Environmental and societal benefits of Onshore Power Supply for Inland Navigation in Flanders (Belgium)

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ABSTRACT

The use of the auxiliary engines by ships when at berth causes greenhouse gas emissions, air quality emissions and noise pollution in the port areas, which are often located in or near cities. Onshore Power Supply (OPS) is an option to provide electricity to the ships from the national grid and to reduce the unwanted environmental impact of ships at berths.

In recent years, the interest in the use of OPS has strongly increased in the Flemish ports and inland waterways. One of the actions to encourage the expansion of onshore power facilities was the setup of the Flemish Shore Power Platform (www.binnenvaartservices.be) which coordinates all actions related to the use, implementation and expansion of this environmentally friendly technology for inland navigation in Flanders.

Data on electricity consumption by a specific ship from two European projects (TEN-T project “Shore Power in Flanders” and CLean INland SHipping project) has been used to quantify the benefit of reducing the emissions of NOx, SO2, PM and CO2 that would occur by using onshore power supply.

Emissions through the use of auxiliary engines (diesel-related emissions), Emissions through the use of OPS (electricity-related emissions), and Net reduced emissions through the introduction of OPS have been calculated.

The results demonstrated that OPS can significantly reduce diesel-related emissions from ships at berth. Through the introduction of OPS the emissions of NOX can be reduced by about 93%. The emissions of PM10 can be reduced by 99% and the emissions of SO2 by more than 96%. The emissions of CO2 can be reduced by more than 90%. The reduced emission of C02 in this study is high compared to other studies, this is due to the low CO2 emission factor for electricity production in Belgium that we applied in our calculations.

In 2016, the use of OPS at only two locations has generated a total societal benefit of € 53,814. The overall use of OPS for only inland navigation in 2016 in the port of Antwerp was 766 MWh, represents a societal benefit of € 108,381.

We conclude from our analysis of the evidence that providing an onshore power supply for vessels at berth can result in significant environmental and societal gains. A communication strategy should be put in place, focusing on adequately informing and thereby stimulating the use of onshore power supply. The results of this paper can be used as basis information to convince the ship-owners of the environmental and societal benefits of OPS. River cruisers have higher power and electricity demand providing a better business case for OPS for inland navigation and a better prospect for market development. Policy makers could produce more net societal gain by implementing incentives and mandates to encourage more shift toward OPS.

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1. INTRODUCTION

Inland waterway transport plays an important role in the transportation of goods within Europe. In the EU27, navigable waterways stretching over 43,000 kilometres connect hundreds of cities and industrial regions. Because it’s connected to Europe’s most important markets, Flanders is the starting point for major freight transport via inland waterways. The river and canal network of Flanders is one of the most dense in the world, extending over 1,357 kilometres.

Inland waterway transport is an emission category that may be relevant for air quality in the vicinity of busy navigation routes or ports. Emissions from inland shipping are usually reported under the source sector non-road transport.
Shore power is the notion which indicates that a ship is connected to a shore side electrical power unit for its power supply on board. Ships at berth basically use their own generators to produce electricity. Running diesel engines in the port however, is unnecessary stressful for the environment. It produces mainly emissions of CO2, NOx, SOx and fine PM10 particles.

During the last years, the interest in the use of Onshore Power Supply (OPS) has strongly increased in the Flemish ports and inland waterways. The continuous expansion of OPS facilities also contributes to the implementation of the Flemish 3E Inland Navigation Covenant of 2009 and the 3E Inland Navigation Plan, aiming amongst others at a significant reduction of CO, NOx, fine particles and CO2. The Air Quality Plan approved on March 30th, 2012 by the Flemish Government containing measures to achieve the proposed NO2 concentrations in 2015, also foresees actions to encourage the use of shore power facility. Meanwhile, the measures for inland navigation (shipping) of the Air Quality Plan were adopted by the Government of Flanders on 30 March 2011 and must therefore effectively be implemented.

