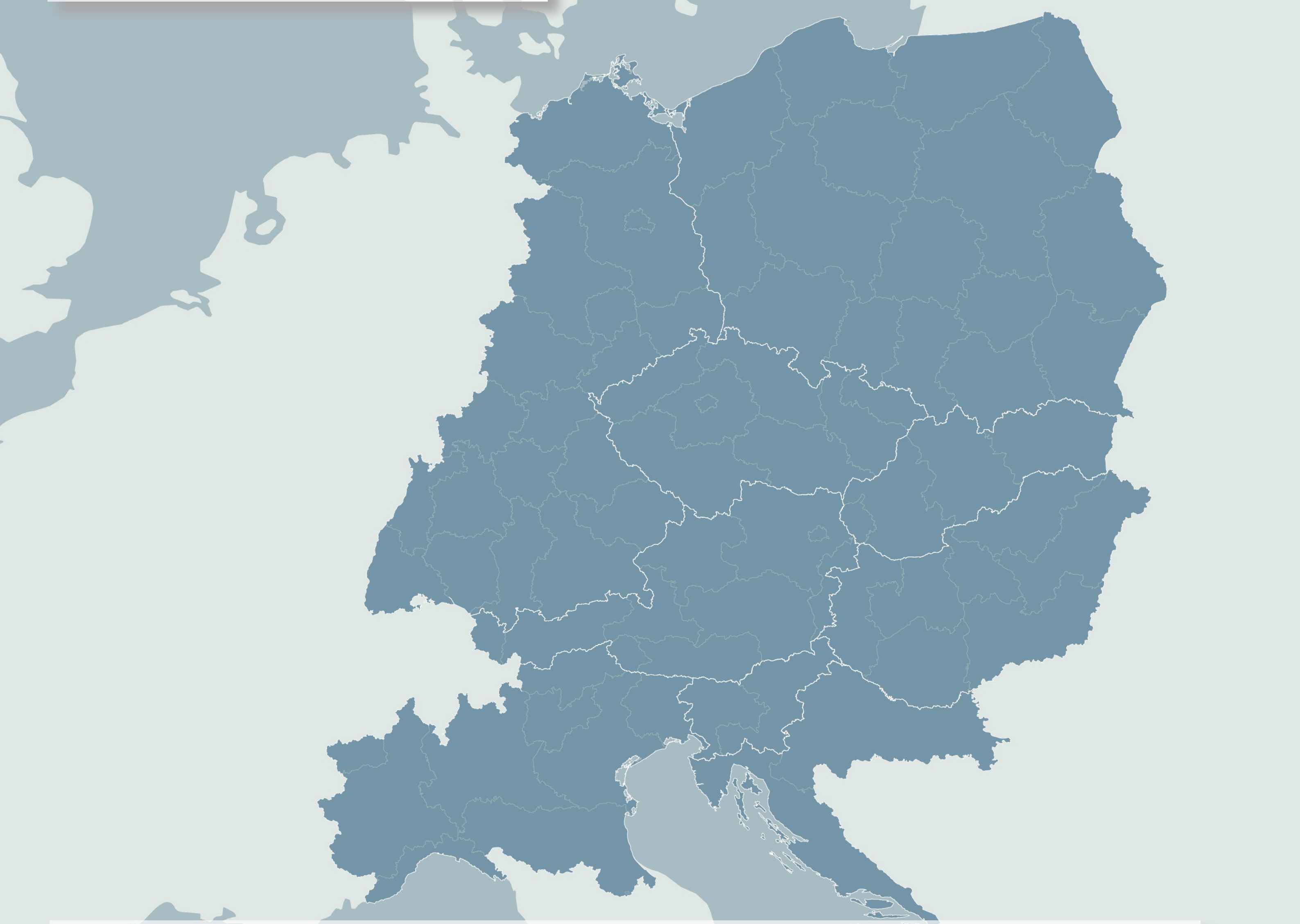
Interreg CENTRAL EUROPE

European Union
European Regional Development Fund

InterGreen-Nodes



CE1444: InterGreen-Nodes

Handbook for the adoption of Clean Fuels at Terminals

Part 3: Vehicles

TAKING
COOPERATION
FORWARD

Index

1. Introduction

Developing innovative solutions for transshipment nodes is risky and ressource-intensive.

