RELIABLE WATERWAY TRANSPORT, FRESH AIR

Port characterization and data collection on existing and planned Onshore Power Supply in the Netherlands, Flanders and North Rhine Westfalia

Deliverable B2.1

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CLEAN INLAND SHIPPING

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Summary

Introduction

The key objective of Action B2 is to assess the environmental and economic benefits of onshore power supply (OPS) for the use of inland vessels and to develop guidance for the provision of grid-connected and mobile OPS and help to justify investments. The action will demonstrate how OPS can improve air quality and aid compliance with emission limits.

In this action we will give insights in the various business models, utilisation of OPS installations and reduced emissions. It is the ambition to outline possible OPS options for certain types of ports or port sections. Task B2.1 specifically, studied the characteristics of OPS initiatives in the Netherlands, Belgium (Flanders) and Germany (North Rhine-Westphalia and Lower Saxony).

Port Characteristics (Chapter 1)

For the business case of providing OPS, the following port characteristics are most relevant:

- type of berth (cruise, cargo and/or other)
- frequency and duration of mooring
- cost structure and pricing of OPS (price per kWh delivered)
- capacity of OPS cabinets installed (power rating, number of ships to be served)
- local governmental policy (willingness to invest in OPS, generator ban or not, enforcement)
- attitude of freight shippers towards OPS at their private quays (possibly by obligation)

When planning OPS, we should especially consider locations (i) where air quality and/or noise concerns are most pressing (near city centres and residential areas), (ii) where there is highest potential that OPS will be used. OPS is most needed and could be most successfully provided at quays, piers and docks in seaports and inland ports in the following situations, placed in priority order:

Table 0.1 Prioritization OPS investments

	Type of berth	Environmental (air quality, noise, CO2)	Economical (business case for port)
1	River cruise berths in home ports, ports of call and off-season (repair) ports	+++ if at city centre	+++ high power consumption
2	Waiting docks and overnight mooring for cargo vessels in home ports for skippers and crews, ports of distress along international (TEN-T) corridors (e.g. Waal river), and docks in/near seaports where vessels are waiting for consignments)	++ if near residential areas + if not	++ medium consumption due to relatively long connection time
3	Cargo terminals in Core and Comprehensive TEN-T network with sufficiently long duration of loading and unloading, provided that there is no interference between OPS and (un)-loading activities	++ if near residential areas + if not	+++ if usage of OPS energy directly impacts fuel savings for cargo terminal + low consumption due to relatively short connection time
4	Home ports for nautical service vessels (e.g. river police, fireboats, towboats)	+ often far from residential areas	+ OPS demand can easily be estimated, therefore better dimensioning
5	Maintenance and repair yards	++ if near residential areas + if not	0 most likely that the yard owner organises OPS themselves

Generic results data analysis and case studies (Chapters 3 and 4)

- The data analysis corroborates that the energy consumption by cruise vessels is much higher than for cargo and other vessels. It should therefore be easier to build the business case for OPS on river cruisers, although the costs (CAPEX and OPEX) will also be higher.
- The frequency and duration of mooring is most of all determined by (macro, meso, micro) economic factors, such as demand for cargo transport from or to a port, and demand for cruise holidays. No skipper will deliberately visit a port because of the quality or pricing of OPS on offer. The utilization of berths, and therefore of OPS provided there, will be higher in bigger and more important (frequently visited) ports.
- The utilization of OPS cabinets for cargo ships is the highest in the places where ships are waiting for new cargo for extended periods of time. Such places are found in the ports where the consignment is coming from, so in seaports like Rotterdam and Antwerp, and not along waterway routes. When it comes to OPS

utilization rate, this category of sites is followed by the weekend and night locations. This could however not be verified in the dataset.

- Other locations where vessels moor for longer periods are maintenance and repair yards and home ports for nautical service vessels (e.g. river police, fireboats).
- When visiting a port, the acceptance and willingness of skippers to use OPS is a relevant factor. We assume however that this is not a factor that differs between ports, although it does matter whether there is an on-board generator ban in place or not.
- The cost structure for providing OPS may differ in ports or at quays within ports, when clever solutions can be found for installing OPS cabinets and cabling, e.g. using medium voltage grid connections rather than low voltage (which provides better power purchase rates) or registering a group of OPS cabinets under one meter (which means that a lower energy tax rate applies).
- When the price of OPS is too high then it is attractive for the skippers to generate their own electricity on board, especially when diesel fuel is cheap. The price of OPS is more or less the same in most of the Netherlands and Flanders. There are cases where lower rates are charged or OPS is offered for free.
- According to interviews with port authorities and OPS service providers it is likely that the user acceptance of OPS has improved because of better technology, better service contracts (user apps, one invoice etc.), general habituation and the on-board generator bans that are in place in many ports. One interviewee at a port authority said that skippers and crew were initially hostile with regard to OPS but now show acceptance and appreciation of its convenience for life on board. First they complained about having to lift heavy cables, that OPS was dangerous and costly, and later that the system was not working properly and often gave faults. Now, there are actually nil complaints. Not even about the pricing, though that may happen again if the tariff would increase, he said.
- The type of port management (private, public) is important for the ability and willingness to invest in and make policy to promote use of OPS.
- The benefit of OPS to society will be highest in locations that are close to residential areas where vessels' noise and emissions cause nuisance and health impacts. This will increase the willingness to invest in and make policy to promote use of OPS.

Key findings data analysis Netherlands (Chapter 3)

- The dataset of Involtum consists over more than 50,000 transactions and a total of almost 14 million kWh electricity provided.

- The number of transactions and electricity provided increased significantly over the period 2011-2014.
- The median power consumption per transaction, differentiated to type of berth, was 64 kWh for river cruise vessels, 47 kWh for cargo vessels, and 35 kWh for other vessels. The median values are substantially lower than the averages (680 kWh for river cruise vessels, 177 kWh for cargo vessels, and 176 kWh for other vessels) due to the occurrence of some very large electricity transactions.
- River cruisers consume most of the OPS energy per transaction in the Netherlands. Although the number of transactions is highest for cargo vessels, and the average duration of the transactions is longer for cargo vessels too, the river cruisers consume on average four times more energy per transaction, and are therefore the most important OPS customers for port authorities.
- The average transaction time is higher than the median, up to 3 times. The typical ship (median) uses OPS during 19 to 24 hours.
- There is a relatively small portion of “high power demanding ships” (heavy users), which significantly raises the average consumption per transaction. For example, the ships with more than 10,000 kWh per transaction use on average 146 kW; this is 2 times more than the average power provided (namely 66 kW).
- Only 6% of the transactions are transactions of less than 3 hours. That could infer that using OPS during cargo loading and unloading is not common. This conclusion is confirmed by interviews with port authorities and OPS providers.
- The Involtum data reveal that over 90% of the total 2011-2015 energy consumption took place at 21 berth locations (out of 83 in the dataset).
- This distribution gives insight in the utilization of OPS locations. A relative small number of locations are heavy utilized. This is corroborated by Port of Amsterdam estimate that currently 70% of the total OPS energy consumption (for river cruise vessels) in the Netherlands is in Amsterdam. Also Port of Rotterdam stated that it is likely that several of their “heavy user quays” are quays where cargo vessels are waiting for new consignments for cargo.
- The increase in supply of OPS energy (2011-2014) is not caused by increased transaction time. The number of transactions per connection stayed fairly constant. Instead the installation of new connections fostered the growth of OPS energy consumption in ports.
- The average utilization time of OPS connections for cargo vessels is app. 20% based on time, and 90% for river cruise vessels (calculated for tourist season only). The data show however that there is quite uneven distribution of utilization of the connections.
- The expectation would then be that the utilization rate per connection increases, but the data provided by Involtum do not support this.

- The top-25 ships consumed approximately 25% of the total OPS electricity in the period 2011-2015. These ships use OPS at relatively few places.
- We can conclude that a small number of heavy OPS users (vessels) at a small number of berths and a small number of connections make up the vast majority of OPS transactions and energy consumption. This is instructive for policy making that aims to implement OPS as a measure for air quality improvement in ports. It suggests that the focus of OPS policy should be on targeting potential heavy users, selecting sites for OPS provision in a demand-driven approach and in close collaboration with the ship owners and their principals. Ideally the ship owners articulate their demand for OPS in locations that suit them and the authorities facilitate accordingly. This way the public funding can be concentrated on those OPS sites that will show the highest utilization and therefore maximum public benefit (improving air quality and reducing noise).

Environmental benefits (Chapter 5)
Onshore power can significantly reduce diesel emissions from ships at dock. In the specific case of Port of Antwerp, the emissions of NOx were reduced by about 93% through the introduction of OPS. The emissions of PM10 were reduced by 99%, and the emissions of SO2 by more than 96%. The emissions of CO2 were reduced by more than 91% when utilizing power from the regional electricity grid.

The potential emission reduction benefits may be estimated for a particular vessel, at berth when connected to shore power. Factors such as the amount of time actually connected, power consumption rate and total time at berth are described in the assessment and relate to the overall effectiveness of onshore power. Because these factors must be evaluated for each situation, total emission reductions may vary. Note that in case of OPS, the exact amount of electricity that is requested by the vessel is delivered as such by the regional grid. In case of the use of auxiliary engines, however, the generator will be running at its full capacity, (rather) independently from the very demand of electricity on board the ship. Hence, the power provided and the fuel consumed may be higher than the actual demand of electric power in the latter case. This element was taken into account in the analysis.

The assessment suggests that onshore power may be most effective when applied at terminals with a high percentage of frequently returning vessels, typically river cruise ships and cargo ships.

Improving the business case for providing OPS
The breakdown of the OPS business case shows that CAPEX is very dominant. There is a need for cheaper solutions for OPS. Maybe innovative technologies can be introduced from electric vehicle charging domain.

It is proposed that CLINSH free up budget to challenge the market through a contest to come up with cheaper solutions in a paid consultancy job. It could be offered to the winner that their solution will be used in a TEN-T project for OPS in core and comprehensive ports in the Netherlands, Flanders and NRW (and possibly elsewhere). This contest could be facilitated in task B.2.4 and led by Nijmegen, Port of Ghent and EICB.

Other, less impactful improvements of business case are:

- combine greenfield OPS investments with other spatial economic works.
- reduced/no energy tax
- lower service fees
- combination of services (waste, electricity, water) in one Service concept.
- apply a facilitative framework (generator ban with enforcement and "behavioural campaign", i.e. stick and carrot approach).

Task 2.2 will study such options for improving the business case.

Building blocks for Cost Benefit Analysis
If the environmental and societal benefits were used in a cost benefit analysis, this would imply that the rationale for investing in OPS would be higher. It should be investigated further to what extent the impact of these environmental and societal benefits would have a meaningful impact on (positive) investment decisions.

Proposed outline for best practice guide (Task 2.5)
If authorities consider using the OPS instrument for air quality improvement then their strategy should be to:

- invest in OPS where air quality and/or noise concerns are most pressing
- and where the cost effectiveness of euros spent for emissions reduced is highest
- consider the top-5 type of locations as above
- take into account that the business case for the ship owner should be at last neutral (this means: accept low OPS revenues)
- impose and enforce an auxiliary engine ban in the port wherever OPS is available
- promote the use of OPS among ship owners (see measures from TEN-T Shore Power in Flanders) and their clients

- use TEN-T funding for OPS in Core and Comprehensive ports and possibly other funding for other ports including recreational ports.

To determine the cost effectiveness of euros spent on OPS sites, Task 2.5 will develop a calculation model (a “menu” with building blocks) to be part of the best practice guide.
To support skippers’ decision making also a calculation model may be developed to compare costs of using auxiliary engines versus OPS versus shaft generators + batteries versus PV + batteries versus hybrid driveline.

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1. Introduction

The key objective of Action B2 is to assess the environmental and economic benefits of onshore power supply (OPS) for the use of inland vessels and to develop guidance for the provision of grid-connected and mobile OPS and help to justify investments. The action will demonstrate how OPS can improve air quality and aid compliance with emission limits.

Five tasks have been defined to achieve this key objective:

Task B2.1	Port characterisation & data collection on existing and planned OPS, inventory of solutions
Task B2.2	Market consultation and technical/economic options review to identify options for generating/supplying grid or locally generated power and compared with on-board generation
Task B2.3	Standards & regulations identification and harmonisation.
Task B2.4	OPS pilot (a) server procurement for OPS in Ghent: (b) mobile OPS demonstration.
Task B2.5	Deployment & best practice guide. To explore the impact of differing levels of harmonisation on inter-operability and OPS adoption levels.

The Action B2 research will give insights in the various business models, utilisation of OPS installations and reduced emissions. It is the ambition to outline possible OPS options for certain types of ports or port sections (in Task 2.5).

Task B2.1 studied the characteristics of OPS initiatives in the Netherlands, Belgium (Flanders) and Germany (North Rhine-Westphalia and Lower Saxony). The goal of the study is:

- to describe the different modes of OPS which have been installed in ports and along waterways, and the existing plans for OPS installations. This information is also needed for B2.2.
- to examine locations that might benefit from OPS as well.
- to characterize ports so that costs and impacts can be compared, and priority locations can be identified.

2. Port characterization

2.1 Types of ports

A port is a facility for receiving ships and transferring people and cargo.[1] It provides shelter to ships against high waves and strong currents, is deep enough to provide anchorage for ships and other craft, and provides port facilities such as accommodation for ships and cargo handling facilities. The port can be a natural situation or an artificial construction, which provides a place for the loading and unloading of cargo. Ports can be for large sea-going ships and/or for inland waterways such as rivers and lakes. The depth of the ports plays a vital role in allowing various types of ships to enter and dock at the port.

Seaports & inland ports

Seaports are the most common types of ports around the world used for commercial shipping activities. Seaports are situated along the coastline and enable the accommodation of both small and large vessels. A seaport can be further categorized as cargo port, cruise port, ferry port, fishing port, recreational port or military port.[2]

The CLINSH project focuses on inland ports. Inland ports are ports built on smaller water bodies such as rivers, canals or lakes. They can either be for cargo or for passengers or for both. An inland port can be further categorized as cargo port, cruise port, ferry port, fishing port, recreational port or as a nautical or maritime service port.

The Dutch “Inland Ports Monitor” uses the main categories: Multifunctional inland port, Industrial port, Agro port, Sand & gravel port, Inland container port, Passenger port, and Other.[3]

Difference between ports & terminals

Ports are strategic geographical locations situated at the edge of ocean, seas, rivers, or lakes. These locations are then developed to provide facilities for loading and unloading of cargo ships, depending on the purpose for which the port is being used.

A terminal is referred to as the set of facilities at a port where loading and unloading of cargo/container takes place. Terminals are named according to the type of cargo that can be handled by them. Examples are container terminal, bulk cargo terminal, LNG terminal etc.

Cargo ports

These ports act according to the cargo it manages and the facilities available differ from one port to the other. They are also known as "(break) bulk ports". The cargo ports involve many mechanical techniques to load or unload the shipment. A cargo port may be designed to deal with single, as well as multiple types of products. A cargo port that engages in the transfer of containerized goods is referred to as a container port. Numerous operating terminals branch out from individual bulk ports, and are assigned to maintain the various kinds of ship loadings.

Cruise home ports and ports of call

This type of port specialises in dealing with the activities of a cruise ships, and provide the platform for the passengers to enter and disembark the cruises at the beginning and the end of the journeys, respectively. A cruise home port is also capable of providing the essential provisions required for a luxurious cruise voyage, such as fuel resources, fresh drinking water, foods etc. A port of call is a stopover port that is paid a brief visit by a ship on voyage. It is mainly required for necessary cargo discharge, or for carrying out essential repair works. Many passengers can also leave the vessel at a port of call and the ships can replenish their fuel supplies or food storage.

Port structures

Ships are accommodated and handled (loaded and unloaded) at such port structures as wharfs or quays, piers and jetties, docks and dock basins, and sometimes alongside moles or breakwaters. Any place where a ship can safely lie alongside a quay, pier or dock, at anchor or a buoy, and where she can carry out loading/discharge operations or embark and disembark passengers is called a berth.

Public and private port management

For characterisation of ports, it is important to identify whether their management entity is public or private, because this character will greatly influence how investments arise, among others in onshore power supply. It also influences the willingness to make policy aimed at increasing the utilisation of OPS e.g. through an on-board generator ban at places where free connection to OPS is available (a common policy in ports in the Netherlands, although not everywhere).

Public ownership and management can be organised in different ways, e.g. as a municipal service, as a municipal-owned public liability company, or a state and municipal co-owned public liability company. The trend is to increase private ownership of ports.

Size and importance

Ports can be characterized by size (m^2 or quay length), expressed in TEU managed throughout the year, tonnes of cargo handled during the year, or numbers of ship calls per year. Also, the importance of the port for its inland catchment area (hinterland) can be a measure. A relatively small port can have a very important hinterland as a centre of business generation.

Vicinity of port to residences

Some ports are located far from residential areas but others are close by. The relevance for environmental solutions such as OPS is higher if more ships at berth cause nuisance for residents through noise and air pollution.

2.2 Port characterization and OPS

Onshore power supply can be provided to inland navigation vessels at any berth in principle. Considering the scope of CLINSH we exclude seagoing ships and fishery from consideration.

For the business case of providing OPS, the following port characteristics are most relevant (see Figure 2.1):

- type of berth (cruise, cargo and/or other)
- frequency and duration of mooring
- cost structure and pricing of OPS (price per kWh delivered)
- capacity of OPS cabinets installed (power rating, number of ships to be served)
- local governmental policy (willingness to invest in OPS, generator ban or not, enforcement)
- attitude of freight shippers towards OPS at their private quays (possibly obligation)

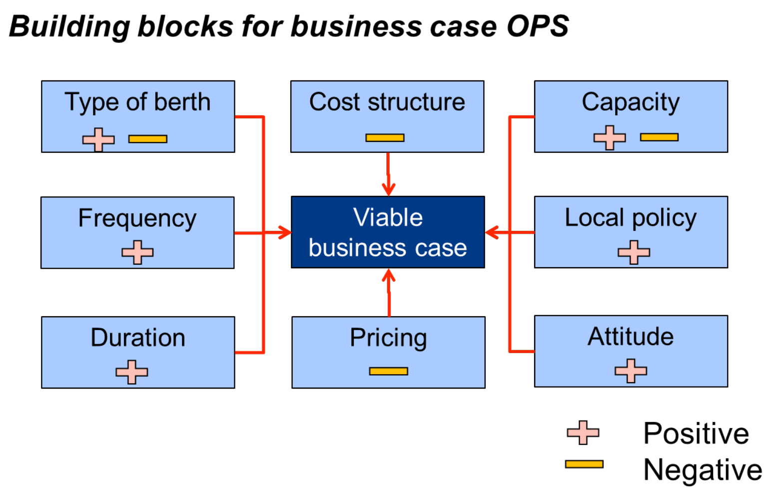


Figure 2.1Building blocks for the business for onshore power supply

To elaborate on this:

- As the data analysis will corroborate, the energy consumption by cruise vessels is much higher than for cargo and other vessels. It therefore should be easier to build the business case for OPS on river cruisers, although the costs (CAPEX and OPEX) will also be higher.
- The frequency and duration of mooring is most of all determined by economic factors, such as demand for cargo transport from or to a port, and demand for cruise holidays. No skipper will deliberately visit a port because of the quality or pricing of OPS on offer. The utilization of berths, and therefore of OPS provided there, will be higher in bigger and more important (frequently visited) ports.
- Another interviewee stated that the utilization of OPS cabinets for cargo ships is the highest in the places where ships are waiting for new cargo for extended periods of time. Such places are found in the ports where the consignment is coming from, so in seaports like Rotterdam and Antwerp, and not along waterway routes. When it comes to OPS utilization rate, this category of sites is followed by the weekend and night locations.
- Other locations where vessels are berthed for longer periods are maintenance and repair yards and home ports for nautical service vessels (e.g. river police, fireboats).
- Mooring at most loading and unloading quays is as short as possible. As noted by one interviewee: “The difference is that river cruise has mooring as core business (to wait for the tourists who do their day trips), while cargo ships moor as short as possible because they earn their money by sailing.”

- When visiting a port, the acceptance and willingness of skippers to use OPS is a relevant factor. We assume however that this is not a factor that differs between ports, but it matters whether there is an on-board generator ban in place or not.
- The cost structure for providing OPS may differ in ports or at quays within ports, when clever solutions can be found for installing OPS cabinets and cabling, e.g. using medium voltage grid connections rather than low voltage (which can give better power purchase rates) or registering a group of OPS cabinets under one meter (which means that a lower energy tax rate applies). These are strategies rather than port characteristics however.
- When the price of OPS is too high then it is attractive for the skippers to generate their own electricity on board, especially when diesel fuel is cheap. The price of OPS is more or less the same in most of the Netherlands and Flanders. There are cases where lower rates are charged or OPS is offered for free. Again, these are strategies rather than port characteristics.
- The type of port management (private, public) is important for the ability and willingness to invest in and make policy to promote use of OPS.
- The benefit of OPS to society will be highest in locations that are close to residential areas where vessels' noise and emissions cause nuisance and health impacts. This will increase the willingness to invest in and make policy to promote use of OPS.

These aspects will be given attention in the data collection (chapter 3) and the case studies (chapter 4).

2.3 Priority sites for OPS

The priority for deployment of OPS is determined by the environmental effect and by the business case. When planning OPS, we should especially consider locations (i) where air quality and/or noise concerns are most pressing (near city centres and residential areas), (ii) where there is highest potential that OPS will be used. Based on the above and on interviews with ports and OPS providers (see next chapter) we expect that OPS is most needed and could be most successfully provided at quays, piers and docks in seaports and inland ports in the following situations, placed in priority order:

Table 1.2 Prioritization OPS investments

	Type of berth	Environmental (air quality, noise, CO2)	Economical (business case for port)
1	River cruise berths in home ports, ports of call and off-season (repair) ports	+++ if at city centre	+++ high power consumption
2	Waiting docks and overnight mooring for cargo vessels in home ports for skippers and crews, ports of distress along international (TEN-T) corridors (e.g. Waal river), and docks in/near seaports where vessels are waiting for consignments)	++ if near residential areas + if not	++ medium consumption due to relatively long connection time
3	Cargo terminals in Core and Comprehensive TEN-T network with sufficiently long duration of loading and unloading, provided that there is no interference between OPS and (un)-loading activities	++ if near residential areas + if not	+++ if usage of OPS energy directly impacts fuel savings for cargo terminal + low consumption due to relatively short connection time
4	Home ports for nautical service vessels (e.g. river police, fireboats, towboats).	+ often far from residential areas	+ OPS demand can easily be estimated, therefore better dimensioning
5	Maintenance and repair yards	++ if near residential areas + if not	0 most likely that the yard owner organises OPS themselves

River cruise vessels berth near city centres and have the best OPS business case because they consume much power per time unit and have high utilization rates. The payback period is reasonable in many cases. Cargo ships mostly berth farther away from residential areas and their OPS business case is worse due to less power consumption per ship per time unit and lower utilization rates of OPS. CAPEX and OPEX costs however are lower than OPS cabinets for river cruise vessels and usage of OPS for skippers also increases comfort on ships during berths (mainly less noise).

