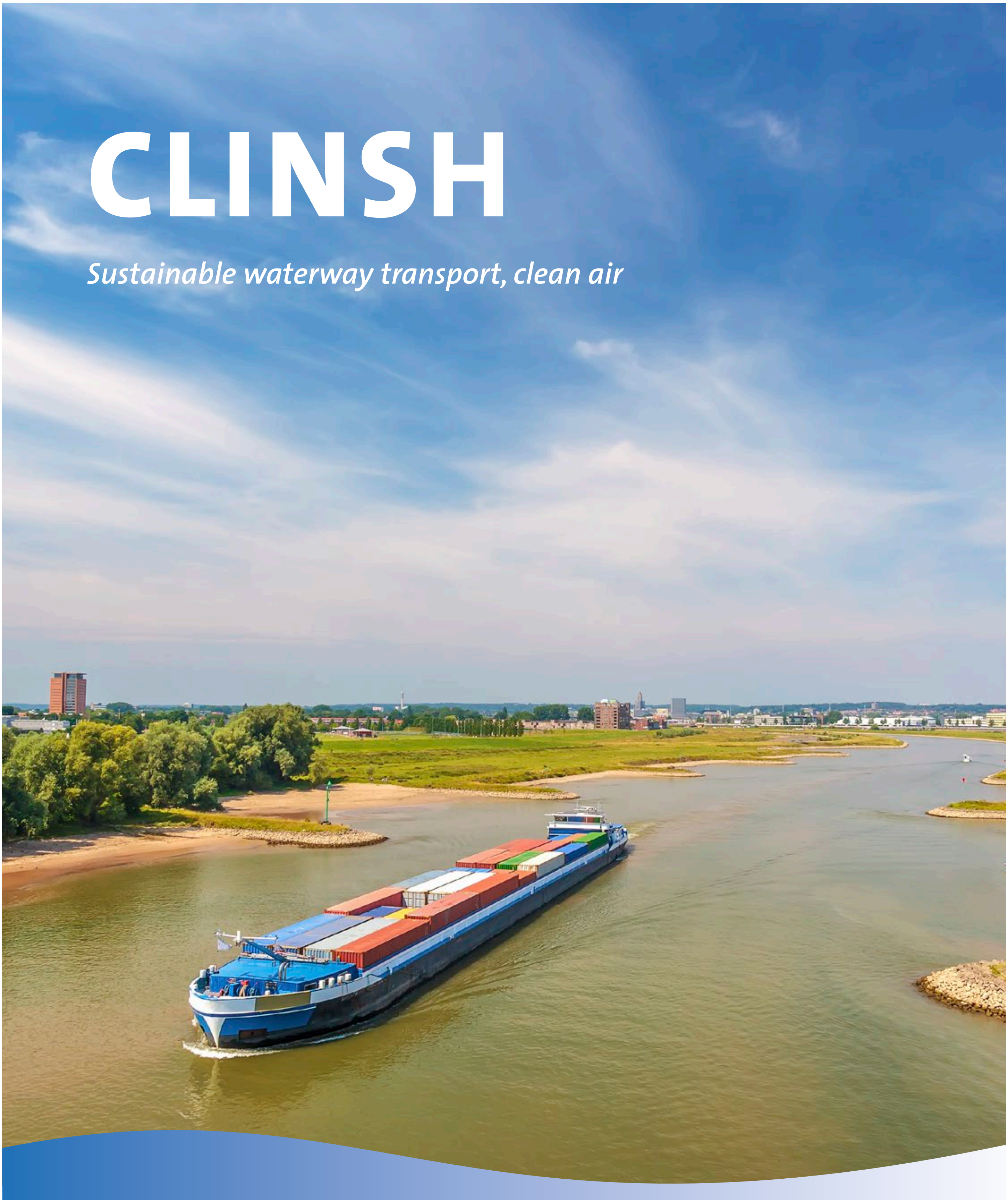
LAYMAN'S REPORT

CLINSH

Sustainable waterway transport, clean air



CLean INland SHipping

Introduction

Due to the presence of an extensive inland waterway network, the major economic centres of Western-Europe are easily accessible by barge. With its prominent, varied fleet and capacity to move large cargo volumes, the inland shipping sector is a cost efficient and sustainable mean of transporting goods and providing services.

The international requirements on clean air, climate change and energy-saving continue to become stricter over time. Therefore, it is also important that the inland shipping sector takes measures to reduce its emissions and footprint.