The InterGreen-Nodes project tested, demonstrated and evaluated a number of possible solutions. They were implemented, tested and discussed with the ports and terminals in the InterGreen-project.

In order to help other ports and transshipment facilities to impelemnt similar solutiopjns, the project set up a series of three handbooks, that cover the following topics:

- Handbook 1: Buildings and built infrastructure requiring buildings;
- Handbook 2: Use of clean, mainly electric vehicles;
- Handbook 3: Use of clean energy systems and energy storage systems.

1.1. Overview over the handbooks and their content

HANDBOOK 1: **Buildings and built infrastructure requiring buildings**

	***Where:*** Berlin (Westhafen port)
	What: Developing and operating an innercity-cargobike hub on the port premise.
	Potential Impact: Shifting freight from truck to cargobike on the last mile, with the potential to use rail for the main run (using the ports rail-road transshipment facilities).
	***Where:*** Port of Budapest
	What: Using BREEAM and LEED ratings to make the effects of environmental friendly building measurable.
	Potential Impact: Environmental friendly building in the areas in energy, land use, materials, pollution, transport, waste and water.

LNG Infrastructure

Where:

Freight Village Bologna

What:

Developing and operating an LNG gas station for trucks, to be used by customers of the freight village.

Potential Impact:

CO_2 reduction (exact numbers still pending).

Solar Energy

Where:

Berlin (Westhafen port) and Port of Koper

What:

Using solar energy to complement the energy mix used by a port.

Potential Impact:

CO_2 reduction (exact numbers still pending).

H2 Energy Storage systems

Where:

various

What:

Using hydrogen fuel cells to store electric energy during high availability times and use them when high energy demand arises.

Potential Impact:

Flattening usage peaks and storing energy from clean energy production, making clean energy use economically more viable).

Electric Ship 	***Where:*** Berlin (Westhafen port) ***What:*** Using an electric ship (with battery electric and hydrogen energy storages) instead of diesel driven ships for transport on inland waterways. ***Potential Impact:*** Significant CO_2 reduction (exact numbers still pending).
Full-Electric Terminal 	***Where:*** Berlin (Westhafen port) ***What:*** Changing port operation processes from conventional (diesel) fuel driven processes to electric drives (e.g. trucks, internal terminal freight transport, general purpose cars, utility vans, rail shunting vehicles). ***Potential Impact:*** CO_2 reduction (exact numbers still pending).

1.2. How to transform your operation

Based on the experiences from the InterGreen-Nodes project, we recommend the following steps, in order to achieve a lasting and sustainable results:

Step 1: From a Task Force:

The implementation of clean solutions into your operations can be challenging and complex. Usually, numerous different areas of your operation will be impacted, ranging from transhipment and transport over energy use to funding and accounting of measures. Sometimes it can be beneficial to include customers or regional officials.

Identify relevant persons and functions at our organization and form a task force, in order to include all perspectives and viewpoints. Regular meetings can be helpful, but at a minimum, all task force members should be updated on any progress regularly and actively asked for their opinion, if their field of expertise is touched upon.

Open discussions, especially at the beginning can help identify possible problems as well as opposing goals.

Step 2: Identify fields of action

The areas, in which clean solutions can be implemented vary widely. To gain an idea what possibilities you have, you can utilize the handbooks in this series and the examples described.

If you are implementing measures of this sort, the first time, it could be advisable to pick a small scale implementation project, such as substituting existing diesel-driven vehicles with "of-the-rack" electric vehicles.

A field of action could also be the use of solutions on a project, you are anyway planning to realize, such as the use of green-building-ratings on a construction project.

