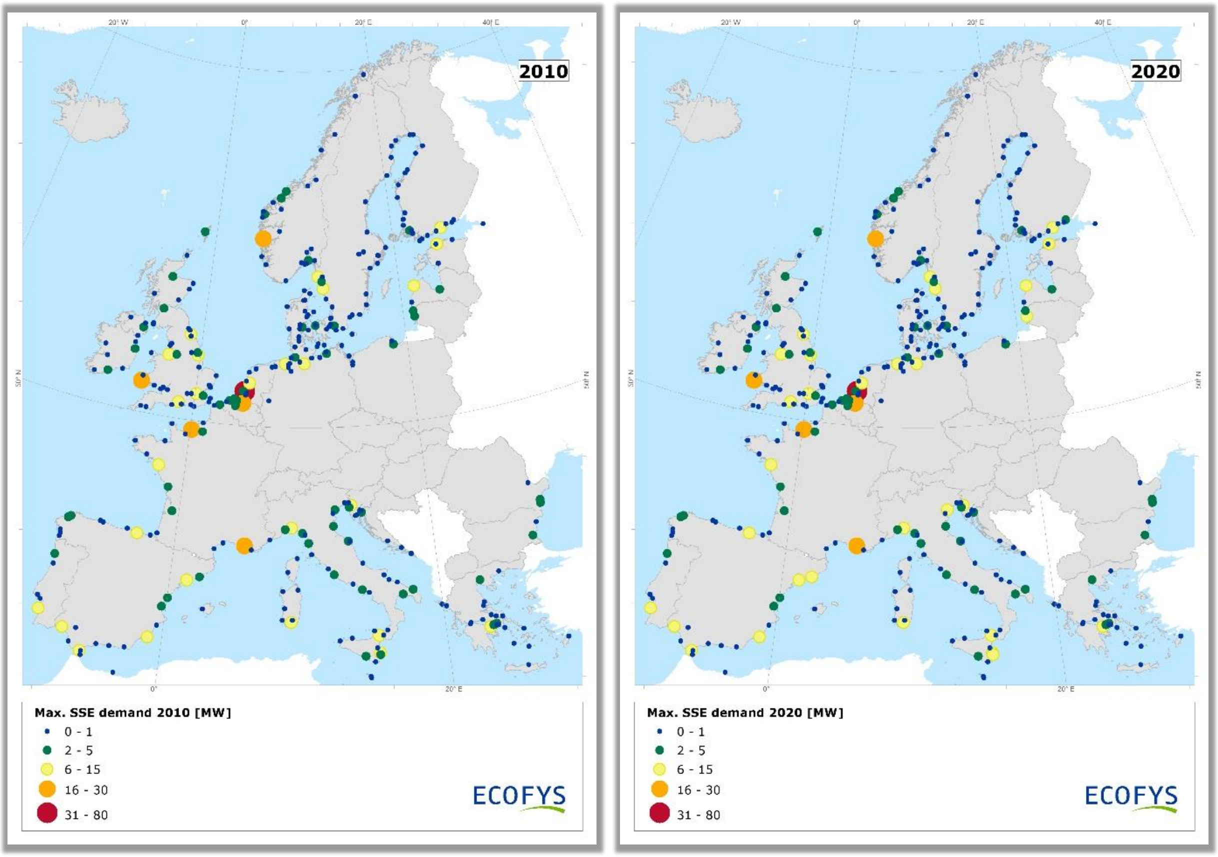


Figure 7: Estimated maximum SSE power demand for each port in Europe 2010 and 2020 (MW)

Figure 8 shows the maximum power demand on the port side in MW on NUTS 3 level. Only those NUTS 3 areas are shown that accommodate a considered port. Port areas (NUTS zones) with high demand are in areas of Barcelona, Gothenburg, Marseille, Athens, Helsinki, Antwerp and Rom.

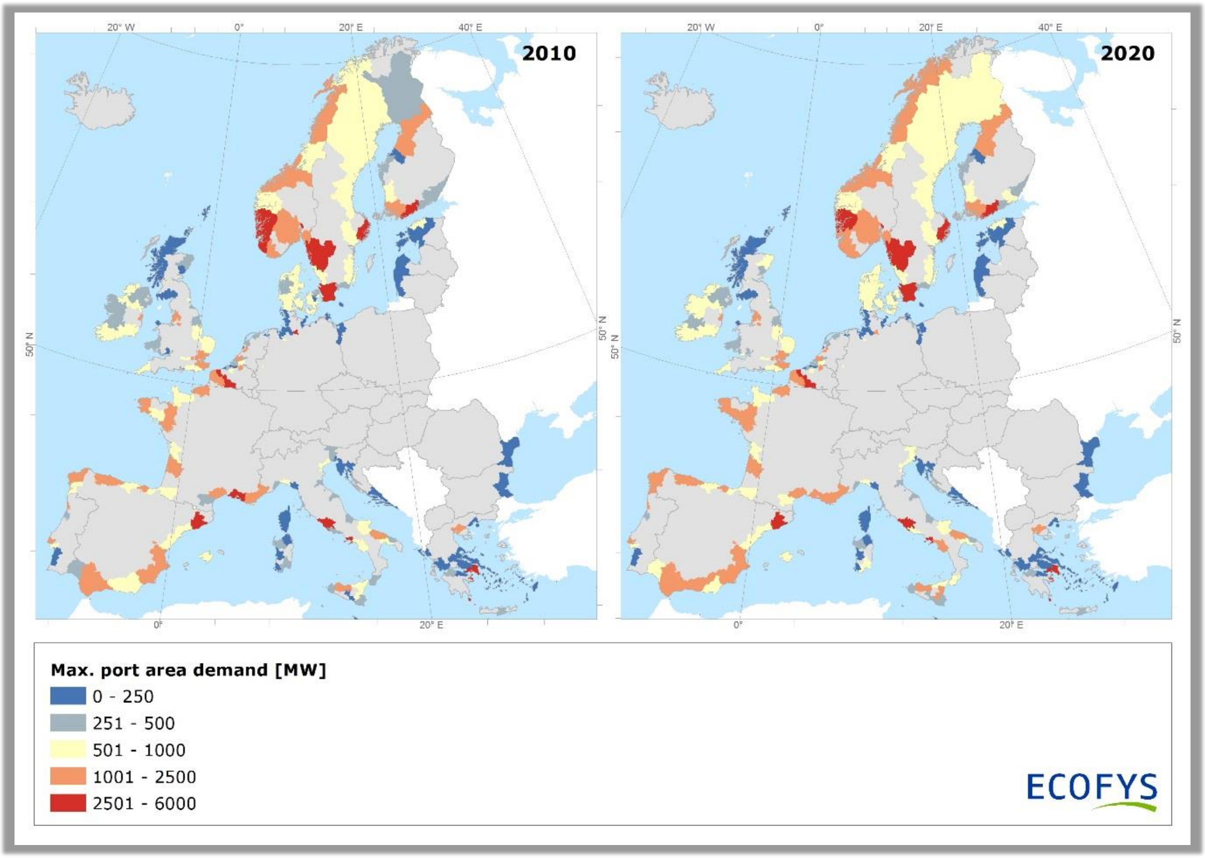


Figure 8: Maximum power demand on the port side in MW on NUTS 3 level. Only zones are shown that accommodate a considered port

2.3.3 Greenhouse gas emission reduction based on the average European carbon content of electricity

The relative emission reduction from SSE instead of using conventional fuels can be calculated using the CO_2 emission factors from the exhaust for the fuel (3.170 for HFO, IEA 2010; for distillates 3.130) and the average emissions factor in Europe: 347 gr/kWh (in 2010) (IEA, 2012). This factor is relatively low because of the large number of nuclear power plants and high share of renewable electricity production. This number is expected to be reduced due to the planned increase in RES shares. For comparison: the CO_2 emission factor for a kWh of electricity from fuel is 566 gr/kWh. Because the generator on board operates with certain efficiency, more kWh of energy is needed to produce a certain number of electric kWh. We use the calculation from (Ecofys: biofuels in shipping): 45% efficiency.

The total fuel used must be calculated before the effect for the whole of Europe can be calculated.

Table 13: CO_2 mission reduction by using SSE in Europe for all maritime shipping

Fuel use for electricity	CO_2 emission from fuel	Equivalent electricity produced	CO_2 emission from electricity	CO_2 emission improvement
1 kg (example)	3.17 kg (for HFO)	5.6 kWh	1.94 kg	-39%
618,961 tonnes (for Europe in one year)	1,962,000 tonnes	3,343 GWh	1,160,000 tonnes	-800,000 tonnes

2.3.4 Societal benefits (monetisation of health impacts)

Shore Side Electricity (SSE) is an option to reduce emissions from the ships while in the port. The extent of the reduction depends mainly on the one hand on the type of fuel burned in the ship (HFO or Diesel) as reference value and on the other hand the energy mix used for the electricity generation on shore. Hall indicates for example for the UK a reduction of emissions of CO_2 (25%), SO_2 (46%), CO (76%) and NO_x (92%) when using SSE as opposed to onboard power generation. Hall used IEA databases on electrical supply and atmospheric emissions to compute the mass of emissions which would be release if ships obtain electrical power from national electricity grids and compared the results to the existing emissions from ships at berth reported in the literature. (Hall, 2009).

In this chapter the potential emission reduction by using SSE is monetized. This means the health benefit by using SSE on ships at berth instead of using the combustion engines of the ships are monetized on port level for the years 2010 and 2020. For this, we look at the marginal damage costs caused by emitted emissions by combustion engines of the ships while they are at berth compared with the ones by using SSE to generate electricity for this time period. The difference with respect to the reduction of this marginal damage costs by using SSE shows the health benefit.

To assess the health benefit on port level the following information / data is merged:

- Dimension of port handling;
- Types of ships berthing in the port;
- Geographical location (SECA zone yes / no);
- Emission factors;
- Energy mix per country;
- Marginal damage costs.

Data on the amount and types of cargo handled in the ports based on Eurostat statistics (e.g. Nottenboom 2012) in combination with own investigations.

Since 2010 in Environmentally Controlled Areas (ECA) the sulphur fuel requirements have been stricter. The ECA's are the Baltic Sea, the North Sea, The Channel and the waters to 200 nautical miles for the coast of US and Canada. Emissions of sulphur oxides are directly related to sulphur content in the fuel oil.

Globally ships are required to lower the sulphur emissions to 0,5% by 2020 (could also be 2025) and 0,1% in ECA's area by 2015. The benefits will therefore be different for the target year 2020. We will use 3.5% sulphur content for non-ECA and 0.1% sulphur fuel for ECA (see Figure below). We are aware that for passenger ships, the sulphur limits are slightly different. Passenger ships operating outside SECAs and on a regular service to or from EU ports to use marine fuels with a maximum permitted sulphur content of 1.5%, from 2020 onwards the 0.5% will also be valid for passenger ships onwards (ECG, 2013).; However, this differentiation is not taken into account in the evaluation.

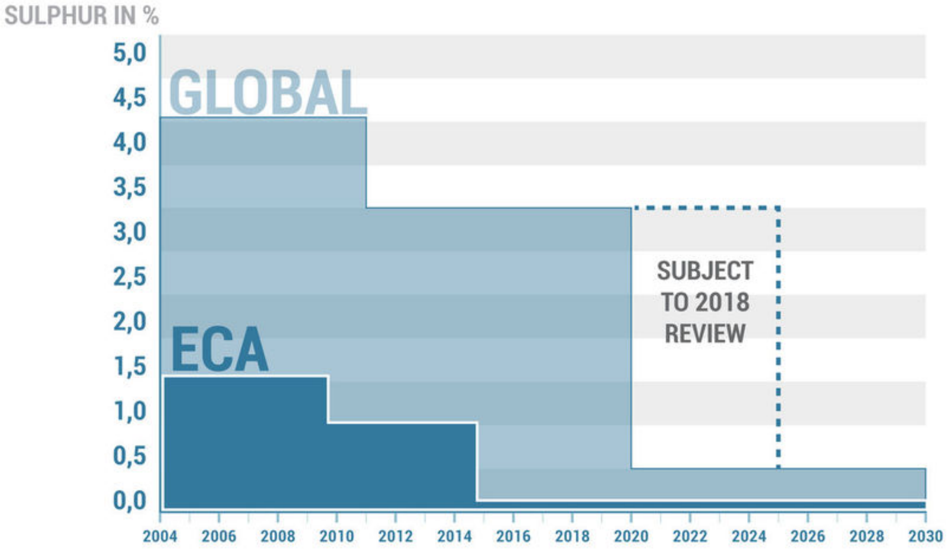


Figure 9: Global and ECA zone sulphur limits (Maritime, 2014)

The emission factors for the fuel used in the combustion engines of the ships used in this study are presented in the next table. We do not take into account the emissions that occur in the production or the transportation of the fuel, we only look at the emissions from the burning of the fuel (end of pipe: in the ports).

Table 14: Emission factor separated between SECA (Sulphur Emission Control Area) zone and non-SECA zone (Doves, 2006)

	Outside of the SECA zone	Inside of the SECA zone
Emission type	Emission factor (g/kg marine fuel) HFO (2.7% S)	Emission factor (g/kg marine fuel) MGO (0.1% S) SECA Region requirements
CO_2	3170	3130
NO_x	68.11	68.11
PM	3.14	2.1
SO_2	54	5
CO	12.15	12.15

The emission factors related to the energy mix of the electricity production for each EU Member State are listed in the table below.

Table 15: Emission factors electricity (only local power plant emissions), (Doves, 2006)

emission	natural gas	coal	wind/water/nuclear	Oil
NOx (g/kWh)	0.35	0.41	0.00	12.142857
PM (g/kWh)	0.0000	0.0033	0.00	0.5607143
SO_2 (g/kWh)	0.02	0.37	0.00	9.6428571
CO_2 (g/kWh)	402	902	0.00	566.07143

The following calculations on health benefits are related to the port level. Due to data availability, the related data on the energy mix are on EU Member State level. The energy mix related to the port level for 2012 is based on the gross electricity generation per EU Member State, published by Eurostat (Eurostat Energy statistics, 2012)[1]. The data for the energy mix for 2020 is based on the electricity generation per EU Member State published by Eurelectric (Eurelectric, 2013)[2].

In order to come from emission factors to health benefits we use the average damage costs for EU25 (excluding Cyprus), scenario 1 prepared under the Clean Air For Europe (CAFE) programme in the study "Cost-Benefit Analysis of Policy Option Scenarios for the Clean Air for Europe programme" from 2005 (Holland, Pye, Watkiss, Droste-Franke, & Bickel, 2005). We chose scenario 1 as it is the one with most moderate cost estimations and illustrates the most conservative approach.

Table 16: Average damages per tonne of emission of NH3, NOx, PM 2.5, SO2 for EU 25 (excluding Cyprus) (Holland, Watlkiss, Pye, de Oliviera, & van Regemorter, 2005)

	Scenario 1
NH_3	€ 11,000
NO_X	€ 4,400
PM	€ 26,000
SO_2	€ 5,600

The results from this analysis are presented in Figure 10 to Figure 13. Figure 10 and Figure 11 depict the marginal damage cost caused by the exhaust of the ships by burning fuel while at berth in 2010 and 2020. Figure 12 and Figure 13 show the monetized health benefit by using SSE instead of burning fuels while ships are at berth as the balance between the marginal damage costs of ships at berth meeting their energy demand by burning fuel and by using SSE. Please note that in Figure 12 and Figure 13 a positive health benefit is visualized as a negative number (in terms of the amount of

---

[1] Table 105 a

[2] Table 3.2.1.1

money which is avoided by using SSE). In regards to PM and sulphur, the values range from smaller positive values to greater negative values. Thus 0- 500 (smallest bullet) means that the use of SSE causes more damage costs than using ships' engines.

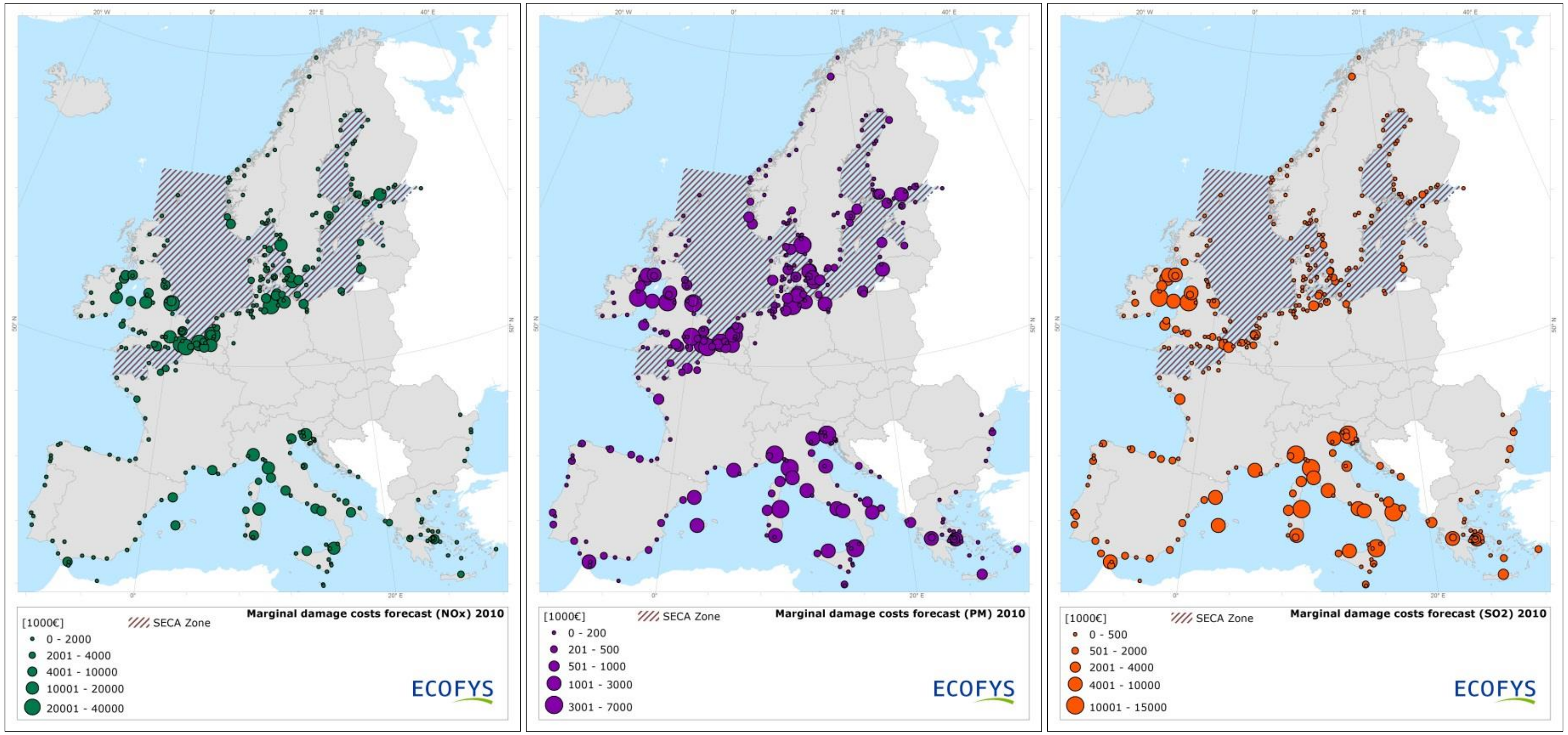


Figure 10: Marginal damage costs forecast for 2010 caused by the exhaust of the ships by burning fuel while they are at berth; calculated after (Holland, Pye, Watkiss, Droste-Franke, & Bickel, 2005)

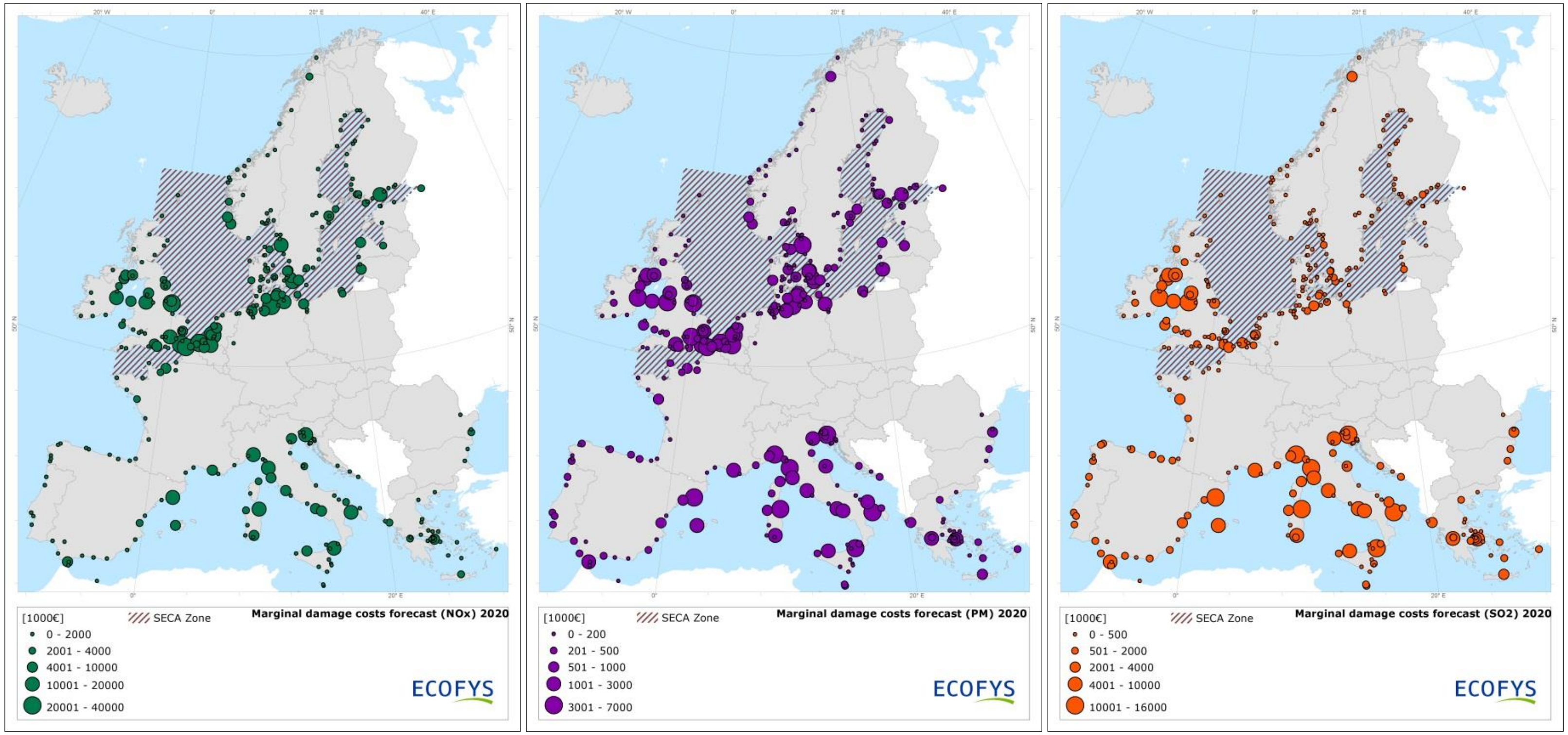


Figure 11: Marginal damage costs forecast for 2020 caused by the exhaust of the ships by burning fuel while they are at berth; calculated after (Holland, Pye, Watkiss, Droste-Franke, & Bickel, 2005)