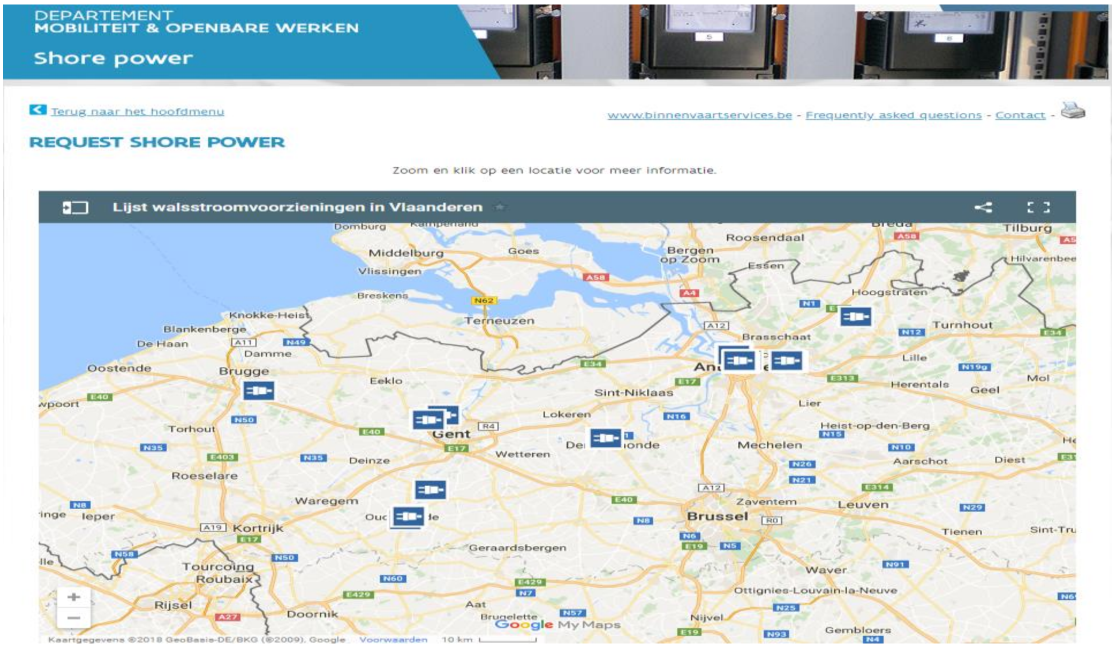

Figure 1. Overview of OPS network in Flanders.

The first action to encourage the expansion of shore power facility has been the setup of the Flemish Shore Power Platform (FSPP) (www.walstroomplatform.be) which coordinates all actions related to the use, implementation and expansion of OPS for inland navigation in Flanders. The Flemish shore power platform is involving the Flemish inland waterways managers, port managers, shippers organisations, ports and water policy officers, and stakeholders.

Several OPS-projects at local scale have been conducted by the partners of the FSPP. One of those projects is the TEN-T project (Shore power in Flanders_2012-BE-92063-S). The project's overall objective was to establish an OPS network (Figure 1), including the development of a management and payment system, for inland navigation in Flanders to contribute to its development as an environmentally friendly alternative to road transport. This management system provides the OPS managers with real time data on electricity consumption by a specific ship in a specific location. This data has been used, in the framework of the CLINSH - CLean INland SHipping project, to assess the environmental and societal benefit of using OPS in inland navigation.

This paper aims to demonstrate that providing an onshore power supply for vessels at berth can result in significant environmental and societal benefit by reducing emission of NOx, SO2, PM and CO2.

2. ESTIMATION OF EMISSION REDUCTION

2.1 Use of data and technical characteristics of the OPS system in Port of Antwerp.

Data on electricity consumption by a specific ship in 2016 at quay K75 and at quay K15 in the Port of Antwerp has been used to estimate emission reductions (NOx, SO2, PM and CO2) by using onshore power electricity.

At K75, nine new onshore power supply systems were commissioned in September 2014 (Figure 2). Seven of these consist of 4 connection points each (1 x 63 A; 2 x 32 A; 1 x universal socket of 230 V). The other two consist of 3 connection points (2 x 63 A; 1 x 125 A), which are dedicated for liquid bulk tankers. The onshore power supply systems at K15 were commissioned in January 2016 and are dedicated for use by river cruises. At this location, four systems consist of 2 connection points each (1 x 400 A; 1 x 125 A).

Figure 2. Shore power installations (low voltage) at quay 75 in Port of Antwerp

In 2016, a total of 203 cargo ships, 183 river cruises, 15 tank ship, and 50 towboat have used the OPS installations at quay K75 and at quay K15. The total electric power consumption of the shore power boxes at K75 and K15 combined, was 19762 kWh for Cargo ship, 2273 kWh for Tank ship, 7066 kWh for Towboat, and 349874 kWh for river cruises.