Ships for transport of oil and gas products are currently excluded from OPS use because of the risk of fire by electric sparks. It is worthwhile to explore whether there are solutions for this category to also use OPS.

The following chapter, and also the case studies in chapter 4, present data collected from the Netherlands, Flanders and North Rhine-Westphalia/Lower Saxony about existing and planned OPS. The data will be used to analyse and validate the suitability of the mentioned potential OPS sites.

3. OPS data collection and analysis (the Netherlands)

3.1 Short overview of OPS in the Netherlands

Onshore power supply was introduced in the Netherlands in 2007 in the Rotterdam Maashaven port basin. Port of Rotterdam (PoR) funded a pilot with 50 cabinets by Utiliq, a subsidiary of Rotterdam-based energy company Eneco. Based on this experience, PoR then decided to roll out OPS across the port. Other authorities followed their example: Amsterdam (before the establishment of Port of Amsterdam as public liability company), province of South-Holland, the Drechtsteden, Zeeland Seaports, Arnhem, Nijmegen and others.

At the start Utiliq was the only provider of an ICT platform for OPS (by the name of walstroom.nl) and the use of this platform was therefore prescribed in the procurement tenders. By 2014, the walstroom.nl network consisted of 988 connections on 67 quays in the Netherlands. In that year, several authorities put out the exploitation of existing cabinets for tender again, and walstroom.nl lost its position to Park-Line Water in Rotterdam, South-Holland, Amsterdam, Zaanstad, Utrecht and Nieuwegein, later joined by Zeeland Seaports, Zaandam and Arnhem. Park-Line Water was linked to the parking payment services provider Park-Line, but has meanwhile become independent.

Today there are therefore two main providers of OPS services in the Netherlands: walstroom.nl (now offered by the company Involtum after Utiliq withdrew from this market) and Park-Line Water. The walstroom.nl network today consists of approximately 51 cabinets in the Netherlands (see https://walstroom.involtum.com/nl/locaties/), whereas the Park-Line network consists of 265 cabinets (see http://www.park-line.nl/water/walstroom). On both websites, it is possible to zoom in on the exact locations. Both companies were willing to provide OPS anonymous user data:

- Involtum (walstroom.nl) kindly provided onshore power consumption data for the locations they exploited in the 2011-2015 period. The exploitation of most of

these locations changed to Park-Line after a new tender in 2015. Data since 2015 were not easily available for data analysis purposes and therefore excluded.
- Park-Line referred to the clients as owners of the data (Port of Rotterdam, Port of Amsterdam, Zeeland Seaports), but in the end only Arnhem provided their data.

The following section presents the data analysis. For the interpretation of the data we also draw upon insights from interviews with representatives of both OPS providers and of port authorities.[4]

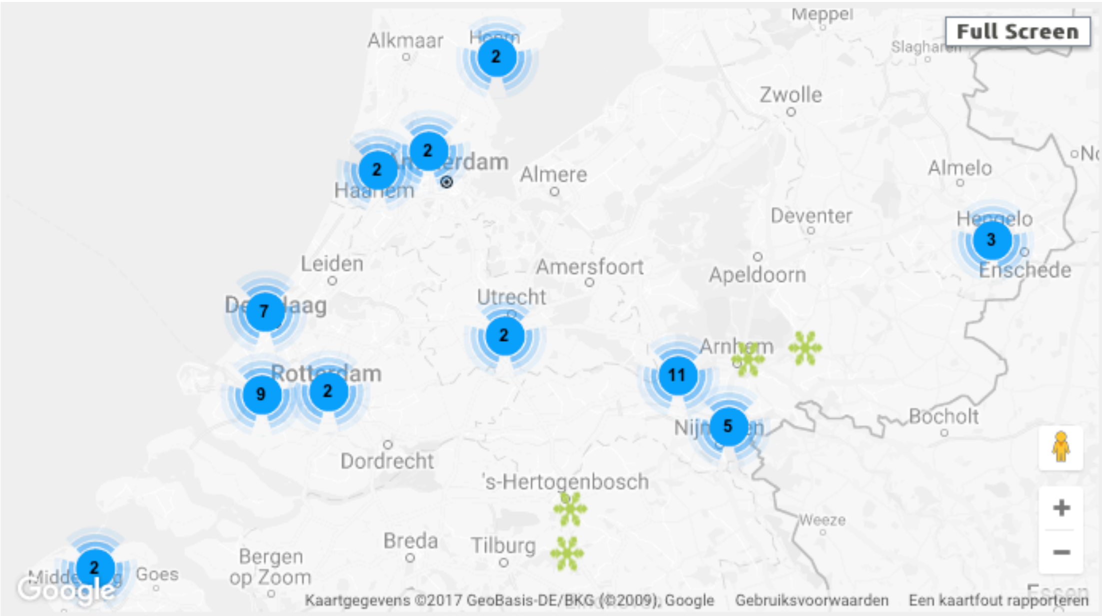


Figure 3.1 walstroom.nl OPS cabinets May 2017

In addition to these providers, there are some other OPS initiatives, but no user data are available yet (the list is not exhaustive):
- Existing: at inland container terminals Nijmegen and Alblasserdam (see case study Arnhem Nijmegen in chapter 4)
- Existing: river cruiser “De Zonnebloem” Arnhem (in season) and Nijmegen (off-season)
- Existing: Nijmegen installed OPS without ICT system in the Waalhaven, where the frequency of use is too low to justify a service contract.
- Planned: at ports of distress along the main rivers (see case study Arnhem Nijmegen in chapter 4)

Figure 3.2 Park-Line OPS cabinets May 2017

3.2 Analysis of Involtum data

The Excel dataset provided by Involtum covered over 50,000 transactions for 83 berths (identified with "port-ID") in the period 2011-2015. (Only part of 2015 is covered.) Each port-ID has multiple OPS connection ID's, which are the individual sockets that ship owners can plug in to. There are usually multiple port-ID's for a town like Nijmegen or port area like Port of Amsterdam. A port-ID can be a quay, a set of quays, or a port basin. Data about the transactions concern:

- Port-ID (n=83) and connection-ID (n=1,158)
- Start time and end of transaction
- Power transfer during transaction (kWh)
- Ship-ID (>2,500).

Involtum provided anonymous data (i.e. no place names attached to port-ID's, connection-ID's and ship-ID's), but did categorize the port-ID's according to the type of berth in order to allow analysis to relate port characterisation and OPS utilisation:

- River cruise berth
- Cargo vessel berth
- Mixed river cruise berth and cargo freight berth
- Recreational vessel (tour boat)
- Other.

For the purpose of this study three main categories were used: (1) river cruise berth including mixed river cruise berth and cargo vessel berth, (2) cargo vessel berth and (3) other. All “faulty transactions” with less than 16 minutes connection time were excluded from analysis. These accounted for a total of 415 transactions.

3.2.1 Results by vessel types

Key data for all vessels

The following table shows the key data of the number of transactions, the average electricity consumption per transaction, the average duration of the transactions, the average power per transaction in the period 2011-2015 and the total delivered energy in kWh per year.

Table 3.3 Key data 2011-2015 all vessels (Involtum data 2011-2015)

Data 2011-2015 All vessels	2011	2012	2013	2014	2015 (part)	Total
# OPS transactions	5,693	12,163	14,388	16,128	2,308	50,680
Average consumption per transaction in kWh	223.40	285.98	276.48	283.05	180.80	270.53
Average transaction time in hh:mm:ss	103:42:41	105:58:06	96:05:50	88:42:03	124:42:39	98:16:15
Average power per transaction in kW	51.7	64.8	69.0	76.6	34.8	66.1
Total delivered energy in kWh	1,271,815	3,478,412	3,977,929	4,565,008	417,281	13,710,445

The average power consumption per transaction, for all locations and all vessels, was **271 kWh.** The average duration of the OPS transactions, for all locations and all vessels, was 98:16 (hh:mm), this equals a total of more than four days.

3.2.2 Transactions differentiated by type of berth

River cruise vessels

The following table shows the number of transactions, average electricity consumption per transaction, the average duration of the transactions and the average power per transaction, and the total delivered energy in kWh, for river cruise vessels in the period 2011-2015.

Table 3.4 Key data 2011-2015 river cruise vessels (Involtum data 2011-2015)

Data 2011-2015 River cruise	**2011**	**2012**	**2013**	**2014**	**2015 (part)**	**Total**
# OPS transactions	737	2,213	2,680	3,610	196	9,436
Average consumption per transaction in kWh	592.07	725.13	722.24	633.71	789.03	680.27
Average transaction time in hh:mm:ss	100:04:38	89:44:46	82:27:38	61:58:58	46:36:48	76:57:59
Average power per transaction in kW	142.0	193.9	210.2	245.4	406.3	212.1
Total delivered energy in kWh	436,353	1,604,715	1,935,608	2,287,702	154,650	6,419,028

Cargo vessels

The following table shows the number of transactions, average electricity consumption per transaction, the average duration of the transactions and the average power per transaction, and the total delivered energy in kWh, for cargo vessels in the period 2011-2015.

Table 3.5 Key data 2011-2015 cargo vessels (Involtum data 2011-2015)

Data 2011-2015 Cargo vessels	**2011**	**2012**	**2013**	**2014**	**2015 (part)**	**Total**
# OPS transactions	4,759	9,342	11,285	12,118	2,110	39,614
Average consumption per transaction in kWh	159,62	191.48	174.61	183.49	124.39	176.83
Average transaction time in hh:mm:ss	106:39:40	114:42:30	101:41:00	98:02:35	132:02:46	105:51:24
Average power per transaction in kW	35.9	40.1	41.2	44.9	22.6	40.1
Total delivered energy in kWh	759,627	1,788,806	1,970,511	2,223,555	262,468	7,004,967

Other vessels

The following table shows the number of transactions, average electricity consumption per transaction, the average duration of the transactions, the average power per transaction and the total delivered energy in kWh, for other vessels in the period 2011-2015.

Table 3.6 Key data 2011-2015 other vessels (Involtum data 2011-2015)

Data 2011-2015 Other vessels	**2011**	**2012**	**2013**	**2014**	**2015 (part)**	**Total**
# OPS transactions	197	608	423	400	2	1,630
Average consumption per transaction in kWh	384.95	139.62	169.76	134.38	81.50	175.74
Average transaction time in hh:mm:ss	46:03:01	30:43:15	33:27:50	46:48:41	39:36:24	37:14:41
Average power per transaction in kW	200.6	109.1	121.8	68.9	49.4	113.2
Total delivered energy in kWh	75,835	84.891	71,810	53,751	163	286,450

The average power consumption per transaction, differentiated to type of berth, was **680 kWh** for river cruise vessels, **177 kWh** for cargo vessels, and **176 kWh** for other vessels. The following figure shows the trend of the electricity consumption per transaction per type of berth from 2011 to 2015.

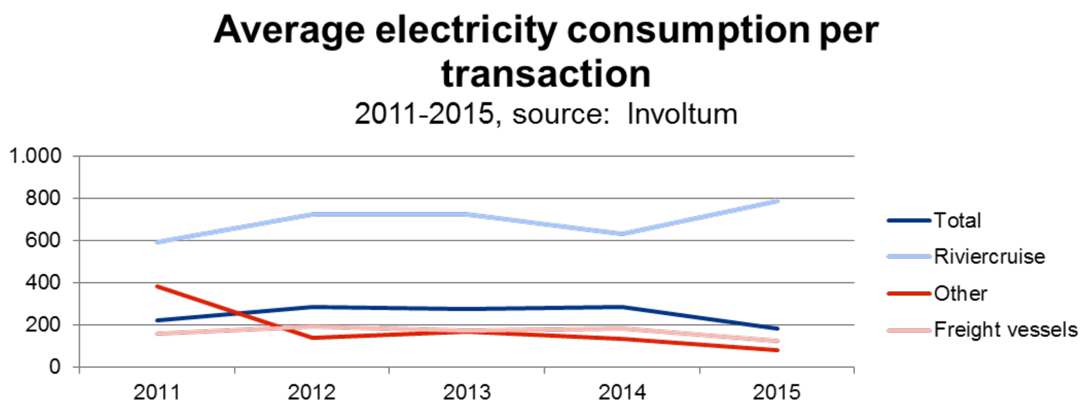


Figure 3.3 Average electricity consumption per transaction by type of berth (Involtum data 2011-2015)

Conclusions

- There was a continuous growth between 2011 and 2014 of the supply of OPS energy through walstroom.nl (Utiliq/Involtum). The loss of a contract (blanket order) in 2015 resulted in major decline.
- Because of the robust growth in those years it is not expected that the OPS energy consumption in the Netherlands decreased in 2015 and onwards. Based on interviews with port authorities and the now leading OPS service provider Park-Line we estimate a consumption of at least 4.5 million kWh in 2017.

3.2.3 Electricity consumption in detail

The average electricity consumption provides a first understanding of the user profile of OPS clients. It is clear that the river cruise vessels use the most electricity per transaction. This is no surprise considering the need for luxurious hotel functions for hundreds of passengers. The trend seems to be that the electricity consumption increases, not surprising because new passenger ships tend to be larger (with more hotel rooms etc.). In addition to the average consumption it is informative to analyse the spread of available data. The distribution of the electricity consumption per transaction is visualised in the figure below and is differentiated by vessel type.

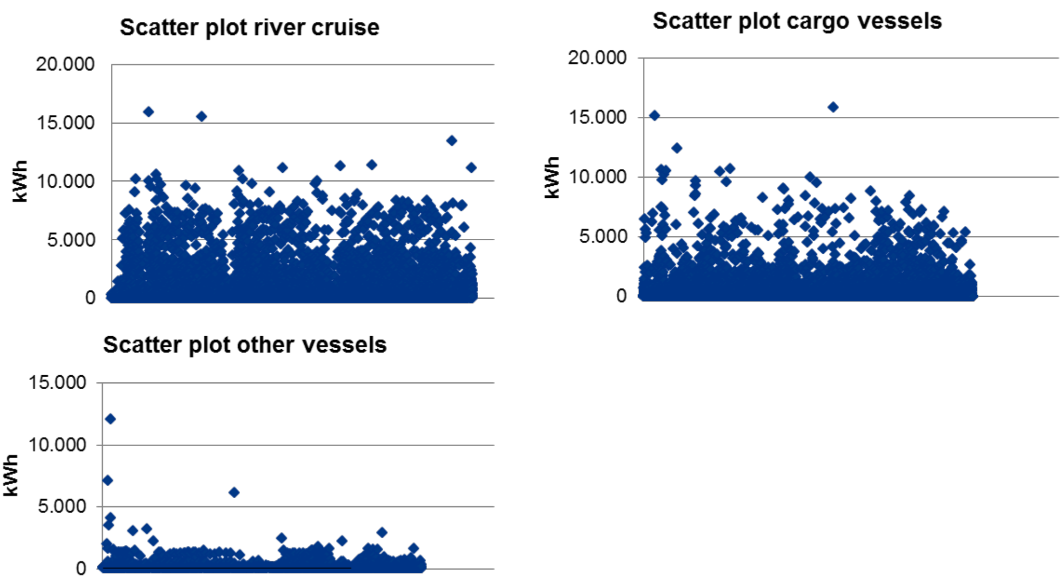


Figure 3.4 Scatter plots distribution of kWh usage 2011-2015 by ship type (Involtum data 2011-2015)

The median is the value separating the higher half of a data sample from the lower half. The median power consumption per transaction, differentiated to type of berth, was **64 kWh** for river cruise vessels, **47 kWh** for cargo vessels, and **35 kWh** for other vessels. The median values are substantially lower than the averages (**680 kWh** for river cruise vessels, **177 kWh** for cargo vessels, and **176 kWh** for other vessels) due to the occurrence of some very large electricity transactions. These are caused by a limited number of heavy users in each category, including vessels that are berthed using OPS for a week or even a month continuously.

The next step is to analyse the duration of the OPS transactions to find explanations for the differences.

3.2.4 Duration of OPS transactions

The average duration of the OPS transactions, differentiated to type of berth, was 105:51 (hh:mm) for cargo vessels, 76:58 (hh:mm) for river cruisers, and 37:15 (hh:mm) for other vessels. The following figure shows the trend of the average duration of transactions, differentiated to type of berth, in the years 2011-2015.

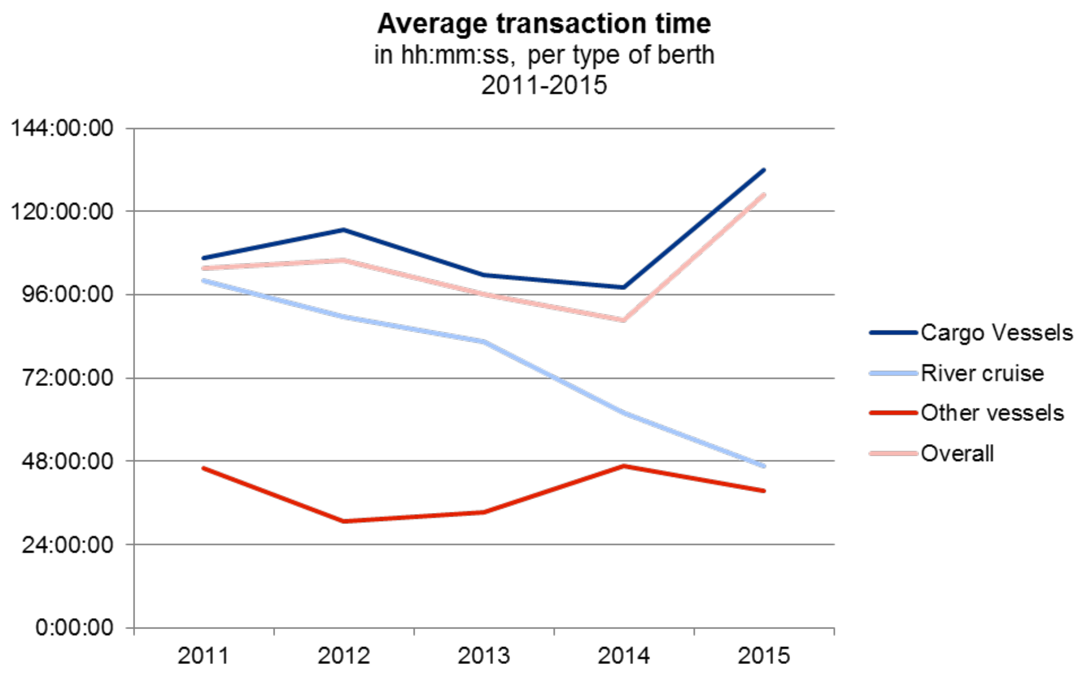
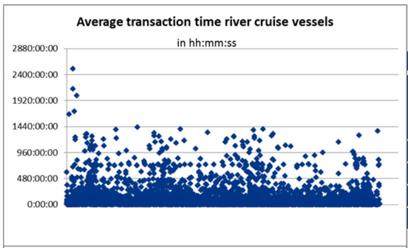


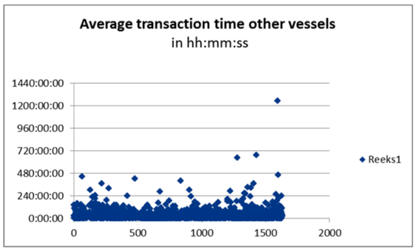
Figure 3.5 Average transaction time per type of berth over period 2011-2015 (Involtum data 2011-2015)

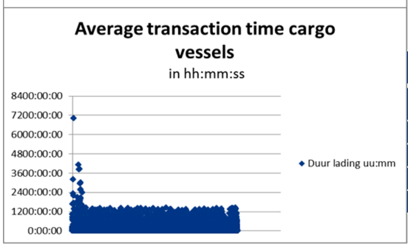
Noteworthy is the decline in the average transaction time of river cruise vessels in 2015 (figure 3.5) whereas the electricity consumption increased in the same period (figure 3.3). This means that the average power demand of the ships is increasing. For other vessels and cargo vessels the decline in the average transaction time coincides with the decline of the electricity consumption in 2015.

Besides the average transaction time, the distribution of the transactions is also relevant. The analysis below provides the minimum, maximum, percentile 1,2 (median) and 3. It can be concluded that the average transaction time is 2-3 times higher than the median transaction time. This also corresponds with the results of the average and median values of the OPS energy consumption per transaction in kWh, but the difference between median and average transaction time per connection is much smaller.



	River cruise	Other
MIN	0:01:24	0:01:13
Q1	12:26:18	5:54:45
MEDIAN	24:12:23	19:25:59
Q3	63:32:08	44:21:24
MAX	2509:55:49	1253:35:45





	Cargo vessel
MIN	0:00:28
Q1	14:51:33
MEDIAN	39:10:34
Q3	89:38:42
MAX	7005:58:28

Figure 3.6 Transaction times plotted per berth type (Involtum data 2011-2015)

Port authorities in the Netherlands often have an on-board generator ban in place where free connection to OPS is available to force skippers to use OPS. The enforcement of this generator ban often applies when a ship is at berth for more than three hours. To give an idea: the Involtum data show 3,173 transactions of the 50,265 (excluding the false connections with less than 16 minutes connection time) with a transaction time shorter than three hours. This equals 6% (7% when including the false connections). So, even though it is probably not obliged (or enforced) to connect to the grid for these short periods, these shippers still connect to the grid. This shows an “intrinsic” motivation.

Conclusions

- River cruisers consume most of the OPS energy per transaction in the Netherlands, namely 680 kWh on average. Although the number of transactions is highest for cargo vessels, and the average duration of the transactions is longer for cargo vessels too, the river cruisers consume on average four times more energy per transaction, and are therefore the most important OPS customers for port authorities.
- It is notable that the average transaction time is higher than the median, up to 3 times. This is caused by a relative small number of ships that make heavy use of electricity during a long period of connection. The typical ship (median) uses OPS during 19 hours (river cruise), 24 hours (other) or 39 hours (cargo vessels) and consumes 35 kWh (other), 47 kWh (cargo vessels) or 64 kWh (river cruise).
- There is a relatively small portion of “high power demanding ships”, which significantly raises the average consumption per transaction. For example, the ships with more than 10,000 kWh per transaction use on average 146 kW; this is 2 times more than the average power provided (namely 66 kW).
- Only 6% of the transactions are transactions of less than 3 hours. That could infer that using OPS during cargo loading and unloading is not common. This conclusion is confirmed by interviews with port authorities and OPS providers.