ABOUT CLINSH

CLINSH – **CL**ean **IN**land **SH**ipping - is a 5-year project in which emission reducing technologies and alternative fuels have been tested in practice for the Inland Waterway Transport (IWT) sector. This has provided valuable information about their effectiveness and operating costs. The main objective of CLINSH is to contribute to better air quality in urban areas. This has been undertaken by looking into:

- The performance of various emission reduction techniques and alternative fuels was tested on 43 ships.
- Emissions from the ships were monitored in real life conditions partly before and after the adjustments. Onshore measurement has also taken place in some ports and along the river Rhine.
- Measurement results have been collected in a database and used to provide tools for shipowners, local, regional, national and European governments for (new) policies on greening the fleet.
- Using shore power instead of onboard diesel generators for heating, lighting and other demands for berthed ships reduces emissions and improves air quality in ports.

STRONG PARTNERSHIP

The CLINSH project (September 2016 – December 2021) is a cooperation between 18 partners from 4 European countries, including universities, port authorities, local governments and private companies. The CLINSH project benefits from co-funding from the EU LIFE+ Programme. The total project budget is over €8.5 million.

1. Objectives

The environmental problem targeted by the CLINSH project is air pollution by Nitrogen Oxides (NO_X) and Particulate Matter (PM) caused by the emissions of the Inland Waterway Transport (IWT) sector. Awareness has grown that inland shipping activities have a significant contribution to the concentrations of these substances. These emissions affect the air quality of the areas along rivers and canals and since many inland ports are situated in, or close to cities, the air quality of urban areas is directly affected. While the IWT sector has a smaller contribution in total air pollution, the long-term effect of continuous and unregulated emissions contributes to adverse human health effects (e.g., bronchitis, asthma, lung cancer), crop losses, building damage and biodiversity loss.

Compared to road fleets, inland waterway fleets expel lower emissions for every ton of cargo displaced per kilometer, however, emission limits for new engines are significantly less strict than those for road transport. This, combined with long-term lifetime of ship engines, has resulted in a suboptimal environmental performance of the inland navigation sector. With emission legislation for the IWT sector only being implemented since 2002, the IWT sector has thus been underexposed in EU legislation. Hence there is an urgency to improve the emission performance of the IWT fleet.

Over a period of two years, CLINSH has demonstrated the environmental benefit of emission reduction technologies for inland shipping, of which the results have been used as input for our policy recommendations on emission reduction of the IWT fleet to improve air quality.

Figure 1: Inland waterway motor vessel monitored in CLINSH

2. Methodology and Approach

The CLINSH project has delivered the first comprehensive estimate of IWT emissions and reduction opportunities based on real-life emissions measuring and of vessel movement monitoring in West-Europe. 43 vessels have been monitored for their exhaust of NO_X and PM as well as fuel consumption during normal operation for a longer period of time. The emission measurement results have been used to model the emissions for the Western European IWT fleet and assess the impact of the cleaner technologies and fuels on future fleet emissions and air quality in the areas of Antwerp, Rotterdam, Nijmegen and greater Duisburg *(Figure 2)*.

The monitored fleet consisted of a large variety of vessels with different engines classified as "CCNR0" (i.e., unregulated), CCNR1 and CCNR2 (i.e., CCNR or Stage IIIA), that apply different exhaust abatement technologies such as SCR(-DPF) (i.e., Selective Catalytic Reduction and/or Diesel Particulate Filter), diesel-electric, Fuel-Water-Emulsion (FWE) or usage of alternative fuels such as GTL or LNG *(Table 1)*:

The vessel categories in the modelled fleet consisted of various vessel types with classifications based on power-ratings or ship lengths:

- Passenger vessels
- Push boats
- Different types of Cargo Vessels
- Coupled Convoys
- Ferries
- Tugboats/Workboats

This was done for a range of vessel categories, with a sub-classification for low, medium and high fuel consumption vessels.