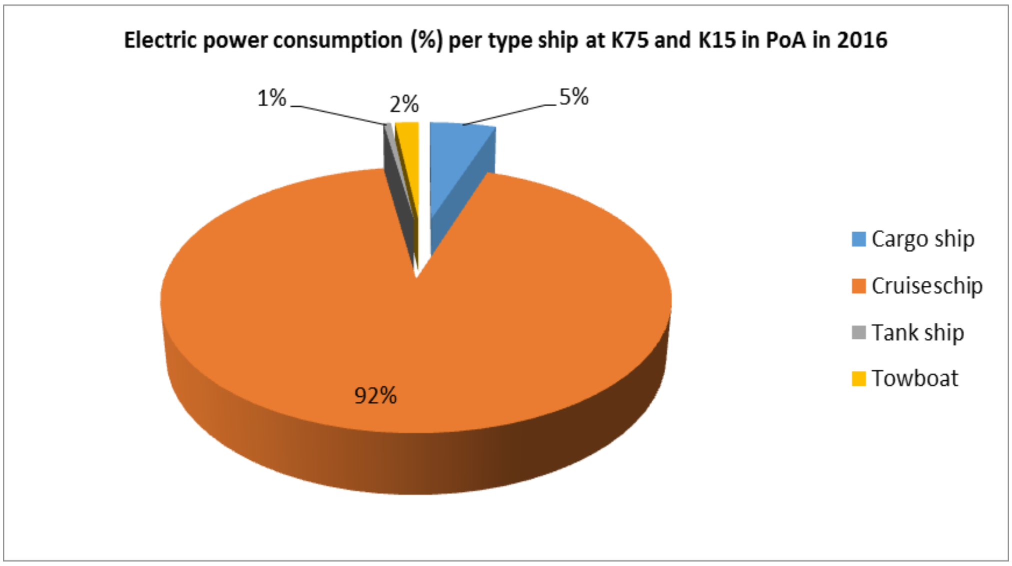

Figure 3. Electric power consumption (%) per type ship at K75 and K15 in Port of Antwerp in 2016.

The electric power consumption of the river cruises represent more than 92% of the total electrical power consumption (Figure 3). However the cargo ships spent longer time at berth (61 %) than river cruises (22%) (Figure 4).

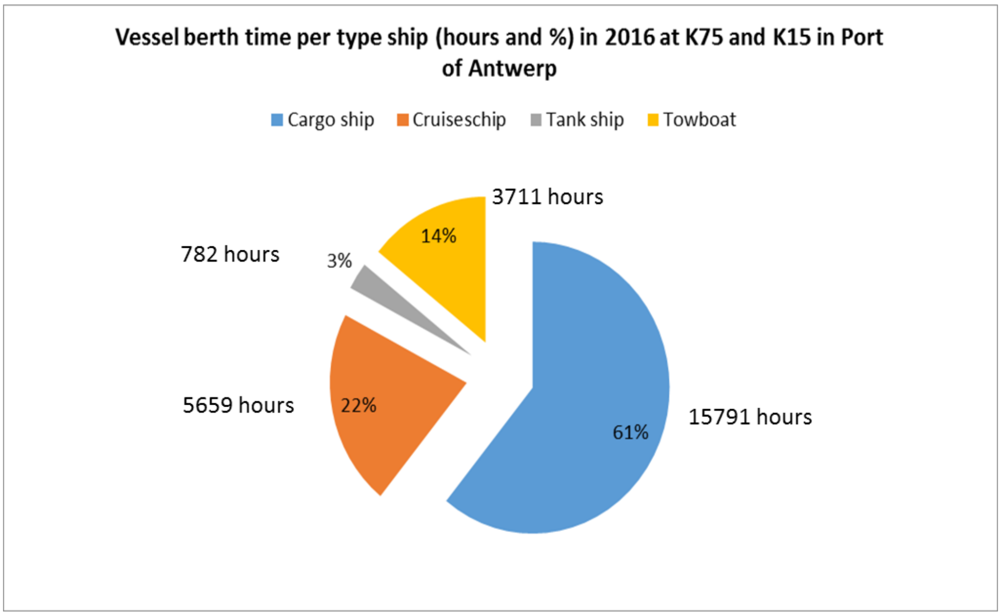

Figure 4. Vessel berth time per type ship (hours en %) at K75 and K15 in Port of Antwerp in 2016.

River cruises have higher power and electricity demand and thus provide a better business case for OPS and better prospects for market development.

2.2 Assessment to quantify the benefit of reducing NOx, SO_2, PM and CO_2 emissions.

One measure to reduce emissions from Auxiliary Engines while at berth is to provide electricity to the ships from the national grid. Onshore power supply (OPS) 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.