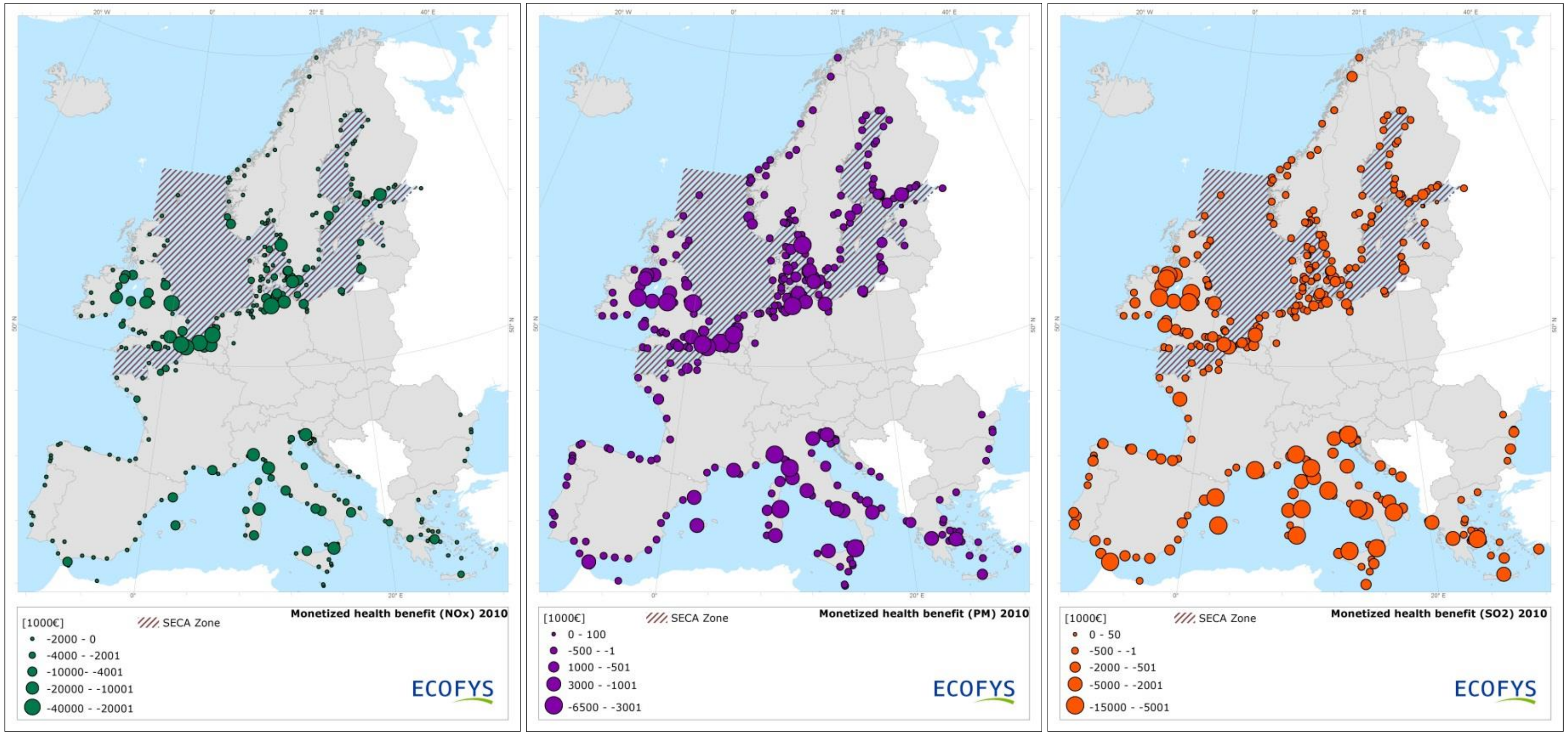


Figure 12: Monetized health benefit by using SSE instead of burning fuels while ships are at berth, 2010; calculated after (Holland, Pye, Watkiss, Droste-Franke, & Bickel, 2005), depending on port handling of each port, energy mix on EU MS level, average damage costs for EU25 (excluding Cyprus)

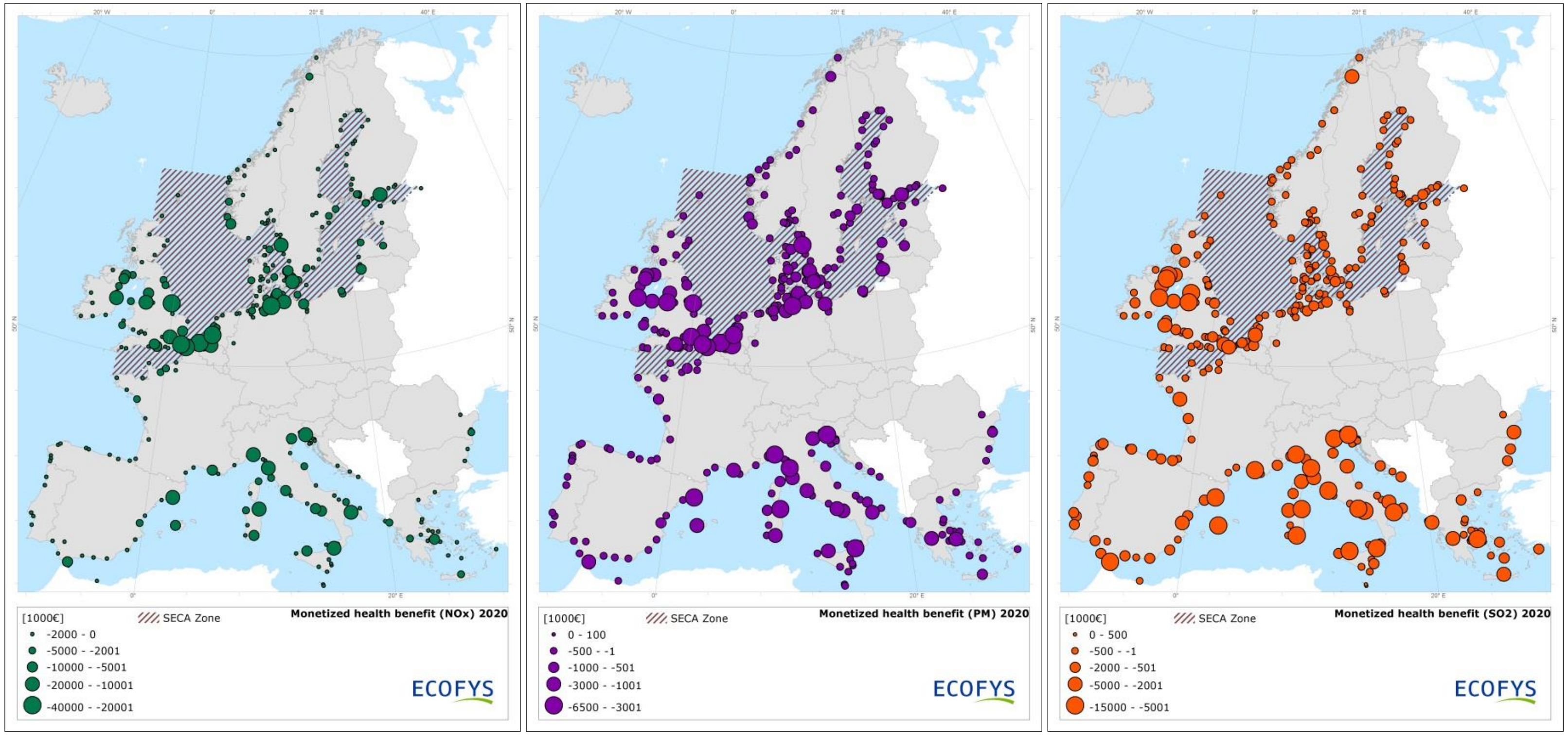


Figure 13: Monetized health benefit by using SSE instead of burning fuels while ships are at berth, 2020; calculated after (Holland, Pye, Watkiss, Droste-Franke, & Bickel, 2005), depending on port handling of each port, energy mix on EU MS level, average damage costs for EU25 (excluding Cyprus)

As the energy demand of ships at berth depends mainly on the type of ship, the sum of the energy demand mainly depends on the amount of hours of each type of ship at berth and the combination of berthing ships-types due to the main goods handling or cruiser / ferry presences at the port.

The fact that the maps show the combination of changes in the energy mix and demand increase of electricity due to increased economic activity in the ports compared to the high amount of Euros figured out in the maps, the visualization only differs in a small way between 2010 and 2020. This remains the case even if there are changes in allocation.

Figure 10 and Figure 11 shows that with regard to NOx for a lot of high-traffic ports, the forecasts for marginal damage costs are very high. Ports in UK, France, Belgium, The Netherlands, Germany, Denmark, Sweden, Italy, Greece and the Mediterranean Islands need to focus on mitigation activities. Regarding PM, the marginal damage costs are rated much lower in the forecast compared to NOx. Concerning sulphur, the marginal damage costs in the SECA zone are relatively low. The amounts for the Mediterranean area, Ireland and the west part of the United Kingdom are remarkably high.

Figure 12 and Figure 13 show the monetized health benefit in total for each port if the potential of SSE would be exploited. The maps visualize a high health benefit by using SSE especially in the main ports of Benelux, Germany, Italy and UK. Also high health benefits could be reached in ferry terminals.

The maps also show that to lower sulphur emissions outside the SECA zone, SSE would be an appropriate solution as it would reduce emissions and damage costs in these areas.

These maps show that already with the actual and targeted energy mixes, relevant health benefits could be achieved by using SSE instead of burning fuel while ships are at berth.

It should be emphasized here that if we look at the island states which are producing more that 80% of their electricity supply by burning oil (it is mainly an equivalent to HFO), the investment in SSE infrastructure won’t bring a monetized health benefit or even more – the use of SSE could cause more marginal damage costs than burning fuel in the ship engines. This conclusion does not mean that these islands shouldn’t take SSE into account. It means that these states could procure great positive effects if they could find a way to raise the share of renewable energy in total or locally at the port side through generating energy by wind or solar.

The assessment of this report shows that the environmental and economic benefits of the use of SSE (due to lower marginal damage costs caused by harmful emissions) highly depends on the energy mix of the electricity supply and that the health benefits even could be higher if the ports satisfied their electricity demand with a high percentage of renewable energy. It can therefore be concluded that a business case for the investment of SSE infrastructure also highly depends on the energy mix if the damage costs of the harmful emissions are taken into account. As Ecofys will elaborate policies and political instruments further in chapter 5, it will only be touched upon here. Especially for countries or islands for which electricity generation depends highly on fossil fuel and will still depend on it by 2020, are highly recommended to develop instruments which combine the investment in SSE infrastructure and electricity generation by renewable energy locally on port or at the regional level (e.g. self-generation). This aspect needs to be taken into account if business cases are to be created for all stakeholders on SSE, especially for ports.

2.3.5 Economic costs and benefits

Maritime

The investment costs for the electrical system on the sea ship side is significant (approximately € 500,000 for a typical 2MVA connection). Retrofit option is 1 million US$ per ship. Maersk chose to put additional equipment in a container on the aft deck in the lowest container (MAERSK, 2014).

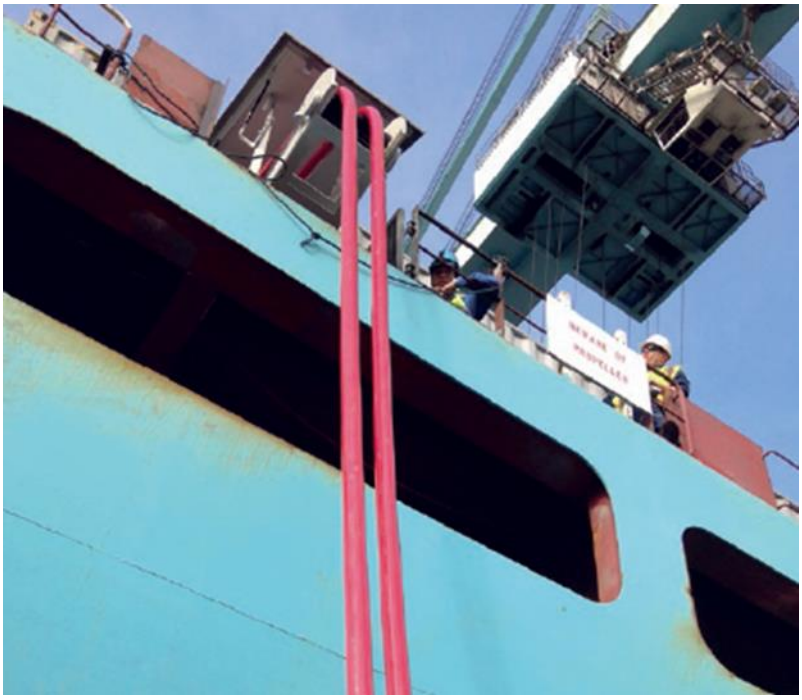


Figure 14: SSE cables from MAESK container ship (Maersk Line, 2014)

Two cables for the container ship provide a 5.5MW connection. Maersk also needs a transformer, since the voltage onboard is 450, while the connection provides 6.6kV (MAERSK, 2014). 99% of the ships operate at 60Hz, so in all European ports frequency converters are necessary (MAERSK, 2014).

The business case is best for the ships that visit the dock frequently and/or use a lot of electricity while moored. Often the investments on the shore side (in millions for sea ports) are done by port operators, and energy utilities, with support from (local) governments.

Los Angeles already invested 150 million US dollars in SSE infrastructure (MAERSK, 2014).

The rates per kWh are dependent on the electricity price and the installation costs differ per kW for the electricity connection. Due to the magnitude of power consumption, the rates charged to the seagoing ship operators will likely be close the electricity prices charged to local industrial/commercial users (Sisson & McBride), but could be somewhat higher because of the high initial investment costs for the electricity connection. Studies have shown that SSE can often be beneficial for the ship-owners and the port operators compared to generating electricity using fuel onboard (Sisson & McBride), but stakeholder opinion are quite divers about the cost-effectiveness of SSE.

Inland Shipping

In Rotterdam, the fares charged per kWh for inland ships are close to the fares charged to households in the Netherlands (€ 0.17/kWh – € 0.34/kWh) (Walstroom, 2013).

3 Barriers for Shore Side Electricity in ports – shaping the supply

In this section, we assess the main barriers with respect to the development of the necessary SSE infrastructure. Interviews were carried out with the key stakeholders on the EU and US SSE market. The result of the stakeholder consultation is given below. In parallel, the technical status quo and the barriers were investigated through literature review. Furthermore, we estimated the impact of SEE implementation on the electricity grid and detected sensitive areas. This section closes with the establishment of the carbon content of electricity provided.

3.1 Barriers to EU-wide implementation of SSE: results from the stakeholder consultation

Ecofys interviewed relevant stakeholders to investigate general barriers such as social issues, technology compatibility aspects and financing that influence SSE development. The interviews give insight into barriers for SSE and potential alternatives as seen in practice. Among the interviewed stakeholders are European associations including ESPO, EFIP, and ECSA, international organisations such as WPCI, port authorities such as Rotterdam, SSE equipment providers including ABB, Siemens, and Schneider Electric, and Container shippers such as Maersk Line.
In this section the following questions were answered:

- What main barriers exist for the deployment of SSE? (Economical, Regulatory, Practical, etc.)
- What good practices exist in the deployment of SSE?
- How can the business case for SSE be improved?
- For which operations is SSE a feasible option in the period 2013-2020?
- What alternative options to SSE exist and in which circumstances are these alternatives feasible?

The sections below present a summary of stakeholder responses.

3.1.1 Inland shipping

The acceptance of SSE in inland ports is limited, despite the apparently beneficial potential. Inland ships are in waiting areas for a long time, typically much longer than maritime shipping. River cruises with their higher power and electricity demand provide a better business case for SSE, also because the market development projections for the future are positive. However, in general, there seems to be a consensus on the limited potential for SSE for inland ships in ports. Up until now, only few connection stations are installed, which are rarely used. Slow steaming is seen as a better and more effective option to reduce CO_2 emission for inland shipping.

3.1.2 Maritime shipping

SSE is still young and too new for many ports; experience is lacking and authorities might not promote or bring in the utility. Some interviewees consider the implementation and regulation to be very easy, as long as enforcement is structured in the right way. Other stakeholders still experience insecurity, for example with the ownership of the SSE utilities. Otherwise, the existing practices report predominantly positive feedback, although in these cases it has to be considered that they have political backing. The first step should be to focus on harbours or quays areas in the port where impacts are most beneficial, like passenger waiting areas, ports close to residential areas, cruise ship, quays.

Economic barriers were highlighted as important barrier for stakeholders. The underutilisation of the SSE connection is not supportive of a strong business case, and very high investments are required from both shore and ship side. A key challenge is that the investors do not necessary benefit economically from it and the social and environmental benefits are difficult to quantify. Additionally, the impact depends much on the exact location of the ships, for example the distance to residential areas. One business case could be that port operators invest in the power supply and sell electricity to the berthing ships. A local approach would be recommendable. It could reduce the cost for the grid connection; ideally would be local renewable electricity production.

For maritime shipping, it is important to have user a friendly system in place that enables easy connecting and disconnecting. It might be that traffic is moving too fast in some ports or quays, and that Roro’s or ferries’ berthing time is too limited to make use of SSE (e.g. Calais’ Roro and ferry harbour). This has to be considered for each port or quay individually.

Beside SSE, other technologies are also being piloted in various ports. Interviewees mentioned solutions like LNG barges or ships (e.g. Hamburg); LNG is technically regarded as SSE. LNG could work in areas where the grid is weak or where there is no room on the berth. But it also comes along with some uncertainties, such as methane leakage. Scrubbers were mentioned as a potential alternative, with the drawback that they emit “yellow water”. SSE could also be used to power battery powered ships.

In practice, an approach is required that uses combination of different solutions including SSE but also other approaches. A suitable and sustainable solution should be sought for each individual port and harbour.

Today’s incentives often do not cover all costs and do not support the companies equally. Companies that pursue opportunities more proactively receive more funding.

One of most mentioned obstacles is the difference in tax on the electricity and the fuel, because SSE currently competes with the fuel which is not taxed.

The rollout of SSE will require companies and ports to cooperate. In addition, policy support is needed to ensure a broader implementation of SSE technology.

3.2 Technical barriers: infrastructural implications

Although international standards were recently set, SSE is facing technical challenges. The literature review revealed major challenges, which are explained briefly below. The following chapter will give some insight in the technical barriers and infrastructural implementation.

Power supply/demand cover
The maximum total power on the shore side needs to be considered. A suitable power supply should cover the ships demand, which depends on the visiting vessels. The costs of supplying high voltage power can vary significantly if investment in transformer stations is required (WPCI, 2013). In most ports there is access to electricity at different voltage levels. Ports close to a housing or industrial area, medium voltage power (6.6-11 kV) may often be available close at hand or within a few kilometres. Ports that only have low power voltage (400-480V) should analyse the need for their visiting vessels to see if expansion of their grid is beneficial.

Different voltage levels on the ship and port side, and impact of max power demand. Requirements on the ship side and the maximum total power demand on the shore side need to be considered. The Standard - IEC/ISO/IEEE 80005-1:2012 – (mentioned above) covers and standardises the port side voltage level to 6.6-11 kV. The maximum power demand from the port side needs to be matched to the vessels berthing at the quays. A transformer is either needed on board each ship or on the port side to match the different voltage power systems of the vessels. The power demands of the vessels vary between 0.4 – 20MVA (see Table 17 and Table 4). The maximum power demand has a substantial effect on the costs of a SSE system and it is therefore important to chase energy reduction and peak clipping options and to evaluate peak power demand in advance (WPCI, 2013).

Table 17: Suitable power supply for the different vessel types (Radu & Grandidier, Shore Connection Technology - Environmental Benefits and Best Practices -, 2012)

Vessel type	Occurrence	Necessary power supply in berth (MVA)
Cruise ships > 200m	-	10-20
Tanker > 200m		3-11
Container/Reefer > 200m		3-6
Bulk/Cargo/Container/RoRo < 100m	+	0.3-3

Different frequency on the ship and the port side

The different power frequency systems on the ship and port side present another challenge. This is one important point that is not covered by the new released standard - *IEC/ISO/IEEE 80005-1.*
Electricity supply in Europe has a frequency of 50 Hz, whilst in other countries in the world a frequency of 60Hz is implemented (see Figure 15). The majority of the ocean-going ships have electricity systems that are adapted for electricity with a frequency of 60 Hz. Some ships that only travel within Europe or the Baltic region have electricity systems adapted to 50 Hz, including, for example, many Ro-Ro vessels (PORT OF GOTHENBURG, ABB, Ramböll Sverige AB, & Vinnova, 2012).

Figure 15: Power frequencies throughout the world (ABB, 2011)

Furthermore power frequencies vary between vessel types and sizes. Table 18 gives an overview.