Figure 2: The four areas for air quality modelling in clinsh

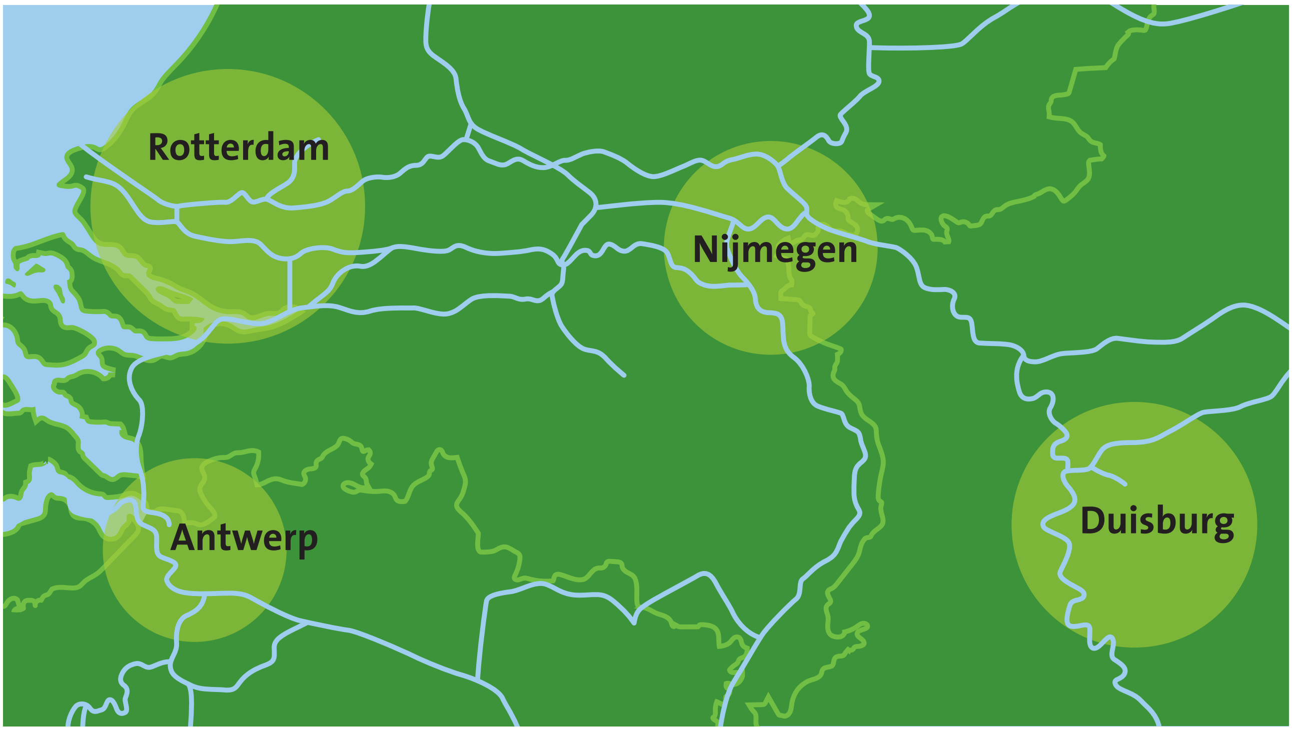


Table 1: Fleet propulsion methods assessed

Fleet Propulsion Method	Features
ccnr2/ccnr1/unregulated ("ccnro")	• Standard diesel engines with various classifications currently used by a large portion of the fleet
Stage V/marinized Euro VI	• Integrated with scr and dpf • Lower emissions of NO_x and pm
After-treatment systems (scr and/or dpf)	• Selective Catalytic Reduction used for NO_x reduction, requires urea • Diesel Particulate Filter for trapping pm
Gas to Liquids (gtl)	• Sulphur free, no aromatic hydrocarbons • Lower emissions of NO_x and pm compared to diesel
Liquid Natural Gas (lng)	• Lower fuel costs per energy unit • High investment in fuel system and storage tanks
Fuel Water Emulsion (fwe)	• Emulsification of water and diesel before injection • Potential for reduced fuel consumption
Hydrotreated Vegetable Oil (hvo)	• Biofuel for diesel engines • Lower emissions of NO_x and pm as well as CO_2

EMISSION FACTORS BASED ON REAL LIFE MEASURING

From the measurement results, CLINSH has developed emission factor functions that relate emissions of NO_X and PM to the power usage of the engine (% of maximum engine power) for each ship in the CLINSH fleet. *Figure 3* displays an example of the NO_X emission factor function for a measured CCNR2 engine.

Table 2 shows average emission factors based on the measuring campaign, together with values from literature for techniques for which the emission factors could not be measured. The resulting emission factors are also expressed as a percentage relative to CCNR2 emission values.