We used historical vessel call data at K75 and K15 in Port of Antwerp to quantify the benefit of reducing the emissions of NOx, SO_2, PM and CO_2 that would occur if onshore power were used.

The equation (1) has been used to calculate the net reduced emissions through the introduction of OPS :

$$A = B - C \qquad (1)$$

A: Net reduced emissions (kg)
B: Emissions through the use of auxiliary engines (kg)
C: Emissions through the use of OPS (kg)

2.2.1 Calculation of diesel-related emissions through the use of auxiliary engines (B)

The amount of fuel used by ships during berth at the quay is a measure of the emissions. The used amount of fuel is the product of the number of ships, length, power output and specific fuel use to a certain amount of energy. The equation (2) has been used for calculating emissions from inland shipping (Denier van der Gon, & H., Hulskotte, J. 2010) :

B (kg) = Number of ships x Time at berth (h) x Power (kW) x Specific fuel consumption (kg fuel/kWh) x Emission factor (kg/kg fuel). *(2)*

Number and vessel berth time per ship have been provided by the management system of Port of Antwerp.
The available data on power of auxiliary engine per ship has been derived from the database of the Belgian Federal Public Service Mobility and Transport.
Accurate estimates of emissions from ships at berth demand reliable knowledge of the fuel consumption while at berth and associated fuel characteristics. For the missing data the average value of 100 kW has been used according to the TNO-report (Hulskotte et al 2008).
For the specific fuel consumption a representative value of 200 grams per produced kWh gas oil (Hulskotte et al 2008) has been used. Table 1 gives the different emission factors (g/kWh) per type of fuel used for the CO_2, NOx, PM10 and SO_2.

	CO_2	NOx	PM10	SO_2
Gas-oil	3160	50	2	2

Table 1. Emission factors per type of fuel used for the CO_2, NOx, PM10 and SO_2 as reported in the TNO-report (Hulskotte et al 2008).

2.2.2 Calculation of emissions through the use OPS (C)

The local emissions avoided by the introduction of OPS lead to additional emissions in other locations resulting from the generation of the electricity. The equation (3) has been used for the calculation of emissions from the use of OPS :

C (kg) = consumption OPS-electricity (kWh) x emission factors for electricity production in Flanders/Belgium. *(3)*

The emission factors that apply to the current electricity production in Belgium have been used (table 2). Those factors are relatively low in Belgium (as example. 285 g CO2/kWh) compared to the average emissions factor in Europe (402 g CO2/kWh) because of the use of the nuclear power plants and the use of renewable electricity production.

	CO2	NOx	PM10	SO2
Emission factor	285	0.325	0.005	0.06

Table 2. Emission factors (g/kWh) for electricity production in Belgium (Milieurapport 2016).

<u>2.2.3 Net reduced emissions when using OPS (A)</u>

As mentioned previously the net reduced emissions when OPS has been used was calculated using the equation (1). In Figure 5 shows that the absolute amounts of emissions saved or reduced can be mainly found in the substance CO2 and relatively in NOx. The biggest emission reductions comes from the cargo ships and river cruises that use the most energy in absolute terms.