3.2.5 Results by berth types

The previous section analysed the available OPS transaction data from the perspective of vessel types, focussing on two main indicators for the OPS utilisation, kWh consumption and transaction time, and providing insights in the distribution of the findings. After the “vessel” perspective the following section analyses OPS consumption in the main ports from the perspective of berth types. This section will give port authorities and cities insights in the utilisation of OPS in typical ports.

OPS transactions in top-21 quays and port basins

The port basins and quays can be ranked by the amount of OPS energy consumed. The Involtum data reveal that over 90% of the total 2011-2015 energy consumption took place at the top-21 berths. This is shown in the following figure; the full overview of the 83 (anonymous) berths can be found in annex 2.

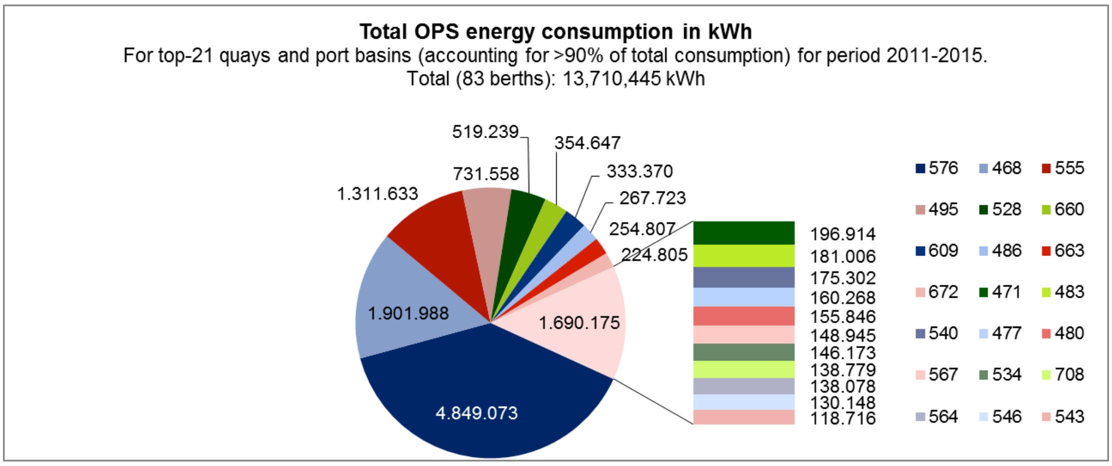


Figure 3.7 Total OPS energy consumption in kWh for top-21 quays and port basins (Involtum data 2011-2015)

The figure gives an overview of the distribution of the OPS energy consumption for the top-21 quays and port basins. A total of 13,710,445 kWh was consumed in the period 2011-2015. At each of these top-21 quays more than 100,000 kWh in total was consumed in the 2011-2015 period. The figure shows that one quay/port basin accounts for more than 35% of the total consumption of OPS in the Netherlands in this period.

River cruise

The following table shows the annual and total (2011-2015) OPS energy that was consumed in all port-ID's for river cruise berths. There was a strong growth in the volume of OPS energy delivered to ships during 2011-2014. Because a number of ports terminated their contract with Involtum for exploitation of OPS there is few data available for 2015 and onwards. Because of the robust annual increase of supply of OPS energy, we estimate expect that this trend continued in 2015 and onwards.

Table 3.8 River cruise OPS energy consumption per port-ID per year (Involtum data 2011-2015)

Port-ID	2011	2012	2013	2014	2015 (part)	Total kWh	Growth 2014-2015
576	375.218	1.320.142	1.491.738	1.661.975		4.849.073	+11% *
528	18.858	125.908	172.644	201.724	105	519.239	+17% *
660		48.090	127.430	179.127		354.647	+41% *
567	21.581	38.364	44.262	44.554	184	148.945	+1% *
708				65.597	73.182	138.779	+12%
564	1.921	39.366	40.352	49.146	7.293	138.078	+22% *
657		47	16.336	15.353	42.576	74.312	+177%
558	6.079	9.882	22.118	30.705	43	68.827	+39% *
474	11.719	15.265	19.831	18.375	258	65.448	-7% *
717				13.166	12.110	25.276	-8%
714				4.045	10.153	14.198	+151%
537	977	7.651	897	2.367		11.892	+164%*
705				1.568	8.746	10.314	+458%
Total kWh	**436.353**	**1.604.715**	**1.935.608**	**2.287.702**	**154.650**	**6.419.028**	
Growth by year		+268%	21%	18%	N/A		

** = 2013-2014 growth*

The following figure gives an overview of the total OPS energy consumption for all river cruise berths for the years 2011-2015.

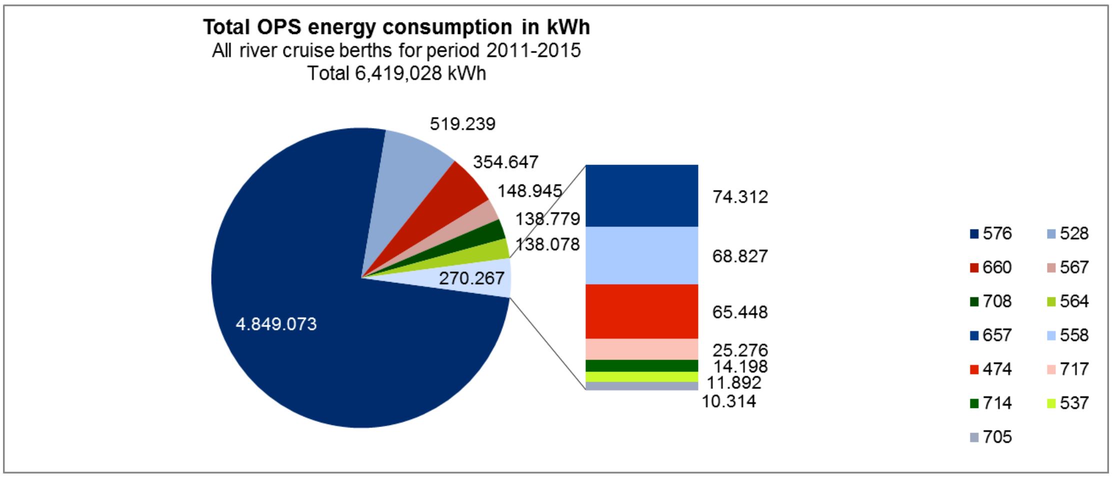


Figure 3.8 Total OPS energy consumption in kWh for all river cruise berths (Involtum data 2011-2015)

Involtum flagged 13 quays in their port-ID dataset as river cruise quays. The distribution of the total consumption per quay shows that port-ID 576 accounts for more than 75% of the total consumption of river cruise quays in the Netherlands and around 35% of the total OPS energy supply during 2011-2014.[5] Port-ID 576 has

12 connections. The high electricity consumption for this port-ID suggests that this port-ID includes multiple cabinets under one Port-ID.

A Port of Amsterdam interviewee estimated that currently around 70% of the total OPS energy consumption in the Netherlands is supplied by Amsterdam. It is therefore likely that port-ID 576 concerns the river cruise quays in Amsterdam.

Port of Amsterdam actually expects shortfall of OPS capacity because of the growing popularity of river cruise tourism.

Cargo vessels

The following figure shows the OPS energy consumption for the top-14 cargo vessel berths (port basins and quays) in the years 2011-2015. These berths account for over 86% of the total 2011-2015 OPS energy consumption by cargo vessels.

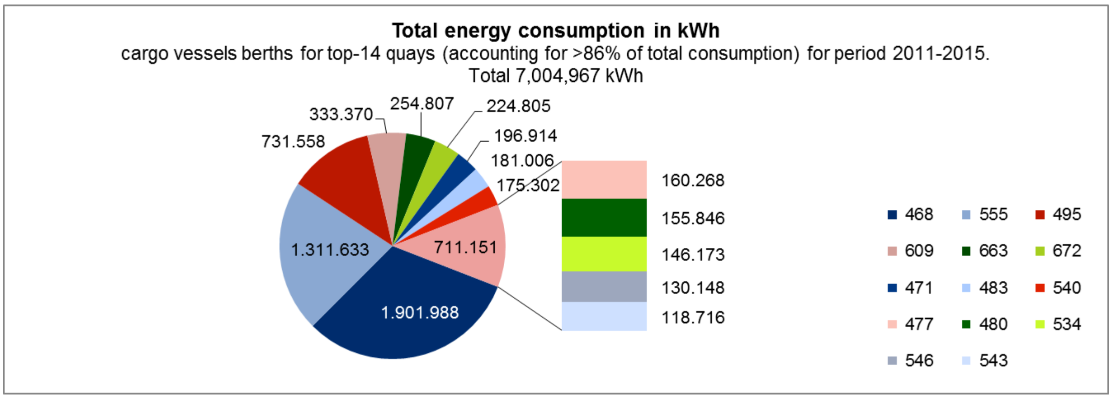


Figure 3.9 Total energy consumption in kWh for top-14 cargo vessel berths (Involtum data 2011-2015)

Based on an interview with the Port of Rotterdam it is likely that several of these quays are quays where cargo vessels are waiting for new consignments for cargo.

Other vessels

Finally, the following figure shows the OPS energy consumption for the category of other vessels' berths in the years 2011-2015. This is a rather small percentage of the total OPS energy consumption and only applies to 2 port-ID's, namely 486 and 621.

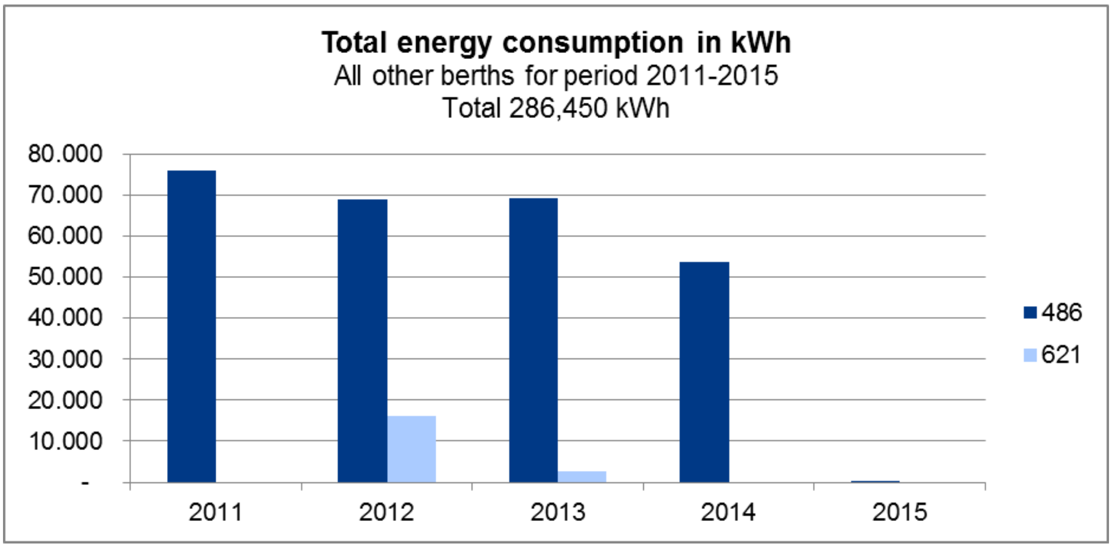


Figure 3.10 Total energy consumption in kWh for all other berths (Involtum data 2011-2015)

Conclusion
There is very uneven distribution of OPS energy consumption by berths. A large proportion of the consumption is concentrated at a limited number of berths. This is the case for both river cruise vessels and cargo vessels.

3.2.6 Connections (individual sockets)

How can we explain the growth in OPS energy consumption between 2011 and 2014? More transactions and/or longer transactions? And more transactions because of more connections and/or better utilization of connections?

The trend in average duration of transactions was already presented (figures 3.5 and 3.6). The average transaction time increased between 2011-2012 from 104 hours to 106 hours, then declined to 96 hours in 2013 and further to 89 hours in 2014. (2015 figures excluded because of limited sample). This means that the increase in OPS energy consumption cannot be explained by transactions becoming longer, but has to be due to more transactions.

The following figure gives an overview of the active number of connections (sockets) for vessels per year, specified per berth type.

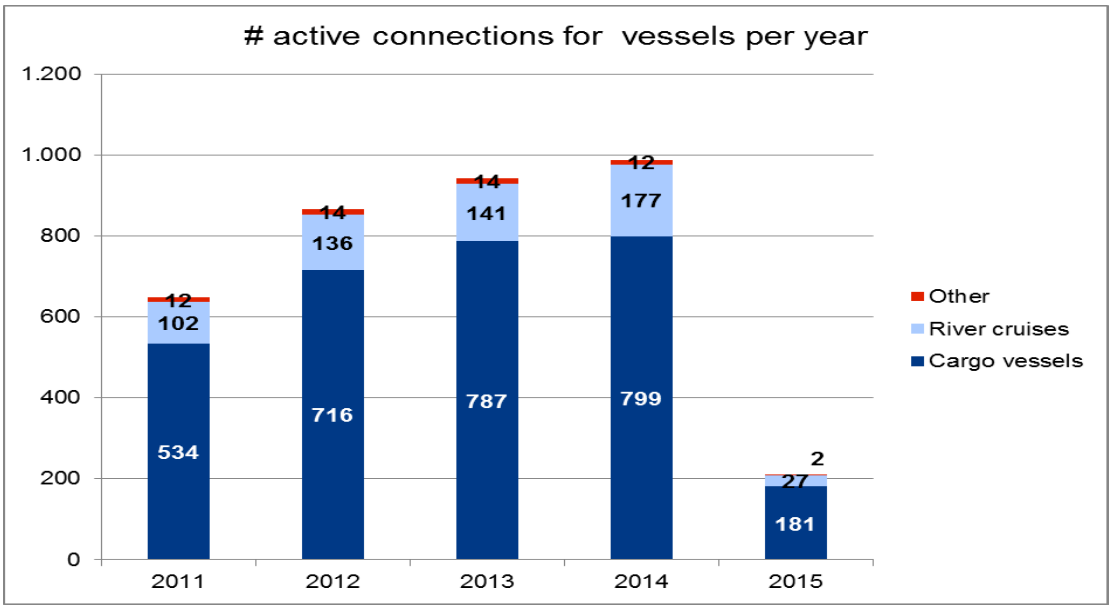


Figure 3.11 Number of active connections/sockets for vessels per year (Involtum data 2011-2015)

The figure above shows a clear increase in the number of operational connections (sockets). The table below links the growth of OPS energy supply to the increase in number of sockets. The conclusion is that the increasing number of operational sockets fostered the increase in supply of OPS energy in ports from 2011 to 2014.

Table 3.9 Supply of OPS energy (kWh) and growth in number of operational connections/sockets (Involtum data 2011-2015)

	2011	2012	'11-'12	2013	'12-'13	2014	'13-'14	2015 (part)	'14-'15
Growth of OPS energy supply (kWh)									
Cargo	759.627	1.788.806	+135%	1.970.511	+10%	2.223.555	+13%	262.468	-88%
Cruisers	436.353	1.604.715	+268%	1.935.608	+21%	2.287.702	+18%	154.650	-93%
Other	75.835	84.891	+12%	71.810	-15%	53.751	-25%	163	-99,7%
Total	1.271.815	3.478.412	+174%	3.977.929	+14%	4.565.008	+15%	417.281	-91%
Growth of # of individual connections/sockets									
Cargo	534	716	+34%	787	+10%	799	+2%	181	-77%
Cruisers	102	136	+33%	141	+4%	177	+26%	27	-85%
Other	12	14	+17%	14	+0%	12	-14%	2	-83%
Total #	648	866	+34%	942	+9%	988	+5%	210	-79%

The figure below shows the number of transactions per active number of connections for vessels per year, specified per berth type. This provides a measure for the utilisation rate of the OPS facilities. The figure shows that there is a fairly constant number of transactions per connection over the years.

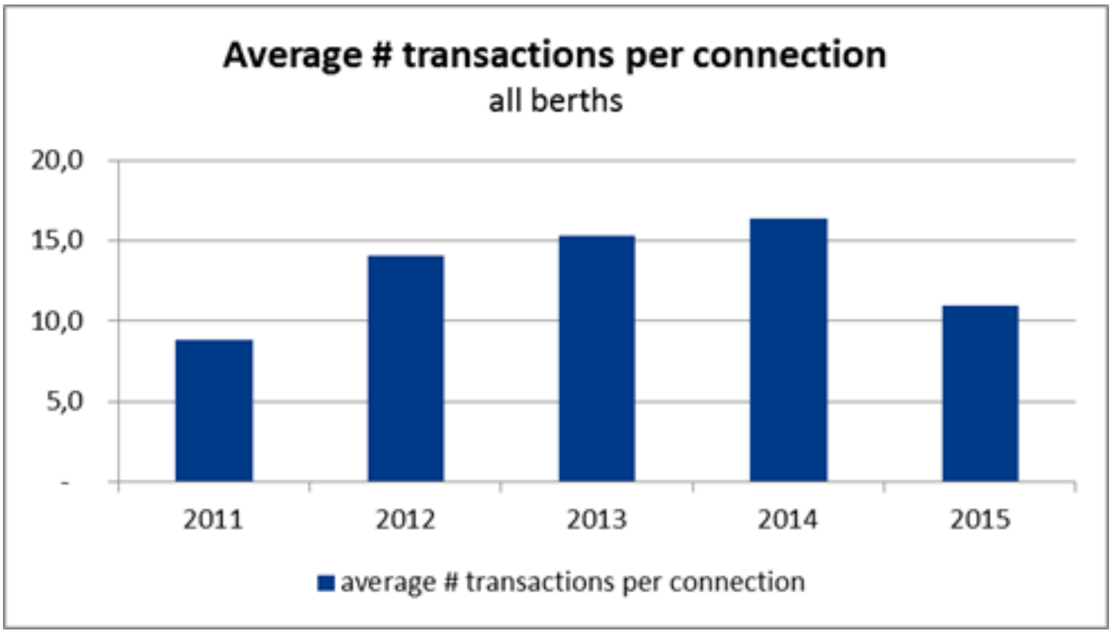


Figure 3.12 Average number of transactions per connection per year (Involtum data 2011-2015)

The utilization rate can be expressed as the percentage of time that the OPS connection is used by ships. According to interviewees the utilisation rate is typically 90% for river cruise during the tourist season, and 20% for cargo vessels. For illustration: one connection in Nijmegen provided electricity during 2,820 hours in 2016, which is 32% of the annual hours. If we assume that the tourist season last four to five months, then 90% utilisation in this period seems possible. In principle, it would be possible to determine utilisation rates for all port-ID's in the dataset.

20% utilization is in line with the data provided by Involtum:

- Average time of OPS use is app. 100 hours per transaction
- Average number of transactions per connection is 16
- This results in 18% utilization rate per connection (based on time).

However, the median for the annual total transaction time per connection was only 518 hours in 2011 (6% utilization), 875 hours in 2012 (10%), 850 hours in 2013 (10%), and 816 hours in 2014 (9%). This means that there is quite uneven distribution of utilization of the connections. Many connections are sparsely used, whereas others are heavily used.

According to interviews with port authorities and OPS service providers it is likely that the user acceptance of OPS has improved because of better technology, better service contracts (user apps, one invoice etc.), general habituation and the on-board generator bans that are in place in many ports. One interviewee at a port authority said that skippers and crew were initially hostile with regard to OPS but now show acceptance and appreciation of its convenience for life on board. First they complained about having to lift heavy cables, that OPS was dangerous and costly, and later that the system was not working properly and often gave faults. Now, there are actually nil complaints. Not even about the pricing, though that may happen again if the tariff would increase, he said.

The expectation would then be that the utilisation rate per connection increases, but the data provided by Involtum do not support this.

Conclusions

- The increase in supply of OPS energy is not caused by increased transaction time as transactions actually became shorter on average after 2012. The number of transactions per connection stayed fairly constant. Instead the installation of new connections fostered the growth of OPS energy consumption in ports.
- The average utilization time of OPS connections for cargo vessels is app. 20% based on time, and 90% for river cruise vessels (in the tourist season only). The data show however that there is quite uneven distribution of utilization of the connections. Many connections are sparsely used, and others heavily used.

3.2.7 Results for top-25 OPS energy consuming ships

The third way to analyse the use of OPS in the Netherlands is from the perspective of the ships with the highest OPS energy consumption. The following figure gives an overview of the 25 (anonymous) ships with the highest energy consumption in the 2011-2015 period.

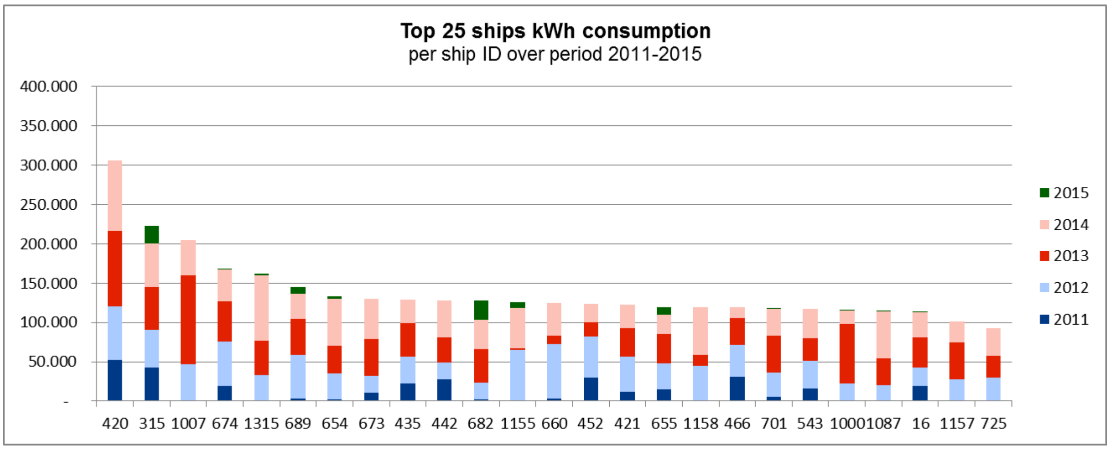


Figure 3.13 Top-25 ships kWh consumption per year 2011-2015 (Involtum data 2011-2015)

Ship-ID number 420 by far consumed the most electricity during the period 2011-2015, followed by ship-ID's 315 and 1.007. For these top-25 ships we see a wide distribution in the electricity consumption per ship-ID from over 300,000 kWh to below 100,000 kWh over 2011-2015.