Figure 3: NO_X emission factor function for a CCNR2 engine

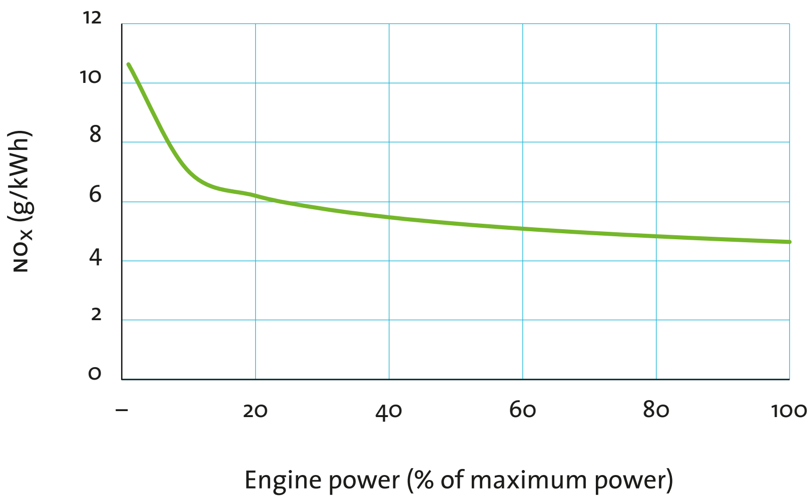
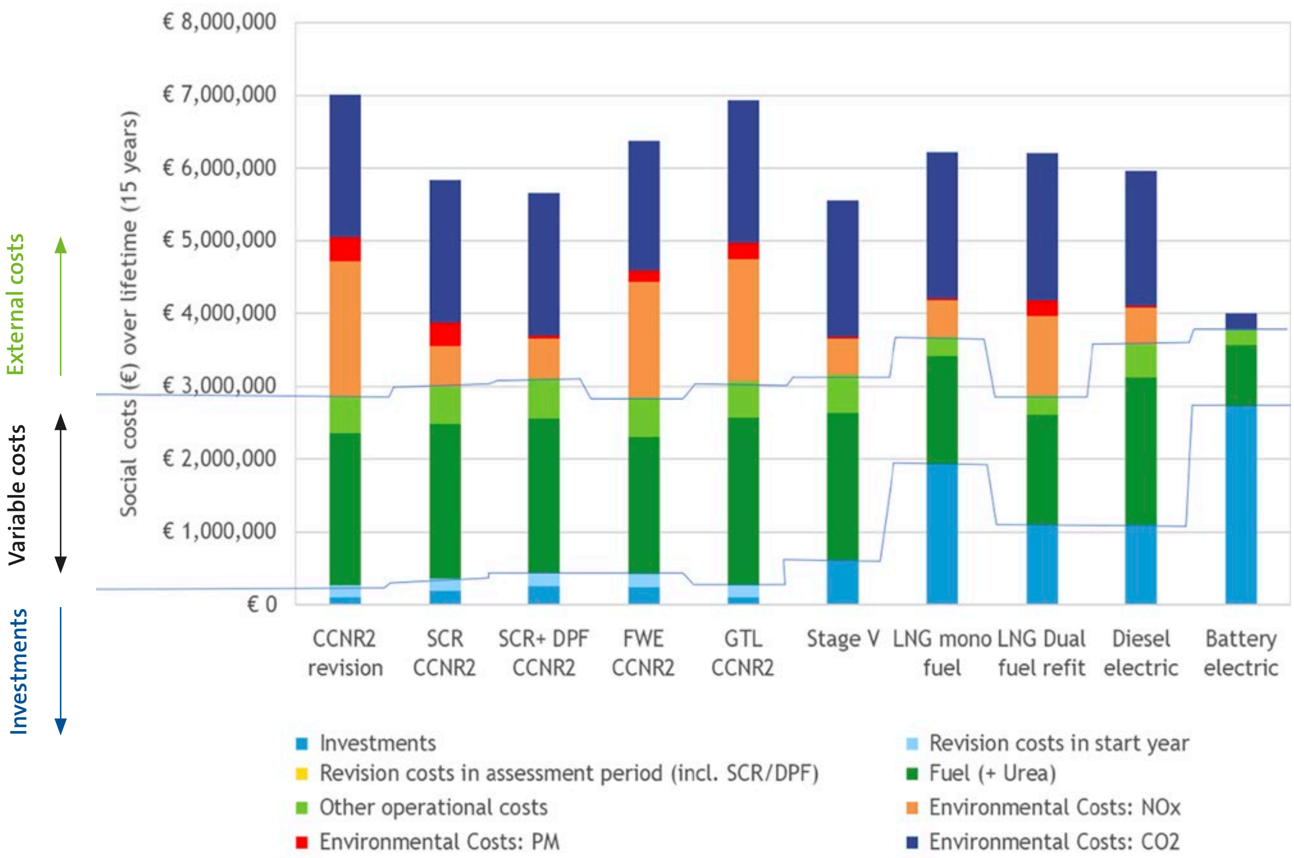


