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Shore Side Electricity in Europe: *Potential and environmental benefits*

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HIGHLIGHTS

- We model Shore Side Electricity (SSE) options for ports in the European region.
- The economic and environmental potential for SSE in Europe is quantified.
- The expected barriers for wide implementation of SSE are depicted.
- We recommend policy actions that could accelerate SSE implementation.

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ABSTRACT

In the context of reducing emissions from the transport sector, the EU Commission envisions a strong modal shift to energy efficient modes including maritime shipping and inland shipping, as an alternative for road transport. In view of the expected growth of the sector, the emissions from waterborne transport are a key concern. When at berth, ships typically use their auxiliary engines to generate electrical power for communications, lighting, ventilation and other on-board equipment. The extended use of vessels' auxiliary engines augments greenhouse gas (GHG) emissions and air pollution in the adjacent ports, which are typically located in or near densely populated areas, thus leading to dangerous health and environmental effects. Shore Side Electricity (SSE) is an option for reducing the unwanted environmental impacts of ships at berth, i.e. GHG emissions, other air pollutants (NO_x, SO_x, PM) and noise of ships using their auxiliary engines. This paper quantifies the economic and environmental potential for SSE in Europe, through detailed estimation of in-port ships' emissions and relevant energy demand, providing an insight of the expected barriers for implementation and formulating recommendations on policy actions that could accelerate the implementation of SSE in European harbors.

1. Introduction

Various research studies indicate that the global carbon dioxide (CO_2) inventory of shipping reaches 1 billion tons, contributing about 3% to relevant global emissions, on a par with aviation and about 5 times less than road traffic. There are three major emission sources to air from ships: main, auxiliary engines and boilers; while CO_2, nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC), sulphur oxide (SO_2) and particulate matter (PM) are the main air emissions attributed to the international shipping.

The contribution of ships emissions has been increasing (global NO_x and SO_2 emissions from all shipping represent about 15% and 13% of the relevant air pollutants from anthropogenic sources reported in the latest IPCC Assessment Report – AR5), while on the other hand, the emissions from other sources are declining. Mid-range emissions scenarios show that, by 2050 and in the absence of relevant policies, ship emissions might grow by 50–250% compared to 2012, depending on future economic and energy developments and due to the continuing growth in international seaborne trade (Buhaug et al., 2009; Harrould-Kolieb and Savitz, 2010; Merk, 2014; Smith et al., 2014; Eyring et al., 2005).

In Europe, where SO_2 emissions have shown a decreasing trend for 25 years, the emissions from ships are particularly important: in the year 2000 emissions from international shipping in the seas surrounding the European Union (EU) were between 20% and 30% of the land-based emissions, while in 2020 emissions from maritime activities are projected to be about as large as those from land-based sources (Schembari et al., 2012). In 2010, shipping accounted for 15.3% of the EU's transport greenhouse gas emissions, which was more than aviation emissions (12.4%). A recent report showed that ships arriving at or departing from EU ports

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emitted 180 million tons of CO_2 in 2010, which was 4% of the EU's total emissions (Ricardo-AEA, 2013).

The impact of ship exhaust emissions upon the health of human population near port areas has been previously evaluated. According to global annual estimates, nearly 70% of the PM emissions due to shipping (ranging between 0.9 and 1.7 million t) occur within 400 km of the coast (Chang and Wang, 2012). In harbor cities or in cases where ports are located near to densely populated areas, ship emissions could often be one of the dominant sources of urban pollution. Although emissions due to ships' activities around ports account for almost 5% of the total emissions from navigation activities (Dalsoren et al., 2009), the continuously increasing amount of goods and passengers transported between ports during the last years has led to increased air pollution in ports. Furthermore, emissions from ships (either docked, moving or maneuvering in-port) are transported in atmosphere hundreds of kilometers away, thus contributing to air quality deterioration on land, even if they are emitted at sea (Eyring et al., 2010).

Air pollution can cause serious health problems including lung cancer, cardiovascular disease, and birth defects. PM emissions from marine vessels are related to increased cardiovascular hospitalizations (Tian et al., 2013) and have been estimated to be responsible for about 60,000 annual cardiopulmonary and lung cancer deaths mostly along European, East Asian, and South Asian coastal areas (Corbett et al., 2007). The estimated cost to society of the abovementioned annual deaths exceeds US $300 billion per year (EPA, 2010). Air pollution in cities is a key concern for the European Commission, as it leads to negative health and environmental effects and the ambition to "Internalize costs for local pollution and noise in ports" has been already expressed (European Commission, 2011).

However, the shipping sector has significant abatement potential, and environmental gains can be achieved through appropriate measures. Proposed solutions for improving air quality in coastal areas and ports include the establishment of reduced speed zones (RSZ), emissions control areas (ECAs) and adaptation of alternative maritime power technologies for vessels while they are at berth (Buhaug et al., 2009). When at berth, ships typically use their auxiliary engines 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 solidification of the heavy fuels.