Table 18: Summery of frequency systems (Ericsson & Fazlagic, 2008)

Vessel type	50 Hz	60 Hz
Container vessels (< 140 m)	63%	37%
Container vessels (> 140 m)	6%	94%
Container vessels (total)	26%	74%
RoRo- and vehicle vessels	30%	70%
Oil and product tankers	20%	80%
Cruise ships (< 200 m)	36%	64%
Cruise ships (> 200 m)	--	100%
Cruise ships (total)	17%	83%

A ship constructed for 60 Hz power frequency might be applicable to use 50 Hz power frequency for some devices, such as domestic lighting and heating. Nevertheless it cannot use 50 Hz for the operation of motor driven devices such as pumps, winches and cranes. Therefore, vessels using 60 Hz power frequency will require 50 Hz electricity to be converted to 60 Hz by a frequency converter (de Jong, Hugi, & Cooper, 2005). Either the ship or port side need to provide a power frequency converter in such cases where the power frequencies do not match.

The success of SSE depends on the attitudes of parties on the shore side as well as vessel owners. Some ship owners have already invested in SSE equipment on board their ships. These include NYK Line, Evergreen, Princess Cruise and Holland America Line, China Shipping, Evergreen, MOL, Stena Line, Wagenborg, TransAtlantic, SOL, TransLumni, ICL, and Cobelfret. (WPCI, 2013). The release of the ISO standard was an important step to dismantle some technical, practical and economical barriers. There are only minor issues from the technical view point, neglecting economic aspects. Even for the 50/60 Hz obstacle, which is still widely discussed, there are technical solutions in place (i.e. a converter) that allow the ports to support both system if needed. Stakeholders are still suspicious about the grid stability, when the power demand grows by using SSE. In the following section this will be further investigated.

3.3 Impact of EU-wide SSE implementation on the electricity grid

In this section the impact on the electricity network infrastructure is investigated. We use a unified approach for the assessment of the impacts on the ports. The impact on the network infrastructure depends highly on the expected demand increase, the existing network condition and plans for the future. Since it is very difficult to assess the detailed impacts for each port area (detailed power flow simulations for the specific networks are needed), we quantify the impacts based on the use of the *demand increase indicator (*Figure 19*)* which equates to the expected electricity demand increase through calculating SSE divided by the electricity demand of the specific area*.* We assess the SSE demand on a NUTS 3 level of detail using the detailed Ecofys database. We investigate impacts on the ports in the following two distinct levels:

- Impact on distribution networks in the vicinity of the port.
- Impact on the transmission system level.

The investigation of the impacts of SSE on the electricity network infrastructure for inland shipping revealed no serious impact on the grid. In Europe, inland ships can be compared with normal households. Accordingly, the impact on the electricity grid is similar. Every day electricity utilities connect new residential houses or areas to the electricity network without major implications. Therefore, no serious grid impacts are expected for SSE inland port areas. In the following section (3.3.1-3.4) the focus is on the impact on the electricity network infrastructure from maritime SSE.

3.3.1 Impact on distribution networks in the vicinity of the port (SSE Demand increase indicator)

The impacts to local distribution grids are directly assessed by the *demand increase indicator (*Figure 19*)*. The different areas are classified based on the expected load increase and the general strength of the local network. The strength of the local network is assessed based on the location of the port with respect to the industry, demand centres (large residential areas) and large power plants. Our qualitative assessment of the strength of the local network is performed in NUTS 3 level of detail using the detailed Ecofys database.

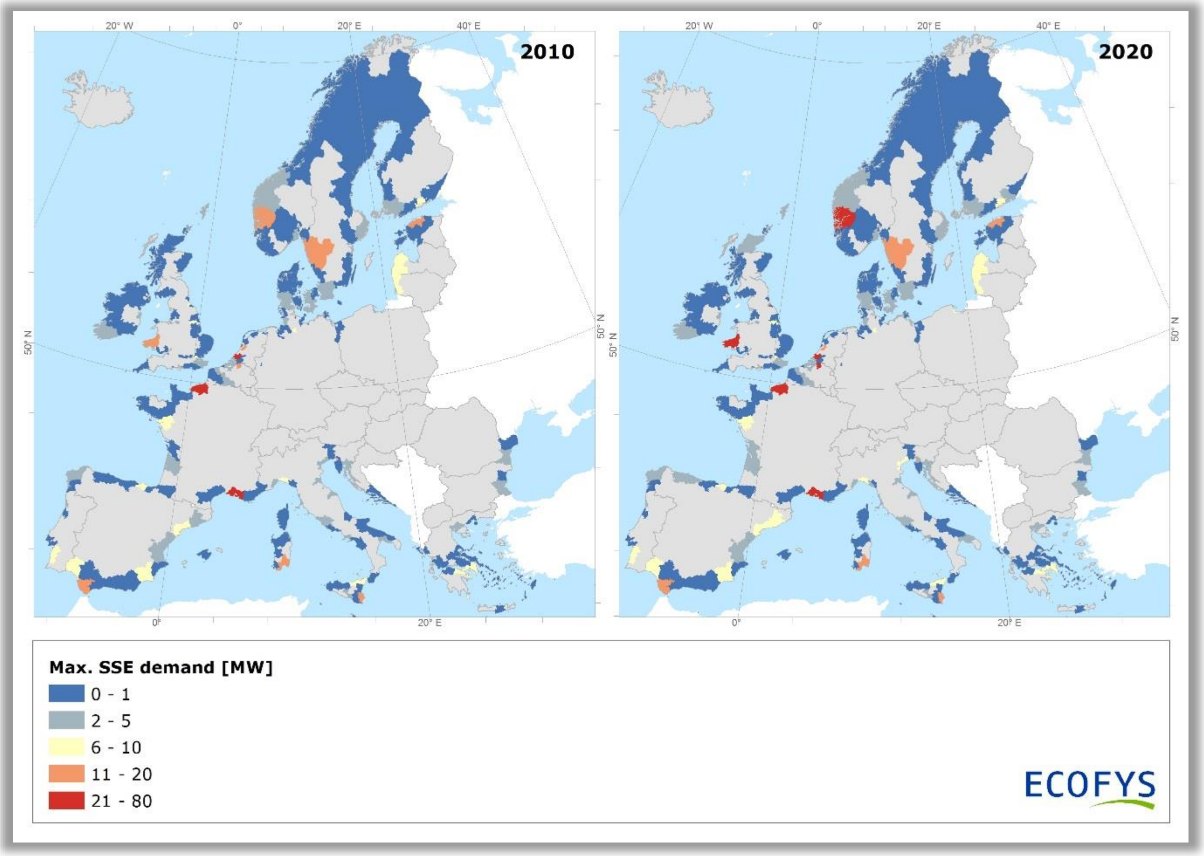


Figure 16: Estimated max. SSE power demand for each port in Europe distributed on NUTS 3 level for 2010 and 2020 (MW)

The SSE power demand was calculated for each port area in 2010 and 2020 and mapped in Figure 16. *Figure 17* gives a good overview of the SSE power demand distribution. The areas of highest SSE peak demand are Rotterdam (71 MW in 2010 and 78 MW in 2020) and Marseille (25 MW in 2010 27 MW in 2020), followed by Milford Haven and Bergen (both 19 MW in 2010 and 20 MW in 2020). These are seen as red and orange areas in Figure 16. As can be seen, high impacts are expected only in a limited number of ports, while for the majority no serious impact should be expected.

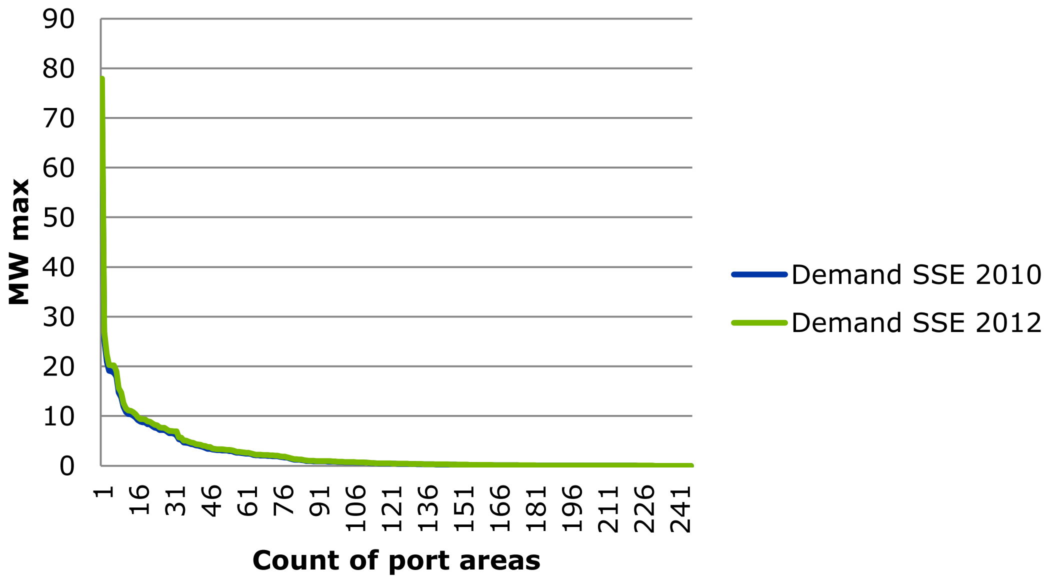


Figure 17: Distribution of the SEE demand, in 2010 and 2020.

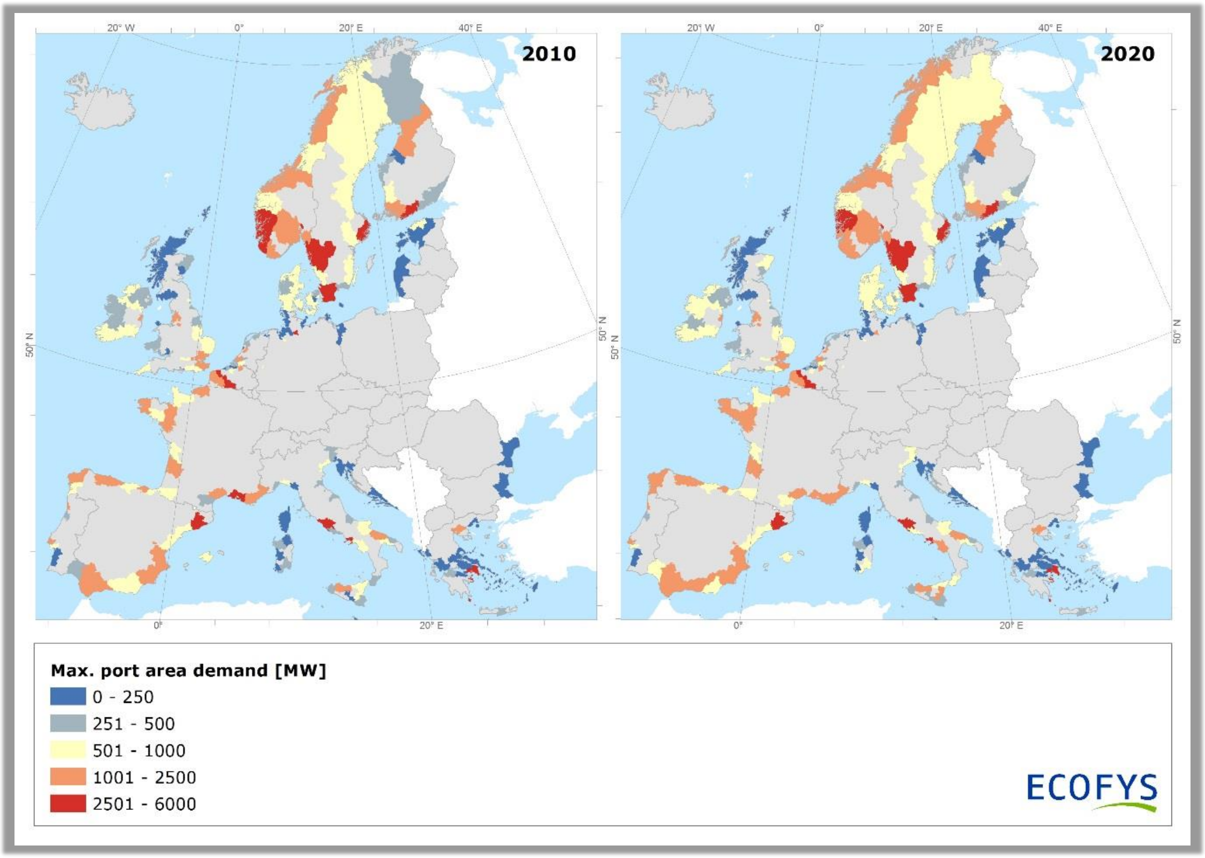


Figure 18: Estimated maximum port power demand in Europe distributed on NUTS 3 level for 2010 and 2020 (MW)

In a next step, the existing power demand on the onshore side was calculated for the same port areas as before in 2010 and 2020, shown in Figure 18. The red areas flag port areas with larger demand increases, whilst green areas show low demand increase. Areas with larger demand increase are mainly zones with big cities, industrial grounds and high populations, such as Barcelona, Athens, and Hamburg.

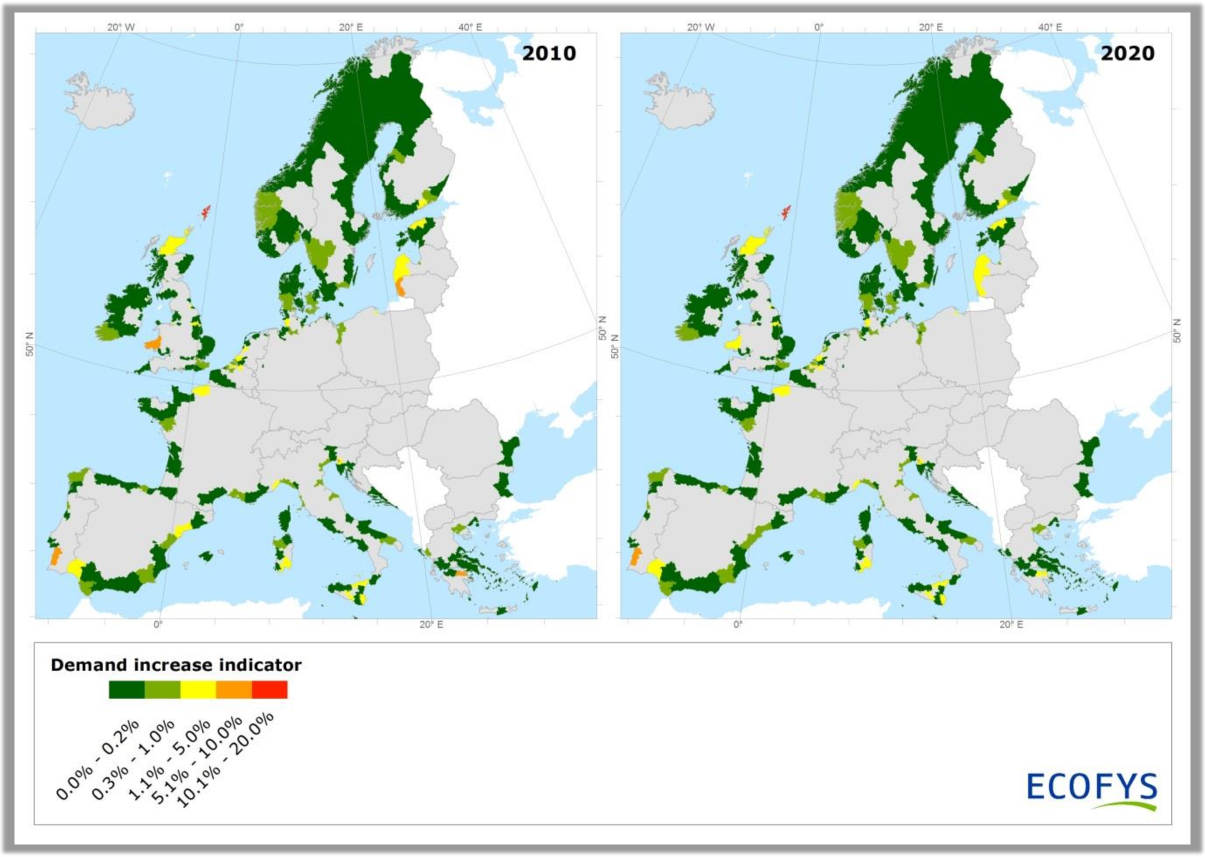


Figure 19: Demand increase indicator on NUTS 3 level, only zone shown that accommodate a considered port

The *demand increase indicator* equals to the expected electricity demand increase due to SSE divided by the electricity demand of the specific area*.* It is based on the peak demand. The result is given in Figure 19. It is important to understand the magnitude of the demand increase. If this is low, the impact to the investment is also low. The demand increase indicator (%) is important for understanding the impact to the local grid; if this is high it is more likely that the local grid may suffer.

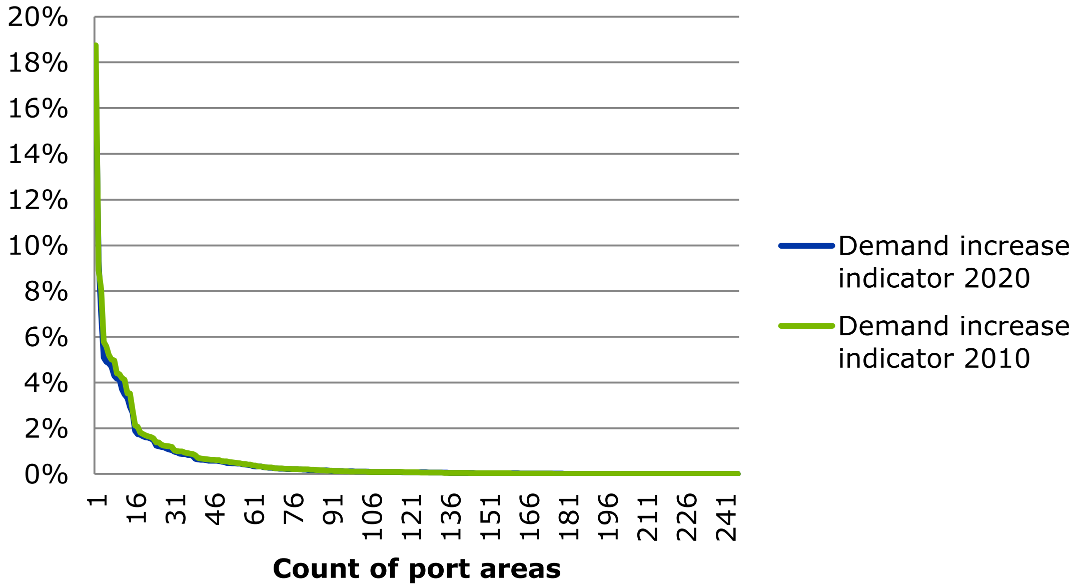


Figure 20: Distribution of the SEE demand increase, in 2010 and 2020

Eight possible *key sensitive areas* were located with a demand increase indicator ≥ 5% where SSE demand impact might lead to a *"significant"* demand increase on the grid system, as shown in Table 19. Only 15 of the total areas have a demand increase indicator above 2% and about 50 above 1%, which can be visibly seen in the distribution of the SEE demand increase, given in Figure 20. It shows that SSE does not seem to cause major concerns or cost from the grid investment side.

Table 19: Possible *sensitive areas* (NUTS3 zones with and a demand increase indicator ≥ 5%)

NUTS 3 ID	Country	Ports in this NUTS 3 Zone	MW max SSE (peak)	MW max port area (peak)	Demand increase indicator
UKM66	United Kingdom	1	4	22	19%
ES704	Spain	6	10	90	11%
DE945	Germany	1	8	94	9%
PT181	Portugal	1	7	81	8%
ITD44	Italy	1	12	206	6%
GR253	Greece	1	7	129	6%
UKL14	United Kingdom	2	19	368	5%
LT003	Lithuania	2	8	166	5%

In general, a demand increase of 20% is not seen as problematic for the grid, especially if we take into account that the SSE implementation is a medium long term process which is aligned with the grid extension planning. A closer look at the numbers of the identified possible sensitive areas shows that the general demand of these areas is relatively low. Therefore, the impact of the SEE demand increase appears quite high, even though the actual SSE demand is not very high from a grid capacity perspective.

3.3.2 Impact to the EU transmission system

In this section the impact to the EU transmission system is further investigated. In cases where the demand increase indicator from section 3.3.1 shows significant growth, the impacts to the transmission system of the area are estimated. To assess the strength of the transmission system in the area, we investigate the expected congestion level of the identified zone based on the analysis provided at the Ten Year Network Development Plan (TYNDP) of the European Network of Transmission System Operators for Electricity (ENTSOe, 2012). The TYNDP analysis shows the key drivers and expected bottlenecks in the transmission system in the EU. The maps on the following pages visualize the results.

Figure 21: Layer-overlay, ENTSO-E TYNDP 2012-2016 (ENTSOe, 2012) and SSE demand increase Indicator

We overlap the outcome of the demand increase indicator with the Grid development drivers and medium/Long term grid development plans in the EU zone based on the ENTSOe Ten Year Network Development Plan (ENTSOe, 2012), see *Figure 21: Layer-overlay, ENTSO-E TYNDP 2012-2016* and SSE demand increase Indicator and Figure 22: Layer-overlay, ENTSO-E grid development drivers and SSE demand increase indicator. This approach allows us to assess the key impacts of load increase to the transmission system. This is done in the following section.