To ensure a seamless implementation, include the task force from step 1, into your decision.

The result of Step 2, could be a list of possible actions.

Step 3: Calculate probable outcomes

A first quick calculation on costs and CO2-savings can help you make a first decisions and circle in, on a number of solutions, you would like to focus on.

The InterGreen-project developed a methodology that can help you, do this calculations. You can find it on the InterGreen-Website:

- https://www.interreg-central.eu/Content.Node/InterGreen-Nodes.html

The three files you need are:

- Fact Sheet of Key Performance Indicators (KPI) System: https://www.interreg-central.eu/Content.Node/InterGreen-Nodes/CE1444-O.T3.1-fact-sheet-Tools.pdf
- Standard Operating Procedure (SOP): https://www.interreg-central.eu/Content.Node/InterGreen-Nodes/CE1444-O.T3.1-SOP.pdf
- KPI System Excel file: https://www.interreg-central.eu/Content.Node/InterGreen-Nodes/O.T3.1-Basic-Model-KPI-System.xlsx

Step 4: Form a strategy

Plan your next steps. This handbook series can hep you to identify these steps, absed on the experiences of others.

Discuss the strategy with your task force from Step 1.

Step 5: Implement

Step 6: Use results for marketing an PR

Include your marketing department and draw up a strategy, to inform others about your success.

2. The Basics of the Full electric Terminal Pilot in Berlin

The “full electric Terminal pilot” is meant to demonstrate the viability of electrifying numerous processes along the complete added value chain.

It consists of elements, that are already electrified on a regular basis in numerous ports (such as using electric cranes for transhipment). But it also changes other elements of the added value change to electric drivetrains.

The specific InterGreen-demonstrator-elements are situated in the Berlin Westhafen-port, operated by BEHALA. They consist of:

- Electric rail-shunting Vehicle,
- Electric Crane,
- Electric Terminal Tractor, that doubles as a 40 t road vehicle,
- Electric general purpose cars and
- Electric utility van (for use by maintenance personnel, equipped with maintenance tools).

2.1. Step by Step description of the implementation and Lessons Learned and Experiences

All vehicles used in this demonstrator, are battery electric. As opposed to other drive-train- and energy-storage-solutions, it is not necessary to install large Meta-infrastructure for the operations of battery-electric vehicles, as the electric grid for recharging electric vehicles is already in place, while other solutions would need their own supply and production infrastructure (e.g. for hydrogen or bio-methane).

As electric vehicles come with certain constraints, the purchase process differs greatly from that of conventional vehicles. For example: The range of an electric vehicle depends greatly on its battery capacity. However, batteries are the most expensive component of any electric vehicle, with prices between 500 € and 1.000 € per kWh. A battery too small would lead to a vehicle that would not meet the operator’s demands, a battery too large, would lead to much higher operating costs, than necessary.

The specific characteristics of electric drivetrains have a number of additional positive effects in an urban environment:

HIGH EFFICIENCY in urban areas: Electric motors provide their maximum torque across the complete performance spectrum, enabling quick accelerations at any speed, while conventional engines only provide maximum torque over a certain rate of rotation. Practically this means, that an electric motor can accelerate with less energy-demand than a conventional motor. This leads to a lower energy-demand, especially in urban environments, where vehicles have to decelerate and accelerate often. This leads to a more efficient energy use from “tank/battery” to wheel. Conclusions about the total energy efficiency can only be drawn, when the whole energy-supply chain is considered and will differ, depending on the method of electricity production.

REDUCED NOISE EMISSIONS could allow for new logistics concepts: e.g. night deliveries in urban areas for example to stores. It also allows for direct delivery into buildings, for example:

transportation of trailers with production material, directly to production/assembly lines, without additional transhipment at a loading dock. Tough loading and unloading can still emit noise, this noise can be minimized by technical solutions (rubber wheels on transport carts, rubber buffers etc.). The relative quietness of electric vehicles can make them a hazard, when other road users (mainly pedestrians and cyclists) are not able to hear the electric vehicle. Technical solutions, such as noise emitters are currently being discussed.