Shore Side Electricity (SSE) is an option for reducing the unwanted environmental impact of ships while in the port, i.e. greenhouse gas emissions, air quality emissions and noise pollution. The extent of the emissions reduction depends mainly on the type of fuel burned from the ships as reference value and on the energy mix used for the electricity generation onshore. Hall indicates 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 on-board power generation (Hall, 2010). Implementation of a SSE provision system implies that when at berth, the ship is plugged into the port electricity network instead of using its auxiliary engines. 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. Also conditions vary for different seaports and inland ports, which are typically visited by different ship types (type, size, cargo, etc.). 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. 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, while Los Angeles already invested 150 million US dollars in SSE infrastructure. 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, Stena Line, Wagenborg, TransAtlantic, TransLumni, etc. (WPCI, 2013).

This paper quantifies the economic and environmental potential for SSE in European ports, provides insights into the barriers for implementation and formulates recommendations on policy action that could be undertaken to accelerate the implementation of SSE in European harbors.

2. Methods

2.1. Defining the demand and potential impacts

A detailed and accurate port specific characterization (including a ship emissions inventory and an energy demand evaluation) is necessary and crucial for environmental and health impact assessment and for policy oriented decisions. Generally, the existing approaches for creating ship related inventories are divided in "top-down" and "bottom-up" (or "activity-based") approaches. The former are fuel-based methods that estimate either emitted air pollutants or energy demand relying on the reported amounts or marine bunker fuel sales, while for the latter fuel consumption-based or ship movements-based methods are employed. Bottom-up approaches would generally be more accurate than top-down, but significant effort is required for data mining and management especially for large scale studies. (Miola and Ciuffo, 2011; Smith et al., 2014).

This study has combined both top-down and bottom-up evaluations, in order to assess the market potential of SSE in all EU ports. A two-step process was followed: at first a detailed analysis for typical port types (representing the cargo/passenger handling in Europe) was conducted, and then the results were projected to all EU ports based on the type of traffic each port handles (in this respect, each port was represented as a mixture of the selected typical port types).

Initially a top-down approach was implemented in order to evaluate the ships related electricity demand (for 2010 and 2020) in EU ports. This analysis employed various typical parameters (type/size of ships and number of ship calls in each port, average hoteling time, typical fuel and electricity consumption per ship type/size, efficiency of auxiliary engines, etc.) and its final output was the amount of electricity needed if all ships visiting EU ports would use SSE. The methodology allowed the estimation of the energy demand as well as the port infrastructure requirements. The theoretical maximum potential of SSE was estimated as the electricity needed to replace fully the fossil fuel consumption of ships in EU ports in 2020 (Ecofys, 2015).

In the next step of the evaluation, a bottom-up approach was undertaken 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 the analysis was based on the types of goods that are most transported by sea and inland waterways. Seven typical port types were selected that represent the average cargo/passenger handling in EU ports. For each port type the evaluation included different number of calls per ship per year, hours at berth connected and number of ships. The studied port types were:

- Liquid bulk port (60,000,000 t annually ≈ Marseille);
- Container (including an average of 5% reefer) port (2,000,000 TEU annually ≈ Barcelona);
- Bulk port (25,000,000 t annually ≈ Hamburg);
- Ferries and RoRo port (557,000 t 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 t annually ≈ Drachten, The Netherlands).

These ports were the base case scenarios and were assumed to handle only one type of cargo, unlike existing ports which handle a mixture of goods. Based on the information gathered from the abovementioned ports, specific combinations matching the cargo profile of European ports were made and the following key parameters for the main sea ports were estimated:

- 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 EU grids.
- Greenhouse gas emission reduction based on the average EU carbon content of electricity.
- Societal benefits (i.e. monetization of health impacts).

Based on the detailed mapping of the estimated SSE potential, the economic, social and environmental benefits and costs of SSE have been analyzed and the health benefits of lower air pollution in monetary terms have been estimated. Ships that have a high electricity demand overall and per berth are the first ones for which SSE will be beneficial. High energy consumption in ports and low peak power demand would further improve a potential business case. Cruise ships and RoRo present the best candidates for SSE, as in average the peak power demand per ship is 7–10 MW and 2 MW for these two ship categories respectively.

In particular, for cruise ships, an important factor that needs to be considered is the fact that such a ship apart from transferring passengers, also assumes the simultaneous function of a luxurious resort hotel and a leisure center throughout its journeys. This so called "hotelling" function is mainly responsible for the excessive energy demand of cruise ships, especially during their staying at berth in ports. It has been confirmed that cruises emit significantly more carbon emissions and use more fuel per p-km than economy class aviation. The average energy consumption for one guest night on-board the cruise vessels has been estimated to 1600 MJ, far greater than global average energy use per guest night for staying in a hotel (130 MJ per visitor night). The operation of a cruise ship (mainly due to the "hotelling" amenities included) is still about five times higher than the average energy use for the most luxurious hotels (322 MJ per visitor night) which would include many of the same comforts, such as swimming pools, casinos, gyms and restaurants. (Howitt et al., 2010).