Several ships show increasing electricity demand over the years, for example the ship-ID's 420, 673 and 1,087. This is however not the case for all ships. Annex 2 gives the total list of the electricity consumption per ship-ID for the top-25 ships.

It is relevant to see if the OPS demand for the top-25 ships differs during the seasons. The figure below gives the OPS consumption per quarter for the top-25 ships. These 25 ships account for an OPS electricity usage of 3,607,010 kWh in the period 2011-2015 or approximately 25% of the total consumption.

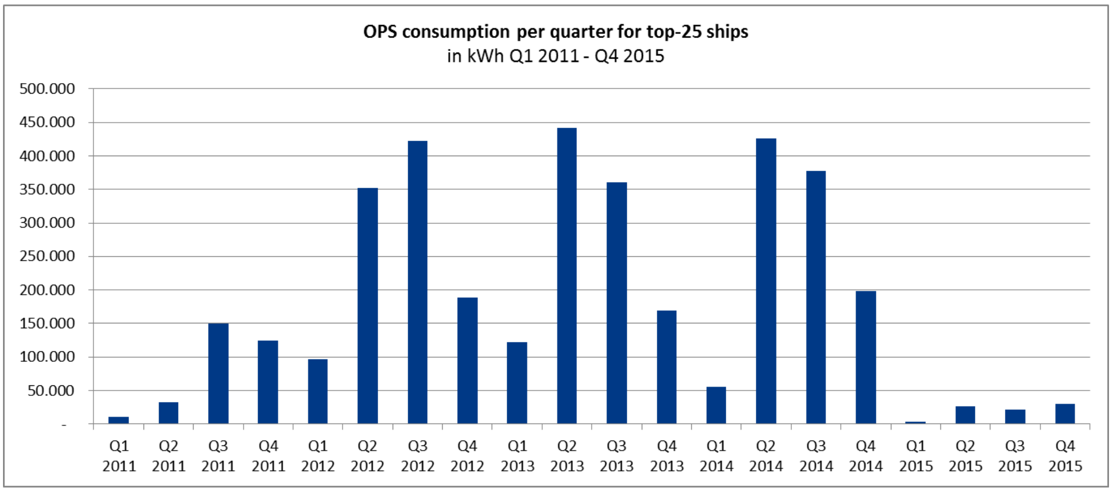


Figure 3.14 Total OPS energy consumption per quarter for top-25 ships in kWh (Involtum data 2011-2015)

This figure shows the seasonal effects of the OPS usage of the top-25 ships. The OPS energy consumption is the highest in Q2 and Q3 of each year. A likely explanation is that river cruise vessels are operational mainly between May and September and then use a lot of energy for hotel functions. Because of the anonymity of the ship-ID data we do not know for certain if a ship-ID is a cargo vessel or a river cruise vessel, or another. From the analysis by berth we do however know at which type of location (cruise, cargo or other) a ship connects its electricity cable to the OPS cabinet. Although there is no strict division between cruise and cargo at locations with mixed OPS cabinets, it is possible to conclude from the data which ship-ID's are river cruises or cargo vessels based on their transactions at river cruise berths or cargo vessel berths.

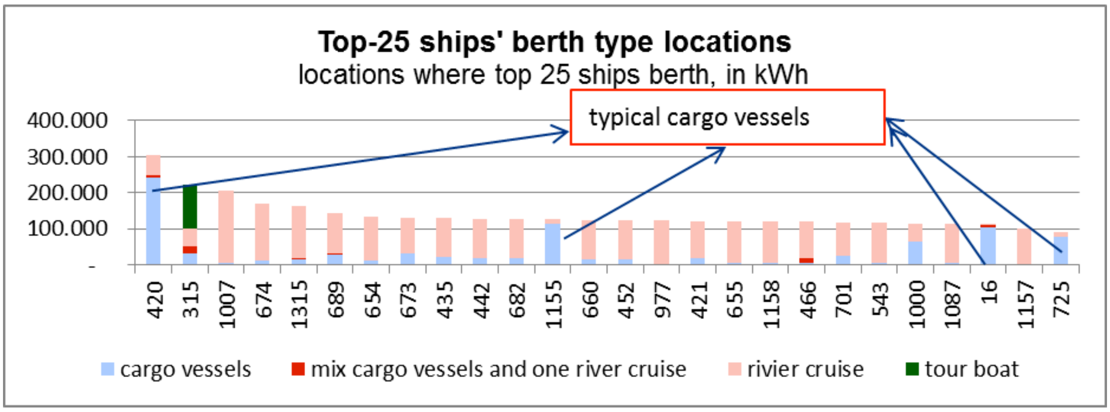


Figure 3.15 Top-25 ships' berth type locations (Involtum data 2011-2015)

For example, ship-ID 420 normally takes electricity from port-ID locations that Involtum marked for “cargo vessels”. Ship-ID 1,007 uses almost always the river cruise berths.

Number of unique port visits per ship

The table below lists the unique number of ports of call for the top-25 OPS energy consuming ships during 2011-2015. That is to say: the ports where these ships at least once used OPS.

Table 3.10 Unique number of ports of call where top-25 ships use OPS (Involtum data 2011-2015)

Ship-ID	# ports of call	# total kWh	Ship-ID continued	# ports of call continued	# total kWh continued
420	11	306,161	452	7	123,540
315	8	222,643	977	7	122,739
1007	7	205,078	421	7	122,152
674	6	168,448	655	5	119,591
1315	3	162,559	1158	6	119,551
689	4	145,175	466	3	119,290
654	2	133,124	701	5	117,414
673	5	130,350	543	2	117,252
435	2	129,563	1000	3	115,759
442	7	127,622	1087	4	114,126
682	6	127,471	16	2	113,310
1155	7	126,263	1157	3	101,227
660	4	124,256			

This table shows the number of different ports where the ship has used OPS. It is notable that the ships that use OPS often do so in relatively few ports. For example (cargo) ship-ID 16 consumed 113,310 kWh of electricity at only 11 unique (different) OPS locations over the period 2011-2015. Also other vessels (often river cruise vessels) use OPS at relatively few places. There could be different explanations:

- these ships have only few ports of call because they have usually the same itineraries (cruise ships) or clients (cargo vessels)
- OPS is lacking at other ports of call for these ships
- OPS is available in their other ports of call but for whatever reason the ships do not use it.

The anonymity of the ship-ID’s prevents further investigation into the reasons.

Conclusion

- The top-25 ships consumed approximately 25% of the total OPS electricity in the period 2011-2015. These ships use OPS at relatively few places.
- Combining the conclusions in this and earlier paragraphs, we can conclude that a small number of heavy OPS users (vessels) at a small number of berths and a small number of connections make up the vast majority of OPS transactions and energy consumption.
- This is instructive for policy making that aims to implement OPS as a measure for air quality improvement in ports. It suggests that the focus of OPS policy should be on targeting the potential heavy users, selecting sites for OPS provision in a demand-driven approach and in close collaboration with the ship owners and their principals.
- Ideally the ship owners articulate their demand for OPS in locations that suit them and the authorities facilitate accordingly. This way the public funding can be concentrated on those OPS sites that will show the highest utilization and therefore maximum public benefit (improving air quality and reducing noise).

4. Case studies

This chapter describes three regional case studies of (successful) implementation of Onshore Power Supply (OPS). The case studies concern (1) Arnhem Nijmegen City Region, (2) Antwerp/Flanders and (3) North Rhine-Westphalia. The case studies describe the implementation of OPS for river cruise vessels and freight vessels. We have also identified other types of vessels (see chapter on port characterisation).

4.1 Arnhem Nijmegen city region

4.1.1 Introduction

The Arnhem Nijmegen City Region is situated at the heart of a metropolitan area in the east of the Netherlands. The region is flanked by the Randstad conglomeration (west), the Brabant cities and Flemish Diamond (south), and the Ruhr area conglomeration (east). The region has a total population of more than 750.000 inhabitants. The cities of Arnhem and Nijmegen are the focal points of the region, both in terms of inhabitants and economic activity.

Figure 4.1 Arnhem Nijmegen City Region in perspective

One of the unique characteristics of the region is the presence of waterways. The Rhine, after crossing the border, divides into the Rhine (along Arnhem) and Waal (along Nijmegen) that flow west towards the seaports of Rotterdam and Amsterdam. The IJssel branches off the Rhine at Arnhem and flows north via Doesburg. Inland waterways are an important modality for the transportation of goods. 2.1 million TEU containers and 141 million tonnes of goods were transported on the river Waal across the German and Dutch border in 2014. This equals 125,000 ship movements.

Inland waterways are not only vital for the economy from a transportation perspective, they also function as a recreational mode for river cruises. The Arnhem Nijmegen region has a strong recreational sector and the cities Arnhem and Nijmegen function as boarding places for river cruises along the Rhine and even up the Danube.

Improving Air Quality

Inland waterway transport is one of the cleanest modes of transport, but it still constitutes a significant part of the emissions in the region. Public bodies in the region have developed policy measures to decrease the emissions of inland shipping and to improve the air quality in the region. Policy measures were funded by the national programme on air quality (NSL) and other programmes.

Since 2011 the Arnhem Nijmegen City Region specifically developed policy measures to improve the air quality for the inland waterway transport mode. This programme functioned as a means to help ship owners and waterfront industry to invest in measures to decrease the emissions by ships. This programme also funded public investments in Onshore Power Supply in Arnhem and Nijmegen.

Onshore Power Supply in Arnhem Nijmegen City Region

Table 4.1 shows the existing publically (co)-funded OPS in the Arnhem Nijmegen City Region. Included are also three ports of distress along the Waal and IJssel that are being renovated or newly constructed on behalf of Rijkswaterstaat (national Department for Public Works and Waterways).[6]

The initiatives in table 4.1 will be described in this case study. For each initiative, we will describe the following aspects: (A) the policy background, (B) the implementation and current use, (C) the business case and (D) opportunities to increase the use of OPS.

Table 4.1 OPS in Arnhem Nijmegen City Region: existing and planned

Onshore Power Supply in Arnhem Nijmegen City Region				
Location	City	Ownership	Connections	Target group
Waalkade	Nijmegen	Public	4 cabinets with each 12 connections.	River cruise and freight ships (short stay)
Waalhaven	Nijmegen	Public	16 connections on high water-level jetty	Freight ships, overnight (long stay)
Lindenberghaven and eastern Waalkade	Nijmegen	Public	1 multi-use cabinet for events and recreational ships	Recreational ships,
Container Terminal Nijmegen	Nijmegen	Private	2 cabinets with 1 connection each	Container ships
Kanaalhavens	Nijmegen	Private	1 mobile generator with 1 connection	Mobile, diverse
Nieuwe Kade	Arnhem	Public	5 cabinets with 2 connections each	River cruise
Container Terminal Doesburg	Doesburg	Private	1 cabinet with 1 connection	Containerships
Port of distress along Waal river	Lobith	Public	Realisation planned in 2018 for 18 berths	Freight ships, overnight (long stay)
Port of distress along Waal river	Spijk	Public	Realisation planned in 2021 for appr. 50 berths	Freight ships, overnight (long stay)
Port of distress along IJssel river	Giesbeek	Public	Realisation planned in 2020 for 17 berths	Freight ships, overnight (long stay)

4.1.2 Nijmegen

A Policy background

The city of Nijmegen had an extensive air quality programme to meet the air quality standards in 2017. Besides policy measures for road transport (passenger and freight) and industry, the city developed policy measures for the reduction of emissions from inland waterway transport. In 2013 the city invested in OPS as part of a renovation project of the *Waalkade*. The goal of the project was to reduce the NO_x emissions by 2.1 ton/year, PM_{10} by 85 kg/year and CO_2 by 133 ton/year. The installation of OPS would reduce the exposure to NO_2 by 1-2 ug/m^3 and to PM_{10} by 0,1-0,2 ug/m^3. This corresponds to a decrease of the NO_2 concentration in the air by 3 to 6%.

The installation of OPS for river cruise vessels and freight vessels on the *Waalkade* was part of a broader policy package of the Arnhem Nijmegen City Region, which included an on-board generator ban on places where free connection to OPS is available, differentiation of port dues for clean vessels according to the "Green Award" certification, development of a LNG bunkering site on the Waal and a subsidy scheme for low-emission shipping technologies.

Figure 4.2 Example of an OPS cabinet on Waalkade in Nijmegen

B Implementation and current use

OPS was installed with a grant from the national air quality programme (NSL) in several locations in Nijmegen. At the *Waalkade* 4 OPS cabinets were installed where both river cruise ships and inland waterway freight ships can be connected. These cabinets have 12 connections for 230 V/16A, 400 V/32A, 400V/63A and 400V/125A, and each cabinet also has a Powerlock connection (400Volt/400A). A single cabinet can connect multiple cargo ships at the same time, or one river cruise ship.

A challenge in Nijmegen is the protection of the cabinets in case of high water, as the quay often overflows after winters. This was one of the conditions in the tender. Nijmegen issued a public tender for the construction and exploitation of the OPS units. In hindsight, it can be concluded this was done from a predominantly technical perspective. Little practical (operational) feedback was gathered before the tender and therefore some operational / technical issues cause negative experiences among skippers.

One issue is the limited room in the cabinet to connect the power cables. The cabinet doors were provided in accordance with the tender, but they cannot always close as the outlet opening is too small. In these cases, the cabinets stay open, or the doors are forced closed. In case of rain there is a risk of power failures. Also, the switch part is not sufficiently protected against rain when it must be enabled or when maintenance must be carried out.

Due to the positioning of the cabinets, sometimes the distance between the cabinets and the ships is too long for the length of the skippers' power cables to connect to the cabinets. This sometimes leads to tension of pulling on the cables because of swell.

These technicalities could have been prevented when the tender documents would have been discussed with skippers and market parties. In general however, the municipality of Nijmegen is satisfied with the OPS.

Nijmegen concluded for the *Waalkade* a service contract with the company walstroom.nl (Involtum) to provide a payment platform, the (dis)-connecting for the meters, administration, invoicing and helpdesk. Nijmegen takes care of the management & maintenance itself. Nijmegen does not have a service contract for the other public quays in Nijmegen (*Waalhaven* and *Lindenberghaven*); here the municipality organises the payment, administration and invoicing etc. itself. The *Waalhaven* is used mainly by Nijmegen-based skippers and crews during the Four Days Marches festivities and over Christmas time, whereas the *Lindenberghaven* is a recreational port.

The following figure shows the electricity delivered in Nijmegen according to data provided by Nijmegen and Involtum. The data show a strong increase in 2016; this is expected to continue in 2017.

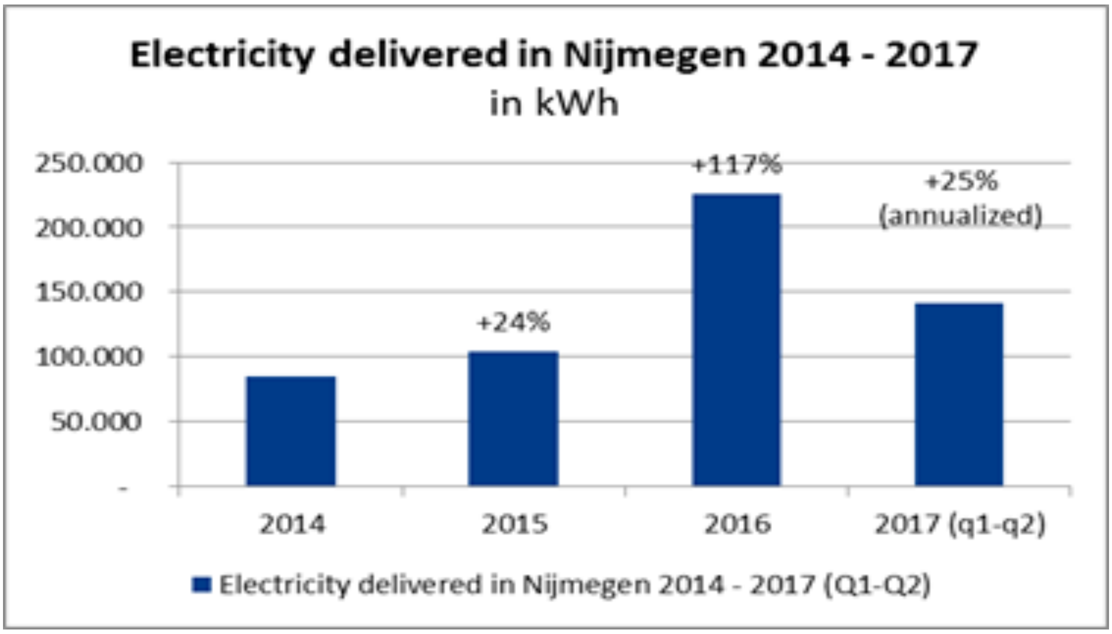


Figure 4.3 OPS electricity delivered in Nijmegen 2014-2017.

The data are broken down per OPS cabinet in the figure below (2014-2015 only).

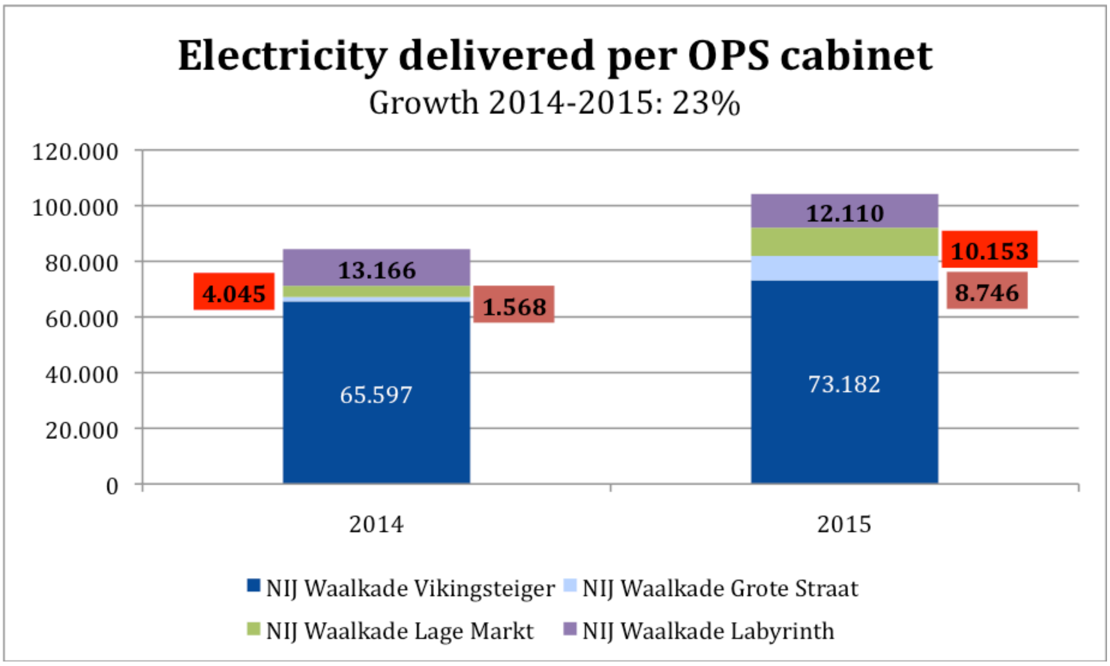


Figure 4.4 Electricity delivered per OPS cabinet 2014-2015.

The OPS cabinet *Vikingsteiger* showed the highest increase (in absolute terms). Relatively the cabinet *Waalkade Grote Straat* shows the highest increase to approximately 9,000 kWh. Notable is the 8% decrease in supply from the cabinet *Waalkade Labyrinth* to 12,110 kWh. The number of operational connections (individual sockets) increased from 14 in 2015 to 15 in 2015 and the user profile per connection changed. Details of this operation profile are available in Annex 3.

The average transaction time was 20 hours in 2014. This increased to 42 hours in 2015. This is below the national average for river cruise locations (see chapter 3).

The average consumption per transaction was 664 kWh in 2014. This increased to 709 kWh in 2015. This was above the national average in 2014, and below it in 2015.

C Business case

The business case for OPS in Nijmegen is currently negative. The initial investments were approximately € 1,000,000. 50% co-funding was obtained by the air quality programme, which significantly decreased the investment costs for the municipality. No exploitation model was made before the tendering and Nijmegen does not calculate depreciation costs.

The costs for management & maintenance have not structurally been attributed to the exploitation of OPS, but maintenance (repairs) usually costs € 4,500 a year. A fixed fee of € 1,150 per quarter is paid for the service contract for the operational platform. Nijmegen also pays electricity purchases and the energy taxes.

The city is paid 27.45 eurocents per kWh (incl. 21% VAT). This rate was not calculated based on a business model but is the same as the usual rates for OPS in the Netherlands.

This leads to the following indicative business case.

Gross revenue (226,000 kWh)	€ 49,000
Costs of electricity purchase (12 ct/kWh)	€ 27,000
Net revenue	€ 22,000
Annual repair costs	€ 4,500
Operational platform	€ 1,150
Depreciation (10 years, excluding interest)	€ 50,000
Net result exploitation	-€ 33,650

Adopting the calculation method for societal and environmental benefit applied to OPS in Port of Antwerp (chapter 5 of this deliverable), then the 2016 benefit of OPS in Nijmegen is € 31,977. So the costs of providing OPS are more or less balanced by the societal and environmental benefit.

D Opportunities to increase the use of OPS

Nijmegen estimates the utilisation of the OPS cabinets for the river cruise ships at about 90% of the moorings. The remaining 10% that are not connecting often have valid reasons (cables too short from assigned berth, short stay, cabinets fully occupied / use of Powerlock by other ships). For the freight ships the use is estimated at about 20% of the moorings. The 20% utilisation rate of OPS for freight ships is in line with other Dutch ports.

There are few opportunities to increase the utilisation of OPS in Nijmegen. Already a high percentage of the river cruise ships connect to OPS. It has occasionally occurred that no electricity was consumed while ships were connected. In such cases the port master will talk to the skipper, or if that is not successful, could also contact the owner. The online platform offers the possibility to see which ships are connected and where. Enforcement is hardly necessary because using OPS is also in the shipping company's own interest as it gives the clients a more pleasant stay on board (no noise and soot on deck).

An increase of the use of OPS for river cruise ships is in fact only possible when there is more "traffic" to the port (primarily an economic rationale) or when spatial/ economic considerations lead to a different design of the quays. For example, there may be a possibility for the mooring of cruise ships at the current designated spot for loading/unloading skippers' cars on the *Waalkade*. Then an OPS cabinet should also be installed there. This cabinet can be positioned in such a way that today's problem of "too short cables" is also resolved.