Table 2: Emission factors derived from CLINSH measuring campaign [c] and literature [l]

	NO_X emission factor (g/kWh)	NO_X emission relative to CCNR2	PM emission factor (g/kWh)	PM emission relative to CCNR2
CCNR0 diesel	10.59 [c]	205%	0.406 [l]	308%
CCNR1 diesel	8.31 [c]	161%	0.132 [l]	100%
CCNR2 diesel	5.16 [c]	100%	0.132 [l]	100%
GTL	4.55 [c]	88%	0.091 [l]	69%
FWE	4.14 [c]	80%	0.066 [l]	50%
SCR-DPF CCNR1*	2.07 [c]	40%	0.132 [l]	10%
LNG	1.80 [l]	35%	0.132 [l]	10%
Stage V diesel	1.80 [l]	35%	0.132 [l]	10%
Euro VI diesel	0.40 [c]	8%	0.010 [l]	8%

* Compared to CCNR1 the NO_X emission level is 25%, i.e., a 75% reduction

Figure 4: Total cost of ownership and social costs for a 110m dry cargo ship with medium fuel consumption



COST OF EMISSION REDUCTION OPTION

For the technologies monitored in the measuring campaign as well as several other emissions reduction options, CLINSH has performed a social cost analysis where the social costs include the **total costs of ownership** of the various technologies (the costs for the vessel owners), as well as the **external costs** of NO_x, PM and calculated CO_2. This was done for a range of vessel categories, with a sub-classification for low, medium and high fuel consumption vessels. It should be noted that the costs are related to the engine (investments, maintenance and operation) and not the complete ship. *Figure 4* above shows the comparison for one vessel category (110 m dry cargo ship, medium fuel consumption).

The options that lead to the highest reduction of emissions are Stage V, LNG, and SCR(-DPF). Fuel Water Emulsion and GTL reduce less in absolute terms but are interesting for ship owners who prioritize cost-effectiveness over total effect. From a socio-economic viewpoint, the most effective is the Stage V/Euro VI engine which achieves the best NO_x and PM emissions reduction and the lowest total social costs (Excluding battery electric and hydrogen).

The collected data on the emission reductions of the 43 barges, together with information from literature, was used to model and simulate fleet emissions and impact on air quality under two scenarios known as **'Baseline'** and **'CLINSH'** scenarios:

Baseline Scenario: business-as-usual approach

- Assumption: no new policies to increase adoption of emission reducing technologies
- Involves a voluntary switch to Stage V type engines only when existing engines are at end of lifetime

CLINSH Scenario: optimal social approach

- Assumption: policy incentives result in a strong adoption of Stage V engines, after-treatment technologies and alternative fuels.
- Involves refit solutions for the part of the inland waterway fleet whose engines are not at end of lifetime or not scheduled for a revision.

These scenarios serve as a basis for investigating the socio-economic and financial aspects of the transition to a cleaner IWT fleet.

Besides emissions from sailing ships, emissions from vessels at berth are also of interest. Emissions at berth can be reduced by using onshore power supply instead of onboard generators fuelled by diesel. CLINSH developed a methodology to assess the emissions of vessels at berth, which involved:

- Port characterization (at what locations should OPS be deployed)
- Available technologies and solutions
- Standards & Regulations and promotional campaigns to increase utilisation of OPS.

Emission results

Table 3 shows the fleet emission modelling results for the selected areas. Whereas the Baseline scenario leads to NO_X and PM emission reductions by 2035 in the order of 20%, the CLINSH scenario reduces these emissions in the order of 80%.

In addition to modelling the IWT emissions for the four regions, the contribution of inland vessels to air quality has also been measured onshore in North Rhine-Westphalia. Measurements in the ports of Neuss/Düsseldorf, Duisburg and on the Rhine have shown that the pollution of ambient air with NO_X and PM caused by the emissions of inland navigation is not as extensive as assumed at the beginning of the project.