In order to further ameliorate the evaluation and assess cruise ships electricity demand in ports, a detailed bottom-up evaluation has been used for 10 of the largest cruise ports in the Mediterranean Sea (representing almost 30% of the total global cruise ship calls). For each studied port and for all approaching cruise vessels, activity profiles have been created; i.e. a breakdown of a ships' movements during modes of operation (i.e. maneuvering or at berth), with engines' types and sizes, engines' load factors, type of fuel consumed and time spent in each mode. Maneuvering refers to the slow speed movement of the ship approaching the port's point of berth, while berthing refers to the dockside mooring of the ship. For every ship call, each of the air pollutants (i.e. GHG, NO_x, SO_2 and $PM_{2.5}$) produced during the ship's activity inside port (inbound-outbound moving, maneuvering and at berth) have been estimated. (Maragkogianni and Papaefthimiou, 2015).

2.2. Monetization of health impacts

The monetization results of the anticipated health benefits of using SSE on ships at berth in EU ports (instead of using their combustion engines) were estimated for the years 2010 and 2020. For this purpose, the marginal damage costs caused by emitted emissions by combustion engines of the ships while at berth have been compared with the ones by using SSE to generate electricity. 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 data were employed: Dimension of port handling; Types of ships berthing in the port; Geographical location (SECA zone yes/no); Engines' emission factors; Energy mix per country. The energy mix related to the port level for 2012 was based on the gross electricity generation per EU Member State, published by Eurostat (2015), while data for the energy mix for 2020 were based on the electricity generation per EU Member State published by Eurelectric (2013).

In order to accurately estimate the total external costs due to emissions to air in ports, results from New Energy Externalities Development for Sustainability (NEEDS) were used. NEEDS is the most updated methodology, covering all major pollutants and all EU Member States. It includes all European sea territories (thus being appropriate for correctly calculating the external costs of maritime transport related emissions), and quantifies not only health effects (that correspond to over 90% of the total external effects) but also the side effects of emitted NO_x and SO_2 on materials (i.e. buildings), biodiversity and crops. For maritime transport, in NEEDS, specific damage cost values for all major pollutants have been calculated for all European sea regions using the EcoSense model (Korzhenevych et al., 2013; Holland et al., 2005).

3. Results

The results of the evaluation of the theoretical maximum potential of SSE in terms of GWh for year 2020 are presented in Fig. 1. If all seagoing ships in European harbors would use SSE by 2020 for covering their energy demand at berth, they would consume 3342 GWh annually (or 3543 GWh if we also consider inland shipping), which is approximately 0.1% of the electricity consumption in Europe as a whole in 2012. Fig. 1 also denotes the excessive energy demand of cruise ships while staying in-port due to their hotelling activities, as their annual electricity consumption in ports (i.e. 1334 GWh) represents 39.9% of the total.

The energy requirements in terms of annual electricity consumption (GWh/a) for EU seaports in 2010 and 2020 have been estimated based on detailed analysis of the traffic in each port, and results are depicted in Fig. 2. 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 small anticipated increase in some areas (Ecofys, 2015).

The detailed study of 10 of the largest cruise ports in the Mediterranean Sea (see Fig. 3) provided the total in-port emissions inventory of cruise shipping which accounted to 225,980.5 t, with NO_x – SO_2 – $PM_{2.5}$ being the minority compared to GHG (6448.9 and 219,531.6 t respectively). Emissions during hotelling were almost 85% of total significantly outweighing those produced during ships' maneuvering activities. Seasonality was found to play a major role, as emissions during summer prevailed due to the augmented in-port presence of cruise ships. An obvious increase in autumn emissions was observed as the touristic season has been extended towards October and November in almost all major ports. The estimated annual electricity consumption for SSE was 121.7 GWh, and it was homogeneously distributed among all ports