RECHARGING AND RANGE: Range is an important issue in the operation of electric vehicles. A number of demonstration projects have tested recharging processes in between tours during one day. However, this has often proved to be impractical, as delays in deliveries often lead to a shortage of time for the recharging process. It seems generally more practical to recharge vehicles during longer non-operations-periods (e.g. during the night). Tests with battery-changing systems (i.e. the whole empty battery is being swapped for a recharged battery) have yet not been proven to be practical, as the very high costs of batteries lead to very high additional investment costs.

A general step-by-step process for the selection and operationalization of electric vehicles could look like this:

Step 1: Define your objective:

To make you introduction process a success, you first should define your objective, in order to have clear indicator for your success. What amount of CO_2 do you want to save, do you want to replace your complete fleet or only certain vehicles, what is your time frame?

Step 2: Estimate the necessary range and annual mileage

If you have your vehicle logbook in a digital format (e.g. Excel) you could proceed as follows:

- Sort all logbook entries by days, so that you get a list for each day.
- Sort each day by tour-length, starting with shortest tours.
- Now you can build categories for short, medium and long tours.
- Evaluate the numbers of each tour-category by length, number of tours per day. Calculate the necessary range a vehicle would need to cover per day, in order to get a value for your range demand. Examine, if perhaps a tour category (depending on your objective) could be covered by electric vehicles. Tweak the category, in order to optimize according to your objective.

Step 3: Decide on Gross-Mass and Payload:

You can use the gross-mass of your current fleet as an indicator and choose a gross-mass as large as the one of the vehicle(s) you wish to replace.

Step 5: Estimate you're the necessary Battery capacity

To calculate the necessary battery capacity in order to reach the required range (estimated in Step 2), the following formula can be used (please keep in mind, that this formula can only give you a rough estimate. Operations in hilly areas may lead to higher energy demands):

$$Battery - Capacity\ [kWh] =$$

$$(max.\, Range\ [km] * 0{,}3413 + Vehicle - Gross - Mass\ [t]\ *\ 1{,}3579\ +\ 28{,}57) * 1{,}2$$

You should try to find a vehicle with a battery capacity at least as large as the one calculated.

Step 6: Estimate your costs

More on this subject in chapter 4.

Step 7: Estimate CO2-savings

In order to estimate your current CO_2 emission, determine the average fuel consumption per km of the vehicles you wish to substitute and multiply this number with the mileage you wish to substitute. Then multiply the result with

- In case of a Diesel-vehicle: 3.16
- In case of a Gasoline-vehicle: 2.88

The results are your current CO_2 emissions in kg, for the vehicles/tours you wish to substitute.

In order to estimate the CO_2 emissions for your planned electric vehicle(s), first ask you energy supplier for the CO_2-factor per kWh. Than multiply this CO_2-factor with the total consumption, you calculated in Step 5.

Step 8: Choose the proper vehicle and contact the vendor

Using the input data from Step 3 and 4, you can use the vehicle catalogue in Annex I to choose some matching vehicles and contact the vendor.

Step 9: Talk to your vendor about charging infrastructure and maintenance

Using the inputs, you determined form Steps 1 to 7, clarify the following questions with your vendor:

- Will you need your own charging stations or are there public charging stations you could use?

  You can find public charging stations on the internet, for example here:

  - www.plugsurfing.com
  - www.chargemap.com
- What would a quick-charging station cost and how much faster would a quick-charging station charge?
- Is it possible to install the necessary charging station on your own electric house-connection/property-connection/company connection/municipal connection?
- You might also need to clarify this question with your energy provider.
- Will the available electric-power be sufficient (especially when charging several vehicles)
- When using a quick charging system: Will you need a load management system?
- Can/shall the charging station-status be diagnosed via the internet for maintenance purposes?
- What services are offered within the maintenance contract for your charging station?
- Does the vendor offer a maintenance contract for the vehicle?