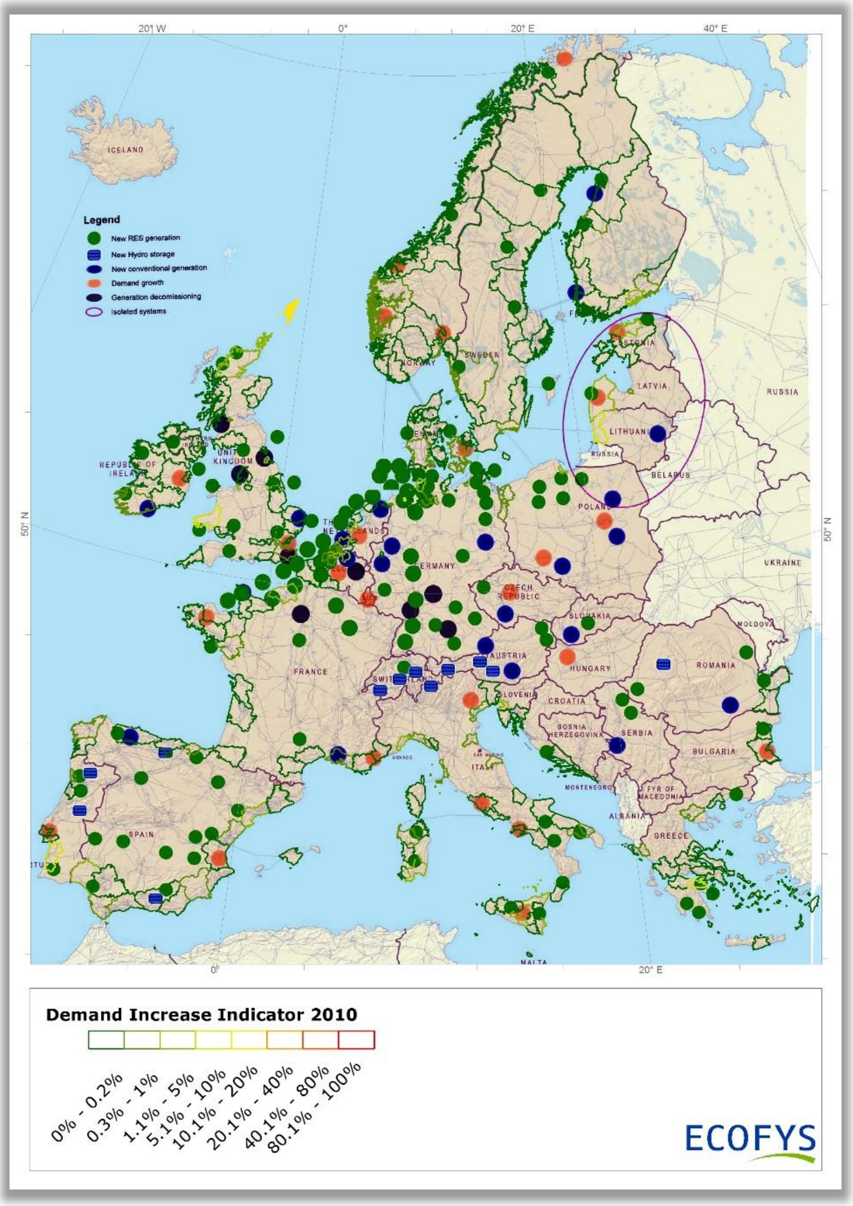


Figure 22: Layer-overlay, ENTSO-E grid development drivers (ENTSOe, 2012) and SSE demand increase indicator

As can be seen, transmission system development is driven by the large increase in RES (green points) in coastal or offshore areas Figure 22. In this respect, a demand increase in these areas can have a positive impact to the transmission system since the renewable electricity can be locally consumed.

3.4 Identification of main sensitive cities/regions in EU

Based on the analysis provided at the Ten Year Network Development Plan of the European Network of Transmission System Operators for Electricity (ENTSOe, 2012), we investigated the expected congestion level of the identified zone to assess the strength of the transmission system in the area for the different port areas. The eight possible *sensitive areas* given in Table 19 were more closely investigated to identify possible obstacles. Figure 23 gives an example of this.

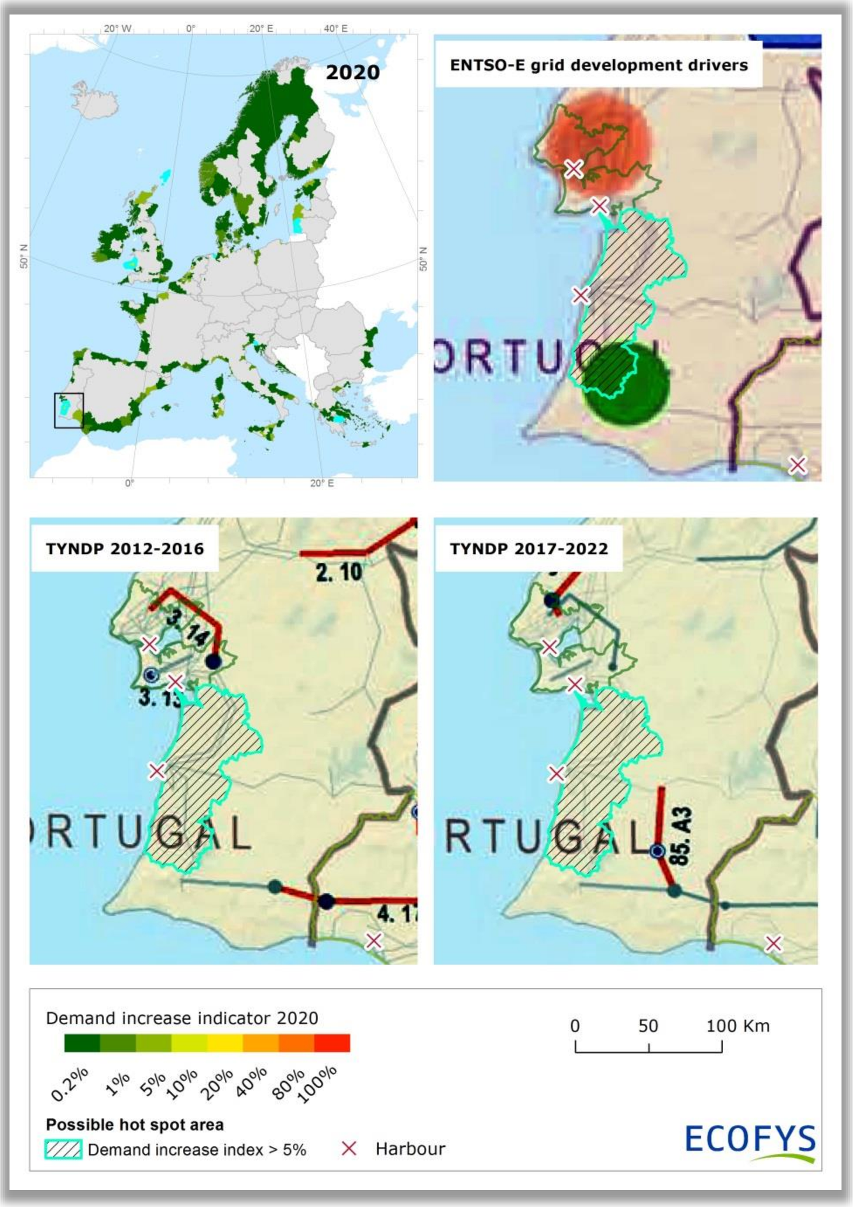


Figure 23: Possible sensitive areas (hot spots) with a demand increase indicator ≥ 5%. Exemplary close up port area Sines, Portugal (Alentejo Litoral)

<u>Port of Sines, Portugal (NUT3 = PT181)</u>:

- No significant problems expected on the transmission system level.
    - New RES plant is planned, SSE could be positive since energy can be consumed locally.
    - Demand increase north of this area does not affect this area, further transmission grid connection are planned.
- Demand increase index is about 8%, but the SSE demand is only 7MW (peak). It is not seen as problematic, although the port area demand with 81 MW (peak) is also quite low. The area is not very densely populated and a major portion of the area demand is probably consumed by the port and industries and medium cities.
- To adapt the technical and economic investments to the additional SSE demand does not overload the capacities of the daily scope of a grid provider.
- A local supply approach might be sufficient for this area and could lead to some extra income for the port operators or surrounding industries.

In general, no severe obstacles are expected on the transmission level for all observed areas. The demand increase caused by SSE is a rather minor impact, at least from the transmission grid perspective. SSE might even have positive effects for some coastal areas where RES are installed and generation and transmission are growing in future. To exclude all uncertainties on the distribution grid level, further investigation on a local level with advanced modelling needs to be performed. However, the results of this study show that the demand growth caused by SSE is not of a dimension that could cause major challenges, compared to the normal grid extension processes.

3.5 Determination of the carbon content of electricity provided

In this section the carbon content of the electricity provided in EU regions is estimated based on the key indicators of the carbon content in the electricity generation mix of each country. We analyse the development of the electricity generation mix in the latest years and the projections for the future and calculate the carbon content of the electricity provided to the SSE ports.

Because the electricity market acts on national level and the consumed electricity mix cannot be distinguished between the input fuel types for each port region in counties, our approach is to perform the analysis on a country/electricity market level. We therefore estimate the average CO_2 emission factor (gCO_2/kWh) for each county and classify it into three classes: low <450 gCO_2/kWh, medium ≥450 and ≤650 gCO_2/kWh, and high >650 gCO_2/kWh. Emissions from the use of fuel on-board the ships would fall in the medium category. Based on the electricity demand (GWh/a), we mapped the impact for each for each port (see Figure 24).

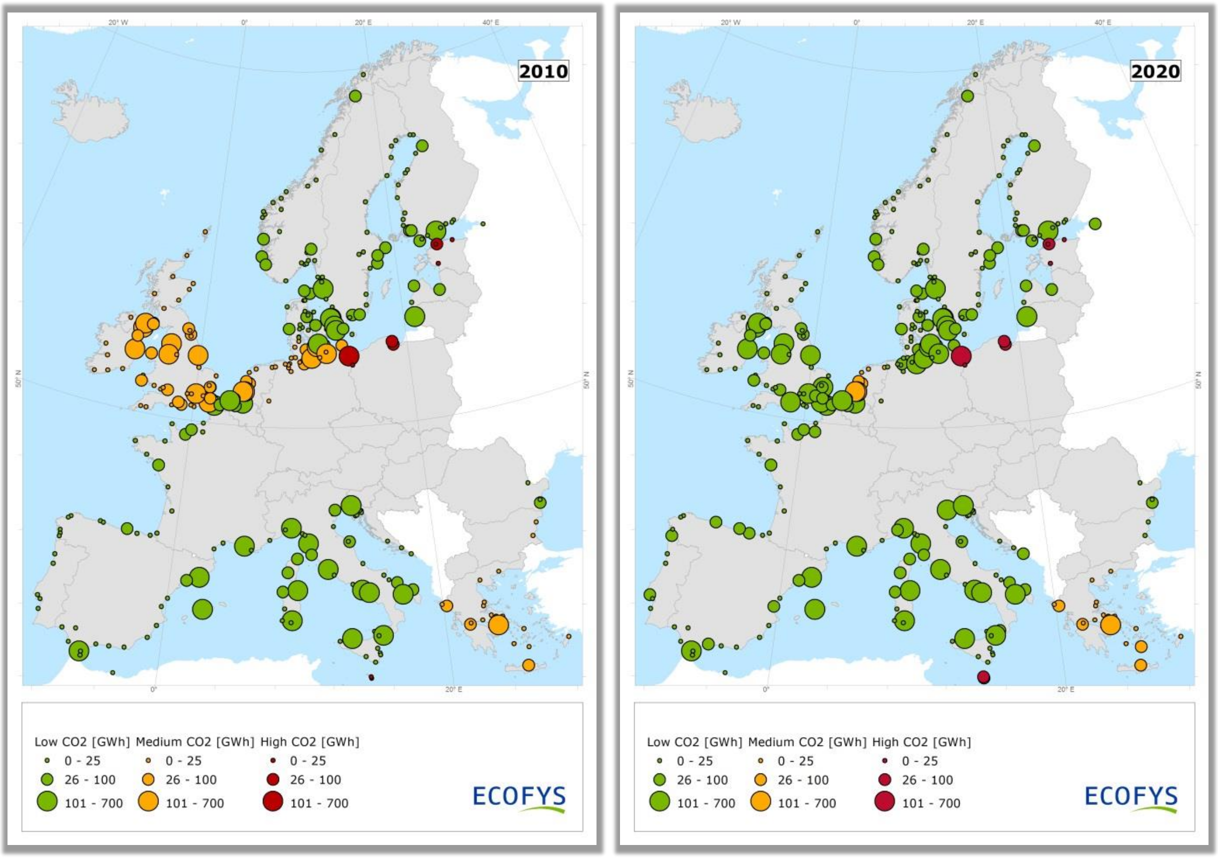


Figure 24: Total SSE electricity demand [GWh/a] for each port. The traffic light colours indicate the carbon that is produced to cover the SSE demand generated by country wide energy production

In countries with high CO_2 emission factors for the electricity supply, the use of SSE from the national electricity grid would lead to more emissions than using the standard diesel generator on-board. This concerns for example Poland and Estonia where the emission factors are high with 835 CO_2/KWh (PL) and 665 CO_2/KWh (EE 2010), mainly due to the high use of lignite and hard coal for energy generation. That does not mean that SSE is not a suitable solution for these areas, because a big advantage is that SSE moves the pollutant (ships) from populated areas such as the port regions to more remote areas where power plants are usually located. Therefore SSE would lower explicit damages such health impacts for those populated areas. Further damage reduction could be achieved, if less carbon intensive emissions electricity generation would be used to supply SSE. The implementation of SSE would decrease CO_2 emissions in all port areas with yellow or green dots, given in Figure 24.

In general these maps need to be read with caution, since the CO_2 emission factors are estimated from a mixture of different energy fuels. For example, France and Finland produce their main electricity with nuclear energy and therefore CO_2 emissions are quite low.

3.6 Conclusions

Barriers to EU-wide implementation of SSE

Inland shipping

The acceptance of SSE in inland ports is limited, despite the apparent beneficial potential, since berthing times are usually much higher than in the maritime shipping. A voltage standard is currently in place, but no standard connector. From the electricity network infrastructure, no major implications are expected, since the demand of inland SSE in the EU is quite low. On the distribution grid level further investigation including detailed modelling would be necessary to give a final recommendation on barriers, especially for areas with weak grids. River cruises, with their higher power and electricity demand, provide the best business case for SSE; strong market development in this niche is also projected. The European Federation of Inland Ports stated that in general there seems to be consensus on limited potential for SSE for inland ships in ports. Slow steaming is seen as better and more effective option to reduce CO_2 emissions for inland shipping.

Maritime shipping

SSE is still a young approach for the maritime ports and the supporting technology is not well established yet. Operational SSE pilots report predominant positive feedback, especially on social and environmental benefits. Governmental support or legislation enforcement was mainly involved in these cases.

The first step should be to focus on harbours or quays areas in the port were impacts are most beneficial, such as passenger waiting areas, ports close to residential areas, cruise ships, and quays.

A key challenge is that the investors do not necessary benefit economically from SSE yet, since the social and environmental benefits are difficult to quantify or to distribute. The economical barrier is high to implement SSE for both shore and ship side. A major barrier is the taxes on the electricity, because it competes with the fuel which is not taxed (or vice versa for the missing taxes on the fuels used for maritime shipping). A potential business case could be for those port operators to invest in the power supply infrastructure and sell electricity to the berthing ships. Applying local approaches could reduce the costs for grid connection, ideally with local renewable electricity production.

Some interviewees consider implementation and regulation to be quite easy, as long as enforcement is structured in the right way. Other stakeholders still experience insecurity, with issues such as the ownership of the SSE utilities. It requires shipping companies, ports operators and electricity utilities to cooperate with the rollout of SSE. Today's incentives often do not cover all costs and do not support companies equally. Governmental support is needed to ensure a broader implementation of SSE technology.

Beside SSE, other technologies are also piloted in various ports over the world. LNG barges or ships is one and is technically regarded as SSE. It also could be used in combination with SSE as fuel for the local energy supply in areas where the grid is weak (island solution). However, LNG also comes along with some disadvantages, for example methane leakage. Scrubbers are another alternative, with the drawback of “yellow water” emissions. Battery powered ships are also a possible alternative, although there is a lack of suitable batteries. In the end, an approach is needed that combines different solutions including SSE but also other approaches. For each port, a case-related sustainable and appropriate solution needs to be considered.

Technical barriers

The introduction of the ISO standard was an important step to dismantle some technical, practical and economical barriers. There are only minor issues remaining from the technical view point, neglecting economic aspects. Even for the 50/60 Hz hurdle, a technical solution is in place (a converter) that allows the ports to support both systems if needed. Stakeholders are still suspicious about the grid stability, when the power demand grows by using SSE.

Impact of EU-wide SSE implementation on the electricity grid

In general, the demand increase is not seen as problematic for the electricity grid, especially if we take into account that the SSE implementation is a medium- to long-term process which is aligned with the grid extension planning in the EU.

A closer look at the numbers of the identified possible sensitive areas shows that the general demand of these areas is relatively low. Therefore, the impact of the SSE demand increase appears quite high, although the actual SSE demand (peak demand) is not very high from a grid capacity perspective.

No severe obstacles are expected on the transmission level for the observed areas. The demand increase caused by SSE is a rather minor impact, at least from the transmission grid perspective. SSE might even have positive effects for some coastal areas where RES are installed and generation and transmission are growing in future. To exclude all uncertainties on the distribution grid level, further investigation on the local level with advanced modelling needs to be performed.

Establishment of the carbon content of electricity provided

For most EU Member States SSE implementation would contribute to decrease CO_2 emission based on the national CO_2 emission factors for electricity generation. In countries with high carbon content in their electricity supply, such as Poland or Estonia, SSE leads to an increase of emissions. Nevertheless that does not mean that SSE should not be used in these countries, because a big advantage is that SSE moves the pollutant (ships) from populated areas such as the port regions to more remote areas where power plants are usually located. Therefore SSE would lower explicit damages such health impacts for those populated areas. Further damage reduction could be achieved, if less carbon intensive emissions electricity generation would be used to supply SSE.

4 Policy analysis and comparative assessment of policy regulations and measures in Europe and California for deployment of SSE in EU ports

In the previous chapters, the potential, opportunities and barriers for SSE were identified. This chapter presents all related regulations and measures on EU and international level and assesses their effectiveness.

This chapter uses two angles to compile existing and potential measures to promote SSE.

1. Assessment of existing policies in the EU Member States embedded in European legislations and punctual, related international activities.
2. Assessment of lessons learnt from of the Californian regulation, which is identified as one that led to a considerable development of SSE infrastructure and use.

Chapter 5 "Setting the Course towards deployment of SSE in Europe" consolidates the set of recommendations and policy measures combined with potentials and barriers investigated through the stakeholder engagement and electricity grid analysis.

4.1 Assessment of existing policy measures

The assessment of existing policies is performed in three levels, i.e. a) international, b) at EU level and c) at Member State level. All publicly available information on regulations, legislations, and communication at the European and Member States' levels are incorporated. For some regulations or measures, the existence of country activities has proven relevant, even though detailed information was not publicly available. In these cases the activities are mentioned without being included into the assessment. Short descriptions of the regulations are provided to get the full picture of the policy landscape which influences the development of SSE in Europe. This assessment is finalized with an overview table in which the regulations are assessed concerning their cost-benefit relation for each relevant actor.

4.1.1 Regulations on international level

The result of the assessment on the international level shows that there are no international policies in place that directly enforce SSE. The International Maritime Organisation (IMO) adopted mandatory emission thresholds and measures to reduce emissions from ships on an international level. Nevertheless, states/countries are free to set standards for berthing vessels.

Two international initiatives should be mentioned within this framework, which are not national or supranational legal instruments but important drivers.

In the following part the main initiatives are described

World ports climate initiative (WPCI)

WPCI is an association of approximately 60 ports around the world. WPCI was initiated by the International Association of Ports and Harbors (IAPH) and formally started its work in 2008. This association is linked to the C40 cities, world port climate conference, regional port branch organizations and the member ports. The association aims to raise awareness on climate change, to publish information on opportunities for mitigation through ports activities and to encourage ports to act.

The WPCI started in 2009 as an initiative promoting SSE in order to reduce local air pollution and greenhouse gas emissions in ports (Dutt, The OPS & LNG projects within World Ports Climate Initiative (WPCI), 2013). To achieve this goal WPCI established a working group on onshore power supply (OPS). This group created a website to promote SSE (www.ops.wpci.nl). The main initiators of this website are the International Association of Ports and Harbors (IAPH), WPCI itself and the ports of Amsterdam, Antwerp, Gothenburg and the Hamburg Port Authority.

International Maritime Organisation (IMO)

In 1997 IMO adopted the first international mandatory measures to reduce emissions from ships.
In July 2011 the parties of IMO adopted a revised form of the Annex VI[3] "Regulations for the Prevention of Air Pollution from Ships" in the MARPOL Convention. This Annex regulates the control of greenhouse gas emissions from ships and as well as mandatory and optional measures to reduce greenhouse gas emissions from international shipping.
This Annex includes a mandatory appliance of two instruments as a mandatory greenhouse gas reduction regime for ships on an international basis (IMO):

- Energy Efficiency Design Index (EEDI). The EEDI stimulates continued technical developments by continuously tightening the minimum requirements for energy efficiency per capacity mile per types of ship. It is a performance based instrument. Measures to be taken are non-prescriptive.
- Ship Energy Efficiency Management Plan (SEEMP). With the included monitoring tool of the Energy Efficiency Operational Indicator (EEOI) the SEEMP assists the ship operators to monitor their activities and benchmark their strategic decisions on energy efficiency.

These international agreements within the maritime industry constitute the basis of the European strategy to reduce airborne emissions from ships. These mandatory emission reductions pave the way for the deployment of SSE on the European and national level.

---

[3] First entered into force on 19.5.2005

MARPOL 73/78

The MARPOL is an international convention for the prevention of pollution from maritime activities. It consists of the convention itself, two protocols and six annexes. The convention entered into force in 1973, the protocol in 1978 and Annex VI in 2005. The latter regulates the prevention of airborne emissions through ships. Thresholds amongst others on NO_x, sulphur used in shipping fuels need to be met. Verification of meeting these thresholds is to be provided by fuel suppliers. 72 of 152 states signed this annex.

International activities on country level (examples)

In **California** (US) the CARB (California Air Resources Board), a department within the cabinet-level California Environmental Protection Agency enforced a regulation for berthing ships at Californian harbours. SSE is one of the options to meet the requirements of the regulation. The regulation and its implementation in practice are described in detail in chapter 4.2. This is the first regulation on regional level (comparable to EU Member State level) which is already in place.

In its 2011-15 five-year plan **China** has identified SSE as a key part of efforts to curb pollution in ports (Radu, 2013). It was not possible to get detailed information on how the Chinese government designed the measures to deploy SSE in Chinese ports through publicly available sources.

4.1.2 Regulations on EU level

This section describes the recommendations, regulations and funding at EU level. The policy and practical activities in the EU Member States are described in the next chapter. That makes the cost-benefit-assessment comprehensive and transparent.