There are only few opportunities to stimulate the use of OPS for the freight vessels. The number of moorings is very dependent on the economy. During loading or unloading goods the ships are moored too short to use OPS, with the exception of container vessels (see section 4.1.5). This is because ships want to leave as soon as possible to go to the next job. This is confirmed by the experience gained from the demonstration of mobile OPS in Nijmegen (see section 4.1.6). The lesson learned is that if ships are at berth for longer time (for example if they wait for freight, or when they are staying in the *Waalhaven*), there are good chances that OPS will be used, provided that the costs of OPS per kWh are not higher than when the on-board generators are used to generate electricity.

4.1.3 Arnhem

A Policy background

With the help of the same policy package of the Arnhem Nijmegen City Region, the city of Arnhem invested in OPS on their *Nieuwe Kade* for river cruise vessels. Like Nijmegen, the city developed policy measures for the reduction of emissions from inland waterway transport. Compared to Nijmegen the number of freight ships that visit or pass by Arnhem is much lower: most ships on the Rotterdam-Ruhr area corridor sail the Waal river rather than the Rhine. On the other hand, Arnhem is a more popular river cruise port, base to several cruise companies, skippers and suppliers and maintenance firms.

Figure 4.5 Overview of river cruise berth Nieuwe Kade Arnhem with OPS cabinets

B Implementation and current use

Since 2016 OPS is available on the *Nieuwe Kade*. In contrast to Nijmegen, there is no on-board generator ban in Arnhem. River cruise vessels make use of OPS on voluntary basis, and use is rather limited. The OPS user data reveal that only few shipping companies used OPS: in 2016 OPS was connected during only 11 visits. Normally during the river cruise season (March-September) on average 3 ships are at berth. During the off-season (October – February) this has been shown to increase up to 35 ships a day. This means the utilisation of OPS in Arnhem is very low (less than 1% based on all visits).

It should also be noted that wrong figures were used for calculations before the tender (number of transactions with skippers instead of mooring periods), so that the grid-connected OPS solution is over-dimensioned based on false assumptions about the number of ships that could be expected.

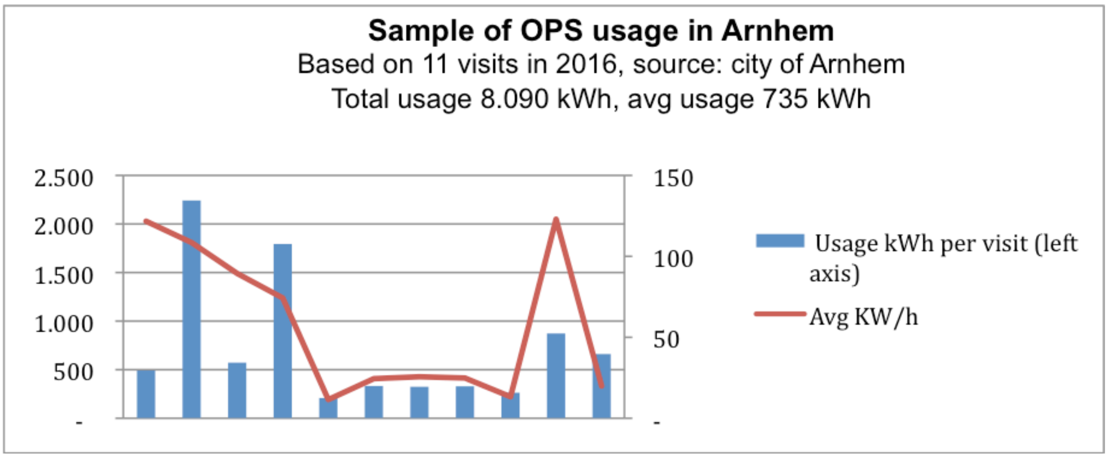


Figure 4.6 Sample of usage of OPS in Arnhem in 2016 (source: city of Arnhem).

The Arnhem port authority thinks that skippers make little use of OPS because of the price and complacency. However, the price of OPS in Arnhem is the same as in a lot of other ports, such as Nijmegen, namely 27.45 eurocents per kWh (incl. 21% VAT). So price should not be a decisive factor.

The municipality of Arnhem is considering a ships' generator ban, but the combination of obligation and the possible increase in costs for businesses is politically sensitive. If studies would show that the business case for river cruise ships with the current diesel prices is cost-neutral or would even be positive, then this supports the case for mandatory use of OPS. The municipality also sees possible problems in enforcing a possible generator ban.

C Business case

The annual fixed costs for the exploitation of the OPS facilities at *Nieuwe Kade* currently amount to € 35,000 (including depreciation). This is currently not recovered, and the costs burden the budget of the municipal port authority. Arnhem only received an income of roughly € 2,000 from OPS sales in 2016.

Last year Arnhem analysed the business case for OPS for skippers in the context of the future vision for its ports. Arnhem concluded that there was no business case for OPS for the river cruise ships, as a generator ban would lead to higher operational costs for skippers, based on their discussions with the skippers and a study by TU

Delft which concluded that the larger the generator's power capacity, the lower the cost of on-board generated electricity (per kWh).

Another aspect is that ships of the same company berthed beside each other in the port tend to link power cables, so that for example one on-board generator powers 4 ships (for hotel functions). This does not happen between competitors. Finally, the low price of diesel in recent years had a very negative impact on the business case for skippers using OPS.

As a result, the city of Arnhem has not issued a generator ban to date. Mid-2017 however, due to complaints by residents about noise of generators and because OPS at *Nieuwe Kade* is underused, the city is again investigating whether to issue a generator ban.

D Opportunities to increase the use of OPS

Besides the investigation to issue a generator ban in the city there are other opportunities to increase the usage of OPS, namely:

- New online services for skippers to increase use of OPS (in combination with payment of port fees, water intake)
- Clean mobile Energy project in which a local PV-park will deliver electricity to grid connected OPS.

4.1.4 Container Terminals Nijmegen and Doesburg

A Policy background

In response to the subsidy scheme of the Arnhem Nijmegen City Region for investing in low-emission technologies for inland waterway transport, the privately held container terminal BCTN applied for a grant to install OPS on their quay for providing electricity to their own (chartered) container ships.

B Implementation and current use

The total investment costs for four connections were € 45.000 (pulling cables over 40 to 320 meters from the existing transformer cabinet and installing four Mennekes five-pole 63A sockets). 50% investment subsidy was granted.

Figure 4.7 OPS sockets on BCTN quay (source: BCTN)

C Business case

The motivation for OPS on their terminal was that BCTN normally pays the diesel for the ships they charter. The savings on diesel used by the on-board generators provide a solid business case. This is notable because, based on market consultations, there is hardly a business case for providing OPS during loading and unloading of freight vessels. Container terminals can be an interesting exception if the following conditions are in place:

- The costs and benefits of implementing and exploiting OPS are in one hand,
- Time of loading/unloading is long enough.

BCTN report savings of ca. 8-9 litres/hour of diesel for their chartered ships. There are also indirect benefits such as lower maintenance costs for the ship owners. The use of OPS is mandatory at the terminal if ships stay for loading or unloading longer than 3 hours, provided that connecting to OPS can be done safely.

The following business case for a 208 TEU ship is illustrative:

A container ship arrives at BCTN four times a week and starts unloading for 6 hours and continues to load for 6 hours each time. The total berth time per visit is 12 hours. During this time, approximately 8-9 litres/hour diesel will be saved. The average costs of diesel are currently 700 euro per tonne or app. 70 eurocents per litre. This will result in savings of app. 10.000-15.000 euro per year (12 * 8 * 4 * 50 * 0,7 = € 13.440). The investments can thus be earned back in 3-4 years, BCTN provides the electricity via a low-tension grid to the skippers for free and no service model (for administration, (dis)-connecting the meters, invoicing etc.) is applicable so no other costs than management, maintenance, depreciation and electricity purchase (with energy taxes) are involved.

D Opportunities to increase the use of OPS

BCTN sees opportunities for other inland container terminals to install OPS if a user-friendly concept can be developed. BCTN also installed OPS at its terminal in Alblasserdam (in the Rotterdam area) for four ships.

BCTN cannot provide electricity for the cooling of reefer containers during loading/unloading because the installed OPS connection has insufficient capacity, but this could be a viable business opportunity for others.

OPS was also installed at another container terminal in the Arnhem Nijmegen region. Logistics service provider Royal Rotra applied for subsidy for the installation of OPS as part of their plan to construct a container terminal on their warehouse premises in Doesburg. The total investment costs were € 80.000 for hardware of the OPS cabinet, construction works, pulling cables and installation of electrical connections on the premises. The Arnhem Nijmegen City Region awarded 35% investment subsidy.

Figure 4.8 Overview Container Terminal Doesburg (the OPS cabinet is on the far left) via [Flickr](), published by Rotra Leading Logistics

The OPS is operational since 1 January 2017 and has only been tested so far. That means there are no user experiences yet. Different from the approach of BCTN, CTD (Rotra) charges 27.45 eurocents (incl. VAT) per kWh to skippers. Rotra commissioned a service contract for administration, (dis)-connecting the meters, invoicing etc. to Involtum.

Besides OPS for ships during loading and unloading, Royal Rotra also provides power for the cooling of reefer containers at the terminal.

4.1.5 Pilot with mobile OPS in Nijmegen

A Policy background

As part of the policy package on clean inland shipping (section 1.1.1.), the city of Nijmegen wanted to demonstrate the use of a mobile OPS generator in the port of Nijmegen.

Nijmegen aims to improve the air quality in its ports among others through its local regulation. The municipality thereby finds that facilitating grid-connected onshore power is not the solution to reduce on-board generator emissions in all locations. In some cases, grid-connected onshore power is not technically feasible, in other cases the social advantages do not outweigh the costs of facilitating onshore power supply. A pilot was held to evaluate whether a mobile OPS generator could be an alternative in such locations.

Search locations for the demonstration were the industrial part of the port where no OPS is installed, waiting areas for docks and the Waalhaven (where no OPS is available). The mobile OPS demonstration was intended to complement the grid connected OPS.

B Implementation and current use

The demonstration took place in 2016. The generator uses a 30 kW micro-turbine fuelled with compressed methane gas from cylinders, all packaged together in a shortened 20-foot ISO container that is easily transported on the back of a lorry. Its objective was to test the demand for onshore power with mobile units, to find out whether the technology is practical and meets the users' requirements, and to find out in which case(s) mobile onshore power is useful in addition to grid-connected onshore power.

Figure 4.9 Commissioning of the mobile OPS unit in Nijmegen

During this period it became clear which type of ships are or aren't interested in onshore power. In particular ship owners who are mooring to load or unload for rather short periods see little added value in the use of onshore power. It does not matter in their assessment whether grid-connected or mobile onshore power is being offered.

The project showed that mooring during 6 hours or less is too short for the ship owner to use onshore power. 6 hours seem long, but is about the period it takes the vessels to load or unload. During these activities skippers are too occupied to switch the ship to onshore power. The actual actions of connecting to onshore power are not time-consuming: rolling out the connecting cable, logging in and transferring the switch. But the wish to be able to quickly proceed after loading/unloading and the actions required for onshore power together provide a (mental) threshold. Typically skippers operating in the transport of sand/gravel or construction materials have short loading/unloading times and are therefore not likely to use OPS voluntarily.

C Business case

The demonstration indicated that the business case from the perspective of the operator of the OPS unit is very difficult. This is because of the high transportation costs for the replacement of CNG bottles combined with the relative short running time. The demonstration showed that the ships typically do not use more than 8 to 10 kWh. At such load the OPS unit uses approximately 100 m^3 per 24 hours and can supply power during one weekend.

From a business case perspective it is concluded that the period between two fillings is too short: the unit must be able to function longer on one filling of fuel.

D Opportunities to increase the use of OPS

The demonstration showed that mobile (or temporary use of) OPS can function as a pioneer for the realisation of grid-connected OPS. With real-life data the tendering of a grid connected OPS could be based on actual demand and user profiles, which in turn would lead to better modulated grid connected OPS solutions.

The technical problems that arose during the demonstration period were all solved or could be solved. Practice shows that the concept can gain a lot from a longer running time (i.e. the time during which the unit can supply power without having to refuel). The option to make a temporary connection to the gas grid is possible at quays where there is a nearby gas pipeline available. At other quays, a good alternative could be to use LNG stored in a tank with sufficient capacity (app. 10 m^3) inside the unit and/or an extra container with an LNG tank beside the unit.

The energy content of LNG is much higher than CNG, allowing the unit to work for about 13 days in the cases with a demand of app. 10 kWh per day. A disadvantage of the LNG is that 2,500 litres must be refilled whereas LNG is delivered really only per tanktruck, implying that a tanktruck with 40 m^3 (40,000 litres) of LNG would be on the road to deliver 2,500 litres. In order to make this economically viable there must be either a LNG filling station nearby, so that the delivery could be taken up in the route to the filling station, or there should be more onshore power units to refill in one route.

Another option is to integrate the unit into a moving vehicle, in order to be able to drive the unit to a LNG filling station. Such implementation is ideally suited to supply event power for short periods, or as a quick alternative should a grid-connected power outlet fail.

4.1.6 Port of distresss

A Policy background

A port of distress ("overnachtingshaven") is formally a port, provided by Rijkswaterstaat in a number of places along the main rivers, specifically intended for inland navigation. Rijkswaterstaat defines ports of distress as follows: "Ports of distress are resting areas where inland waterways can safely stay overnight." The ports are not longer than about 2 hours (approximately 30 kilometers) apart, so that the ship owners can comply with the prescribed sailing and rest periods from the

Inland Shipping Act. Depending on the location, ships may stay in the port of distress up to 24 hours or 3 times 24 hours.

There are three ports of distress on the Waal and IJssel in the Arnhem Nijmegen City Region that are being renovated or newly constructed on behalf of Rijkswaterstaat (national Department for Public Works and Waterways). These are Lobith, Spijk and Giesbeek. The provision of OPS is included in the plans for these locations.

B Implementation and current use

The implementation of OPS at ports of distress in the Arnhem Nijmegen Region is still under construction, so there are no experiences. Because the national Department for Public Works and Waterways (RWS) will realise multiple locations with OPS they will issue a template for realising (demand driven) OPS facilities.

C Business case

Currently there are no detailed analyses about the expected business case. However, we expect – based on the good geography and mandatory OPS usage a fairly good business case. Because the realisation of OPS is part of a bigger plan it is expected that the costs attributed to OPS are lower.

D Opportunities to increase the use of OPS

Mandatory use of OPS will influence the uptake of OPS usage, however in general it will mostly be macro driven.

4.2 Antwerp / Flanders

4.2.1 Introduction

The Port of Antwerp, the second largest seaport in Europe, is located in Belgium along the river Scheldt, roughly 100 km from the river's mouth in the Northsea. In 2016, a total amount of 214.1 million ton of goods were loaded or unloaded from marine vessels, consisting of 117.9 million tons of containers, 69.2 million tons of liquid bulk, 14.4 million tons of breakbulk and 12.6 million tons of dry bulk. Due to its central location in Europe and its direct connection to the river Rhine, main consumer markets in the Netherlands, Germany, Luxemburg, Switzerland and France belong to the natural hinterland of the port. On a yearly basis, nearly 50,000 barges are handled in the Port of Antwerp, including over 200 container shuttles per week to more than 80 destinations in 7 countries. Port of Antwerp (PoA) aims to transfer 40% of all goods to and from its hinterland by barge in 2030.

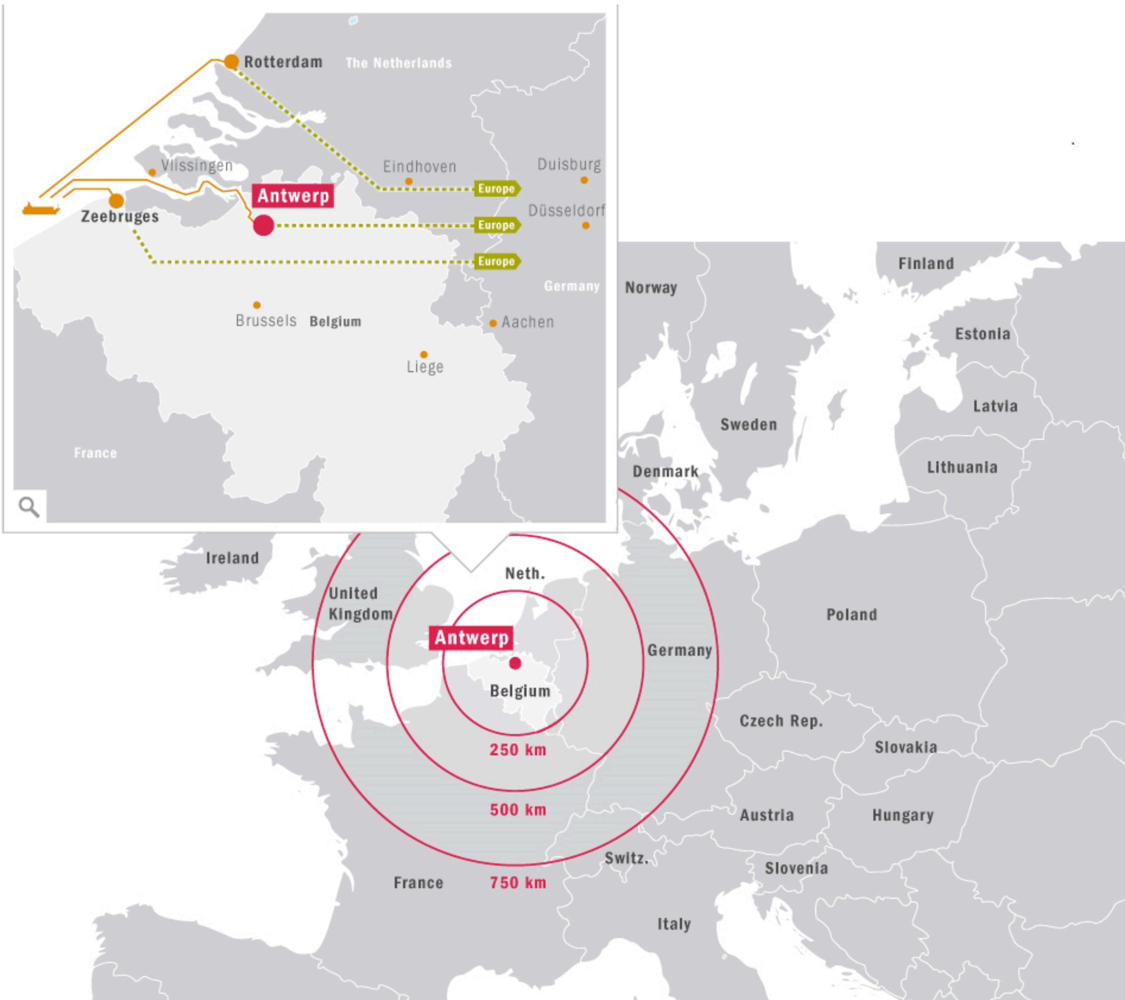


Figure 4.10 Location of Port of Antwerp in Europe and distances to main destinations in the hinterland

4.2.2 Policy background

Flemish region

Several initiatives have been taken in the past decade that are at the basis of the current Flemish policy for the provision of onshore power supply:

1. The Flemish 3E (Ecology/Economy/Energy Efficiency) inland navigation covenant, was founded in 2009 under the auspices of the Flanders Inland Shipping Network (FISN). Among the objectives of the covenant were the reduction of CO, NOx, PM

and CO_2, which was translated into the **3E Inland Navigation Plan**. This action plan provisioned among others the continuous expansion of onshore power supply in Flanders.

2. The **Air Quality Plan**, approved on 30 March 2012 by the Flemish Government, contained measures to reduce NO_2 concentrations by 2015. The Plan also foresaw actions to encourage the use of onshore power supply.

As a result, the Flemish Shore Power Platform was founded, with members representing the inland navigation sector, the Flemish waterway managers, the Flemish ports and chaired by the Flemish government. A few of the results that were delivered by the Platform are:

- Grants or financial support from the Flemish Government for shore power infrastructure in the framework of Flemish Climate Fund;
- A common communication strategy referring to the user friendliness and the ecological soundness of electricity at berth;
- Regulation and policy to encourage the use of shore power (including the current investigation to discourage the use of diesel generators when onshore power supply is available);
- Uniform management and payment system across Flanders;
- Uniform price of 0.27 €/kWh (VAT excluded) for the end user to purchase shore power in Flanders;
- Compilation of an action plan to promote the use of shore power within the framework of the European TEN-T project Shore Power in Flanders.7

The platform was renamed in 2015 to the Flemish Inland Navigation Services Platform (*Vlaams Binnenvaartservices Platform*) and since then is guided by the action plan that was compiled within the Shore Power in Flanders project.

Port of Antwerp

Since 2010 PoA offers services like electricity supply, water dispensation, port reception facilities, which are included in the basic tasks of the port. Therefore a big part of these services are provided by the port authority itself. This fits perfectly in the previous and current business plan with which we try to realise a vital and effective port (*integration of several services*), a sustainable port (*lowering the emissions of pollutants*) and a driven port (*intensive dialogue with port users*).
To optimize these services, the market was consulted in 2011 to modernize the existing OPS installation for barges in the port area. Included in the consultation were the payment options. A steering committee was put together to work out the

organization of paying services for barges (electricity, water dispensation, waste, ...) within the port area. Two aspects need to be mentioned, namely:

- Most important aspect: PoA sells electricity to third parties, which is subject to strict conditions. However PoA belongs to the exceptions of the prohibition of "private distribution network" (see article 4.7.1, §2 of the Energy decree).8 If we manage the OPS distribution net and deliver the power to barges, then this service is subordinate to all other services delivered by PoA. Similar examples are yacht clubs where the delivered power is included in the berth, as just a small part of the whole sum of services.
- In Port of Antwerp, it is prohibited to use a generator on board of barges to generate electricity if the ship is berthed and can physically be connected to the onshore power cabinets of the Port Authority (see article 3.9.1 of the Municipal port police regulation).[9]

Finally in 2012 the management committee started with the implementation of the shore power cabinets and payment services for barges at K75 (quay 75). In the years following 2012, PoA wanted to extend the OPS infrastructure for barges in the Antwerp port area. Even so, PoA aims for a uniform paying service for OPS in Flanders. The previous action is done in cooperation with other stakeholders like MOW (Flemish department of Mobility and Public Works), LNE (Flemish department of Environment, Nature and Energy) and the Vlaamse Waterweg (a public authority that manages the most important water ways). For more information see the platform for barges services.[10] All these actions fit with the action plan "Fine dust and NO_2 for city and port of Antwerp - period 2014-2018".