- What services are offered within the maintenance contract for the vehicle?
- Does the vendor offer you a guarantee on battery-life?
- Does the vendor offer you a battery exchange after a certain mileage?
- Where are the next maintenance service stations for your electric vehicle?

2.2. Cost and emission effects

Electric rail-shunting vehicle

The KPI model developed in InterGreen-Nodes DT3.1.2. in order to calculate costs and GHG-emissions was used for the BEHALA electric rail shunting vehicle Windhoff ZRW 50 in Westhafen. Before, a diesel-fuelled road-rail vehicle, a Unimog, has been used for shunting operations. The vehicle was operated by two people, a driver and a shunter. In 2014, the Unimog was replaced by an electric shunting vehicle. Now, only one operator is needed for the shunting, as the vehicle is remote controlled and no driver required.

The differences between the Unimog and the Windhoff rail shunting vehicle in terms of environmental impact were observed between 2012 and 2019.

	Unimog (diesel)		Windhoff ZRW 50 (electric)		
Year	2012	2013	2017	2018	2019
GHG-emissions (kgCO_2e/km)	22.83	13.88	3.59	4.42	3.42

The differences between the vehicles are clear. While the Unimog emits an average of 18.35 kg of CO_2e per kilometer, the greenhouse gas emissions for the electric vehicle are just 3.81 kg of CO_2e per kilometer. This corresponds to a decrease of 79%.

Regarding the costs, literature doesn't provide any detailed information on shunting vehicles. What can be said, though, is that the costs for energy for the electric shunting vehicle per kilometre per year are notably lower than for the Unimog, due to the also lower level of consumption per kilometre. For the Unimog, energy costs amount to 5,32 €/km on average, whereas costs for the electric version are at 1,74 €/km. Together with the savings allowed by the reduction of employees needed for the process, these are already two cost factors indicating at least an ability to compete with the diesel vehicle regarding the costs.

Terminal tractor / 40t truck Terberg YT202EV

We used the KPI model developed in InterGreen-Nodes D.T3.1.2.in order to calculate costs and GHG-emissions for the YT202EV and put them into comparison with diesel-trucks, used parallel in the same processes at Berlin Westhafen.

CO_2-emmissions are on average lower for the electric vehicle. CO_2 emissions depend on the energy mix used (for the electric vehicle), as well as from the driving style and traffic situations (accelerating often in urban traffic, leads to higher fuel use and therefore CO_2 emissions):

	Diesel-truck			E-truck		
Year	2012	2013	2014	2017	2018	2019
GHG-emissions(kgCO_2e/tkm)	0.32	0.34	0.22	0.24	0.25	0.18

We also put the Total Cost of Ownership (TCO) in relation to a Diesel truck. Due to higher purchasing costs, electric vehicles are usually more costly, than their diesel—counterparts. Additionally the YT202EV is a specialized vehicle, produced in small series, increasing the purchasing costs further.

	Diesel-truck			E-truck		
Year	2012	2013	2014	2017	2018	2019
TCO [€/year]	27,352.62	27,942.24	26,643.65	48,862.36	47,886.40	47,738.32

3. The Basics of the Electric Ship Pilot in Berlin

The ELEKTRA is an inland waterway pusher boat, currently (October 2020) under development by InterGreen partner BEHALA. The project is coordinated responsibly by the Technical University Berlin (TU Berlin). The project consortium consists of the company ANLEG as a specialist for hydrogen pressure tanks, the company BALLARD as a manufacturer of fuel cell systems, BEHALA as the shipowner, the shipyard Hermann Barthel, the company EST as a manufacturer of accumulator systems, IMPERIAL as a shipping company, SER as an electrical system integrator and TU Berlin, represented by the department Design and Operation of Maritime Systems as a scientific partner. The boat is being developed, with the climate policy goals of the Federal Republic of Germany as the main focus and funded by the Federal Ministry for Digital and Transport.