4.1.2.1 Regulations

EU Directive 2005/33/EC

The European Parliament and Council issued the Directive 2005/33/EC on 22 July 2005, amending Directive 1999/32/EC. The main purpose of the Directive is to achieve acceptable levels of air quality in coastal areas by reducing emissions from shipping, such as sulphur dioxide and particulate matter. In order to achieve this goal, the Directive regulates the sulphur content of heavy fuel oil and marine fuels and encourages Member States to promote trials and use of new emission abatement technologies. Among other regulations, Member States are required to control the sulphur content of marine fuels used by inland waterway vessels and ships in berth in Community ports (2005/33/EC, Art 4b), allowing only a "maximum limit of 0.1 % sulphur by weight for marine fuels" (2005/33/EC, Art. 4b) from 1 January 2010 onward. The Directive encourages land-based electricity supply insofar as ships which switch off all engines and use shore-side electricity while at berth in ports are exempt from this sulphur restriction. Furthermore, the fuel requirements set by the Directive do not have to be met during trials of new emission abatement technologies (2005/33/EC, Art. 4c).

Commission Recommendation 2006/339/EC

The European Commission issued the Recommendation "on the promotion of shore-side electricity for use by ships at berth in Community ports" (2006/339/EC) on 8 May 2006.

The purpose of this non-binding recommendation is to encourage European Member State governments to engage in activities that promote shore-side electricity and ultimately improve port air quality beyond existing international regulations set by the IMO.

All Member States are encouraged to "require, incentivise or facilitate ships' use of land-based electricity while in port" (2006/339/EC, 1), in an effort to improve air quality and noise nuisance, particularly in ports where pollution limit values are exceeded or public concern is expressed. The European Commission encourages Member States to consider economic incentives to operators to implement SSE, taking advantage of the possibilities set out in Community legislation. The Member States should actively work within the IMO to further develop and harmonise international standards on the electrical connections. They are urged to promote awareness among the main actors from local authorities to port authorities etc. as well as industry and encourage authorities and industry to exchange knowledge on practical implementation. Furthermore, the Member States are requested to report to the Commission on their actions to reduce the emissions in the ports that are caused by ships. This request is not defined by concrete time limits or other specifications.

An Annex provides technical, environmental and economic information on shore-side electricity, especially on cost-benefit aspects, and draws preliminary conclusions.

Commission Communication (2007) 575 and Proposal for a Council Directive amending Directive 2003/96/EC (2011)

The Communication, issued by the European Commission on 10 October 2007, proposes an Integrated Maritime Policy for the European Union in order to promote the protection and sustainable use of the Union's maritime resources. The Communication's main purpose is to define a set of tools as well as five action areas for a future mainstreaming of EU maritime governance. The first action area "Maximising the Sustainable Use of the Oceans and Seas" (COM(2007) 575, 4.1.) acknowledges the role of European seaports in determining the quality of their surrounding urban and natural environments. In this context, the Commission states that it will "make proposals to reduce the levels of air pollution from ships in ports", mainly through encouraging land-based electricity supply for ships in berth, "by removing tax disadvantages for shore side electricity" (COM(2007) 575, 4.1.).

The respective revision of the Energy Tax Directive (2003/96) necessary to facilitate this exemption from energy taxes for onshore power was tackled in 2011 "Proposal for a Council Directive amending Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity". Among others, the purpose of the proposed Directive is to provide a framework for CO_2 taxation and to complement the carbon price signal of the ETS. Specifically, the proposal recommends adding a new exemption from energy taxation to Article 14 (2003/96/EC) for shore-side electricity provided to ships while at berth for a period of eight years. The exemption is meant as a first incentive for development and application of this relatively new technology. Furthermore, for the period after the first eight years, the proposal suggests the elaboration of a more comprehensive framework for the development of common technical standards for on-shore power supply systems and their adoption within the International Organization for Standardization.

EU Directive 2008/50/EC on ambient air quality and cleaner air for Europe

On 21 May 2008, the European Parliament and Council adopted the Directive 2008/50/EC. Purpose of the Directive is to reduce air pollution levels and harmful impacts, particularly on sensitive populations and the environment as a whole. Article 24 requires Member States to draw up short-term action plans for zones where pollution levels are at the risk of exceeding the thresholds specified in Annex VII. The actions plans are to indicate measures to reduce pollution, including pollution from ships at berth.

EU Proposal for a Directive on the deployment of alternative fuel infrastructure

The European Parliament and Council passed the legislative resolution (provisional agreement) on the proposal for a directive on the deployment of alternative fuel infrastructure on 15 April 2014. The main purpose of the proposed directive is to foster the market uptake of alternative fuels and encourage the Member States to actively promote their use. Paragraph 16 of the legislative resolution acknowledges the potential of shore-side electricity to reduce environmental impacts in ports, particularly where air quality is low and noise levels are high. Furthermore, it states that the standardization of shore side electricity supply should not impede the use of systems already in place prior to the enacting of the proposed directive, asking the Member States to allow the upgrade of existing systems without requiring full compliance with the technical specifications. In Article 3 of the proposed directive, Member States are required to adopt national policy frameworks for the market and infrastructure development of alternative fuels in the transport sector, explicitly including infrastructure for shore side electricity supply in maritime and inland ports: By 31 December 2025, Member States are required to install or renew such infrastructure, as a priority in ports of the Trans-European Transport Networks Core Network (TENT-T) (COM(2011) 169/3). Annex III 1.3 defines the technical specifications that the SSE infrastructure has to comply with.

TENT-T Programme

Furthermore, the TEN-T Programme was established by the EC in 2006 to support the construction and upgrade of transport infrastructure across all EU Member States. The Programme is managed by the Innovation and Networks Executive Agency (INEA) and provides funding for projects in all transport modes, such as air, rail, road, and maritime/inland waterways, explicitly including shore-side electricity. The aim of the programme is to develop the defined key links and interconnections within Europe for mobility, remove bottlenecks, filling in especially cross-border sections, cross natural barriers and improve interoperability on major routes. Between 2007 and 2013 the EU allocated € 8 billion to this programme. This funding is a co-funding between Member states / the applying body and the EU. The Member States itself could apply for the funding as well as public or private bodies with the agreement of the Member State (INEA 2014d).

The focus of the TENT-T programme for the mode water lies on three main areas (INEA 2014c):

- Inland waterways;

- Seaports;
- Motorways of the Sea (MoS).

Projects that target ports mainly support links to islands, interconnection ports and hinterland transportation and infrastructure. Some of the projects focus on shore-side electricity, e.g. projects in Germany (port of Hamburg) and Belgium. These projects will be described under the Member States information in the next section.

Marco Polo Programme

The main purpose of the EU Marco Polo funding programme is to shift freight transport from road to sea traffic to reduce its environmental impact. Among others, the programme co-finances "projects which implement innovative technologies or operational practices which significantly reduce polluting emissions of maritime transport" (INEA 2014a) by supplying up to 20% of the investment costs (Radu, 2013). Some Member States applied for Marco Polo funding for SSE infrastructure investments.

4.1.2.2 Comparative assessment

Within the EU framework the commission published a non-binding recommendation directly on SSE in 2006 as the 1st concrete action to deploy SSE in Europe (2006/339/EC). This recommendation takes mainly the Member States into the responsibility to build up instruments and regulations to deploy SSE. Ports are in the focus of providing infrastructure to speed up the development. These recommendations lead to high investments especially on port level and political activities plus investments on Member State and subnational level. Such form of recommendation is considered not a strong instrument to speed up the SSE development. Instead, a more binding form of regulation is recommended, as the EU proposal for a binding directive on the deployment of alternative fuel infrastructure which was approved by the European Parliament in April 2014.

The assessment shows that the main financial burden lies on the ports. EU regulations need to be conducted with financial or organisational supporting schemes for the infrastructure investments.

Other recommendations are supporting the use of SSE as (2005/33/EC) in which the use of SSE allows an exemption of the 0.1% sulphur content. The communication (COM(2007) 575, 4.1.) and (2003/96/EC) are promoting the reduction of the financial disadvantage of SSE due to electricity taxes. This is an important issue which needs to be solved in an overall approach and established in all Member States.

The electricity that is used for SSE is currently taxed and covered by the EU-ETS, unlike the fuel that would have otherwise been used in the auxiliary engines. Tax exemptions on the electricity for SSE would create a level playing field and a better business case for SSE. The current possibility for Member States to include activities or installations (i.e. ships or ports) into the EU-ETS, according to Article 24 of Directive 2003/87/EC would partially solve the difference. None of the Member States has used this option so far.

At the same time the a.m. instruments take the ports into the responsible of providing infrastructure without providing supporting components. These supporting components could be e.g. financial, organizational or administrative support to enable the ports to start the investments in infrastructure and to get the right stakeholders on board. Directive 2008/50/EC provides an instrument to define focus areas and actions on Member State level. This instrument takes ship owners and ports in the same way into responsibility to take actions to reduce emissions in port area.
The assessment shows that ports would need more support to meet the investment requirements and to speed up the deployment of SSE in European ports than the ones currently in place via the existing TENT-T and Marco Polo programmes

The following table provides an overview on the relevant EU communications, regulations etc. in the form of a qualitative cost-benefit-analysis. Cost is interpreted as financial investments and effort to be taken.

Table 20: Cost-Benefit-Analysis EU measures

Regulation / policy action	Ships	Ports	Local / national authorities	EU	Electricity producer	Electricity devices suppliers
1. EU Directive 2005/33/EC (binding) During trials of new abatement technologies ships are exempt from the sulphur reduction regulation	Ships using SSE are exempt from the 0.1% sulphur content in fuel regulation + exempted from regul. - have to install **SSE** instead	Not mentioned	+ emission and noise reduction on local level + supporting national **R&D** on ships + saving costs to control sulphur content of fuels used in inland waterway vessels and at berth. - enforce sulphur content regulation - secure required level of air quality	+ Actions rely on Member states' responsibility + emission reduction	Not mentioned	+ economic incentive for R&D in new abatement technologies on ships (due exempt from sulphur reduction)
2. Commission Recommandation 2006/339/EC (non-binding)	+incentives or requirement by Member States (MS) for SSE installation recommended (incentives not defined)	+ economic incentives by Member States (MS) for investments in SSE infrastructure recommended (amount and type of economic incentive not specified)	+ emission and noise reduction on local level - investments in promote awareness, activities in IMO on standards and norms, activities on knowledge exchange	+ actions relay on MS responsibility + emission reduction	++ new potential business + if SSE required for ships, secured demand of SSE infrastructure -Investments in R&D - Business case / market size not clear - no requirements on infrastructure investments	++ new potential business ++ new products to sell -R&D costs

Regulation / policy action	Ships	Ports	Local / national authorities	EU	Electricity producer	Electricity devices suppliers
3. Commission Communication (2007) 575 and Proposal for a Council Directive amending Directive 2003/96/EC (2011)	exemption from electricity tax for ships using SSE while at berth (8 years) + reduction operational costs for electricity - doesn’t reduce the gap between fuel costs and electricity cost completely	Acknowledge the determining role of ports on quality of their surroundings + potentially more ships with SSE demand -> emission ↓ - provide infrastructure for “clean solutions”[4]	- MS: reduced additional receipts due to tax exemptions on electricity - development of common technical standards for SSE and their adoption within the International Organization for Standardization	encouraged to mainstream EU maritime governance in an integrated maritime policy for the EU - action required	++ reduced prices for electricity without reduced turnover	++ higher demand for SSE-technologies
4. EU Directive 2008/50/EC on ambient air quality and cleaner air for Europe	- reduced pollution if they enter specific zones required for ships	- if port is situated in a zone with exceeding harmful pollution levels reduce pollution required	+ emission reduction in most harmful zones - draw up short-term action plans to reduce pollution in highly polluted zones, also ports, reducing pollution from ships at berth	+ actions rely on MS responsibility + emission reduction	Not mentioned	Not mentioned
5. EU Proposal for a Directive on the deployment of alternative fuel infrastructure (2014)	++ rise of SSE infrastructure in ports	+ existing infrastructure: standardization of SSE supply should not impede the use of systems already in place - upgrading of existing infrastructure required - SSE Infrastructure installation in all ports of TENT-T Core network by 2025	- adopt national policy frameworks for the market and infrastructure development of alternative fuels, explicitly SSE	+ actions rely on MS responsibility + SSE deployment in MS	++ new potential business	++ new potential business upgrading of existing infrastructure + new business required compliance with new technology standards - R&D costs
6. TENT-T programme	+ co-funding opportunity	+ co-funding opportunity	++ co-funding opportunity	+ growths of innovations, roll-out infrastructure + emission reduction potential - - expenses	++ co-funding opportunity	++ co-funding opportunity
7.				+ growths of innovative		

---

[4] In the regulation the following paragraph is related to ports: “This exemption should apply during a period long enough in order not to discourage port operators from making the necessary investments”

Regulation / policy action	Ships	Ports	Local / national authorities	EU	Electricity producer	Electricity devices suppliers
Marco Polo Programme	🟩	🟩	🟩	🟥 technologies	🟩	🟩

🟩 Xx = Costs < benefits
🟨 Xx = Costs = benefits
🟥 Xx = Costs > benefits

4.1.3 Regulations on EU Member States level

Information on stimulus plans or regulations on the national level enacted by Member States are very rare. Within Member States, there are, however, initiatives and subsidies that support the uptake of SSE.

A number of countries introduced subsidies or use EU co-funding to encourage ports to invest in SSE, e.g. through the European Marco Polo programme or the TENT-T programme.

4.1.3.1 Regulations

Belgium (Flanders)
During the last years, interest in the use of shore side electricity has strongly increased in Flanders.

The Flemish Government implemented the 3E-Inland Covenant and the 3E Inland Navigation Plan 2009 which aims at a significant reduction of CO, NO_x, CO_2 and PM in inland shipping.

The Air Quality Plan was approved in 2012. This plan implies concrete measures to meet the 2015 targets. The proposed measures include encouraging the use of shore side electricity (Government of Flanders, 2012).

In order to optimize and standardise the possibilities of offering shore side electricity, in 2012 a SSE coordinator was appointed by the Environment, Nature and Energy Department (LNE) and the Mobility and Public Works Department (MOW). This position is provided for in the Air Quality Plan in the context of the application for postponement of the NO_2 standards (Government of Flanders, 2012).

In 2012, the Flemish Department of Mobility and Public Works launched the project “Shore Power in Flanders”, co-financed by the TEN-T Programme. The project aims at enhancing the level of SSE services for inland shipping in Flanders by carrying out market studies and pilot implementation. Furthermore, the installation of a uniform payment system with a dedicated web application as well as SSE power boxes in three different locations is planned. The project will also develop a strategy to stimulate the expansion of this environmental friendly technology by investigating how a national network of SSE facilities should be expanded to meet the rapidly growing demand (INEA, 2014a). The project's total cost is estimated at € 2,244,000, of which 50% is contributed by the EU through the TEN-T Programme (INEA 2014a)

The Netherlands

Several Dutch provinces, municipalities and port authorities created the initiative Walstroom in cooperation the Dutch energy company, Eneco. Walstroom is co-funded with support from the European Regional Development Fund of the European Commission and is an electricity provider or facilitator (Walstroom, 2013). Throughout the Netherlands Walstroom provides 1,100 quayside electricity connections which are daily used by over 3,900 inland vessels. Supported by an intelligent ICT system, the vessel owner could use the electricity connections in different ports and will be invoiced only by Walstroom on a monthly basis. The ports guarantee green electricity, they define the electricity price, Walstroom relays it to their customers.

The quayside electricity connection is the type 400V/63A/50Hz. The type of plug is a standard 400V 5-pin CEE.

Investments in charging equipment like connection points at ship, retrofit of on-board electricity system or extension cable for the use of Walstroom can be advantageous from a tax point of view through two economic incentive schemes targeted at Dutch companies: The Random Depreciation of Environmental Investments (Vamil) was first developed in September 1991, while the Environmental Investment Allowance (MIA) was introduced in 2000 as support incentives known as 'tax regulations'. The schemes represent two ways for companies purchasing new environmental technologies to reduce their overall cost. The Vamil scheme offers a liquidity benefit and additional interest income. Businesses which use the Vamil scheme as an operating asset are allowed to randomly or freely write off this operating asset. The MIA incentive is a pure tax deduction tool, allowing a partial write-off (up to 36%) of an investment in environmental technology against tax. It offers extra tax relief to businesses that invest in environmentally friendly operating assets (Netherlands Enterprise Agency).

Since the new harbour regulation for Rotterdam was implemented in 2010 the use of SSE in the port of Rotterdam is obliged for inland ships[5].

Sweden

As a way to reduce emissions of sulphur, a government bill was put forward in 2010 proposing a lower energy tax for electricity used by ships when in port (Swedish Parliament 2010) (PORT OF GOTHENBURG, ABB, Ramböll Sverige AB, & Vinnova, 2012). The tax was lowered from 28.0 Öre/kWh (€ 3.09) respectively 18.5 Öre/kWh (€ 2.04) to 0.5 Öre/kWh (€ 0.06) for shore side electricity, respecting the minimum rate of taxation for electricity as laid down in Directive 2003/96/EC. The proposed change in the Swedish Energy Tax Act has now been implemented and came into force on 1

---

[5] http://www.transport-online.nl/site/nieuws-spoorluchtzee/index.php?news=163#.U2yOkFd7Qvk, 9.5.2014; Preannouncement http://www.portofrotterdam.com/nl/actueel/pers-en-nieuwsberichten/Pages/20091009_01.aspx

November 2011. The reduced rate of electricity taxation is applied to all supplies of shore-side electricity of at least 380 volt to vessels used for commercial shipping of at least 400 gross tonnages (Decision 2011/384/EU). The limit is considered appropriate so as to ensure that the absolute majority of vessels used in international traffic and larger vessels used in national traffic will be covered by the proposed reduction. These are the vessels considered to be responsible for the largest part of emissions caused by the running of auxiliary motors on board while berthed in ports.

Port-specific initiatives: According to Swedish law, all ports have to apply for a license to operate. The environmental authority on the regional level decides on the environmental conditions required for this operating authorisation. Several licenses given out to Swedish ports by the responsible Environmental Permit Offices have in recent years included environmental conditions regarding SSE. In 2012 the Port of Gothenburg was requested to conduct feasibility studies investigating the possibility of offering SSE, among other requirements The studies have to be conducted every five years from 2016 onward for all quays in the energy, car and cruise terminal. The container and RoRo terminals were, in turn, asked to engage in continuous dialogue with the most frequent ship owners and provide them with information concerning the SSE possibility (Dutt, 2014).

In Sweden national financial support schemes have been set up for projects reducing emissions to air as well as greenhouse gases. The Port of Gothenburg has applied twice for this financial support for SSE installations and received it (Dutt, 2014).

Sweden was also a partner of the TENT-T project "On Shore Power Supply - an integrated North Sea network"[6] before it was cancelled (INEA, 2012a).

Germany

In Germany no direct national regulation on the use of SSE exists. Provisions concerning the use of SSE are stated directly in port regulations of each port. These stated provisions differ for each port and depend on whether or not the port is associated with the federal government or the local authority, as well as its specific emission thresholds, requirements on air quality, noise etc. (BSH, 2014).

In its 2011 Act for the Amendment of the Energy and Electricity Tax Act (Gesetz zur Änderung des Energiesteuer- und Stromsteuergesetzes 2011) the German government reduced the tax rate for electricity to the European minimum rate of € 0.50/MWh (2003/96/EG) for shore-side electricity supply of commercially-used ships and vessels (EnergieStGuaÄndG 2011). This act reduces the price difference between fossil fuels like diesel and HFO and SSE, but doesn't solve the problem completely. No taxes are raised in Germany on diesel and HFS used in the maritime sector.

In 2013 the Hamburg port authority started a 2 ½-year project on SSE. It includes a pilot charging infrastructure as well as a study on feasibility, emission reduction and practical guidelines. The total

---

[6] Together with Denmark, Belgium and UK

cost of this project is € 7 million including a 50% EU subsidy by the TENT-T programme (INEA, 2012a).

Two German ports (Kiel and Lübeck) already offer SSE for ships at berth. In 2015 the installation of a SSE infrastructure will be finalized at the cruiser terminal Hamburg-Altona. This infrastructure will be the 1st flexible charging point worldwide with the ability to charge big cruisers as well as smaller ships (Neumeier, 2013; Zeiss, 2013).

The German Federal Waterway Administration (Bundeswasserstraßenverwaltung) recently invested € 4.7 million in the development of charging infrastructure for inland shipping. On three German channels (Wesel-Datteln-Kanal, Dortmund-Ems-Kanal, Küstenkanal), SSE is available (Wasser- und Schifffahrtsverwaltung des Bundes, 2014).

However, the German association for inland shipping (Verband Binnenschifffahrt) stated in 2013 that the current legal situation in Germany also creates investment barriers as it does not allow for the costs of construction and maintenance of SSE infrastructure to be passed on to the end customer (BDB, 2013).

Other Member States

It should be mentioned that in some other EU Countries, SSE technology and various kinds of local regulations, communications, and funding schemes are in place. However, through publicly available sources, the aforementioned measures cannot be elaborated upon further than they are the following statements.

In **Estonia** SSE activities are in place[7] which could not be defined in this report in detail.

In **France** the national Ministry of Ecology, Energy, Sustainable Development and the Sea stated the environmental importance and feasibility of SSE technology in its final report on the characteristics of sea and river vessels in 2010. SSE infrastructure is planned in the Ports of Marseille and Le Havre (Ministère de l'Ecologie, du Développement Durable, et de l'Energie, 2010)

In **Italy** SSE infrastructure is planned in the Ports of Civitavecchia, Rome, Genoa, Livorno, and Venice.

4.1.3.2 Comparative assessment

The comparative assessment shows that in some Member States first activities on SSE has been started. However, information on stimulus plans or regulations within the Member States are very rare.

---

[7] http://www.evs.ee/tooted/evs-en-15869-2-2010

Maritime

Assessing the regulations on Member State level a finding is that only a few Member States provide information on regulations to support SSE even countries in which SSE activities could be proved.
The most important steps for maritime shipping are the tax reductions in Germany and Sweden. However, even these regulations are not closing the gap between the tax free shipping fuels and electricity prices.

Sweden provides a best practice example to deploy SSE as it makes the use of SSE or similar technologies an obligatory part of the operating authorisation of the port. This obligation is combined with a national financial supporting scheme. This combination makes the necessary difference to speed up the use of SSE.

In a number of countries EU co-funding is used to invest in SSE, e.g. through the European Marco Polo programme or the TENT-T programme. These instruments are filling the gap of missing financial support on Member State level for charging infrastructure investments.