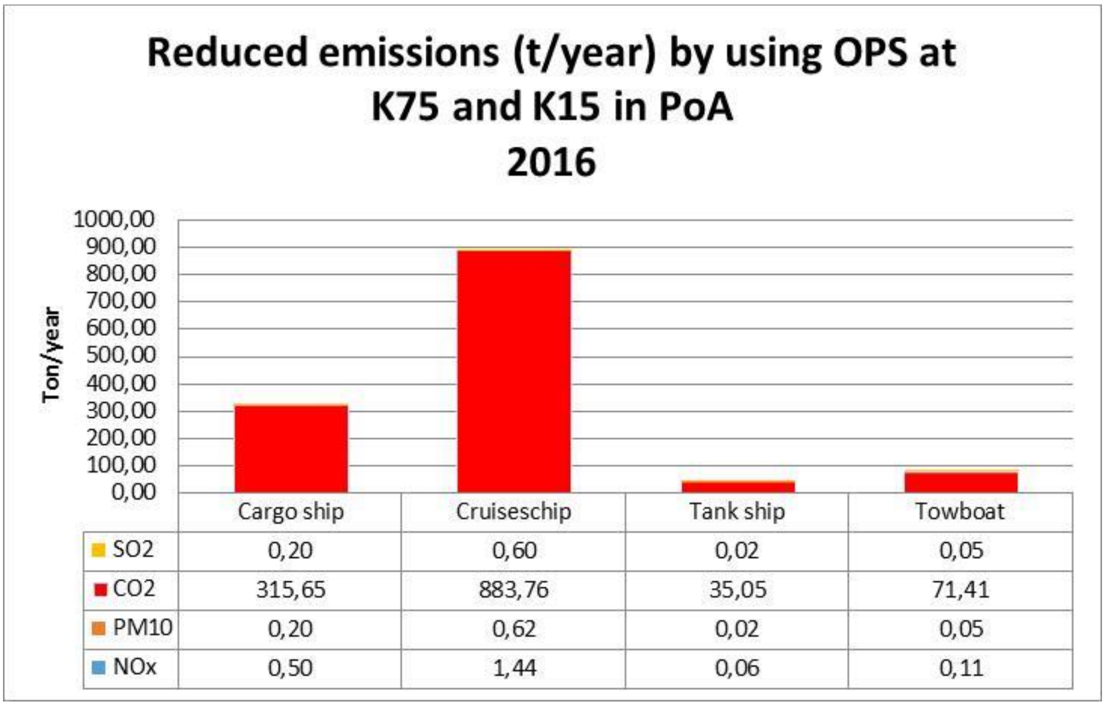

Figure 5. Reduced emissions (t/year) by using OPS at K75 and K15 in Port of Antwerp.

The relative savings of emissions is more interesting because this says more about the specific benefit of the introduction of OPS. Table 3 presents the estimated percentage values of emission reduction efficiencies of OPS in 2016 at K75 and K15 in Port of Antwerp.

Type ship	NOx (%)	PM10 (%)	CO2 (%)	SO2 (%)
Cargo ship	98,74	99,95	98,25	99,42
Cruise ship	92,69	99,72	89,86	96,63

Tank ship	98,69	99,95	98,19	99,40
Towboat	98,02	99,92	97,26	99,09

Table 3. Estimated percentage of emission reduction efficiencies of OPS in 2016 at K75 and K15 in Port of Antwerp

2.3 Assessment of societal benefit of using OPS.

Using historical vessel data, we identify combinations of vessels and berth at K75 and K15 terminals that has been switched to onshore power to the largest societal benefit. The electricity consumption through the use of OPS at K75 and K15 in 2016 has been calculated.
We used the monetized societal benefit (mainly health care) when using onshore power. Taking into account the societal costs (mainly health care) of NOx, CO_2, PM_{10} and SO_2, we assumed that the use of 1 MWh onshore power has a societal benefit of 141.49 euro (AEA Technology Environment 2005). This societal benefit has been used for all combinations of vessels and berth in 2016 at K75 and K15 in 2016.

Table 4 shows the monetized health benefit by using OPS instead of burning fuels while ships are at berth. It is clear that river cruises have the most societal benefit when using OPS while at berth. This is because of the high electricity consumption by the river cruises.

Type of ship	Societal benefit of using OPS (EURO)
Cargo ship	**2,806**
Cruiseschip	**49,682**
Tank ship	**323**
Towboat	**1,003**

Table 4. Potential societal benefit (Euro) of using OPS at K75 and K15 in Port of Antwerp in 2016.

3. DISCUSSION

Proper estimation of shipping emissions is essential for an impact assessment of shipping on air quality and health in port cities and coastal regions. However it is important to stress that the objective of the current report is not to report on the methodologies to estimate emissions from inland shipping. The methodology for calculating emissions from inland shipping has been described by several reports (Hulskotte et al., 2003c; Oonk et al., 2003a; Klein et al. (2007); Hulskotte H.J & Jonkers S 2008; Hulskotte & Van der Gon, 2010 …). The objective of this paper is to demonstrate the environmental and societal effects of using OPS in inland navigation by using the methodology described in Van der Gon, H & Hulskotte, (2010). The relative savings of emissions is more interesting because this says more about the specific benefit of the introduction of OPS.
Inland shipping is an emission category that may be highly relevant for air quality in the vicinity of busy navigation routes or ports.

The results demonstrated that OPS can contribute to a largely emission reduction at local level. Figure 5 shows that the greatest reduction has been noted for the CO_2 compared to the other pollutants. This is mainly due to the fact that the CO_2 emission factor that apply to the current electricity production in Belgium is relatively low (285 g CO_2/kWh compared to the average emissions factor in Europe 402 g CO_2/kWh), because of the use of the nuclear power plants and the use of renewable electricity production in Belgium.