Table 3: Annual emissions from IWT in the model regions for the Baseline 2020/2035 and clinsh 2035 scenario (kilotons)

	Rotterdam		Nijmegen		Antwerp		Duisburg	
In kilotons/year	**NO_x**	**PM_{10}**	**NO_x**	**PM_{10}**	**NO_x**	**PM_{10}**	**NO_x**	**PM_{10}**
Baseline 2020	2.68	0.09	1.32	0.04	0.97	0.03	2.05	0.06
Baseline 2035	2.06	0.07	0.97	0.03	0.75	0.03	1.59	0.04
Clinsh 2035	0.72	0.03	0.28	0.004	0.27	0.01	0.45	0.01

Table 4: Socio-economic costs for the two scenarios

	Baseline scenario	Clinsh scenario	Difference
Social costs with 15 years lifetime (M€)	26,139	21,280	**-4,859**
Total cost of ownership with 15 years lifetime (M€)	10,751	11,512	**761**
Initial investment costs (M€)	1,123	2,393	**1,270**

Benefits for society

Results in *Table 4* show the financial requirements for fulfilling the clinsh and Baseline scenarios according to the socio-economic analysis. The clinsh scenario shows that these investments have a significantly higher societal benefit (public health benefits, biodiversity loss prevention, etc.) **(€4.9 billion)** than the technical investment costs **(€1.3 billion)** and the additional total costs for ship owners **(€0.76 billion).** These investments therefore make sense from a socio-economic viewpoint and should be facilitated for the coming years, while developing and introducing zero-emission solutions that improve air quality and also mitigate climate change in the longer term.

The socio-economic analysis further shows that Stage V/Euro VI engine renewal is optimal from a societal perspective for many ship types in the next 10-15 years. The relatively high investment costs for these engines are partly compensated by improved fuel efficiency and low emissions as demonstrated for the Euro VI engines in the monitoring fleet. However, the preferable options from a societal point of view do not correspond with the preferred options from the individual entrepreneur's perspective (investments and total cost of ownership).

The challenge lies in synchronizing the societal and individual interests since there is scarce capital availability by the shipowners. **An incentive scheme should make at least Stage V, SCR+DPF, Fuel Water Emulsion and GTL attractive for the entrepreneurs to invest in.** This requires **policy intervention through investment support to ship owners** and/or **differentiated tax schemes that support low emission technologies** in order to reduce the environmental costs from pollutants and to enable and motivate ship owners to opt for better solutions.

The results from the OPS demos showed that the contribution of emissions at berth to total IWT emissions in ports varies but remains well below 10%. However, these emissions often take place at berths situated near highly populated areas where many people are exposed to these emissions as well as noise. Thus, investing in OPS where **air quality and/or noise concerns are most pressing** and where the **cost effectiveness of euros spent to reduce emissions is highest** should be emphasized. The top-3 type of locations are river cruise berths, waiting docks and overnight mooring, and tanker berths. **Adoption of an EU-wide permanent tax exemption for OPS would encourage the deployment and use of OPS.**

Figure 5: Onshore Power Supply Unit

3. Policy Recommendations

- CLINSH calls for investment in readily available emission reduction measures, until zero-emission technologies are mature, for the existing IWT fleet that improves air quality (mainly NO_x and PM emissions). The social benefits of these measures as shown in the CLINSH scenario (€4.9 billion) are considerably larger than the investment costs (€1.3 billion) and the total extra costs for the ship owners (€760 million).

- Individual ship owners find it difficult to invest in emission reducing technologies and upgrades due to the additional costs and expenses of utilizing these technologies. Effective policy intervention is needed through investment support to ship owners and/or differentiated tax schemes that support low emission technologies to enable ship owners to opt for better solutions.

- EU and Member States should provide incentives for accelerated adoption of available emissions reduction options through an IWT Greening Fund or grant schemes. Budget for the fund or grant schemes could be raised by allocating revenue from the taxation of IWT fuels.

- Given the scarce capital availability in the IWT sector it is recommended to seek permission to provide investment support up to 80% over the price difference (befitting EU state aid laws conforming with the EU taxonomy) combined with low-interest loans.

- Local regulations can help make the transition (via lower emission technologies) towards Zero Emissions. Aligned with financial support for engine renewal and emission reduction techniques until 2035 (Greening Fund) and ahead of a possible Stage V (or equivalent) emissions standard for the existing fleet (in 2035) could be the implementation of low emission zones in ports. CLINSH recommends investigating the feasibility and impact of such zoning.

- Invest in OPS where air quality and/or noise concerns are most pressing and where the cost effectiveness of euros spent to reduce emissions is the highest. Developing funding mechanisms to realize OPS in core locations can lead the way for a zero-emission power infrastructure by 2050.

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