Inland shipping

For inland shipping the information availability is also relatively rare. An important outcome is here that activities on Member States level are more in forms of financial incentives. The German Federal Waterway Administration even invests nearly € 5 million for SSE infrastructure. The Dutch government created economic incentives for investments on ships and ports side and initiated the so called Walstroom initiative to create a business operation case for selling SSE to the barges. In combination to this initiative e.g. the port of Rotterdam made SSE obligatory for inland ships in the port. Belgium as well designed a regulatory framework of defining emission thresholds for inland ships and creating an air quality plan together with establishing a coordinating administration department. This is a good effort to create a structure of pushing and pulling factors.

The following table gives as an overview on the relevant regulations and funding schemes in the form of a qualitative cost-benefit-analysis. Cost is also interpreted as effort to be taken.

Table: 19 Cost-Benefit-Analysis Member States instruments

	Regulation / policy action	Ships	Ports	Local / national authorities	EU	Electricity producer	Electricity devices suppliers
Germany	Act for the Amendment of the Energy and Electricity Tax Act (2011)	++ reduction of electricity tax to the (EU) minimum of 0,50 €/MWh for SSE - bear the installation costs of SSE on ships	Not mentioned	+ comply with EU pollution standards - less tax revenue	++ emission reduction ++ no EU responsibility	+potential new business	+ increased sales of SSE infrastructure on ships
	Federal Waterway Administration invested recently 4.7 Mio € in charging infrastructure	+ could make use of the obligatory investment	++ do not have to invest	+ comply with EU pollution standards - investments	++ emission reduction ++ no EU responsibility	+potential new business	++new business
Sweden	Energy Tax Act (2011)	++ reduction of electricity tax to the (EU) minimum of 0,5 öre/kWh for SSE - bear the installation costs of SSE on ships	- SSE use not obligatory for ships -> financial profitability of SSE installation not secured	+ comply with EU pollution standards - less tax revenue	++ emission reduction ++ no EU responsibility	+potential new business	+potential new business
	operating license for ports by environmental authority including environmental conditions of onshore power supply	- ships could have the obligation to meet specific targets	- operation permits based a.o. on SSE investments	+ comply with EU pollution standards	++ emission reduction ++ no EU responsibility	+potential new business	+potential new business
	national financial support available for air emissions and greenhouse gas saving projects	+ improved SSE conditions in ports	++ Ports could receive financial support for SSE installations	- financial expenses for ports investments in SSE	++ emission reduction ++ no EU responsibility	+potential new business	+potential new business
The Netherlands	Random Depreciation of Environmental Investments (VAMIL, 1991), Environmental Investment Allowance (MIA, 2000)	++ Economic incentive for investment in SSE technology	++ Economic incentive for investment in SSE technology	+ comply with EU pollution standards - reduced tax revenue	++ emission reduction ++ no EU responsibility	++ Economic incentive for investment in SSE technology	+ increased sales of SSE technology in ports/on ships

	Regulation / policy action	Ships	Ports	Local / national authorities	EU	Electricity producer	Electricity devices suppliers
	Walstroom initiative	+ less cost, less opportunity costs for electricity supply	+ no investments in quayside connection infrastructure by ports	+ co-funding by EU regional development fund	- co-funding of Walstroom infrastructure investments	+potential new business + co-funding of Walstroom infrastructure investments	+ new business
	Rotterdam harbour regulation, 2010	-use of SSE is obliged for inland ships	+ emission reduction - need to provide infrastructure	+ emission reduction	++ emission reduction ++ no EU responsibility	+potential new business	+ new business
Belgium	Air Quality Plan (2012),	encourage the use of SSE;	encourage the use of SSE;	encourage the use of SSE;	++ emission reduction ++ no EU responsibility	+potential new business	+potential new business
	Air Quality Plan (2012), Establish a shore power coordinator by LNE and MOW[8]	+ clear contact point + possibility of improvements on standards and access to SSE	+ clear contact point + possibility of improvements on standards	+ clear responsibility + cross stakeholder approach - costs for coordinating position		+ clear contact point	+ clear contact point
	3E-Inland Covenant and the 3E Inland Navigation Plan, 2009	- emission threshold	- emission threshold	+ emission reduction	++ emission reduction ++ no EU responsibility	+potential new business	+potential new business
	Tent-T project shore power Flanders	++ investment in standard SSE boxes, uniform payment system by government	+ investments in SSE co-financed			+potential new business	+potential new business

Xx =Costs < benefits

Xx = Costs = benefits

Xx = Costs > benefits

4.2 Assessment of California SSE regulation

Introduction to the California Air Resources Board Measure

In December 2007, the California Air Resources Board (CARB) approved the "Airborne Toxic Control Measure for Auxiliary Diesel Engines Operated on Ocean-Going Vessels At-Berth in a California Port" Regulation, commonly referred to as the At-Berth Regulation. The purpose of the regulation is to reduce emissions from diesel auxiliary engines on container ships, passenger ships, and refrigerated-cargo ships while berthing at a California Port. The regulation defines a California Port as the Ports of

---

[8] Environment, Nature and Energy Department (LNE); Mobility and Public Works Department (MOW)

Los Angeles, Long Beach, Oakland, San Diego, San Francisco, and Hueneme. The At-Berth Regulation provides vessel fleet operators visiting these ports with two options to reduce at-berth emissions from auxiliary engines: 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 technique(s) that achieve equivalent emission reductions.[9]

4.2.1 Description of the California Air Resources Board Measure

In the section below Ecofys has detailed the two options of the CARB regulation.

Reduced Onboard Power Generation Option
This option includes the following requirements currently in effect:

2014 Requirement: When a fleet (vessels of 1 operator/owner) is visiting a California port at least 50 percent of the fleet's visits to the port shall meet the onboard auxiliary diesel engine operational time limits. This means three hours total per visit to a berth, provided the visiting vessel uses a synchronous power transfer process to change from vessel-based power to shore-based power. Or this means five hours total per visit to a berth, provided the visiting vessel does not use a synchronous power transfer process to change from vessel-based power to shore-based power. The fleet's onboard auxiliary-diesel-engine power generation while docked at the berth has to be reduced by at least 50 percent from the fleet's baseline power generation. [10] The baseline power generation is the power that would have been used when no shore side power would have been used.

2017 Requirement: At least 70 percent of the fleet's visits to the port shall meet the onboard auxiliary diesel engine operational time limits as described under the 2014 requirements. The fleet's onboard auxiliary-diesel-engine power generation while docked at the berth has to be reduced by at least 70 percent from the fleet's baseline power generation.[11]

2020 Requirement: At least 80 percent of a fleet's visits to the port shall meet the onboard auxiliary diesel engine operational time limits (see 2014 requirements) and the fleet's onboard auxiliary-diesel-engine power generation while docked at the berth shall be reduced by at least 80 percent from the fleet's baseline power generation.[12]

The CARB provides exemptions to the limits on the hours of operation in case of an emergency event or United States (U.S.) Coast Guard or the Department of Homeland Security Inspections.

The percent reduction of onboard electrical generation from auxiliary diesel engines while vessels are docked at berth is calculated as follows:

---

[9] http://www.arb.ca.gov/ports/shorepower/shorepower.htm
[10] http://www.arb.ca.gov/ports/shorepower/finalregulation.pdf
[11] http://www.arb.ca.gov/ports/shorepower/finalregulation.pdf
[12] http://www.arb.ca.gov/ports/shorepower/finalregulation.pdf

Percent Reduction = [Baseline fleet power generation (BFPG) – Power provided by fleet's auxiliary engines] / (BFPG)

Explanation: the percent reduction is calculated by calculating the reduction of the use of the vessel's auxiliary engines versus an old baseline situation. Standard power requirements for vessels are being used for calculating this reduction.

Equivalent Emissions Reduction Option

The second compliance option is referred to as Equivalent Emissions Reduction Option. This option provides vessel owners with the possibility to use earlier or access emission reductions in later commitment periods. This option is not available for the 2014 and 2020 compliance period because CARB wanted to realize full compliance with no exceptions in those years. The option also allows for vessel owners to use alternative technologies for compliance. No alternative technologies have been approved yet. One technology is currently being tested to be allowed by CARB. The alternative technology provision has been allowed by CARB to include other technologies besides shore side power only. [13]

Table 21: Fleets must plug in at the following levels and reduce onboard power by these levels (Port of Long Beach, 2014)

Year	Shore Power Regulation (% of fleet's visits to each California port)	Equivalent Emissions reduction Option
2010-2011	Shore-power equipped ships must use SSE if available at berth	10% Emission reduction
2012-2013	Shore-power equipped ships must use SSE if available at berth	25% Emission reduction
2014-2016	50%	50% Emission reduction
2017-2019	70%	70% Emission reduction
2020+	80%	80% Emission reduction

Why shore side power regulation in California

The CARB measure has specifically been designed to reduce the emissions from diesel auxiliary engines mostly focusing on PM and NO_x. When using shore side power, CO_2 emission reductions are a positive effect as well. The measure focuses on container vessels, cruise vessels and refrigerated vessels. Certain and stable power is very important for these vessel types. The measure has been designed to target vessels that visit frequently and have high emissions while at berth. General cargo vessels have lower emissions. While designing the measure CARB had information available on the emissions from all vessel types. This helped CARB in designing the measure effectively. In the design phase the focus was on developing regulation with lower relative cost than regulations for other sectors.

---

[13] http://www.arb.ca.gov/ports/shorepower/finalregulation.pdf, p.12

Older Shore Side Electricity systems were designed for the navy. These systems took a lot of time to connect and a lot of man power. This was not a problem for the Navy because of the availability of manpower and much longer times at berth (e.g. 30 days). Instead of one cable these systems used several cables. CARB focused on Shore Side Electricity technology to allow for innovation and to tailor systems more towards the needs of vessel owners', ports and other stakeholders'. CARB did work as much as possible with vessel owners, ports and other stakeholders to make the measure work. The result is that the target group, to a certain extent, decides how to comply themselves. A main benefit is that this approach allows for innovation. The measure is designed to be phased in gradually and move to the full 80% in 2020. This gives the stakeholders time to get on board. Currently only shore side power is approved by CARB but a few other technologies are in CARB's testing trajectory. CARB will release information about these options when they are approved.

The rule to connect within 3 hours was developed based on estimation from CARB, which in turn was based on expert judgments. There are a few exceptions on connecting within 3 hours such as delays caused by the coast guard. March 2015 is the submission deadline for the 2014 reporting year, the first year with the more extensive 50% requirement. In 2015 additional information will be available on how realistic it is to comply with the measure. After the first year of comprehensive checks of information quality, CARB is likely to move to infrequent spot checks.

Cost and benefit assessment of the California Air Resources Board Measure
The following table visualizes the cost-benefit allocation among stakeholders which has been worked in the previous section.

Table 22: Cost-Benefit-Analysis California

	Regulation / policy action	Ships	Ports	State		Utility	SSE project developers
CARB	Airbone Toxid Controle Measure ….	+/- Depending on energy price a part of the expenses are covered.	- Capex and opex for SSE systems. + Enabling emission reductions improves emissions footprint	++ Polution reduction* - Infrastructure grant of 2-3 M per SSE sytem.		+ More electricity sales - Potentially more emissions from power generation.	++ A sales opportunity for developing SSE systems. Job creation and economic effect.

Xx = Costs < benefits
Xx = Costs = benefits
Xx = Costs > benefits

It is challenging for vessel owners and ports to develop a positive business case on shore side electricity based on energy cost. However, CARB indicated that it evaluated several measures for preventing local emissions and concluded that shore side electricity is one of the most attractive measures to reduce damage costs caused by harmful emissions by the shipping economy. The emission reductions from the regulation will reduce the number of people exposed to a cancer risk of 10 in a million by 70 percent by 2020. Statewide, the emission reductions due specifically to the regulation will prevent approximately 990 premature deaths by the year 2030, as well as result in other health benefits. The economic benefit for the avoided premature deaths and other related health effects is estimated to be \$3.1 to \$5.7 billion[14].

In an early feasibility stage, CARB concluded that the regulation will reduce PM by 85 tonnes per year and NO_x by 4,700 tonnes per year. The cost to reduce NO_x alone is about \$12,000 per tonne and about \$690,000 per tonne for PM. This assumes that all the costs of the regulation go to reducing either NO_x or PM.

4.2.2 Implementation / Operation of the California Air Resources Board Measure

The first shore-based system for cruise ships was realized in Juneau, Alaska. This system has been developed with heavy involvement of cruise lines. Other options are system development by a port or by a project developer. California has 3 systems installed in San Diego, over 25 in LA/LB and 12 in Oakland. In addition there are systems in use in Seattle, Vancouver, Halifax and New York.

Most shore side power systems are only recently installed in California. For this reason there is little information available about actual maintenance cost. Information systems help the operation of shore side power. Both shore side and vessel side power systems are available on the market and are actually being developed. Power costs are allocated by the utility company sending a bill to the port and the port charges terminal operators and in turn, terminal operators charge vessel owners.

Cruise vessel shore side power systems generally have a capacity from 11-20 MW. Currently systems are limited to about 11-12 MW. Container vessels require a capacity of 1-7.5 MW. Refrigerated cargo vessels have a default power requirement of 1.3 MW for Break Bulk and 3.3 MW for when fully containerized. Shore Side Electricity systems generally support 6.6 and 11 KV. An example of the energy use of a medium sized cruise vessel's energy use is 30 MWh for a day of 10 hours connected to a shore side power system, making the average capacity around 3 MW. This is true for a moderate climate and in the summer this capacity can at least double.

The systems are either developed by the ports themselves or by independent shore side power project developers. Besides the actual shore side power, project developers generally offer project development services and operations and maintenance services. Developers may also have a database with information on power characteristics when vessels connect. Besides the implementation of shore side power systems, vessels need to be retrofitted with a shore side power connection. Developing a shore side power system can take up to two years. Technically, however, systems can be developed in under a year. In the US several shore side power systems have been developed. The technology is moving toward proven technology.

---

[14] http://www.arb.ca.gov/regact/2007/shorepwr07/uid2007.pdf

While designing its measures CARB allowed ports and vessel owners to provide feedback in the measure development process. The actual workload for ports and vessel owners are limited. For ports these efforts include managing utility bills, analyzing power use allocation to vessels, and interaction with CARB on progress. For the measure the port also has to submit an annual activities report to CARB. Vessel owners are required to keep track of their shore side power performance. This includes information about time at berth, total time connected, connected and disconnected time and prevented fuel use. Vessels owners keep track of the information in excel workbooks and some are considering developing a compliance information system.

Below a general overview is given of the cost and benefits with regard to shore side power systems in California:

- All-in investment for developing a cruise vessel shore side power system for the port ranges from $3-5M. This excludes energy infrastructure cost. Which push system cost to $6-7M.
- Several prices of producing on board power have been mentioned. These range from 11 to $21ct/kWh. The energy price is an important determinant for the financial attractiveness of using shore side power.
- A cruise call can differ in duration. Examples of the electricity cost for a large cruise vessel in San Diego is around $13,000 and for smaller cruise vessels is around $7,000.
- Cruise vessel systems are usually not in use the all year round. For this reason the systems need to be re-commissioned annually for around $50,000.
- Connecting vessels each time costs around $2,500-3,500.
- Cruise owners are usually looking for utility rates of around 10ct/kWh for realizing a return on their investment (mostly equipping vessels with a connection).
- Equipping cruise vessels costs about $1.5-1.7M
- Container vessel shore side power and on-vessel systems have a lower investment.
- Equipping a container vessel costs about $500-1,000k.
- The State of California has provided several grants to port for shore side power system development. These grants range from $2.5-3M per system per berth.

4.3 Reflection

4.3.1 European and Member State regulations and activities

On the EU-level ports are in the focus of regulations to deploy SSE. This seems to be obvious as the infrastructure is a key element to expand the use of SSE. These regulations result mainly in high investment requests to the ports.

But ports are not convinced of the benefits, especially regarding air quality. They would like to see how SSE compares to other emission reductions in ports and still have many questions. The main barrier is the high investments on port level without a view for revenues at the moment.

The cost-benefit analysis on the EU and Member States-level shows as well that ports incur the worst cost-benefit balance. Without being in charge of fulfilling requirements, electricity producers and electricity devices suppliers profit the most from the regulations.

Thus, this relatively new situation where new infrastructure needs to be provided for ships raises the question who should pay for it. The answer is not so obvious, since there are many stakeholders involved with different business cases in ports (national governments, local governments, port authorities, port operators and utilities).

There are presently no international requirements that would mandate or facilitate the use of SSE obligatorily. There are international laws (e.g. UNCLOS: UN Convention on the Law of the Sea) that may hamper the mandating of the use of SSE. UNCLOS delineates five sea zones and defines the rights and responsibilities of nations in their use of these zones. Therefore National States need to carefully consider whether they are allowed to set standards for berthing vessels. California has such standards in place: the Canadian law makes ship owners responsible for using SSE.

Within the EU framework, the Commission published a non-binding recommendation on SSE in 2006 as the first concrete action to deploy SSE in Europe. The most promising political action in Europe is the EU proposal for a binding directive on the deployment of alternative fuel infrastructure which was approved by the European Parliament in April 2014.

Furthermore, some EU regulations did not integrate SSE as a concrete measure but left room for different options to meet the requirements of the regulation. Consequently, these regulations could directly or indirectly stimulate the deployment of SSE in the Member States.

Following the role of the EU, the regulations address the Member States and port authorities while binding sector-specific thresholds address the main contributors as the ships. The cost-benefit tables illustrate that ports are addressed through regulations to provide infrastructure for SSE but do not profit from offset measures. Electricity producers and electricity devices suppliers seem to profit from these regulations without the need for investments.

Some smaller activities on SSE are visible on the Member States level although only little information about regulations is available. The assessment on the Member States level shows the following aspects:

a. In Europe, inland shipping is structurally more ahead than seaport activities;
b. Seaport activities relate mainly to infrastructure funding (e.g. TENT-T, Marco Polo);
c. Local political pressure is a helping and pushing factor.

The German inland waterway administration invests in charging infrastructure and connected three channels to the grid. Sweden shows a quite high SSE activity. The integration of SSE or similar technologies into the port operating permission illustrates a strong instrument. Funding such as the Marco Polo program or TENT-T supported SSE activities in diverse ports.

Ports claim that on the EU-level workshops, campaigns, etc. could be organized to bring the relevant people together to learn from each other and to build up awareness in an effort to reduce barriers. The actor who benefits most from the air quality improvement (or potential network improvements) should be on board as well as the utilities, because SSE might create a new area of business for them.

An obligation for ports and ships to install the SSE infrastructure could be one option to deploy SSE in a greater extent.

Energy tax reductions are positive signals for the use of SSE and will reduce the operational costs for ship owners, but efforts will not be effective enough as long as fuels for shipping are excluded from taxation.

In this diverse legal and institutional situation for the seaports as investor of the charging infrastructure, a business case is still missing. A gap exists between requirements addressing the port authorities and the economic and operating actors in the port. The authorities have to invest in installing charging infrastructure and operational cost but do not have the opportunity to refund the investments. Thus, one way to fund the investments would encourage the ports to invest in the infrastructure. Another way would be to help the ports create a business case (e.g. to get investments refunded without losing ships at berth due to increasing or too high electricity prices). The actor who sells the electricity would need to reimburse partly the infrastructure investment as this actor uses the infrastructure as a mean to sell its product. (e.g. similar to the grid charges for electricity as they would benefit most by increasing business).

The Swedish law which included SSE into the operating authorisation of the port is also a promising option to deploy SSE if it is combined with the issue explained above. The Californian course, which includes making ship owners responsible for using SSE or similar technologies and supporting ports in providing adequate infrastructure, seems to be a promising way.

4.3.2 California Air Resources Board Measure

The European Commission considers a voluntary approach and according to vessel owners' experience, this could work. For example, in Seattle this has worked as well. The Californian approach focuses more on collaboration rather than on compliance. The ports generally do not see an interesting business case in SSE; they only implemented SSE when it was obligatory.

Thus, CARB has set a regulation framework for ships docking at Californian ports including subsidy for infrastructure investments. The most attractive reason for ports to invest in SSE infrastructure was the regulation. They had to provide the infrastructure as a task of general public interest. But they also got a co-funding for the investment. The recommendations are ambitious but seem to be achievable on this stage. Meeting the required 80% emission reduction beyond 2020 will be challenging for fleets. It is nonetheless difficult in California to create a business case for the ports. Therefore, CARB took the health benefits into account (equal to avoided damage costs through harmful emissions) as an argument for municipalities and port authorities. Ports stated that SSE could become one component of a sustainability strategy.

As a result of the Californian regulation electricity rates became an additional competing element between the ports and fluctuations in the electricity price became a price risk for vessel owners. Stakeholders claimed a fix price level for a SSE which is even not warranted in California.

The operational experience in California shows that the first connection of a vessel at a SSE system in a port took up to 20 hr. This is a circumstance which needs to be improved and needs to be avoided when designing a system within Europe.

An interviewee stated that it is important to keep in mind, that the impact on the grid could be significant and could be an economic barrier due to higher electricity charges for the operator due to higher peak demand. This potential impact would mainly depend on the local distribution network and the overall port demand. This study based on the assessment on the high voltage level doesn't share this belief for European ports. This issue could be a barrier, but it could also be a beneficial for a business case. Following the road-based e-mobility discussion, the ships potentially could support the security of energy supply via an intelligent load management (smartgrids). This could be interpreted as a benefit depending on whether or not the charging infrastructure or the ships could be used, as well as storage space for fluctuated energy sources.

A gradual implementation (start with big ports and frequent visitors), like in California might also prove successful in Europe. However, in Europe vessel-based regulations might be better than based regulations considering there are so many ports in Europe.

An important difference between the USA and Europe to keep in mind is that vessels generally use 60 Hz, which is the US standard. In the EU the power systems are on 50 Hz. This will impose an additional cost for implementing shore side electricity in the EU which is internationally compatible.

5 Setting the Course towards deployment of SSE in Europe

This chapter focuses on how to enable the transition towards SSE in EU ports, aiming to define a clear set of recommendations and possible measures for the stimulation of the deployment of SSE in Europe's ports towards 2020.

This study estimates the potential SSE in Europe in reducing carbon emissions by 800,000 tonnes of CO_2, i.e. a reduction in yearly CO_2 emissions for all maritime shipping of 39%. The total impact on the EU electricity consumption is around 0.06%. Cruise, RoRo and Containerships show the best business case for SSE with regards to high energy demand/low power requirements.