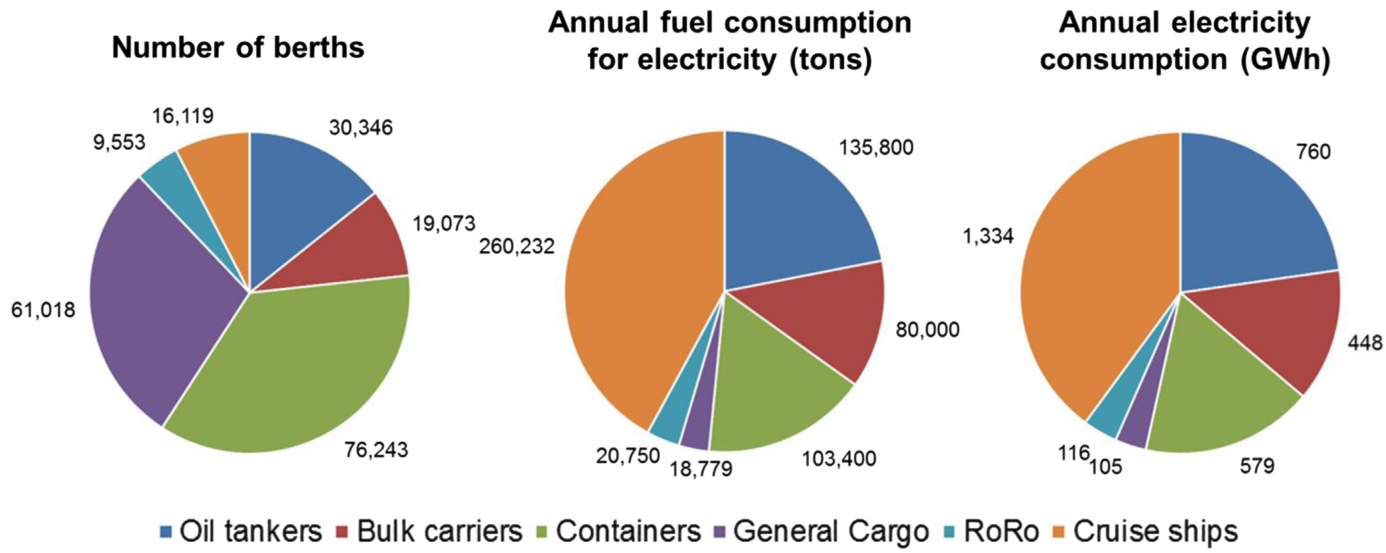

Fig. 1. Technical details and evaluation of the theoretical maximum potential of SSE of ships at berth in EU ports for year 2020.

depending on the number of ship calls. The estimated cruise ships emissions inventory is significant in terms of human health impacts (especially for the of $PM_{2.5}$ emissions), thus highlighting the need for relevant policy-making and control action especially in-port related residential areas.

The detailed monetization results of the anticipated health benefits of using SSE on ships at berth in EU ports (instead of using their combustion engines) for year 2020, are presented in Fig. 4. The monetized health benefits (by using SSE instead of burning fuels while ships are at berth) were calculated as the balance between the marginal damage costs of ships at berth meeting their energy demand by burning fuel and by using SSE. Thus, a positive health benefit is visualized as a negative number (in terms of the amount of money which is avoided by using SSE). With regards to

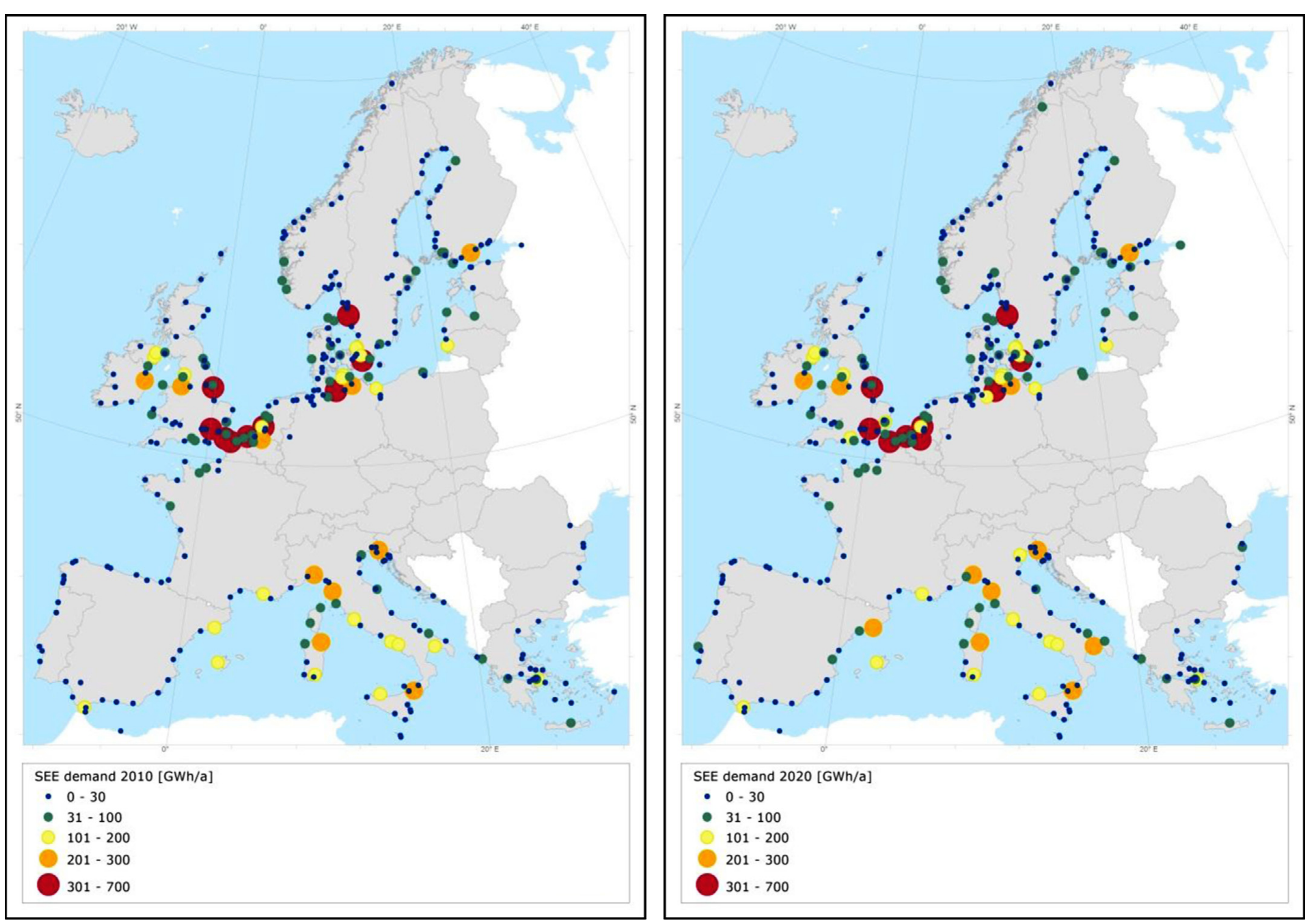

Fig. 2. Estimated SSE yearly energy demand for each port in Europe for 2010 and 2020 (GWh/a).