This is an very important issue. If renewable energy from water or wind is used, CO_2 emissions will be zero or near–zero, thus clearly giving the greatest CO_2 reductions. In Belgium, most electricity suppliers are able to supply renewably-sourced power. Implementation of OPS provides an opportunity not only to improve air quality, but also to reduce emissions of carbon dioxide, one of the main contributors to global warming. By switching from fuel oil to gas as an energy source or, better still, to sustainably green generated wind power, for example, CO_2 emissions can be curbed.

Figure 5 shows also that the greatest emission reductions comes from the cargo ships and river Cruises that use the most energy in absolute terms. The assessment suggests that onshore power may be most effective when applied at quays with a high percentage of frequently returning vessels, typically river cruises and cargo ships. The electrical power consumption of the river cruises represent more than 92% of the total electrical power consumption (Figure 3). However the cargo ships spent longer time at berth (61 %) than river cruises (22%) because of the highest number of cargo ships compared to river cruises (Figure 4). This means that the river cruises having higher power and electricity demand and less time at berth (compared to cargo ships) may provide a better business case for OPS for inland navigation and a better prospect for market development.

The relative savings of emissions in percentage is more interesting because this says more about the specific benefit of the introduction of OPS. In term of percentage of emission reductions, it seems that the emissions of PM_{10} can almost be completely avoided by 99% by the introduction of OPS. Emissions of SO_2 can almost be completely avoided by 99% for Cargo ship, Tank ship and Towboat and by 90% for Cruise ship. Emissions of CO_2 can almost be completely avoided by 98% for Cargo ship, Tank ship and Towboat and by 90% for Cruise ship. The reduction emission of C02 in this study is high compared to other studies (between 50% and 70% as reported as reported in the TNO-report by Hulskotte et al 2008, this is due to the low CO_2 emission factor for electricity production in Belgium that we applied for the calculations.

The percentage emission reduction has been estimated for a particular vessel, at berth when connected to shore power. Factors such as power consumption rate, type of auxiliary engine, type of fuel and total time at berth as described in the assessment were used to relate the overall effectiveness of onshore power. Because these factors must be evaluated for each situation, percentage of total emission reductions may slightly vary from vessel to vessel. The methodology can be used to further improve the emission estimates by using better local data (especially data on emissions factors for different auxiliary engines) when they become available.

In term of potential societal benefit, the local use of OPS in 2016 at only K75 and K15 has generated a total potential societal benefit of € 53,814. In 2016 was the overall use of shore-based power for only inland navigation in the port of Antwerp 766 MWh, representing a potential societal benefit of € 108,381.
The rates per kWh are dependent on the electricity price and the installation costs differ per kW for electricity connection. Due to the magnitude of shore power consumption, the rate charged to the inland navigation ships are close to the fares charged to households in Belgium, despite the high initial investment costs for electricity connection. Studies have shown that OPS can be beneficial for the ship-owners and port operators compared to generating electricity using fuel on-board, but ship-owners opinion are quite diverse about the cost effectiveness of OPS. Therefore a communication strategy should be put in place, focusing on adequately informing and thereby stimulating the use of onshore power supply. The results of this paper can be used as basis information to convince the ship-owners of the environmental and societal benefits of OPS.
Policy makers could also increase the net societal benefit by implementing incentives and mandates to encourage a shift toward onshore power supply. River cruises have higher power and electricity demand and thus provide a better business case for OPS for inland navigation and better prospects for market development.

4. CONCLUSION

Providing an onshore power supply for vessels at berth can result in significant environmental and societal benefit. Carbon dioxide emissions decrease substantially and emissions of Sulphur dioxide, PM10, and nitric oxide are reduced to a minimum. Through the introduction of OPS the emissions of NOX can be reduced by about 93%, emissions of PM10 can be reduced by 99%, emissions of SO2 by more than 96% and emissions of CO2 can be reduced by more than 90%.

Implementation of OPS provides an opportunity not only to improve air quality, but also to reduce emissions of CO2. By switching from to an green energy source generated wind power, for example, CO2 emissions can be curbed up to 99%. This result should be used as basis information to convince the ship-owners of the environmental and societal benefits of OPS.

Policy makers may play an important role to increase the net societal benefit by implementing incentives and mandates to encourage a shift toward onshore power supply. River cruises have higher power and electricity demand and thus provide a better business case for OPS for inland navigation and better prospects for market development.

River cruises have higher power and electricity demand providing a better business case for OPS for inland navigation and a better prospect for market development. Policy makers could produce more net societal benefit by implementing incentives and mandates to encourage more shift toward OPS.

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