4.2.3 Implementation and current use

Technical characteristics of the onshore power supply systems

At quay 75, nine new onshore power supply systems were commissioned in September 2014. 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 quay 15 were commissioned in January 2016 and are dedicated for use by river cruises. At this location, four systems each consist of 2 connection points each (1 x 400 A; 1 x 125 A).

Figure 4.11 Locations of quay 15 and quay 75 in the Antwerp harbour

Use of the onshore power supply systems

To raise awareness and to stimulate the use of onshore power supply, the electricity was provided free of charge until early 2015, after which the uniform price of 0.27 €/kWh was charged. Once registered online, the skipper can connect and disconnect to the system by using the ENI-number of his ship. This can be done either by text message (sms), by calling or through the website www.binnenvaartservices.be. The electricity consumption can then be monitored continuously on the website. The ship owner receives an invoice of the consumed electricity on a monthly basis.

In the period between September 2014 and June 2017, 140 unique users used the onshore power supply systems at quay 75 and made a total of 707 connections. In 2016, 57 unique river cruise vessels used the systems at quay 15 and made a total of 222 connections. The total consumption of electricity at quay 75 between September 2014 and December 2016 was 74,491 kWh (Fig. 3). The total consumption of electricity by river cruise vessels at quay 15 in 2016 only was 373,125 kWh (not shown in the figure).

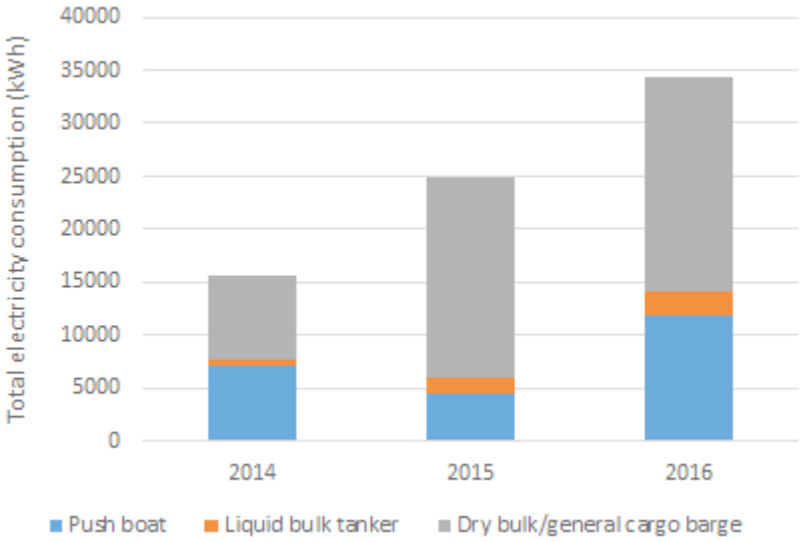


Figure 4.12 Total electricity consumption at quay 75 by push (tow) boats, liquid tankers and dry bulk/general cargo vessels between September 2014 and June 2017

Table 1 Average power and average connection time by different types of vessels at the onshore power supply systems at quay 15 and quay 75

	Average power (kW)	*Average connection time (h)*	*Average energy per transaction (kWh)*
River cruise	*73.93*	*33*	*2.440*
Push boat (tow boat)	*1.81*	*116*	*210*
Liquid bulk tanker	*3.77*	*27*	*102*
Dry bulk/general cargo barge	*1.24*	*74*	*92*

It should be noted that these average figures from this sample are not in line with the overall results from the data analysis form the Netherlands. However, it was concluded that the indicator 'average' is statistically less relevant than the median. If we compare the results from this sample with the median results from the data analysis in the Netherlands, these results are more in line. Also there are other methodological aspects, such as the split in liquid and dry bulk barges. This distinction was not possible in the data set from Involtum.

4.2.4 Business case

Investment

The 3 OPS installations (including 4 connection points altogether) for river cruises at K15 had an initial total investment cost of € 953,747, of which about € 150,000 were received as co-financing within the TEN-T programme. The depreciation of the installation is calculated based on a lifespan of the installation of 20 years and a residual value of € 120,000. The operational costs consist mainly of maintenance of the installations (€ 25,137 on a yearly basis) and the purchase of electricity (around 0.11 €/kWh). At a selling rate of 0.27 €/kWh, the installation will be earned back after approximately 11 years.

Societal and environmental benefits

For calculating the environmental benefit of OPS, the avoided emissions of a ship with CCR II-generator can be taken into account. The avoided emissions by using 1MWh of shore power supply amounts to 1,064 kg CO_2, 6.71 g SOx, 200 g PM_{10} and 6 kg NOx (on the basis of the incineration of an amount of diesel with the same energy content and taking into account an efficiency of the generator of 25%). Taking the social costs (health care) of these pollutants into account, the use of 1 MWh OPS delivers a benefit of € 141.49 (using cost parameters from AEA Technology environment 2005). See chapter 5 for a more comprehensive calculation of environmental effects.

4.2.5 Opportunities for a better use

All stakeholders are given the opportunity to ask questions or give remarks during meetings of the "Flemish barge services platform" (Vlaamse Binnenvaartservices Platform). The most common topics are the right contact details and the price of onshore power supply.

This Flemish barge services platform promotes OPS by different actions with the involved stakeholders. At the moment 13 actions are launched, each with a deadline and stakeholders (ports, waterway managers, ...) that take the lead. The following actions have the highest priority:

- Proposing a measure to support adaptations to ships for use of OPS;
- Elaborating an open databank with all actual information for the OPS installations;

- The deployment of a uniform management system for OPS in Flanders, including a single sign on for end users;
- Co-ordination of all actions for developing the action plan "enlarge OPS network" with a long-lasting communication campaign for various target groups;
- Embedding of existing instruments.

Final remarks

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. Policy makers could produce a net societal gain by implementing incentives and mandates to encourage a shift toward onshore power. River cruisers have higher power and electricity demand and thus provide a better business case for OPS for inland navigation and better prospects for market development.

4.3 North Rhine-Westphalia

4.3.1 Introduction

North Rhine-Westphalia (NRW) has a dense canal network with direct connections to the ports of the ZARA ports of Zeebrugge, Antwerp, Rotterdam, Amsterdam and the German seaports. The channel system in NRW in the Rhine-Ruhr region with its 5.3 million inhabitants supports the densest network of inland ports in Germany. These inland ports are mainly used for cargo and freight shipping, serving the supply, import and export of the entire region.

By switching to Inland waterway transport the burden on the surrounding rail and road infrastructure is relieved, thereby reducing congestion, energy and fuel costs. In terms of energy consumption per tonne of freight, inland shipping is already regarded as one of the most efficient means of transport. Nevertheless, work has to be done in Germany on the development of modern, energy-efficient and environmentally friendly vessels for inland waterways in order to achieve energy and cost savings as the volume of freight transported by inland waterways increases.

Inland waterway transport is mainly structured into small-scale enterprises, but the organization of transport is mainly accommodated by a few large shipping firms. The increasing interest in inland waterway transport is due to increasing infrastructural bottlenecks in rail and road transport caused by integration, whereas waterways still have high capacity reserves. NRW alone accounts for more than half of the shipping volume of inland waterway transport in Germany (about 221.3 million tons in 2016) more than 54% of which is transported into NRW. These figures reflect the regional importance of the industry, especially with regards to the large-scale industries located in the municipalities along the waterways.

The advantages of inland waterway transport in comparison to road transport have served as a stimulant to further continue the switch from the conventional road transport to the modern inland waterway transport. Inland waterways are an environmentally friendly alternative to trucks, as a ship can replace up to 200 trucks. In fact, inland waterways per tonne of freight produce significantly less carbon dioxide than trucks. Although a ship can replace many trucks, the old diesel engines used in ships blow out a lot of pollutants into the air. This is especially true for the emissions of nitrogen oxides (NOx) and particulate matter (PM_{10}), which in marine engines are now higher than those of road and rail.

Concerning possible measures to reduce emissions from the European barge fleet (about 14,000 vessels), there is a lot to be done in comparison to advanced engine and exhaust gas technologies in road traffic. Air pollutants such as particulate matter, sulphur and nitrogen dioxides cause a higher level of air pollution, especially in cities along the waterways. This is also confirmed by the emission registry of the State Office for Nature, Environment and Consumer Protection of North Rhine-Westphalia (LANUV NRW). The measurement registry showed that in 2014 only 12% of the measuring stations moved within the limits of the EU according to Directive 2008/50 / EC. The increased air pollutants can lead to damaging the health of the citizens that live in near the inland waterways. The consequences are respiratory diseases, specifically asthma, bronchitis and cancer. In the case of an increase in inland waterway transport, the deterioration of air quality is to be feared when the engines currently in operation are used.

For a transit state like NRW with a high population density the need to reduce CO_2 emissions and to improve the air quality especially in the cities along the waterways is crucial. Alternative drives and fuels are necessary for more sustainable Inland Shipping as well as efficiency measurements as onshore power supply.

Port of Duisburg

NRW is by far the largest location for inland ports in Germany. Approximately 120 are located in this state, 23 of which are public; said ports handle 125 million tons of goods excluding private commercial ports. Duisburg, the most important inland port in NRW, located in the heart of the Rhine-Ruhr industrial belt, is also Europe´s largest inland port. A gross 72% of the overall traffic of the port is raw materials, and Duisburg is also the leading inland port for container traffic. The port has an annual container capacity of 3.7 million TEUs. Total throughput rose to 133 million metric tons from 123 million metric tons in 2013, according to provisional figures. Duisburg Port's profit before tax increased to a record €14 million from €12 million in the previous year and revenue grew 13% to €198 million. There are 130 crane systems which have led to a total cargo handled by all Duisburg ports of 133 million tons in 2016; this amount comes from 20,000 ships handled that year.

RheinCargo GmbH

RheinCargo GmbH & Co. KG. is the cooperation between the partners "Hafen und Güterverkehr Köln AG" (HGK) and "Neuss-Düsseldorfer Häfen GmbH & Co. KG" (NDH). Both companies hold a 50 per cent stake in the Freight Group, which was founded in 2012 and which combines the operational areas of port logistics, rail freight transport and real estate.

4.3.2 Policy background

Onshore power supply has been supported on the German national level and by the European Union. Firstly, the federal government acknowledges that onshore power can be used a technical measure in improving efficiency in shipping. The federal government welcomes the funding of projects within the "Connecting Europe Facility" (CEF) framework in order to achieve a constant supply of onshore power. Secondly the European Union based on Article 4 (5) Directive 2014/94/EU calls for the establishment of OPS in sea and inland ports by 31.12.2025, provided there is a demonstration of demand, a positive cost-benefit ratio and possible environmental benefits. The high investment costs for the installation of distribution and connection facilities for the port as well as for ships led to incentives such as the Electricity Tax Act (StromStG) which stipulates a reduced electricity tax rate of 0.50 per MWh to be put in place. Furthermore, TEN-T funding can increase the attractiveness of OPS compared to the on-board power generation.

To master the challenges that German ports face the German cabinet has released the new national port concept 2015. Some of the challenges that the concept aims to tackle are cargo handling growth, tougher competition, stiffer demands on environmental protection, and security. One of the key objectives of the National Port Concept is the strengthening of climate and environmental protection in ports, e.g. through alternative fuels and the onshore power supply of vessels. Another aim of the federal government from the National Port Concept is to adapt the EU Energy Tax Directive to the point where a compulsory tax exemption exists for onshore power to provide commercial shipping services. Lastly the Federal Government is discussing further possibilities to support the supply of onshore power.

A problem the supporters of OPS face is that the electricity demand can amount to quite a few MWh, thus new electricity generation facilities would have to be built to supply the ships. To achieve this, considerable investments are being made for the transmission of the extra electricity quantities to be generated at the level of the distribution networks as well as on the ships. This presents more favourable conditions in the area of inland waterway transport as a result of the requirements for emission reduction and especially noise protection being met.

Funding possibilities

When searching for funding possibilities in NRW the main focus must be towards the Leitmarktwettbewerb.NRW (competitions in the leading markets of NRW). Furthermore an agency such as the State Agency for Environment NRW (LANUV) deals with the reduction of pollutions (mainly particles and NOx). Possible sources of funding other than in NRW for onshore power projects are the German federal government level and the European Union.

The German federal government has introduced different directives and programmes to fund onshore power projects, some of which are the BMVI Funding Directive Innovative Port Technologies (IHATEC) where technical innovations are being promoted to increase energy efficiency in the port and reduce environmental pollution. Another directive is the BMWi funding programme "Innovative shipbuilding secures competitive jobs" where eligible innovations are provided when demonstrable improvements in quality and performance are achieved in the environmental sector (e.g. optimization of fuel consumption, engine emissions, waste and safety) are demonstrated. Innovative promotion can be applied to existing shipyards responsible for shipbuilding and ship repairs. Finally, the federal government has created a supporting line for up and coming engineers, which is a Cooperative Promotion within the framework of the "Research at Colleges”.

The European Union has founded funding programmes for funding onshore Power projects; the first of these is the CEF programme, which states:

- For Inland Waterways, priority will be given to the provision of alternate fuel infrastructure, such as LNG, Methanol or electric charging.
- For Inland ports, priority will be given to providing or improving the introduction or implementation of fixed infrastructure regarding alternative energy, e.g. LNG bunkering and shore-side electricity.

The second programme that supports onshore power projects is the Horizon 2020 programme, which includes the research themes:

- MG-2.1-2017: Innovations for energy efficiency and emission control in waterborne transport. Proposals should address one or several of the following aspects: Development, demonstration and evaluation of innovative pollution reduction and control technologies and modelling and simulation of solutions with full-scale verification.
- MG-7-3-2017: The Port of the future. Research and innovation actions should address several of the following aspects: Low environmental impact, climate change adaptation and mitigation, and moves towards the circular economy.

4.3.3 Implementation and current use

Technical characteristics of the onshore power supply systems

In Germany there is a wide, but non-uniform network of onshore power facilities. The majority of the Onshore Power facilities available in Germany are operated by the Federal Waterways and Shipping Administration (WSV). These differ in their dimensioning as well as in the design of the payment systems. There is a tendering process going on carried out by the WSV for OPS in ports of distress.

On the busy Rhine and Wesel-Datteln canals, on the Dortmund-Ems channel and on the coastal canal, 16 or 32 A and 400 V is available. The North German inland waterways, the Mittelland channel and the Elbe side channel mainly provide ships with 16A and 230 or 400 volts. A similar range of different systems can be found at the onshore stations equipped with onshore power in the German inland ports. The CEE plug is the standard throughout Germany.

In the last few years onshore power has been implemented in several ports in NRW, starting from the port in Cologne where at the end of 2015 eleven charging stations were set up in the *Rheinauhafen* for the supply of cargo ships. In Düsseldorf since the spring of 2016, hotel and cruise ships can be supplied with onshore power from three cabinets at three piers of RheinCargo, below the Düsseldorf Rhein terraces, and one cabinet for leisure boats and houseboats was installed in the Düsseldorf Marina. Finally, in the Neuss-Düsseldorf port, an OPS cabinet for the connection of cargo ships has been installed.

A project which organizes Onshore Power Supply is RheinEnergie's SchiifsTankE-project in Cologne. River cruisers can reserve and start OPS under the same app as electric car users (TankE); OPS for freight vessels is reserved and started by sms.

In the largest port of NRW, operated by Port of Duisburg AG, there are onshore power connections for 4 ships (380 and 400 volts). Billing is done with coins (to be bought by the harbour master). Investment costs for a completely new onshore power facility are estimated to start from €30,000. There are planned onshore power cabinets for river cruise ships on Mercator Island. According to the port: "The industry is reluctant to use land-based power plants, for reasons of cost, no uniform billing systems and handling."

In the north of the "Oberkassel bridge" in Düsseldorf, two piers will be equipped with power connections for ships in the coming months. The work will take place from 18/09/2017 to 31/01/2018. On the banks of the river Rhine in the Düsseldorfer district of the old town, hotel and cruise ships berth especially at the time of trade fairs. In order to maintain the power supply on the ships, the diesel engines of the ships run during these times. The considerable emissions of particulate matter, CO_2 and noise can be avoided in the future if the ships are supplied with electricity from onshore power.

Use of the onshore power supply systems

There are many other ports in NRW where onshore power is not yet widely used, these ports are both publicly and privately owned.

85% of cargo ships on the Rhine have an average travel time of 14 – 18 hours, so there is an idle time of 6-10 hours for which onshore power supply is suitable. In addition, there may be longer (sometimes lagging) periods of time, especially for trade fair and hotel ships, so that OPS is of particular interest for these ships.
The main issue is the right and accurate dimensioning in developing onshore power supply. RheinEnergie has dimensioned the capacity needs for their OPS units for cruise vessels with the following parameters based on their own measurements

(initially they thought that 50 kW would be sufficient but the measurements showed otherwise):

- Hibernating medium-sized river cruise vessel: 78 kW
- Hibernating river cruise vessel: 125 kW
- River cruise vessels with full hotel function: 300 kW.

The figure below shows the current situation. One (initially rented) transformer with one (self-developed) OPS cabinet (with Powerlock) has been installed for 10 ships; three more of such installations are planned until end of the year. Then the total installed power will be 3 MW. This is dimensioned for 34 vessels including 3 that provide hotel function. The maximum average power required for 10 ships has been measured at 1,748 kW (real-time monitoring), but there are peaks especially when air-condition compressors switch on.

Figure 4.13 Figure –Overview port of Cologne, OPS for river cruisers of Viking Company

4.3.4 Business case

Investment

The costs for the entire installation for the port of Cologne are estimated to be below €1 million. A major part of the cost is of earthworks for cables. The fact that the cogeneration plant is adjacent avoids the need for expensive grid reinforcements, but it was not a reason to choose this location. The rate for OPS in Cologne is €0.26/kWh including VAT, but 2 €cts energy tax can be reclaimed from the tax office. The amount of energy consumed at this location is not enough to qualify for the cheaper rate for major consumers. In Duisburg for example the price per (excluding VAT) kWh is 18 cents. The payback time for the Cologne port project is assumed to be between 7 and 10 years. Currently there is no further information with regard to the business cases for the OPS at other ports

Societal and environmental benefits

Onshore power is an option to reduce emissions from the ships while in the port. The extent of the reduction depends mainly on one hand the type of fuel burned in the ship and on the other hand the energy mix used for the electricity generation onshore. Though onshore power supply, fed by a conventional energy mix, has no or only minor ecological advantages compared to the electricity generated on board. This ratio can change as a result of the increasing generation of electricity from regenerative energy sources. A couple of issues that onshore power effectively deals with are that charging stations help in the minimization of noise and exhaust emissions in populated areas and finally charging stations help ensure that crew members and adjacent vessels do not experience noise during rest periods.

4.3.5 Opportunities for a better use

- The establishment of a nationwide network of charging stations attracts high investment costs, which can be represented only with accompanying measures economically. Due to the high diesel prices, onshore power barges can help in reducing fuel costs. These cost advantages would be reduced or abolished if the investment and maintenance costs were re-allocated to inland navigation.
- Onshore power supply is most suitable for river, hotel and mess ships, due to the longer time the ships berth at the ports and are considered to be idle.
- There are regulations for the use of landing stages, but there are no common technical or application standards for the use yet.
- There is a tendering process going on carried out by the WSV for OPS in ports of distress.
- Port operators and investors are interested in mobile onshore power solutions, since these can ensure a demand-driven and flexible use of onshore power. Mobile onshore power solutions provide extra flexibility when peak demands have to be covered. This solution is also feasible for terminals.
- Port services and costs are known for some ports.

Further actions required from NRW point of view:

- Onshore power is currently only offered for river, hotel and fair ships, therefore possibly an expansion of the onshore power facilities for other opportunities.
- Especially mobile OPS could be used to cover peak demands. It would be possible to investigate mobile land-based onshore power facilities more closely and see whether the ports would have a higher acceptance for these than for fixed land-based onshore power units.
- Further researching of port services and costs for some ports.
- A funding programme should be initiated for the ports that have concerns with regards to building onshore power plants.
- The legal framework for the construction and use of shore power stations should also be looked at in more detail.
- In NRW a standardised use of the shore power facilities can be made possible through standardized payment procedures/methods.

5. Environmental and economic benefits

5.1 Introduction

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 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 CO_2. The Air Quality Plan approved on 30 March 2012 by the Flemish Government containing measures to achieve the proposed NO_2 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. For inland navigation this means providing possibilities for support for emissions-reducing technologies, developing a regulatory and logistics framework for Liquid Natural Gas (LNG), making optimal use of shore power opportunities, appointing a shore power coordinator and establishing a shore power platform.

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 this environmentally friendly technology 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 Flemish Shore Power Platform. This includes is the TEN-T project (Shore power in Flanders_2012-BE-92063-S). The project's overall objective was to establish an onshore power network, including a uniform management and payment system (Figure 5.1), on a larger scale for inland navigation in Flanders to eventually contribute to its development as an environmental friendly alternative to road transport.

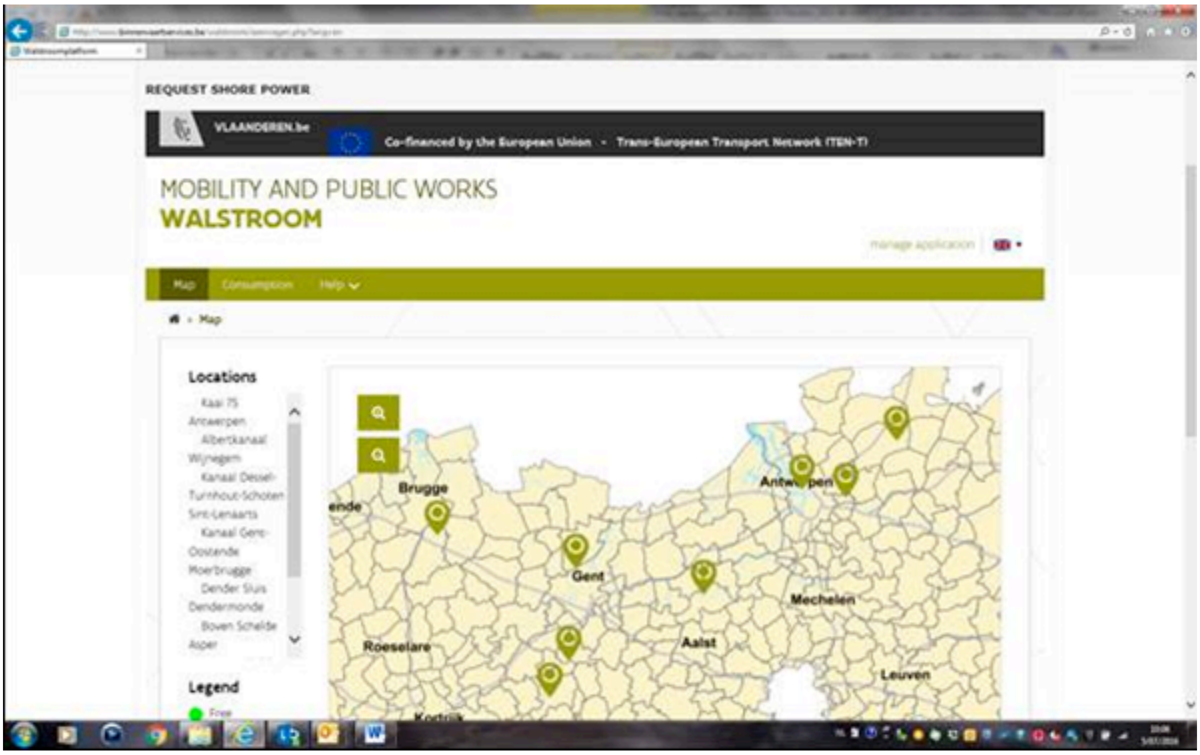


Figure 5.1 Central Management System for OPS in Flanders

Data from the TEN-T project has been used to assess the environmental and economic benefits of OPS. Data on electricity consumption by a specific ship in 2016 at quay 75 and quay 15 (the Kattendijkdock) in the port Antwerp has been used to estimate emission reductions (NOx, SO_2, PM and CO_2) by switching to onshore power electricity and to estimate the cost effectiveness of onshore power electricity.