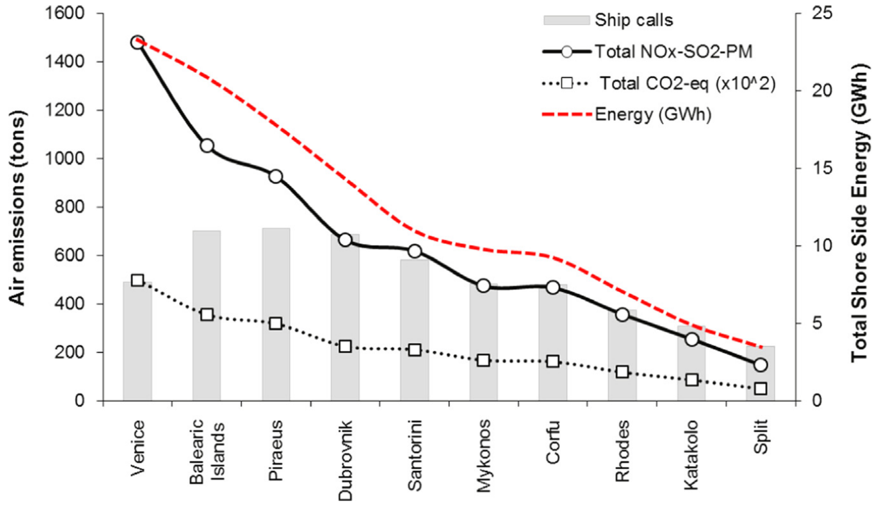

Fig. 3. Annual emissions to air and electricity consumption of various EU ports for cruise ships at berth.

PM and sulphur emissions, the values range from smaller positive values to greater negative values. Thus the smallest bullet (0–100 × 1000€, in monetized health benefit SO_2 in Fig. 4) means that the use of SSE causes more damage costs than using ships' engines.

The total energy demand of ships at berth mainly depends on the amount of hours of each type of ship stayed at berth and the combination of berthing ships-types due to the main goods handling or cruiser/ferry presences at the port. With regard to NO_x emissions 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 NO_x. In Fig. 4, the EU Emission Control Areas (ECA) are also depicted. A sea region is defined as when stricter control measures have been established to minimize airborne emissions. 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. As of 2011 in ECA or in more detail in Sulphur Emission Control Areas (SECA), the sulphur fuel requirements have been stricter. Concerning sulphur emissions, the marginal damage costs in the SECA zones are relatively low. On the other hand the amounts for the Mediterranean area, Ireland and the west part of the United Kingdom are remarkably high.

Based on the methodology described in paragraph 2.2, the total anticipated health benefits by using SSE in EU were estimated to 2.63 and 2.94 billion € for 2010 and 2020 respectively. Fig. 4 visualizes high health benefits especially in the main ports of The Netherlands, Belgium, Germany, Italy and UK, while similar results could be reached in ferry terminals. The maps also show that SSE would be an appropriate solution to lower sulphur emissions outside the SECA zones, as it would reduce emissions and damage costs in these areas. It can be easily inferred that 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, the investment in SSE infrastructure won't bring a monetized health benefit or even more – the use of SSE