The electricity grid analysis on NUTS 3 level shows that the grid is capable of coping with the potential increase in electricity demand of the ports caused by SSE.

From the previous analysis, important conclusions can be drawn regarding possible policy measures for the deployment of SSE in EU ports "to sail for the right course".

For inland shipping and maritime shipping, the situation is slightly different.

5.1 Inland Shipping

The analysis found that the best area to start in inland shipping could be outside ports, in waiting areas for cargo ships and at locations where river cruises berth. A ship while it is stationed should be understood as similar to a household – a household with multiple connection areas to the grid. River cruisers will be able to create best a business case at this stage; therefore, the activities should concentrate on this ship type first. In addition, this ship type provides the best visibility of SSE. Public awareness would help to deploy the use of SSE in inland shipping in a greater scale.

A business case for SSE supply in inland shipping is realistic and in some Member States, initial activities have started. In these Member States some stakeholders are already in place. However, the acceptance of SSE in inland ports is limited, even though its potential would be beneficial. Obligation to use SSE and retrofit infrastructure on ships is a feasible step ahead as the investments are quite low compared with the maritime sector.

There are several barriers to the uptake of SSE in inland ports which should be addressed. In general, there is currently a lack of EU-wide standards on connectors which creates problems to ships that cross Member States borders. Constraints should be minimized and therefore, should be in the focus of the activities. Starting from the most important, the barriers are discussed next and suggestions are made for who should be the action holder.

Technical

Substantial technical problems do not exist for the deployment of SSE in inland shipping. The main barrier here is that there is a voltage standard, but no connector standard. Unfortunately, Germany recently decided to use the electric vehicle connector (type 2) instead of the CEE connector. Thus, the ships need to have different connectors for different countries. A better cooperation between ports in different countries could be beneficial for the uptake of the use of SSE in inland shipping. EFIP could, for instance, take the lead in this.

Regulatory

As long as the regulations demand that SSE must be used, inland shippers will use this. Examples include Rotterdam and river cruises in Germany. The initiative lies here with the ports or local governments to define obligations and to enact an adequate law.

Operational

When especially the billing part is made as easy as possible, this will increase the number of users. An example here is the system by Utiliq in the Netherlands where shippers can reserve a location and start the electricity provision by means of a smart-phone app. The initiative lies here with the ports, or governments to ask for the right service provider.

River cruises with their higher electricity demand and long and frequent stays at berths might provide an easy and highly visible starting point for SSE in inland shipping and will facilitate the creation of a successful business case

Practical

Given the low financial benefit from using SSE, inland shippers are not very willing to take the time to make the connection. When ships are side-by-side the connection is even more difficult. More berths, and more SSE connections on ships (sometimes several along the ships), would make increase the use of SSE. The initiative lies here with the ports and local governments.

The most important barrier at the moment seems to be the low acceptance by relevant stakeholders. There seems to be consensus on limited potential for SSE for inland ships in ports among some stakeholders. Slow steaming is seen as a better and more effective way to reduce CO_2 emission for inland shipping by these stakeholders.

Public awareness activities should focus on two aspects: First, the beneficial aspects for local inhabitants, especially at river sides where a lot of inland ships have their waiting areas for berthing. Second, show the advantage of less vibration and less pollution.

5.2 Maritime shipping

Deployment of SSE in maritime shipping is challenging but necessary to reduce the environmental impact of the maritime sector, especially at local level. That also means that the impact depends much on the exact location of the ports, in particular its distance to residential areas.

SSE is still a new option and many ports do not have experience with it. Some stakeholders consider its implementation and regulation as very easy when enforcement is triggered in the right way. Other stakeholders, however, still have uncertainties for specific aspects, such as the ownership of the SSE infrastructure. Otherwise the reporting of existing practices has provided predominantly positive feedback. It is important however to state that these best practices had political backing.

This investigation found that the potential for SSE in Europe is high and the potential health benefits and greenhouse gas emission reductions are worth deploying the use of SSE. Furthermore, on basis of the NUTS 3 level investigation in the main areas of Europe, the exploration of the SSE potential would not cause serious grid problems.

To set the course the following aspects should be elaborated upon in an integrative process on different levels.

- Discussion on fuel and electricity tax reductions;
- Funding of initial investments in infrastructure;
- Creating an incentivizing system for financing SSE infrastructure (business case development for SSE infrastructure and operation) in an integrative stakeholder process;
- Obligatory use of SSE or similar technologies for ship owners, starting with ship types with the highest financial and environmental benefit.

Our analysis shows that activities which should be supported first should be related to Cruisers and Ferries. These are the ship types with the most publicity for the benefits. Doing so would make it easier to convince more sceptical stakeholders as well.

There are however several barriers to the uptake of SSE in maritime ports which need to be approached. Starting from the most important, the barriers are discussed next and suggestions are made on who should take action on resolving it.

Financial

The economical barrier is an important barrier identified by the stakeholders. The underutilisation of the SSE connection is not supportive for a good business case. To solve this “chicken and egg” problem, the start-up financing should be actively supported from governments or the EU.

The actors who are typically requested to invest on the shore side by current regulations are not the ones with the highest benefits from the reduction of the harmful emissions. This creates a difficult starting point for the development of SSE. Several stakeholders raised the point that an investigation should be conducted into who should pay for the infrastructure. These stakeholders also thought that ports need to be supported and that the EU should play a stimulating role in the deployment of SSE.

One way to solve this could be to create a business case for the ports for partially repayment of the investment by those parties who profit from the infrastructure:

- ports get a charge on the sold electricity as a repayment for the infrastructure from the **electricity supplier**
- ports get a charge on the sold electricity as a repayment for the infrastructure from the **terminal operators**
- ports get a charge on the sold electricity as a repayment for the infrastructure from the **ships**

Another way could be to create a business case in which the central actor would be the electricity supplier.

To make potential ideas and barriers more concrete, we would like to show a parallel development in the road-based e-mobility discussion. The first starting point was that it was expected electricity suppliers would invest in infrastructure. This approach followed the combustion engines systematic in the sense that the one who sells the fuel provides the infrastructure. But in the new e-mobility system, the electricity supplier would not earn money with charging electric vehicles in this decade. The second approach was that local authorities should provide infrastructure as a public service. Currently, however, the vehicle producers (OEMs) are in charge of providing charging infrastructure as they will earn the biggest portion of the e-mobility market. In addition to that, the first startup companies are getting into the market to sell electricity at fast charging stations (e.g. Fastnet in The Netherlands) or to provide the service to vehicle owners to charge everywhere he/she likes and organize the administrative and financial arrangements between the different electricity suppliers (e.g. ubitricity[15], Germany). These companies also invest in the charging infrastructure. In the SSE market, the electricity supplier seems to be the market actor who could earn the biggest share of the market. Market creation needs to be stimulated via integrative stakeholder engagement in which network operators, electricity suppliers, port authorities, terminal operators and the ship owners, define their respective positions.

In any case, it should be avoided that the electricity price for SSE will rise to a relevant competition factor between ports and Member States. In designing a measure it is important to keep in mind the economic and physical size of ports. Smaller ports may have less means to comply with a measure. And the different regulations on energy supply in different countries influence the business case. Price factors such as peak loads need to be taken into account.

The disadvantage of having 60Hz systems onboard ships and 50Hz on shore will not be solved in the near term, requiring expensive frequency converters, which weaken the business case. There is not much which can be done about this issue other than accept the higher costs.

---

[15] www.ubitricity.com

Regulatory

The EU proposal for the directive on the deployment of alternative fuel infrastructure (EU Proposal COM(2013)18, 2013) is a step in the direction of more SSE in Europe.

Regulations on Member State level have to consider the very individual structure of the European ports – even within a Member State (the structure between port authorities, terminal operators, port operators and if they are private or public entities).

Many stakeholders stated that a tax reduction on electricity used in SSE was an appropriate measure. As there are no taxes on diesel and HFO used in shipping, the electricity tax causes a substantial market imbalance and makes the more environmentally harmful fuels cheaper than SSE. The overall goal should be to create a harmonized transport market with balanced initial conditions for each mode and taxation (exceptions) for transport fuels that are adapted to each other.

The electricity that is used for SSE is currently taxed and covered by the EU-ETS, unlike the fuel that would have otherwise been used in the auxiliary engines. The current possibility for Member States to include activities or installations (i.e. ships or ports) into the EU-ETS, according to Article 24 of Directive 2003/87/EC would partially solve the difference. None of the Member States has used this option so far.

The Californian way as a combination of obligations addressed to the ship owners (including a space to meet the target) and financial support for the charging infrastructure investment, seems to be an appropriate way. This regulation would be supported by some stakeholders as well. It should be investigated further whether a specific bonus or support scheme could speed up activities on SSE or how activities could be channelled to the most efficient or beneficially actions. The created regulation needs to take into account that the energy price should not become a competitive component.

Some stakeholders claim the governments should provide financial funds for onboard infrastructure.

Practical

There is still a lack of clarity about the potential and benefits of SSE at levels of ports and local governments. Also shipping companies and ports do not often discuss this issue.

Some stakeholders stated that further feasibility studies needs to be performed. These should be co-fund and would / should provide further information on technology, investments and on business cases.

Soft measures, such as campaigns, workshops and calculation tools could bring more clarity and accelerate the uptake. An example of good promotional activities is from the OPS workgroup within WPCI. This initiative, among others, could be further supported by helping them to improve the tool that is currently being offered and that was enriched in this project.

Workshop, public awareness activities and campaigns need to be built up in an overall stakeholder engagement. A suitable institutional construction could be based upon that of "national platform e-mobility, Germany". All stakeholders are involved, they need to commit themselves to the overall targets and they need to be active members in the established working groups. In the case of the international maritime economy, a cascade of institutional levels would be needed for these working groups.

Operational

In some countries under study where the onshore electricity is produced from oil, there is no benefit regarding emission reduction. However, even in this case the positive impact on health can be significant, since SSE allows removing dangerous pollutants out of highly populated areas, where the impact to the population is marginal.

The potentials for auto-production of RES for ports / port areas should be investigated and business cases for self-consumption via SSE should be created. Funding should be developed to encourage smartgrids implementations and to enable the port or the electricity provider to build up renewable energy generators for the port area including or in combination with the installation of SSE infrastructure on smartgrid implementations. Such approaches could allow the SSE system to support the security of supply on the electricity network level ("ship to grid" or "ship to wind").

Furthermore it is important to have a user-friendly system in place that enables easy connecting and disconnecting. It might be that traffic is moving too fast in some ports or ports quay, so it might be that Roro's or ferries berthing time is too limited to make use of SSE (e.g. Calais' Roro and ferry harbour). This has to be considered for each port or quay individually.

Technical

The success of SSE depends on the attitudes of parties on the shore side as well as vessel owners. Some ship owners have already invested in SSE equipment on board their ships. These include NYK Line, Evergreen, Princess Cruise and Holland America Line, China Shipping, Evergreen, MOL, Stena Line, Wagenborg, TransAtlantic, SOL, TransLumni, ICL, and Cobelfret. (WPCI, 2013). The release of ISO standard IEC/ISO/IEEE 80005-1:2012 was an important step to dismantle technical, practical and economical barriers.

In general the demand increase is not seen as problematic for the electricity grid, especially if we take into account that the SSE implementation is a medium/long-term process which is aligned with the grid extension planning in the EU. No severe obstacles are expected on the transmission level for the observed areas. The demand increase caused by SSE is rather a minor impact, at least from the transmission grid perspective. SSE might even have positive effects for some coastal areas where RES are installed and generation and transmission are expected to grow in the future. To exclude all uncertainties on the distribution grid level, further investigation on the local level with advanced modelling needs to be performed. The results of this study shows that the figures for SSE demand indicate a normal demand increase and should cause minor technical or economic problems compared to the daily grid extension obstacles.

There are only minor issues from the technical view point, neglecting economic aspects. Even for the 50/60 Hz obstacle, which is still widely discussed, there are technical solutions in place (converter) that allow the ports to support both systems if needed. For the ships which operate on a lower voltage than what is commonly offered, a transformer is needed onboard. It could be considered by ports and shipping companies in the development to put only one transformer on shore instead of several onboard the ships. However, the transformer will be the option for the longer term as the 50/60 Hz problematic will not be solved in a midterm perspective.

It would also be worthwhile to compare SSE with the following technologies, which are potential partial substitutes for shore side power:

- Exhaust Gas Scrubbers. Several vessel owners are installing such systems. Mostly to comply with regulations;
- Onboard LNG systems;
- Port side LNG systems. Fixed and mobile systems are being developed.

Scrubbers and LNG provide benefits in terms of local pollution. However, greenhouse gas emissions are not being fully eliminated. An advantage of scrubbers and onboard LNG is that emission reduction can take place while not at berth. But LNG also comes along with some uncertainties, for example methane slip. Another substitute is scrubbers, drawback it emits "yellow water" or battery powered ships. Unfortunately lack of suitable batteries the letter is not a feasible option in the short term. In the end a multifaceted approach is needed, complete with a combination of different solutions that include SSE as well as other approaches. For each port a case-related sustainable and appropriate solution needs to be considered.

5.3 Recommendations at a glance - Key takeaways

Inland shipping

- In order to successfully deploy SSE in inland shipping, a connector standard should be agreed upon for the whole EU. The Commission could play a facilitator role in this process.
- Mandatory use of SSE in waiting areas for inland ships should be agreed upon, starting with river cruisers as their business case is likely to be the most profitable. The initiative should lie here with the Member State governments and ports.
- Financial tools to support the investments on the ship side might be needed to enable the transition.
- Public awareness-raising activities addressing local residents, ports and ship owners could be used as a tool to improve public perception regarding SSE in the inland shipping sector.

Maritime

- Deployment of mandatory requirements and stimulus packages for European ports could be considered to further accelerate the uptake of SSE in European ports.

- First, activities related to cruisers and ferries should be supported and the focus should lie in port areas were impacts are most beneficial to the public, like passenger waiting areas, ports close to residential areas, cruise ships and quays.
- An analysis should be conducted on who should pay for the infrastructure based on the share of the benefits to each of the actors.
- Tax exemptions on the electricity for SSE, or should be considered in order to create a level playing field and a better business case for SSE.
- Member States could include activities or installations (i.e. ships or ports) into the EU-ETS, according to Article 24 of Directive 2003/87/EC, in order to create a better level playing field and better business case for SSE.
- An institutional, interactive stakeholder engagement structure should be designed involving all stakeholders, with clear commitments to overall targets.

Interviewees

Europe:

Organisation	Who	When	Suggested to also interview
ESPO	Antonis Michail	April 8th	-Rotterdam, Gothenburg, Antwerp -Hamburg (not so positive about SSE)
Spliethof	Sjoerd Hupkes Wijnstra	Early 2014	-Los Angeles Port
InterFerry	Johan Roos	April 7th	-Mr Bob Brouwer (Stena Line) -Colorline (visit)
EFIP	Kathrin Obst	April 8th	-
	Eugenio Quintieri		-
Port of Rotterdam	Maurits Prinssen	April 10th	-Mr. Eric Caris (Los Angeles Port) -Mr Bob Brouwer (Stena Line)
ECSA	Benoit Loicq	April 9th	-Mr Jan Helge Pile at Colorline
Utiliq	Maarten Hektor	March 14th	-
Eurelectric	Aura Caramizaru	April 9th	-
	Senan McGrath		-
SSE equipment providers	Folker Franz (ABB)	April 8th	-
	Knut Marquart (ABB)		-
	Pierre Lucas (T&D Europe)		-
	Juergen Moser (Siemens)		-
	Marc Lemper (Siemens)		-
	Bertrand Deprez (Schneider Electric)		-
WPCI (OPS)	Susann Dutt	May 6th	-
Stedin	Ton Wirken	May 1st	-Mr Bob Brouwer (Stena Line)
Maersk Line	Jørgen Hansen	May 8th	-
	Jacob Sterling		-
	Niels Bjørn Mortensen		-

USA:

Organisation	Who	When
Port of San Diego	Adam Deaton	Febr. 27th
Cochran	Mike Watts	March 5th
Los Angeles Harbor Department, Environmental Management Division	Carter Atkins	March 6th
Holland America Lines	Arnoud Zeelen, Deputy Director, Electrical Operations	March 11th
Holland America Lines	Tina Stotz, Manager, Sustainability and ISO Systems Management Jonathan Turvey, Senior Manager, Strategic Policy & Planning	March 19th
Port of Oakland	Tim Leong, Engineering and Environmental Planning Division	March 4th
California Air Resources Board	Dave Mehl, Stationary Source Division / Energy Section Jonathan Foster, Stationary Source Division / Energy Section	April 14th

Bibliography

Masson , L. (2013, January 30). Retrieved from plugincars: http://www.plugincars.com/european-commission-wants-act-help-evs-126265.html

ABB. (2010). *Shore-to-ship power.* ABB.

ABB. (2011). *Onshore and onboard - ABB Review 1/2011 .* ABB.

Alphen, M. L. (2010). *Haalbaarheidsstudie Walstroom Binnenvaart en Zeevaart.* Rotterdam: Zeeland Seaports.

BDB. (2012). *Geschäftsbericht 2011/2012 des Bundesverband der Deutschen Binnenschiffahrt e.V.* Duisburg: Bundesverband der Deutschen Binnenschiffahrt e.V.(BDB).

BDB. (2013). *Geshäfstbericht 2012/2013 des Bundesverband der Deutschen Binnenschiffahrt e.V.(BDB).* Duisburg: Bundesverband der Deutschen Binnenschiffahrt e.V.(BDB).

BSH. (2014, 6 5). Bundesamt für Seefahrt und Hydrographie. (I. Dorband, Interviewer)

CE Delft. (2009). *Technical support for action to reduce greenhouse gas emissions from international maritime transport.* Delft: CE Delft.

CE Delft et.al. (2011). *Medium and long term perspectives of IWT in the European Union.* Delft.

Damalas, D. (2012, May 22). European Commission’s website on Energy Efficiency in Fisheries. Vigo, Spain: 2nd International Symposium On Fishing Vessel Energy Efficiency , http://www.e-fishing.eu/paperslist/presentaciones/1.European_Commission%27s_website_on_Energy_Efficiency_in_Fisheries.pdf.

de Groot. (2010, 4 9). Walstroom binnenvaart. *CBRB Express Info*, p. 6.

de Jong, E., Hugi, C., & Cooper, D. (2005). *European Commission Directorate General Environment - Service Contract on Ship Emissions: Assignment, Abatement and Market and Market-based Instruments.* Northwich: Entec UK Limited.

Doves, S. (2006). *Alternative Maritime Power inthe port of Rotterdam.* Port of Rotterdam Authority.

Dutch Inland navigation Information Agency. (2013). The Power of inland navitation 2013-2014. The Netherlands: Dutch Inland navigation Information Agency.

Dutt, S. (2013, July 12). The OPS & LNG projects within World Ports Climate Initiative (WPCI). *Presentation at the Green Energy Port Conference*. Vigo, Spain.

Dutt, S. (2014). (R. Winkel, Interviewer)

ECG. (2013). *Sulphur Content in Marine Fuels.* The Association of European Vehicle Logistics.

ECSA, B. L. (2014, 4 9). Barriers for SSE. (R. Winkel, Interviewer)

EFIP, K. O. (2014, 4 8). Barriers for SSE. (R. Winkel, Interviewer)

EnergieStGuaÄndG. (2011). Gesetz zur Änderung des Energiesteuer- und des Stromsteuergesetzes 2011 . *Bundesgesetzblatt, 2011, Teil 1, Nr. 8*.

ENTSOe. (2012). *10- Years Network Development Plan 2012.* European Network of Transmission System Operators for Electricity.

Ericsson, P., & Fazlagic, I. (2008). *Shore-side Power Supply - A feasibility study and a technical solution for an on-shore electrical infrastructure to supply vessels with electric power while in port.* Göteborg: Chalmers University.

ESPO, A. M. (2014, 4 8). Barriers for SSE. (R. Winkel, Interviewer)

EU Commission Communication COM(2007) 575. (2007). *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. An Integrated Maritime Policy for the European Union in.* Brussels: Commission of the European Communities.

EU Commission Recommendation 2006/339/EC. (2006). *Commissions Recommendation of 8 May 2006 on the Promotion of shore-side electricity for use by ships at berth in community ports.* O.J. L 125/38.

EU Commission SEC(2011). (2011). White Paper on Transport, Roadmap to a single European Transport Area - Towards a competitive and resource efficient transport system. Brussels: European Union.

EU Council Directive 2003/96/EC. (2003). COUNCIL DIRECTIVE 2003/96/EC of 27 October 2003. Restructuring the Community framework for the taxation of energy products and electricity. *O.J. L 283/51*.

EU Council Implementation Decision 2011/384/EU. (2011). Council Implementation Decision of 20 June 2011 authorising Sweden to apply a reduced rate of electricity tax to electricity directly provided to vessels at berth in a port (‘shore-side electricity’) in accordance with Article 19 of Directive 2003/96/EC. *O.J. L 170/36*.

EU Directive 2005/33/EC. (2005). *Directive of the European Parliament and of the Council of 6 July 2005 amending Directive 1999/32/EC.* Official Journal of the European Union L 191/59.

EU Directive 2008/50/EC. (2008). DIRECTIVE 2008/50/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2008 on ambient air quality and cleaner air for Europe. *O.J. L 152/1*.

EU Proposal COM(2011) 169/3. (2011). *Proposal for a Council Directive amending Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity.* Brussels: European Commission.

EU Proposal COM(2013)18. (2013, January 24). Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the deployment of alternative fuels infrastructure.

Eurelectric. (2013). *Power statistics and trends.*

Eurelectric, A. C. (2014, 4 9). Barriers for SSE. (R. Winkel, Interviewer)

European Commission Innovation and Networks Executive Agency (INEA). (2012a). *TEN-T Programme 2007-2013, On Shore Power Supply - an integrated North Sea network, 2011-EU-21002-M*. Retrieved 07 15, 2014, from http://inea.ec.europa.eu/en/ten-t/ten-t_projects/ten-t_projects_by_country/multi_country/2011-eu-21002-p.htm

European Commission Innovation and Networks Executive Agency (INEA). (2012b). *TEN-T Programme 2007-2013, Tackling the environmental impact of shipping: Pilot implementation of a shore-side electricity supply for ships with increased energy demand (market innovation) 2012-DE-92052-S*. Retrieved 6 7, 2014, from http://inea.ec.europa.eu/en/ten-t/ten-t_projects/ten-t_projects_by_country/germany/2012-de-92052-s.htm

European Commission Innovation and Networks Executive Agency (INEA). (2014a). *Motorways of the Sea, Marco Polo Programme*. Retrieved 06 06, 2014

European Commission Innovation and Networks Executive Agency (INEA). (2014b). *Shore Power in Flanders 2012-BE-92063-S.* Brussels: European Commission.