5.2 Environmental impact

5.2.1 OPS data at quays 75 and 15 (Kattendijkdock) in Port of Antwerp

Data on electricity consumption by a specific ship in 2016 at quay 75 and quay 15 (the Kattendijkdock) in the Port Antwerp has been used to estimate emissions reductions (NOx, SO2, PM and CO_2) of onshore power electricity.

The onshore power installations at quay 75 in the Port of Antwerp (Figure 5.2) consist of 9 shore power boxes. Seven boxes are equipped with 4 independent connection points (2 connection points with a supply of 230V/32A and 2 connection points with a supply of 400V/32A) and two boxes with 3 independent connection points (2x 63A 400V and 1x 125A 400V), which ships can use to connect to the electrical grid when at berth.

The onshore power installations at the quay 15 (Kattendijkdock) are dedicated to river cruise vessels and consist of 3 shore power cabinets with a total of 8 recharging points.

Figure 5.2 Shore power installations (low voltage) at quay 75 in Port of Antwerp

Since the launch of the OPS management system of Port of Antwerp on 1 September 2014 until 2016 a total of 1,350 unique users were registered. In 2016, 203 cargo ships, 183 river cruise vessels, 15 tank ships, and 50 towboats have used the OPS installations at quay 75 and quay 15 (the Kattendijkdock). The total electrical power consumption of the shore power boxes at quays 75 and 15 combined, was 19,762 kWh for cargo ships, 2,273 kWh for tank ships, 7,066 for towboats, and 349,874 kWh for river cruise vessels (Figure 5.3).

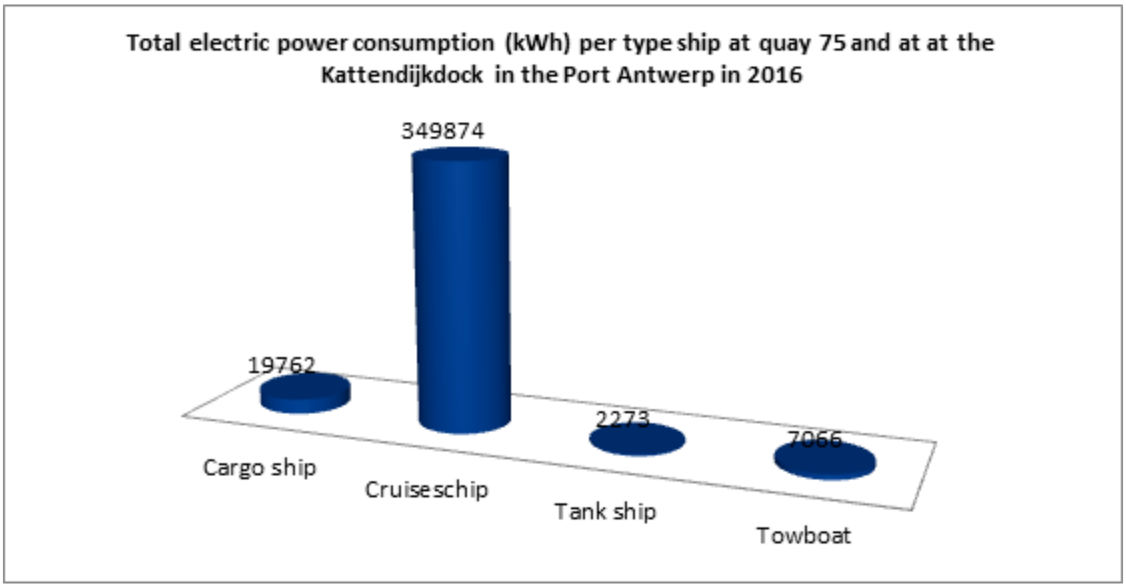


Figure 5.3 Total electric power consumption (kWh) at quay 75 and 15 (Kattendijkdock) in the Port of Antwerp in 2016.

The electrical power consumption of the river cruises represents more than 92% of the total electrical power consumption (Figure 5.4). However the cargo ships spent longer time at berth (61%) than river cruises (22%) (Figure 5.5).

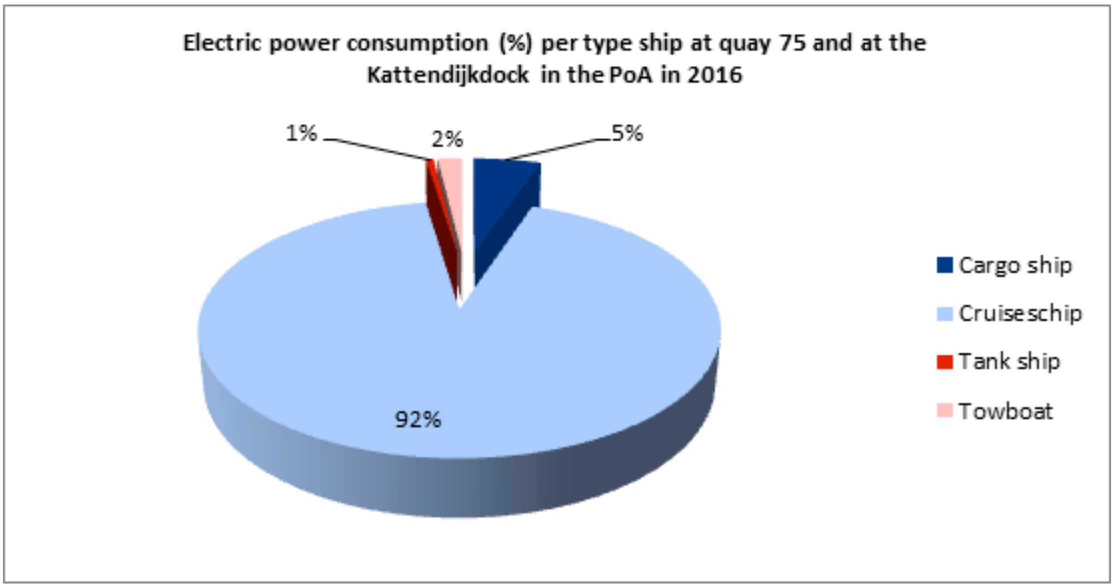


Figure 5.4 Electrical power consumption (%) per type ship at quay 75 and 15 (Kattendijkdock) in the Port of Antwerp in 2016.

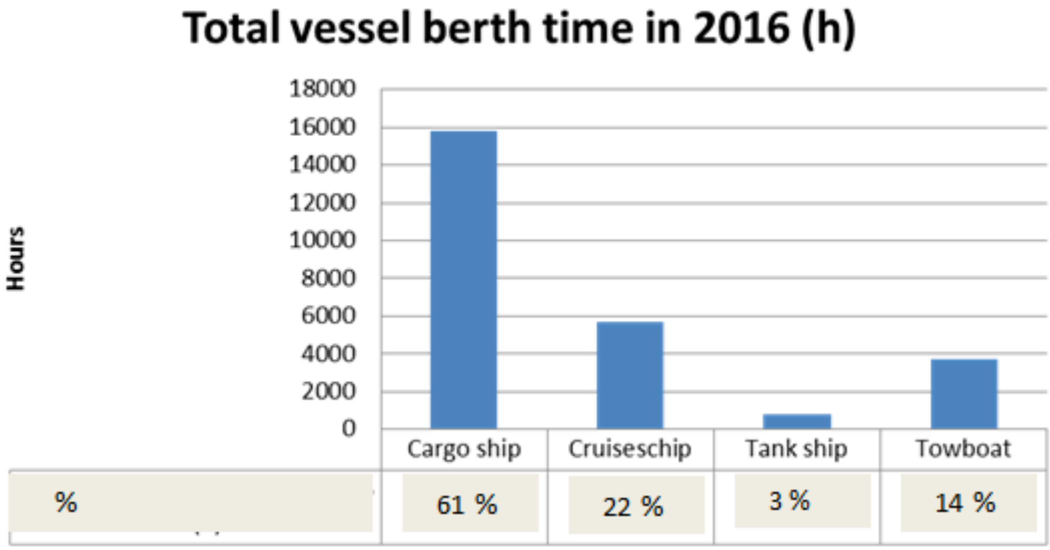


Figure 5.5 Vessel berth time per type ship (hours and %) at quay 75 and at the Kattendijkdock in the Port of Antwerp in 2016.

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

5.2.2 Environmental benefits of OPS

When at berth, ships use their Auxiliary Engines (AE) of the ship to produce electricity for hotelling, communications, unloading and loading activities. 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.

One measure to reduce emissions from AE's 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 an integrated assessment to quantify the benefits of reducing the emissions of NOx, SO_2, PM and CO_2 that would occur if onshore power were used. The assessment is based on vessel call data at quays 75 and 15 in Port of Antwerp.

Emissions from auxiliary engines

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 general formula for calculating emissions from inland shipping has been used:[11]

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

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. For the missing data the average value of 100 kW has been used according to a report by TNO.[12]

For the specific fuel consumption a representative value of 200 grams per produced kWh gas oil has been used.[9] Table 5.1 gives the different emission factors (g/kWh) per type of fuel used for the CO_2, NOx, PM_{10} and SO_2.

Table 5.1 Emission factors per type of fuel used for CO_2, NOx, PM_{10} and SO_2 as reported by TNO [9]

	CO_2	NOx	PM_{10}	SO_2
Gas-oil	3,160	50	2	2

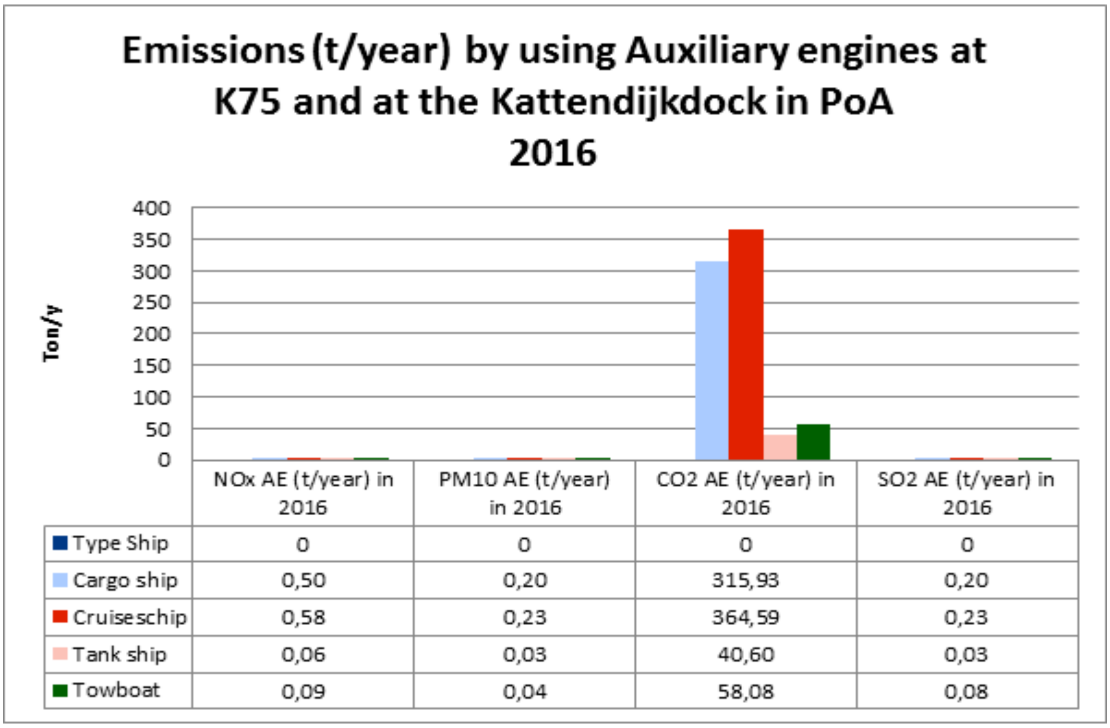


Figure 5.6 Emissions (t/year) by using auxiliary engines at K75 and K15 in the Port of Antwerp in 2016.

Emissions from using OPS

The local emissions avoided by the introduction of OPS lead to additional emissions in other locations resulting from the generation of the electricity. The formula for the calculation of emissions from the use of OPS is:

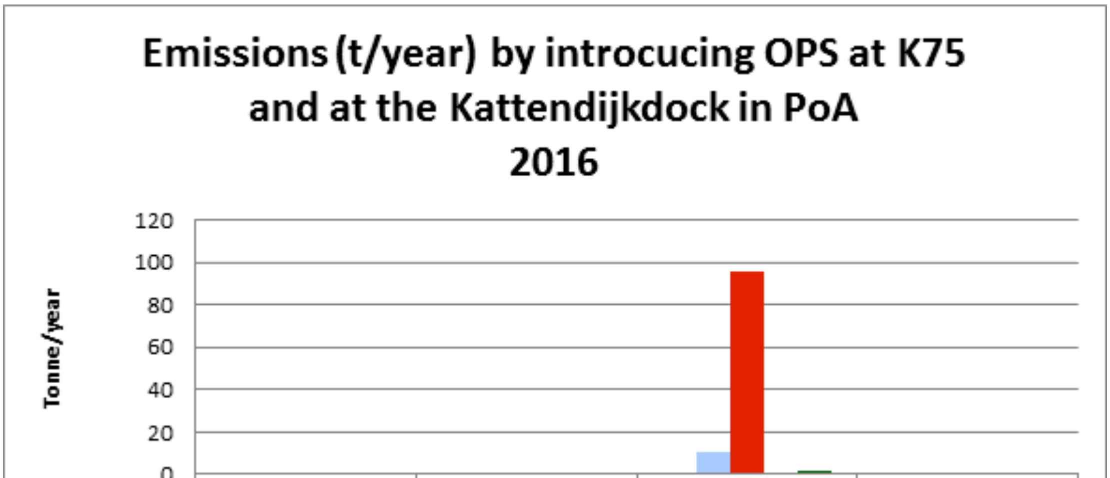
Emission (kg) = consumption OPS-electricity (kWh) x emission factors for electricity production in Flanders/Belgium.

The emission factors that apply to the current electricity production in Belgium were used (table 5.2). Those factors are relatively low in Belgium (285 g CO_2/kWh) compared to the average emissions factor in Europe (402 g $_{CO2}$/kWh) because of the shares of nuclear power plants and renewable electricity production in the national production mix. The factors for other countries are:[13]

- The Netherlands: 392,07 g CO_2/kWh
- Germany: 441,18 g CO_2/kWh
- UK: 486,94 g CO_2/kWh

Table 5.2 Emission factors (g/kWh) applied for electricity production in Belgium.[14]

	CO_2	NOx	PM_{10}	SO_2
Emission factor	285	0.325	0.005	0.06



	Nox	PM10	CO2	SO2
Type Ship	0	0	0	0
Cargo ship	0,0116	0,0002	10,1859	0,0021
Cruiseschip	0,1087	0,0017	95,3287	0,0201
Tank ship	0,0008	0,0000	0,6667	0,0001
Towboat	0,0017	0,0000	1,4516	0,0003

Figure 5.7 Emissions (t/year) by introducing OPS at quay 75 and quay 15 in the Port of Antwerp in 2016.

Net reduced emissions through the introduction of OPS
The formula for the calculating the net reduced emissions through the introduction of OPS is:

Reduced emissions through the use of shore-based power generator-use emission = emission use shore power

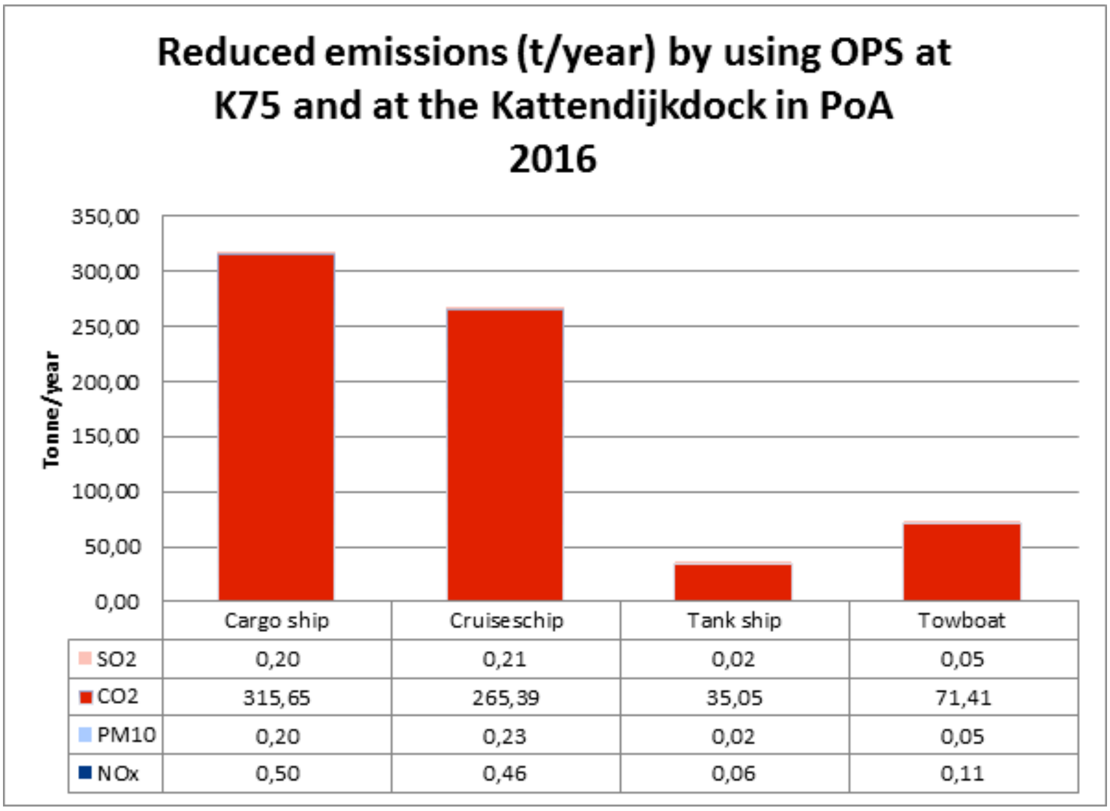


Figure 5.8 Reduced emissions (t/year) by using OPS at quay 75 and quay 15 in the Port of Antwerp in 2016.

In Figure 5.8, it can be seen that the absolute amounts of emissions saved or reduced can be mainly found in the substances CO_2 and NOx. The biggest emission reductions come from the ships that use the most energy in absolute terms: cargo ships and cruise vessels.

Table 5.3 Emission reduction efficiencies (percentages)

Type of ship	**NOx**	**PM_{10}**	**CO_2**	**SO_2**
Cargo ship	98.74	99.95	98.25	99.42
Cruise ship	80.32	99.24	72.69	90.92
Tank ship	98.69	99.95	98.19	99.40
Towboat	98.02	99.92	97.26	99.09

The relative savings of emissions is more interesting because this says more about the specific benefits of the introduction of OPS. Table 5.3 presents the estimated mid-range values of emission reduction efficiencies of OPS in 2016 at quay 75 and quay 15 (Kattendijkdock) in Port of Antwerp. There are for the relative savings of emissions only few differences between the various categories of ships.

The emissions of NOx can largely be avoided by the introduction of OPS. 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 ships, tank ships and towboats and by 90% for river cruise vessels. Emissions of CO_2 can almost be completely avoided by 98% for cargo ships, tank ships and towboats and by 72% for cruise ships. The reduction emission of CO_2 in this study is very high compared to other studies due to the low CO_2 emission factor for electricity production in Belgium. Hall indicates for example for UK a 25% reduction of emissions of CO_2 when using OPS as opposed to on-board power generation.

Conclusion
Onshore power can significantly reduce diesel emissions from ships at dock. Through the introduction of OPS the emissions of NOx can be reduced by about 93%. The emissions of PM_{10} can be reduced by 99%, and the emissions of SO_2 by more than 96%. The emissions of CO_2 can be reduced by more than 91% when utilizing power from the regional electricity grid. This is based on the Belgian energy mix.

The potential emission reduction benefits may be estimated for a particular vessel, at berth when connected to shore power. Factors such as the amount of time actually connected, power consumption rate and total time at berth are described in the assessment and relate to the overall effectiveness of onshore power. Because these factors must be evaluated for each situation, total emission reductions may vary. Note that in case of OPS, the exact amount of electricity that is requested by the vessel is delivered as such by the regional grid. In case of the deployment of auxiliary engines, however, the generator will be running at its full capacity, (rather) independently from the very demand of electricity on board the ship. Hence, the power provided and the fuel consumed may be higher than the actual demand of electric power in the latter case. This element was taken into account in the analysis.

The assessment suggests that onshore power may be most effective when applied at terminals with a high percentage of frequently returning vessels, typically river cruise ships and cargo ships.

5.2.3 Societal benefits (monetization of health impacts)

The electricity consumption through the use of OPS at quay 75 and quay 15 (Kattendijkdock) in 2016 has been calculated in the previous chapter. Using historical vessel data, we identify combinations of vessels and berth at above indicated terminals that have switched to onshore power to the largest gains for society. We used the monetized social benefit (mainly health care) by using onshore power.

The environmental benefit has been carefully estimated, and will probably be higher in reality. The assessment is based on a relatively recent ship with CCR II standards. Considering the existence of many older ships in the IWT fleet the environmental benefits are certainly higher in reality.