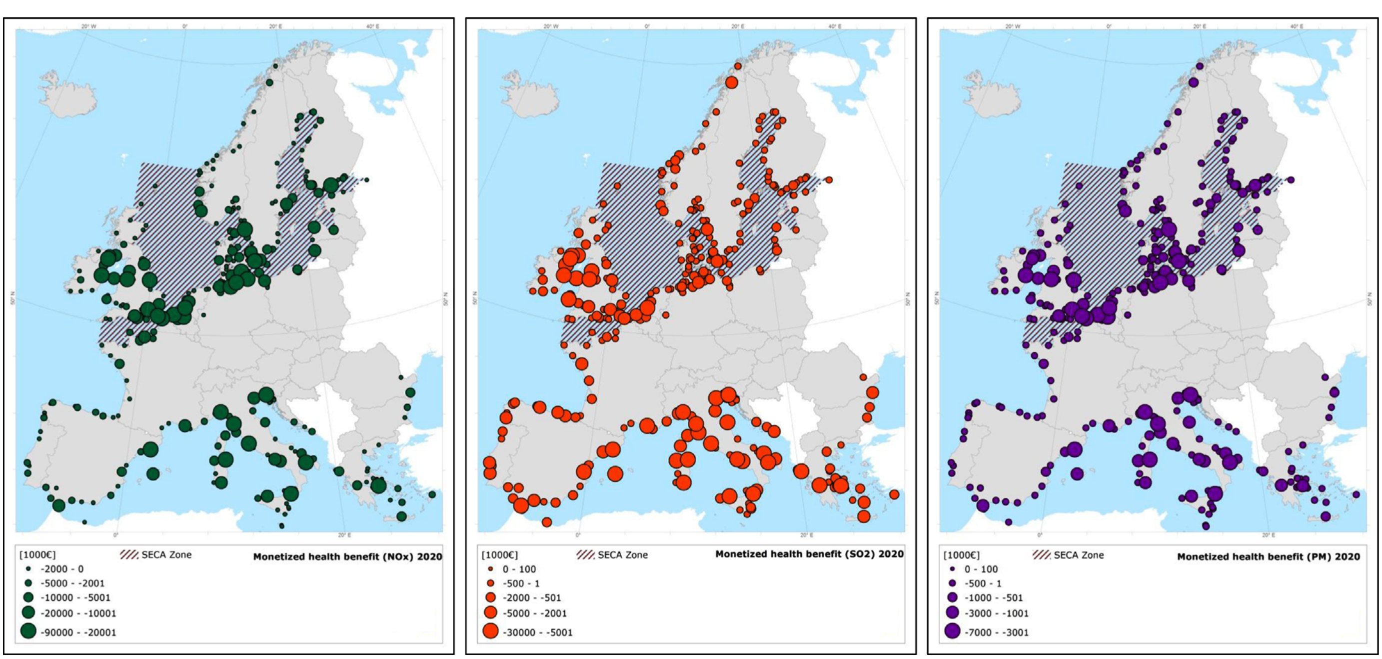

Fig. 4. Monetized health benefit (for NO_x, SO_2 and PM) by using SSE instead of burning fuels while ships are at berth in 2020.

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 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. Especially for countries or islands for which electricity generation depends highly on fossil fuel and will still depend on it by 2020, it is 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.

4. Discussion

4.1. Comparative assessment of relevant EU policies

There are presently no international requirements that would mandate or facilitate the use of SSE obligatorily. Within the EU framework, the Commission has published a non-binding recommendation directly on SSE in 2006 as the first concrete action to deploy SSE in Europe (EU Commission Recommendation 2006/339/EC, 2006). This recommendation refers to the responsibility of Member States to build up instruments and regulations to deploy SSE. Other relevant law enforcing actions propose that the use of SSE will allow an exemption of the 0.1% sulphur content (EU Directive 2005/33/EC, 2005) and promote the reduction of the financial disadvantage of SSE due to electricity taxes (EU COM (2007)575, 2007; EU Directive 2003/96/EC, 2003). Such forms of recommendations are not considered as strong instruments to speed up the SSE development. The most promising relevant political action in Europe is the 2014/94/EU binding directive on the deployment of alternative fuel infrastructure (EU Directive 2014/94/EU, 2014).

The electricity 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 (EU Directive 2003/87/EC, 2003) but none of the Member States has used this option so far.

On the EU-level, ports are in the focus of regulations to deploy SSE and this seems to be obvious as the infrastructure is a key element for the expansion of every new technology. But these regulations result mainly in high investment requests on port level without a view of foreseeable revenues. Thus, this uncomfortable situation where new infrastructure is necessary to be provided for ships to mitigate in-port emissions raises a fundamental 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 and local governments, port authorities and operators, utilities). The preceded assessment shows that the main financial burden lies on the ports, which are directly addressed through regulations to provide infrastructure for SSE but do not profit from offset measures. On the contrary, electricity producers and electricity devices suppliers seem to profit from these regulations without the need for investments. EU regulations need to be implemented in conjunction with financial or organizational supporting schemes for the infrastructure investments.

4.2. Barriers for EU-wide shore side electricity in ports

SSE is still a young approach for the maritime ports and the supporting technology is not well established yet. Operational SSE pilot projects report predominantly positive feedback, especially on social and environmental benefits. Governmental support or legislation enforcement was mainly involved in these cases. The first step towards more massive implementation should be to focus on harbors or quay areas in ports were potential positive impacts will be most beneficial, such as passenger waiting areas, ports close to densely populated regions and cruise ships.

A key challenge is that the potential investors do not necessarily benefit economically from SSE, since the social and environmental benefits are yet difficult to quantify or distribute. A major barrier is the taxes imposed on the electricity, because it competes with the ships' 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 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 application of local renewable electricity production.

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.

In the following paragraphs, the main barriers with respect to the development of the necessary SSE infrastructure are presented. Furthermore, results regarding the impact of SEE implementation on the electricity grid and detected sensitive areas are presented and this section closes with the establishment of the carbon content of electricity provided.

4.2.1. Technical issues

The release of an ISO standard relevant to High Voltage Shore Connection (HVSC) Systems was an important step to dismantle technical, practical and economical barriers (ISO 80005-1, 2012). There are only minor issues remaining from the technical point of view, neglecting economic aspects. For the 50/60 Hz case 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 on-board. It could be considered by ports and shipping companies in the development to put only one transformer onshore instead of several located on 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.