European Commission Innovation and Networks Executive Agency (INEA). (2014c). *TENT-T Programme 2007-2013. Projects on Water*. Retrieved 6 6, 2014, from http://inea.ec.europa.eu/en/ten-t/ten-t_projects/ten-t_projects_by_transport_mode/water.htm

European Commission Innovaton and Networks Executive Agency (INEA). (2014d). *TEN-T programme 2007-2013*. Retrieved 07 21, 2014, from http://inea.ec.europa.eu/en/ten-t/apply_for_funding/follow_the_funding_process/follow_the_funding_process.htm

European Cruise Council. (2012). *2011/2012 Report - Making a real social and economic contribution to Europe's economy.* London: Ashcroft & Associates Ltd.

European Environment Agency. (2011). *Revealing the costs of air pollution from industrial facilities in Europe.* Copenhagen: European Environment Agency.

European Environmental Agency. (2013). *The impact of international shipping on European air quality and climate forcing, No. 4/2013.* Copenhagen: European Environmental Agency.

Eurostat Energy statistics. (2012). Retrieved 07 15, 2014, from http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_105a&lang=en

Ewout Bückmann, M. M. (2008). *Netwerkanalyse vaarwegen en binnenhavens Fryslân en Groningen.* Rotterdam: Ecorys.

Generaldirektion Wasserstraßen und Schifffahrt. (2014). *http://www.wsd-west.wsv.de/Service/Stromtankstellen/index.html*. Retrieved 07 15, 2014, from http://www.wsd-west.wsv.de

Government of Flanders. (2012, 03 03). *Shore-side Electricity: Department of Mobility and Public Works , Ports and Water Policy Division*. Retrieved from http://www.flanderslogistics.be/walstroom/index.php?lang=en

Grossmann, H., Otto, A., Stiller, S., & Wedemeie, J. (2007). *Growth Potential for Maritime Trade and Ports in Europe.* DOI: 10.1007/s10272-007-0223-x: Intereconomics.

Hall, W. J. (2009). Assessment of CO2 and priority pollutant reduction by installation of shoreside power. *Resources, Conservation and Recyclin*, Volume 54, Mai 2010, Issue 7,Pages 462–467, doi.org/10.1016/j.resconrec.2009.10.002.

Holland, M., Pye, S., Watkiss, P., Droste-Franke, B., & Bickel, P. (2005). *Damages per tonne emission of PM2.5, NH3, SO2, NOx and VOCs from each EU25 Member State (excluding Cyprus) and surrounding seas, for Service Contract for carrying out cost-benefit analysis of air quality related issues, in particular in the clean air..* Didcot, Oxon: AEA Technology Environment.

Holland, M., Watlkiss, P., Pye, S., de Oliviera, A., & van Regemorter, D. (2005). *Cost-Benefit Analysis of Policy Option Scenarios for the Clean Air for Europe programme.* Didcot, UK: European Commission DG Environment .

https://walstroom.nl. (n.d.). Retrieved from https://walstroom.nl/en/home/

Hulskotte, J., & van der Gon, H. D. (2010). *Methodologies for estimating shipping emissions in the Netherlands.* Bilthoven: Netherlands Environmental Assessment Agency, (PBL).

IEA. (2012). *CO2 emissions from fuel combustion -Highleights-.* Paris: International Energy Agency.

IHS Fairplay. (2011). *Ship visiting European ports.* Gothenburg: IHS Global Limited.

IHS Fairplay. (2011). *Ships Visiting European Ports.* Gothenburg: IHS Fairplay.

IMO, T. i. (n.d.). *http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Documents.* Retrieved 5 7, 2014, from http://www.imo.org:

http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Documents/GHG%20Flyer%20WEB.pdf

InterFerry, J. P. (2014, 4 7). Barriers for SSE. (R. Winkel, Interviewer)

Ir. J.H.J. Hulskotte, D. S. (2008). *Milieueffecten van de invoering van walstroom voor zeecruiseschepen, riviercruiseschepen en binnenvaartschepen in de haven van Amsterdam.* Amsterdam: Port of Amsterdam.

ISO 80005-1. (2012). IEC/ISO/IEEE 80005-1 Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirements. IEC/ISO/IEEE.

Kollamthodi, S., Pueyo, A., Gibson, G., & et.al. (2013). *Support for the impact assessment of a proposal to address maritime transport greenhouse gs emissions.* Ricardo-AEA Ltd.

Maddox Consulting. (2012). *Analysis of market barriers to cost effective GHG emission reduction in the maritime transport sector.*

MAERSK. (2014, 5 8). MAERSK .

Maersk Line. (2014). *Big impact. Big responsibility Sustainability Progress Update 2013.* Copenhagen: Maersk Line.

Marechal Electric Group. (n.d.). Ports, Marinas, Shipyards & Vessels. Saint-Maurice, France.

Maritime, A. (2014, July 16th). *AEC Maritime ECA legiclation*. Retrieved July 16th, 2014, from AEC Maritime: http://www.aecmaritime.com/eca

Ministère de l'Ecologie, du Développement Durable, et de l'Energie. (2010). DEfinition des CAractéristiques de Navires fluviomaritimes adaptés à la mise en oeuvre de services de transport de conteneurs 45 pieds (DECAN2). France: République Francaise.

Netherlands Enterprise Agency. (n.d.). Retrieved from http://english.rvo.nl/subsidies-programmes/mia-environmental-investment-rebate-and-vamil-arbitrary-depreciation-environmental-investments

Neumeier, F. (2013). Hamburger Senat beschließt Landstrom für Terminal Altona. *Cruiseticks.de*.

Paul-Harvey, W., & Martin, S. D. (2012). *Cold-Ironing as a Cost-Effective Tool for Improving Sustainability in the Shipping Industry.* Durham: Duke University.

PORT OF GOTHENBURG, ABB, Ramböll Sverige AB, & Vinnova. (2012). *Onshore power Sypply in the Port of Gothenburg.* Project Clean North Sea Shipping.

Port of Long Beach. (2014). *Shore Power Regulation Fact Sheet.* Los Angeles: Port of Long Beach.

PWC. (2013). *Study aimed at supporting an impact assessment on: "Measures to enhance the efficiency and quality of port services in the EU".*

Radu, D. (2013, 6 3). Retrieved 5 8, 2014, from http://blog.schneider-electric.com/energy-regulations/2013/06/03/ports-how-does-shore-power-cut-emissions-and-boost-business/

Radu, D., & Grandidier, L. (2012). *Shore Connection Technology - Environmental Benefits and Best Practices -.* Rueil-Malmaison: Schneider Electric.

Ricardo-AEA. (2013). *Support for the impact assessment of a proposal to address maritime transport greenhouse gas emissions.* Brussels: European Commission.

Saison, & McBride. (2011). *The economics of cold ironing.*

Schneider Electrics blog. (n.d.). Retrieved 03 21, 2014, from http://blog.schneider-electric.com/energy-regulations/2014/03/21/regulation-required-developing-shore-side-electricity-greener-ports/

Sisson, M., & McBride, K. (n.d.). The economics of cold ironing. *PORT TECHNOLOGY INTERNATIONAL*, http://www.porttechnology.org/images/uploads/technical_papers/PT40-24.pdf.

SSE equipment providers. (2014, 4 8). Barriers for SSE. (R. Winkel, Interviewer)

STEDIN, W. T. (2014, 5 1). Barriers for SSE. (R. Winkel, Interviewer)

Theodoros, P. G. (2012). A Cold Ironing Study on Modern Ports, Implementation and Benefits, Thriving for Worldwide Ports . Athens: National Technical University of Athens.

Utiliq, M. H. (2014, 3 14). Barriers for SSE. (R. Winkel, Interviewer)

Vesselfinder. (2014). Retrieved 07 15, 2014, from www.vesselfinder.com

Vree, D. (2008). *Haalbaarheidsonderzoek Walstroom Amsterdam.* Amsterdam: Haven Amsterdam.

Walstroom. (2013). Retrieved 2013, from Walstroom: https://www.walstroom.nl/walstroom/clientsite/info/kosten.jsp

Wasser- und Schifffahrtsverwaltung des Bundes. (2014). Retrieved 6 7, 2014, from Service/Stromtankstellen: http://www.wsd-west.wsv.de/Service/Stromtankstellen/index.html

Wikipedia. (2014). Retrieved 07 15, 2014, from http://en.wikipedia.org/wiki/IEC_60309

Wilske, Å. (2012). *Preconditions for connecting ships to Onshore Power Supply in the Port of Gothenburg.* Gothenburg: Port of Gothenburg.

WPCI. (2013). *Onshore Power Supply*. Retrieved April 2014, from http://www.ops.wpci.nl/

WPCI OPS Calculation Tool. (2013). Retrieved 07 15, 2014, from http://www.ops.wpci.nl

WPCI, S. D. (2014, 5 6). Barriers for SSE. (R. Winkel, Interviewer)

Zeiss, H. (2013). Liegezeiten im Hamburger hafen bald umweltfreundlicher. *Institut für Nachhaltigen Tourismus GmbH*.

Annex 1: Technical Status Quo

Equipment needed shore-side and ship-side to apply SSE

A suitable electrical infrastructure to handle shore to ship power connection is required. Equipment and solutions may vary from case to case. The key barrier is that power systems throughout the world are not interoperable, and are operated in different voltage and frequency levels. The major components for the shore –and the ship- side are briefly listed below and a simplified scheme of SSE for sea ships is given in Figure 25.

Shore/Port side

Equipment needed to enable SSE onshore:

Voltage level: In most ports there is access to electricity at different voltage levels. In ports close to a residential or industrial area, medium voltage (6.6-11 kV) is often available.

Substation / transformer: The substation matches the voltage level from the distribution grid (20/100kV) to the medium voltage level of the port area (6.6-11kV). A transformer may be further used to match the port area voltage to the one of the corresponding onboard power systems (low voltage 440/690V (getting outdated, RoRo). In addition the substation and onboard transformer provide the required galvanic separation preventing endangering the port grid by the ship’s electrical system or vice versa. The ports of Gothenburg and Kiel provide power in low voltage level (400-690V) since many RoRo ship in the Baltic Sea still run on the low voltage system (400-690V).

Cables: Cables in the port area are used to deliver the 6.6-20 kV power from the sub-station to the port terminal.

Frequency converter: A frequency converter is needed for matching the onshore power frequency (either 50Hz or 60Hz) to the onboard power system frequency. The majority of the ships operate with 60Hz, and some with 50Hz (more detail Chapter 3.2 and Figure 15*)*

Control panel and switchgear: The control panel (communication system) coordinates the connection and synchronizes the electrical load and frequency for each quay or port part depending on the model. The switchgear interrupts the power supply while connecting the high voltage cables to ensure a safety for the staff and better handling. It should be remotely controlled from the outlet of the quayside.

Connection-/Cable management system: The connection systems vary between ship and quay model respective to the overall approach of the port, e.g.:

- The ship carries the cable on board e.g. on container ships. One reason can be that space on the quay side is limited, since space might be occupied by loading- and uploading infrastructure, especially in harbours for cargo and container. In this case the port side needs to provide infrastructure till the connection station (connector).
- The port provides the cable management system. Cruise ships usually do not carry the cable system onboard; also due to limited valuable space on board. In SSE ports for those models a suitable cable management system would be necessary.

Onboard/Ship side

Equipment needed to enable SSE onboard. The equipment can either be integrated in a new built ship or can also be installed in a "conventional" existing ship (retrofit):

Electrical management and distribution system: Power management system onboard to synchronise the power changeover with the diesel auxiliary engine before the load is transferred.

Control panel and switchgear: See above, 0 Shore/Port side.

Transformer, if not available on shore side:
See above, 0 Shore/Port side
Ships with low voltage auxiliary power system (400-690V) require a transformer to receive the 6-11 kV power supply from the port side.

Connection-/Cables Management System:
See above, 0 Shore/Port side

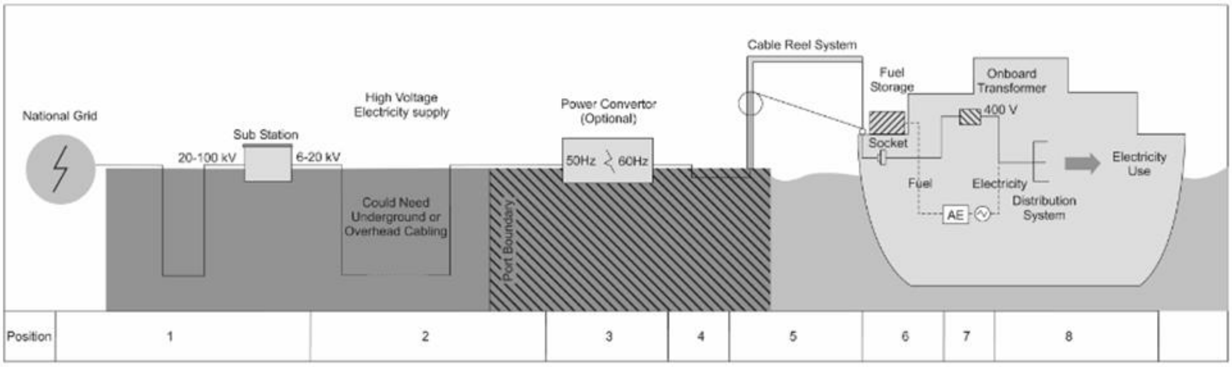


Figure 25: Simplified scheme of SSE for sea ships (EU Commission Recommendation 2006/339/EC, 2006)

State of implementation of SSE infrastructure

Since the year 2000 the numbers of SSE installations are increasing rapidly. Most implementations can be found in northern Europe and on the North American East coast, due to the strong environmental legislation, community pressure and social responsibility. In Asia SSE is seen as approaching technology to reduce air pollution and local emissions (WPCI, 2013).

Seaports with SSE

Table 23 gives an overview of the seaports that implemented SSE infrastructure (high voltage) including ship types, capacity and annual calls. Stockholm also uses SSE, but only of the low voltage type.

The Chinese Ministry of Transport included SSE in their five year *Execution Program for Water Transport Energy Efficiency and Emission Reduction (2011-2015) to drop total emissions form port and vessels* (Radu & Grandidier, Shore Connection Technology - Environmental Benefits and Best Practices -, 2012).

Table 23: Overview of ports with SSE infrastructure (Working Group on Onshore Power Supply, 2013)

Year	Port Name	Country	Capacity (MW)	Freq. (Hz)	Voltage (kV)	Ship types	Berths with SSE	SSE unique calls	SSE annual calls	Supplier
2000-2010	Gothenburg	Sweden	1.25-2.5	50 & 60	6.6 & 11	RoRo, ROPAX	6	11	1515	
2000	Zeebrugge	Belgium	1.25	50	6.6	RoRo	1	3	200	
2001	Juneau	U.S.A	7-9	60	6.6 & 11	cruise	1	3		Cochran Mar.
2004	Los Angeles	U.S.A	7.5-60	60	6.6	container, cruise	24	54	46	
2005-2006	Seattle	U.S.A	12.8	60	6.6 & 11	cruise	2	9	83	
2006	Kemi	Finland		50	6.6	ROPAX				
2006	Kotka	Finland		50	6.6	ROPAX				
2006	Oulu	Finland		50	6.6	ROPAX				
2008	Antwerp	Belgium	0.8	50 & 60	6.6	container				SAM Elec.
2008	Lübeck	Germany	2.2	50	6	ROPAX				Siemens
2009	Vancouver	Canada	16	60	6.6 & 11	cruise	2	10	104	Cochran Mar.
2010	San Diego	U.S.A	16	60	6.6 & 11	cruise	3	4	18	Cochran Mar.

Year	Port Name	Country	Capacity (MW)	Freq. (Hz)	Voltage (kV)	Ship types	Berths with SSE	SSE unique calls	SSE annual calls	Supplier
2010	San Francisco	U.S.A	16	60	6.6 & 11	cruise	1	3	38	Cochran Mar.
2010	Verkö	Sweden	2.5	50		cruise				Cavotec
2011	Long Beach	U.S.A	16	60	6.6 & 11	cruise	1	1	118	Cochran Mar.
2011	Oslo	Norway	4.5	50	11	cruise	1	1	360	
2011	Prince Rupert	Canada	7.5	60	6.6		1			
2012	Rotterdam	Netherlands	2.8	60	11	ROPAX	2	4		
2012	Ystad	Sweden	6.25-10	50 & 60	11	cruise		7		
2013	Trelleborg	Sweden	0-3.2	50	10.5		6			

Seaports planning SSE

Table 24 shows ports that plan to implement SSE in the future. A large number of European ports are currently considering investing in SSE, including the large European seaports of Amsterdam, Marseille, Barcelona, Helsinki and Rome.

Table 24: Ports planning to use SSE (WPCI, 2013)

Port	Country	Port	Country	Port	Country	Port	Country
Amsterdam	Netherlands	**Helsinki**	Finland	**Livorno**	Italy	**Riga**	Latvia
Barcelona	Spain	**Hong Kong**	China	**Marseille**	France	**Rome**	Italy
Bergen	Norway	**Houston**	U.S.A	**Nagoya**	Japan	**South Carolina**	U.S.A
Civitavecchia	Italy	**Kaohsing**	China	**Oakland**	U.S.A	**Stockholm**	Sweden
Georgia	U.S.A	**Los Angeles**	U.S.A	**Oslo**	Norway	**Tacoma**	U.S.A
Genoa	Italy	**Le Havre**	France	**Richmond**	U.S.A	**Tallinn**	Estonia
Tokyo	Japan	**Venice**	Italy	**Yokohama**	Japan	**Hamburg**	Germany

Inland ports with SSE

More information about the locations of SSE connections at inland ports in for example the Netherlands, Belgium and Germany can be found here:

Figure 26: SSE connections at inland ports in the Netherlands [www.walstroom.nl]

Figure 27: SSE connections at inland ports in Belgium [http://www.flanderslogistics.be/walstroom]

Some “stromtankstellen” in Germany:
SSE inland pilot is running in the high populated “Ruhr Area”, where noise disturbance is an issue (BDB, 2012) and (Generaldirektion Wasserstraßen und Schifffahrt, 2014).

Standards

Low voltage (400V)

Systems for SSE in inland shipping are of the low voltage type: 400V. The European Standard for commercial shipping EN 15869-2-2010 described in detail the safety aspects of the connection: three phase, 400V, up to 63A and 50Hz. The SSE Supply Boxes for inland shipping typically have multiple low voltage 400V/63A/50Hz connections (25kW each). 5-pin CEE 5x63A plugs can be used for these connections.

Figure 28: 5 pin CEE connector used in the Netherlands

Some of the Quayside Electricity Supply Boxes also have 230V/16A/50Hz connections (for a CEE 3-pin 16A plug) or 400V/32A/50Hz connections (for a CEE 5-pin 32A plug).

For river cruises (210kW) typically separate cables are used which can handle more current (400A ‘powerlock’). The voltage is also 400V.

Figure 29: 400A ‘powerlock’ connectors

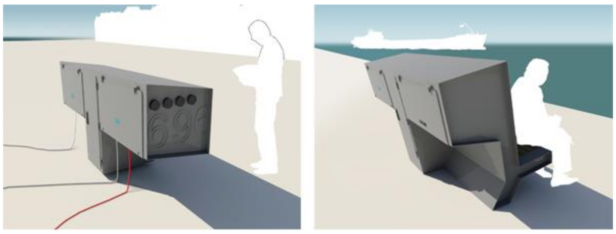


Figure 30: SSE supply box example for Inland Shipping in the Netherlands

In the Netherlands and Belgium typically the CEE standard connector is used (Wikipedia, 2014).
In France Marechal DS Plugs & Sockets Decontactors are used most often (Marechal Electric Group).

The landstrom in Germany is again different. The BDB (Federation of German Inland Waterways Association) calls for an European wide harmonization. Up till now, German SSE inland pilots are based on the connection system for electric cars, following the set of international standards for electrical connectors and charging modes for electric vehicles (EV) and is maintained by the International Electrotechnical Commission (IEC), as shown in Figure 31, (BDB, 2012) and (BDB, 2013).

Figure 31: The "type 2" connector, officially endorsed as the European electrical vehicles plug (Masson , 2013)

Standards for SSE high voltage

In July 2012 the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO) and the Institute of Electrical and Electronics Engineers (IEEE) published the first international standard for SSE systems, the so called "IEC/ISO/IEEE 80005-1 Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirements". This standard also relates to standard IEC 62613-1:2011 - Plugs, socket-outlets and ship couplers for high-voltage shore connection systems. The international standard avoids variances in technical requirement of systems, like voltages, socket design and power plugs. The complete standard is available here:

Key issues addressed (ISO 80005-1, 2012)**:**

- High voltage shore distribution systems;
- shore-to-ship connection and interface equipment;

- transformers/reactors;
- semiconductor/rotating convertors;
- ship distribution systems and;
- control*, monitoring, interlocking and power management systems.*

Since the capacity and power needs of vessels differentiate so much, a single global connection standard for all vessels at all harbours was not feasible. The standard covers requirements for, cruise ships, container ships, RoRo, passenger ships, tankers and LNG carriers.

The standard refers to both the application of international electrical standards already available and installation guidance. The design, installation and testing of high voltage SSE systems is included, but low voltage systems are not covered. The standard includes the shore side as well as ship side devices and also addresses shore-to-ship connection and interface devises. A high share of regulations are related to protection aspects like emergency shut downs. The standard defines a nominal voltage of 6.6 or 11 kV, whereas an explicit frequency (50/60Hz) is not defined ((ISO 80005-1, 2012), (WPCI, 2013)).

Additional and/or alternative requirements may be imposed by national governments or the authorities within whose jurisdiction the vessels are intended to operate and/or by the owners or authorities in charge for a shore supply or distribution system (ISO 80005-1, 2012).

sustainable energy for everyone

sustainable energy for everyone

ECOFYS Netherlands B.V.

Kanaalweg 15G
3526 KL Utrecht

T: +31 (0) 30 662-3300
F: +31 (0) 30 662-3301

E: info@ecofys.com
I: www.ecofys.com