1MWh onshore power provides following prevented emissions:

- For CO_2: 400 litres of diesel are needed to generate 1,000 kWh (1 litre = 10 kWh at 25% engine efficiency). 1 litre diesel generates 2.66 kg CO_2 emissions. So 1000 kWh generates 1,064 kg CO_2 emissions.
- For SOx: 400 litres of diesel are needed to generate 1,000 kWh (1 litre = 10 kWh at 25% engine efficiency). 1 litre diesel generates 0.01679261 g SOx emissions. So 1000 kWh generates 6.71 g SOx emissions.
- For PM_{10} : 1,000 kWh generate 200 g PM_{10} (0.2 g/kWh, CCR II standard).
- For NOx : 1,000 kWh generate 6,000 g NOx (6 g/kWh, CCR II standard).

The social cost (cost of damages caused by the various pollutants) is calculated using cost factors from AEA Technology Environment (2005):

Total social costs = 1,064kg CO_2 * 0.020 €/kg + 6.71 g SOx * 0.031 €/g + 200 g PM10 * 0.18 €/g + 6,000 g NOx * 0.014 €/g = €141.49 per MWh.

Therefore, we conclude that the use of 1 MWh onshore power has a social benefit of €141.49. This societal benefit has been used for all combinations of vessels and berth in 2016 at quay 75 and at quay 15 (Kattendijkdock) in 2016.

Figure 5.9 show the monetized health benefit by using OPS instead of burning fuels while ships are at berth. It is clear that river cruise vessels have the most social benefits when using OPS while at berth. This is because of the high electricity consumption by the river cruises.

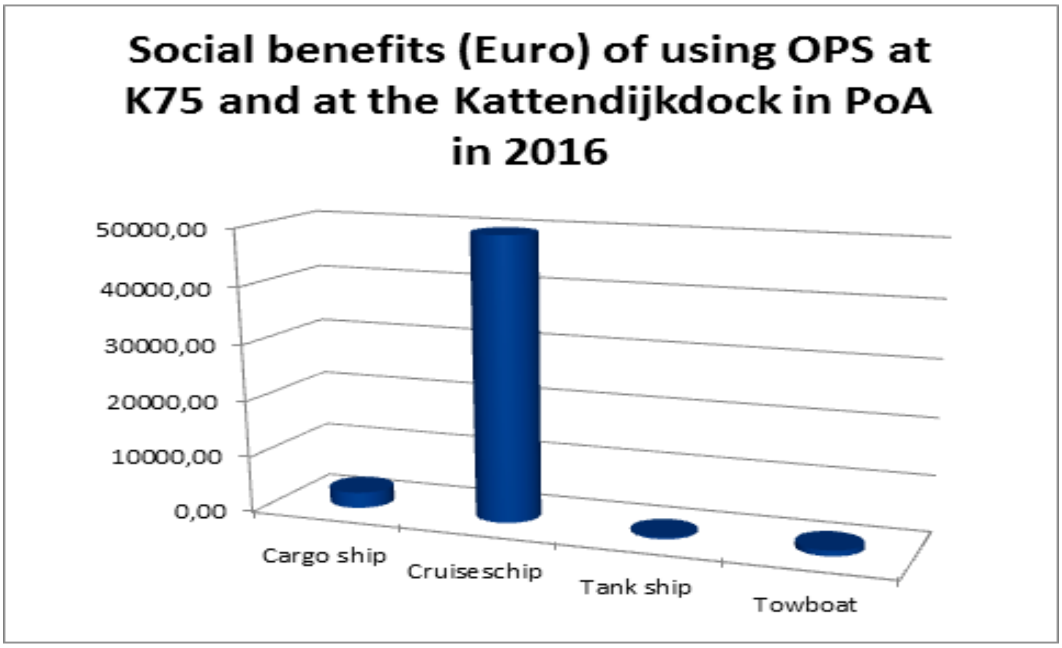


Figure 5.9. Social benefits (Euro) of using OPS at quay 75 and quay 15 (Kattendijkdock) in Port of Antwerp in 2016.

The local use of OPS in 2016 at only quay 75 and quay 15 (Kattendijkdock) has generated total social benefits of €53.814. In 2016 the overall use of shore-based power for inland navigation in the port of Antwerp was 766 MWh, representing a social benefit of €108,381.

Strictly taking into account the return in terms of OPS cash flows, it appears that OPS installations are hardly justifiable from a financial perspective. In other words, in order to make the necessary or desired OPS investments possible, grants will be inevitable and/or existing financial reserves will have to be addressed. But when considering the social advantage of lower emissions by using OPS, this seems to be a decisive factor over the financial argument. Therefore, as the financial benefit is not convincing for the investment in OPS, the ecological aspects of onshore power have to be better used in any communication strategy. This issue will be tackled in task B2.3 and in action D2.

6. Conclusions & follow-up

IWT vessels emit pollutants, both sailing (main engine) and at berth (auxiliary engines). These pollutants can be reduced by alternatives for auxiliary engines:

- (1) use electricity stored in batteries that are charged by a shaft generator or PV panels or main engine in hybrid driveline, or
- (2) use onshore power supply.

Ad (1): these alternatives will be studied/compared in Task 2.2 and compared to OPS. Ad (2) continues below.

Environmental benefits

Onshore power can significantly reduce diesel emissions from ships at dock. In the specific case of Port of Antwerp, the emissions of NOx were reduced by about 93% through the introduction of OPS. The emissions of PM10 were reduced by 99%, and the emissions of SO_2 by more than 96%. The emissions of CO_2 were reduced by more than 91% when utilizing power from the regional electricity grid.

The potential emission reduction benefits may be estimated for a particular vessel, at berth when connected to shore power. Factors such as the amount of time actually connected, power consumption rate and total time at berth are described in the assessment and relate to the overall effectiveness of onshore power. Because these factors must be evaluated for each situation, total emission reductions may vary. Note that in case of OPS, the exact amount of electricity that is requested by the vessel is delivered as such by the regional grid. In case of the use of auxiliary engines, however, the generator will be running at its full capacity, (rather) independently from the very demand of electricity on board the ship. Hence, the power provided and the fuel consumed may be higher than the actual demand of electric power in the latter case. This element was taken into account in the analysis.

The assessment suggests that onshore power may be most effective when applied at terminals with a high percentage of frequently returning vessels, typically river cruise ships and cargo ships.

The absolute emissions reduction is higher the more ships connect to OPS. More ships can connect if (a) there are more OPS sites, (b) more ships are suitable for OPS and (c) more skippers are willing / take the effort to connect. Based on experiences from the Port of Antwerp it can be concluded that informing skippers on the true electricity costs, generated by their generators, and persuading shippers to use OPS as a cheaper and environmental friendlier way, can increase the uptake of OPS usage. Therefore task 2.5 will pay attention to the communication strategy to inform shippers about true costs and compare with OPS.

Increasing OPS utilization

Ships' itineraries are determined by consignments, so the number of ships that visit ports and could connect to OPS follow the consignments and is not influenced by the availability or price or ease of operation of OPS. There are no data that show which percentage of the time a ship that *could* connect, actually connects; there are only data of actual connecting time (and thus utilization rate of the OPS facilities in % of the time.) Roughly: 90% of OPS cabinets for river cruise vessels in tourist season; up to 20% for OPS cabinets for cargo ships.

- Ad (a): this can be increased by building more OPS cabinets and connections, but this is costly so needs to be planned sensibly (see further).
- Ad (b): not all ships are technically equipped to use OPS, therefore Task 2.2 will find out to what extent this is true. Also, e.g. tank ships are blocked by ADN, task 2.3 will address this issue and task 2.2 will study technical solutions (ultrasafe connectors).
- Ad (c): this can be increased by making OPS affordable (compared to using auxiliary engines) and easy (connecting, payment, reservation). The OPS price rate should be set at a level that equals or beats the cost of auxiliary engine power, and could be made variable to follow the diesel price.

Prioritizing location for OPS

When planning OPS, we should especially consider locations (i) where air quality and/or noise concerns are most pressing (near city centres and residential areas), (ii) where there is highest potential that OPS will be used.

- Ad (i): the high-resolution modelling in Action B4 will visualise where the air quality is most pressing.
- Ad (ii): data from the Netherlands, Antwerp and North Rhine-Westphalia show that river cruise vessels berth near city centres and have best OPS business case because they consume much power per time unit and have high utilization rates. The payback period is reasonable in many cases. Cargo ships mostly berth farther away from residential areas and their OPS business case is worse due to less power consumption per ship per time unit and lower utilization rates of OPS. CAPEX and OPEX costs however are lower than OPS cabinets for river cruise

vessels and usage of OPS for skippers also increases comfort on ships during berths (mainly less noise).

The top-5 types of sites for OPS were distinguished in chapter 2. OPS is most needed and could be most successfully provided at quays, piers and docks in seaports and inland ports in the following situations, placed in priority order:

Table 6.7 Prioritization OPS investments

	Type of berth	**Environmental (air quality, noise, CO2)**	**Economical (business case for port)**
1	River cruise berths in home ports, ports of call and off-season (repair) ports	+++ if at city centre	+++ high power consumption
2	Waiting docks and overnight mooring for cargo vessels in home ports for skippers and crews, ports of distress along international (TEN-T) corridors (e.g. Waal river), and docks in/near seaports where vessels are waiting for consignments)	++ if near residential areas + if not	++ medium consumption due to relatively long connection time
3	Cargo terminals in Core and Comprehensive TEN-T network with sufficiently long duration of loading and unloading, provided that there is no interference between OPS and (un)-loading activities	++ if near residential areas + if not	+++ if usage of OPS energy directly impacts fuel savings for cargo terminal + low consumption due to relatively short connection time
4	Home ports for nautical service vessels (e.g. river police, fireboats, towboats).	+ often far from residential areas	+ OPS demand can easily be estimated, therefore better dimensioning
5	Maintenance and repair yards	++ if near residential areas + if not	0 most likely that the yard owner organises OPS themselves

Business case

The breakdown of the OPS business case shows that CAPEX is very dominant. There is a need for cheaper solutions for OPS. Maybe innovative technologies can be introduced from electric vehicle charging domain.

It is proposed that CLINSH free up budget to challenge the market through a contest to come up with cheaper solutions in a paid consultancy job. It could be offered to the winner that their solution will be used in a TEN-T project for OPS in core and comprehensive ports in the Netherlands, Flanders and NRW (and possibly elsewhere). This contest could be facilitated in task B.2.4 and led by Nijmegen, Port of Ghent and EICB.

Other, less impactful improvements of business case are:
- combine greenfield OPS investments with other spatial economic works.
- reduced/no energy tax
- lower service fees
- combination of services (waste, electricity, water) in one Service concept.
- apply a facilitative framework (generator ban with enforcement and "behavioural campaign", i.e. stick and carrot approach).

Task 2.2 will study such options for improving the business case.

Building blocks for Cost Benefit Analysis
If the environmental and societal benefits were used in a cost benefit analysis, this would imply that the rationale for investing in OPS would be higher. On average the societal/environmental benefits could amount up to 30% of the (positive) net cash flow of ports. This is based on the analysis for the OPS in the Kattendijkdok in the Port of Antwerp. It should be investigated further to what extent the impact of these environmental and societal benefits would have a meaningful impact on (positive) investment decisions.

Proposed outline for best practice guide (Task 2.5)
If authorities consider using the OPS instrument for air quality improvement then their strategy should be to:
- invest in OPS where air quality and/or noise concerns are most pressing
- and where the cost effectiveness of euros spent for emissions reduced is highest
- consider the top-5 type of locations as above
- take into account that the business case for the ship owner should be at last neutral (this means: accept low OPS revenues)
- impose an auxiliary engine ban in the port wherever OPS is available and enforce this ban
- promote the use of OPS among ship owners (see measures from TEN-T Shore Power in Flanders) and their clients
- use TEN-T funding for OPS in Core and Comprehensive ports[15] and possibly other funding for other ports including recreational ports.

To determine the cost effectiveness of euros spent on OPS sites, Task 2.5 will develop a calculation model (a “menu” with building blocks) to be part of the best practice guide.
To support skippers’ decision making also a calculation model may be developed to compare costs of using auxiliary engines versus OPS versus shaft generators + batteries versus PV + batteries versus hybrid driveline.

Annexes

Annex 1: Total energy consumption ranking by port-ID (data Involtum 2011-2015, kWh per year)

Port-ID	2011	2012	2013	2014	2015	Total
576	375.218	1.320.142	1.491.738	1.661.975		4.849.073
468	278.506	498.752	561.604	562.377	749	1.901.988
555	52.946	372.358	368.562	517.767		1.311.633
495	93.712	192.104	170.496	275.246		731.558
528	18.858	125.908	172.644	201.724	105	519.239
660		48.090	127.430	179.127		354.647
609		70.480	126.979	135.735	176	333.370
486	75.835	68.815	69.159	53.751	163	267.723
663		34.629	67.729	71.278	81.171	254.807
672		10.344	78.667	66.247	69.547	224.805
471	32.830	50.972	60.305	52.807		196.914
483	25.685	75.873	32.423	21.300	25.725	181.006
540	19.231	51.434	52.163	52.474		175.302
477	34.602	61.083	34.005	30.578		160.268
480	77.055	78.791				155.846
567	21.581	38.364	44.262	44.554	184	148.945
534	9.675	35.152	51.361	49.985		146.173
708				65.597	73.182	138.779
564	1.921	39.366	40.352	49.146	7.293	138.078
546	7.620	37.632	33.463	51.426	7	130.148
543	2.484	23.580	41.665	26.725	24.262	118.716
687			41.745	47.882	13	89.640
465	14.645	33.855	16.026	16.950	39	81.515
549	78.378					78.378
657		47	16.336	15.353	42.576	74.312
558	6.079	9.882	22.118	30.705	43	68.827
474	11.719	15.265	19.831	18.375	258	65.448
600		1.956	30.199	31.561		63.716
603		10.573	26.333	16.674		53.580
606		2.968	21.126	27.316	250	51.660
627		1.893	29.897	18.180		49.970
618		11.788	24.878	11.561		48.227
501	1.960	6.675	16.066	16.792	554	42.047
696			1.135	10.665	22.514	34.314
570	2.291	11.669	8.106	11.931		33.997
507	2.616	13.810	6.805	9.807		33.038
717				13.166	12.110	25.276
588	2.144	8.206	6.627	7.780	5	24.762

624		11.990	7.293	4.307		23.590
681			2.986	8.710	8.214	19.910
675			492	8.796	9.868	19.156
621		16.076	2.651			18.727
489	885	4.880	6.742	5.369		17.876
669		6.927	1.786	2.521	6.555	17.789
513	2.756	14.956				17.712
498	3.181	4.149	5.365	4.840		17.535
714				4.045	10.153	14.198
666		119	4.085	6.295	1.932	12.431
633		1.098	3.331	3.357	4.468	12.254
522	1.386	2.935	4.039	3.816		12.176
537	977	7.651	897	2.367		11.892
705				1.568	8.746	10.314
504	3.684	6.363				10.047
582	476	3.547	2.812	3.175		10.010
531	2.309	2.650	4.351	98		9.408
684			1.436	3.792	3.428	8.656
510	3.287	4.756				8.043
579	535	1.701	1.891	3.120		7.247
678			2.862	2.088	2.101	7.051
561	255	6.659				6.914
699				6.323		6.323
654		5.972				5.972
615		304	1.952	3.104		5.360
552	334	2.162	1.145	974		4.615
642			1.284	2.698		3.982
636		181	1.184	2.505	14	3.884
573	212	1.081	1.746	662		3.701
651		1.510	1.006	771		3.287
591	744	1.906	566			3.216
630		49	1.794	1.128		2.971
645		50	613	1.151		1.814
585	230	1.500				1.730
648		1.657				1.657
612		1.160	492			1.652
597	977	586				1.563
492	659	113	181	567		1.520
711				1.484		1.484
594	88	280	412	341		1.121
519	925	113				1.038
525	90	875				965
702				87	876	963
693			300	432		732
516	234					234
Total	**1.271.815**	**3.478.412**	**3.977.929**	**4.565.008**	**417.281**	**13.710.445**

Annex 2: Top-25 ships, ranked by total electricity consumption (data Involtum 2011-2015, kWh)

Ship ID	2011	2012	2013	2014	2015	Total kWh
420	51.921	68.888	95.549	89.803		306.161
315	42.703	47.417	54.639	55.485	22.399	222.643
1007		46.769	113.319	44.990		205.078
674	19.557	55.624	51.503	40.240	1.524	168.448
1315		32.751	43.805	83.678	2.325	162.559
689	2.862	55.944	45.892	32.342	8.135	145.175
654	2.550	32.688	35.353	59.865	2.668	133.124
673	10.920	20.830	46.699	51.901		130.350
435	22.435	33.684	42.702	30.742		129.563
442	28.212	20.841	32.006	46.563		127.622
682	2.606	21.113	42.733	36.980	24.039	127.471
1155		64.665	2.342	51.643	7.613	126.263
660	3.050	68.967	10.739	41.500		124.256
452	30.375	51.939	18.302	22.924		123.540
421	11.364	45.374	36.033	29.381		122.152
655	14.958	33.143	37.649	23.717	10.124	119.591
1158		44.254	14.487	60.810		119.551
466	31.217	40.264	33.871	13.938		119.290
701	5.197	31.169	47.329	33.183	536	117.414
543	15.923	35.335	28.320	37.674		117.252
1000		22.227	75.486	17.573	473	115.759
1087		20.622	34.202	58.845	457	114.126
16	19.577	22.882	38.882	31.312	657	113.310
1157		28.202	46.067	26.958		101.227
725	1.508	28.717	27.093	35.028		92.346
Total	316.935	974.309	1.055.002	1.057.075	80.950	3.484.271

Annex 3: User profile OPS Nijmegen (data Involtum)

	2014		*2015*		*2014-2015*	
Connection-ID	∑ kWh	∑ connection time hh:mm:ss	∑ kWh	∑ connection time hh:mm:ss	∑ kWh	∑ connection time hh:mm:ss
Grote straat	1.568	369:29:17	8.746	890:29:00	10.314	1259:58:17
13245	845	236:14:30			845	236:14:30
13246	6	17:24:24	7.783	91:04:00	7.789	108:28:24
13249			91	235:11:00	91	235:11:00
13250	716	115:16:21			716	115:16:21
13251	1	0:34:02	818	237:25:00	819	237:59:02
13252			54	326:49:00	54	326:49:00
Vikingsteiger	65.597	1085:47:01	73.182	1044:24:56	138.779	2130:11:57
13241	234	30:41:31	2.315	230:22:00	2.549	261:03:31
13242	1.888	241:03:32			1.888	241:03:32
13243	63.475	814:01:58	70.867	814:02:56	134.342	1628:04:54
Lage Markt	4.045	358:56:10	10.153	469:40:45	14.198	828:36:55
13263			64	5:15:25	64	5:15:25
13264			10.088	458:55:20	13.680	584:42:37
13266	3.592	125:47:17			199	178:40:50
13268	199	178:40:50			254	54:28:03
13269	254	54:28:03	1	5:30:00	1	5:30:00
Labyrint	13.166	730:36:22	12.110	3757:32:41	25.276	4488:09:03
13253	1250	210:53:27	571	181:40:00	1821	392:33:27
13254	2527	221:08:11	2786	196:03:00	5313	417:11:11
13255	8785	62:55:34	6760	69:57:14	15545	132:52:48
13256	500	210:36:04	1601	251:19:27	2101	461:55:31
13257	104	25:03:06			104	25:03:06
13260			70	238:23:00	70	238:23:00
13261			322	2820:10:00	322	2820:10:00
Eindtotaal	84376	2544:48:50	104191	6162:07:22	188567	8706:56:12

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1 The terms port and harbour are often used as synonyms. The difference is that a port normally includes the harbour and the adjacent town or city suitable for loading goods and embarking crew and passengers.

[2] http://www.marineinsight.com/ports/what-are-the-various-types-of-ports/;
Roa, I., Peña, Y., Amante, B., & Goretti, M. (2013). Ports: definition and study of types, sizes and business models. *Journal of Industrial Engineering and Management,* 6(4), 1055-1064. http://dx.doi.org/10.3926/jiem.770

[3] Binnenhavenmonitor 2015, RHV Erasmus University Rotterdam, downloadable from https://www.portofrotterdam.com/nl/nieuws-en-persberichten/onderzoek-naar-prestaties-binnenhavens

[4] Interviews were held with Maarten Hektor, Involtum / walstroom.nl (24 Feb. 2017); Ronald Bijl, Park-Line Aqua (28 Feb. 2017); Berdie de Ruiter & Jacco van der Kaa, Arnhem (28 Feb. 2017); Keesjan Kuijk & Gerard Hendriks, Nijmegen (7 Apr. 2017); Bert van Wijk, Port of Amsterdam (4 May 2017); Henk Voogt, Port of Rotterdam (4 May 2017); Maarten Boer, Port of Den Helder (9 May 2017); Jacco Vader, Zeeland Seaports (10 May 2017); Leen Schipper, Mobiele Stroom (repeated contacts in 2016-2017).

[5] This port-ID was no longer contracted to Involtum in 2015. The consumption at the different connectors is not evenly spread and fluctuates between 0 and 17%

[6] Just outside the region the town of Wageningen has also made OPS available for freight ships staying overnight (not included in this case study).

[7] http://www.binnenvaartservices.be/walstroom/docs/2016-08-tent-walstroom-samenvatting-en.pdf

[8] http://www.vreg.be/nl/privedistributienetten

[9] http://www.portofantwerp.com/en/municipal-port-police-regulation-revision-june-2017-new-0

[10] http://www.binnenvaartservices.be/walstroom/platform.php?lang=nl

[11] Denier van der Gon, H., Hulskotte, J., (2010). Methodologies for estimating shipping emissions in the Netherlands. A documentation of currently used emissions factors and related activity data.

[12] Hulskotte J.H.J., Jonkers S., Milieueffecten van de invoering van walstroom voor zeecruiserschepen, rivercruiseschepen en binnenvaartschepen in de haven van Amsterdam, TNO-rapport 2008-U-R0329/B/2/ TNO Bouw & Ondergrond, Utrecht, The Netherlands, 2008.

[13] IEA (2010). CO_2 Emissions from Fuel Combustion – Highlights (2010 edition). http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2143

[14] http://www.milieurapport.be/nl/feitencijfers/sectoren/energiesector/emissies-naar-lucht-door-de-energiesector/emissie-per-eenheid-geproduceerde-stroom/

[15] TEN-T core network corridors: http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/maps_upload/SchematicA0_EUcorridor_map.pdf; core en comprehensive havens: http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/maps_upload/annexes/annex1/Annex%20I%20-%20VOL%2008.pdf