4.2.2. Economic costs

The investment costs for the electrical system on the sea ship side is significant (approximately € 500,000 for a typical 2 MVA connection). Retrofit option is 1 million US$ per ship. 99% of the ships operate at 60 Hz, so in all European ports frequency converters are necessary (either onshore or on-board), if the regular grid is used. A dedicated 60 Hz network could also be an option. The business case would be best for the ships that visit the dock

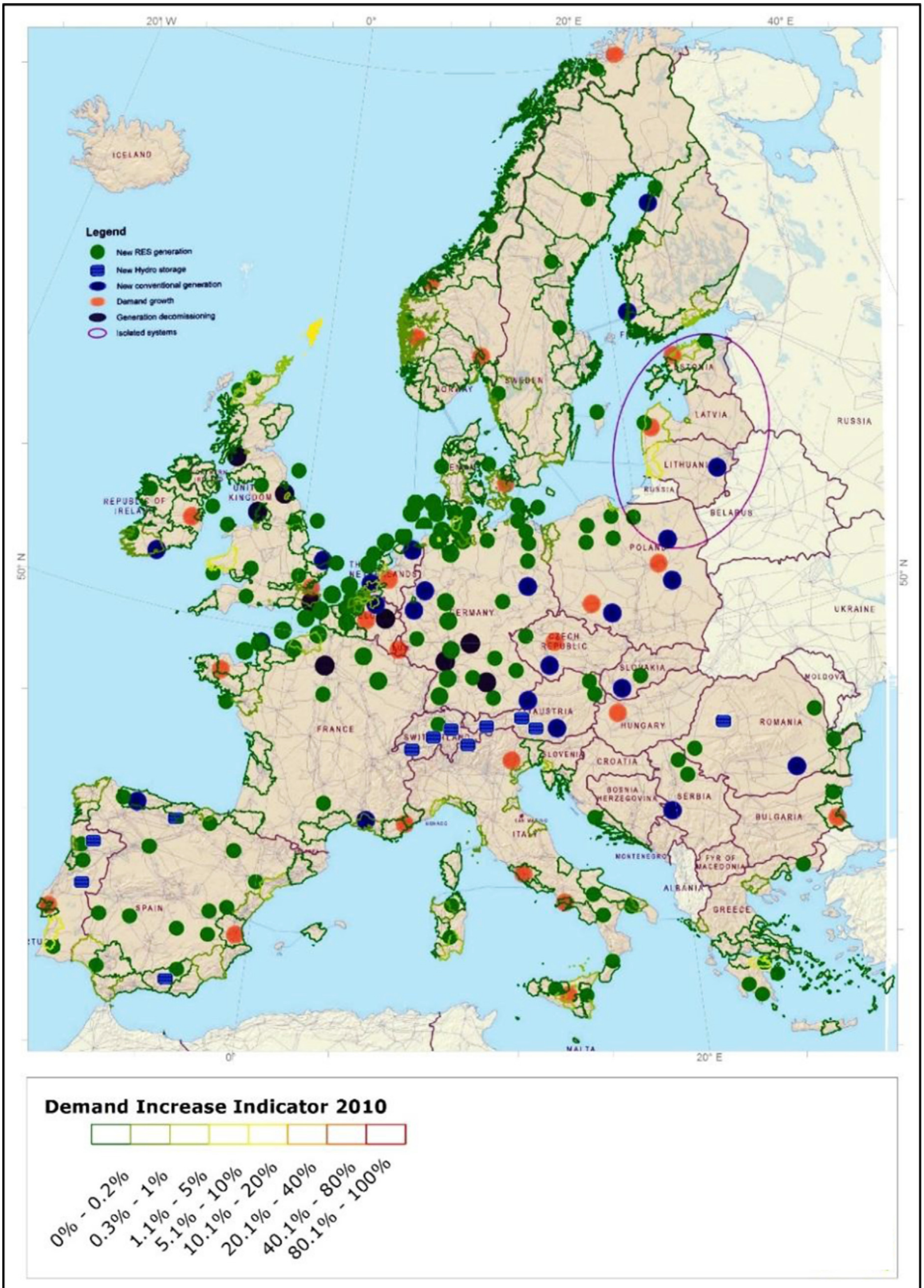

Fig. 5. Layer-overlay, ENTSO-E grid development drivers and SSE demand increase indicator (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.).

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. 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, 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 on-board. (Sisson and McBride, 2010).

4.2.3. Potential impacts to the EU electricity transmission system

The effects of SSE implementation to the EU electricity transmission system were also investigated and the impacts to local distribution grids were directly assessed through a demand increase indicator (%). This 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. The different areas were classified based on the expected load increase and the general strength of the local network, which was assessed based on the location of the port with respect to the industry, demand centers (large residential areas) and large power plants. To assess the strength of the transmission system in the area, the expected congestion level of the identified zone was investigated based on the analysis provided at the Ten Year Network Development Plan (TYNDP) of the European Network of Transmission System Operators for Electricity. The TYNDP analysis shows the key drivers and expected bottlenecks in the transmission system in the EU (Ecofys, 2015; ENTSOe, 2012).

Fig. 5 visualizes these results, by overlapping the ENTSO-E grid development drivers and SSE demand increase indicator. This approach allowed the assessment of the key impacts of load increase to the transmission system. As can be seen, transmission system development is driven by the large increase in renewable energy sources (green points) in coastal or offshore areas. 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.

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 renewables are installed and generation and transmission matters are growing in future.

4.2.4. Carbon content of SSE

The carbon content of the electricity provided in EU regions was also estimated based on relevant data and key indicators of the electricity generation mix of each EU country. The development of the electricity generation mix in the latest years and the projections for the future were taken into account and the carbon content of the electricity provided to the SSE ports was calculated. Thus the potential in reducing carbon emissions through SSE implementation in Europe can reach 800,000 t of CO_2, i.e. a reduction in yearly CO_2 emissions for all maritime shipping of 39%.

For most EU Member States, SSE implementation would contribute to decrease CO_2 emissions. In countries with high carbon content in their electricity supply (CO_2 emission factors larger than 650 gCO_2/kWh produced), the use of SSE from the national electricity grid would lead to an increase of emissions compared to using the standard diesel generator on-board ships. This is the case for example for Poland and Estonia, where the emission factors are 835 and 665 gCO_2/kWh respectively, mainly due to the high use of lignite and hard coal for energy generation. Nevertheless that does not mean that SSE should not be used in these countries, because a big advantage is that SSE moves the pollutant (air emissions from 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.

5. Conclusion and policy implications

This study aims to provide a reference for policy-making on how to enable the transition towards SSE in EU ports and to define a clear set of recommendations and possible measures for the stimulation of the deployment of SSE towards 2020. The presented results indicate that the total anticipated health benefits by using SSE in EU ports were estimated to 2.94 billion € for 2020, while the potential for reduction of carbon emissions reaches the 800,000 t of CO_2. Mitigation activities should at first aim at cruisers and ferries as they present the best business cases for SSE implementation with regards to their high energy demand. Furthermore, the focus should lie in the beginning on areas in the ports were impacts are most intense, like passenger waiting areas, ports close to residential areas, cruise ships and quays.

Deployment of SSE in maritime shipping is challenging but necessary to reduce the environmental impacts of the maritime sector, especially at local level in ports and especially those in close proximity to residential areas. The potential for SSE in Europe is high, while the anticipated health benefits and greenhouse gas emission reductions are proven in this study worth deploying the use of SSE. Furthermore, the exploration of the SSE potential in the main areas of Europe would not cause serious grid problems.

The actors who are typically requested to invest on the necessary infrastructure, 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. 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. The EU as the major institutional entity already plays a stimulating role in the deployment of SSE aiming at the mitigation of induced environmental burdens.

To set the course towards deployment of SSE in Europe the following aspects should be elaborated upon, mainly through relevant policy measures:

1. ***Financial* incentives:** To solve the “chicken and egg” financial 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.

Another important question that needs answer is who should pay for the infrastructure. In general port authorities and relevant stakeholders think 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 cases for the ports for partially repayment of the investments by those parties who profit from the infrastructure. This could include measures as:

- ports get a charge on the sold electricity from the electricity supplier, as a repayment for the infrastructure;
- ports get a charge on the sold electricity from the terminal operators, as a repayment for the infrastructure;
- ports get a charge on the sold electricity as a repayment for the infrastructure from the ships owners–operators.

Another way could be a case in which the central actor would be the electricity supplier, thus bypassing ports. It should be avoided that the electricity price for SSE will vary significantly between ports and Member States, as there are different regulations on energy supply in countries. Price factors such as peak loads also need to be taken into account. In designing a measure it is also important to keep in mind the economic and physical size of ports: smaller ports may have less means to comply with a measure. The 50/60 Hz hurdle weakens the SSE implementation scenarios, but it will not be solved in the near term. There is not much which can be done about this issue other than accept the higher costs.

2. ***Fiscal incentives*:** Regulations on Member States level have to consider the very individual structure of the European ports, as intense variations in the structure between port authorities (private or public entities), terminal operators, port operators, are observed even within the same country.
   A tax reduction on electricity used in SSE might be an appropriate measure. As there are no taxes on fuel 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.
   On the other hand, the electricity currently used for SSE apart from being taxed it is also covered by the EU-ETS, unlike the fuel that would have otherwise been used in the ships auxiliary engines. In order to ameliorate this environmental discrepancy the Member States are allowed to include activities or installations relevant to ships or ports into the EU-ETS, but none has yet used this option.
3. **Operational issues:** In some EU countries where the onshore electricity is mainly produced from oil, there is no benefit regarding emissions 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 potential for energy production through renewables for port authorities should be investigated and business cases for self-consumption via SSE should be created. Funding should be developed to encourage implementation of smart-grids and enable port authorities or the electricity providers to build up renewable energy generators for the port area including or in combination with the installation of SSE infrastructure on smart-grid implementations. Such approaches could allow the SSE system to support the security of supply on the electricity network level.
   Furthermore, it is important to have a user-friendly system in place that enables easy connecting and disconnecting. Traffic is probably moving too fast in some ports or the berthing times of RoRos or ferries might be too limited to make use of SSE, but these issues have to be considered for each port or quay individually.
4. **Technical assessment:** The success of SSE depends on the attitudes of both parties on the shore side (i.e. ports) as well as ship owners. Some vessel operators have already invested in SSE equipment on-board while the release of the relevant ISO standard was a crucial step. For the disadvantage of having 60 Hz systems on-board ships and 50 Hz onshore, a technical solution (converter) is in place that allows the ports to support both systems if needed.

In general the demand increase caused by SSE is not seen as problematic for the electricity grid (at least from the transmission grid perspective), 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 EU areas. SSE might even have positive effects for some coastal areas where the share of renewables is expected to grow now or in the future.

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