The ELEKTRA is a hybrid-electric test vehicle for use in the Berlin-Brandenburg region and between Berlin and Hamburg, with electrical energy being provided by batteries, as well as hydrogen fuel cells.

3.1. Step by Step description of the implementation

The investment costs for the boat are well above comparable conventional push boats. But this is at least part due to the fact, that the ELECTRA is an experimental vessel. The total investment volume (including development costs and infrastructure are in the realm of about 13 Mio. €.

The implementation consists of:

- The development of the ship itself.
- Construction of the ship
- Implementation of a landside charging stations for the batteries

- Implementation of a hydrogen infrastructure, which consists of pre-filled hydrogen tanks, that are loaded onto the ship.
- Provision of electrical energy for land and water transport along inland waterways and in ports
- Development of logistics points for the hydrogen supply of land and water vehicles
- Development and analysis of possible operator and billing models

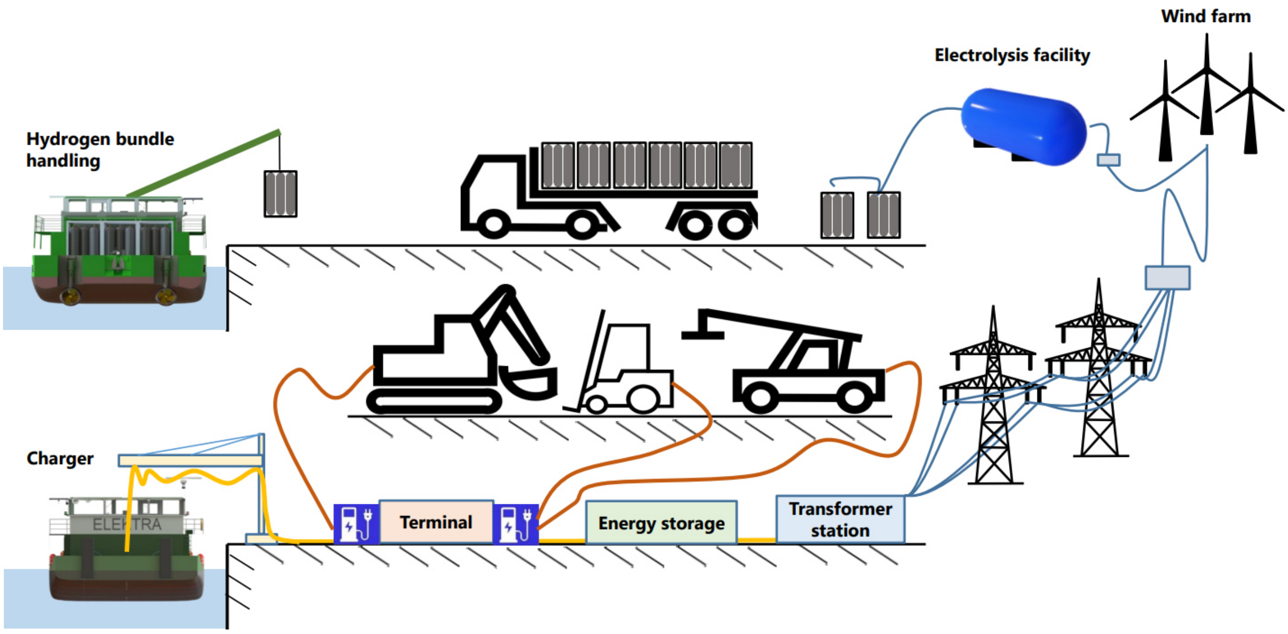


Figure 1: The ELEKTRA and its energy infrastructure (source: © TU Berlin)

3.2. Cost and emission effects

The ELEKTRA is still in its development phase. There are many uncertainties left especially concerning the costs, which is the reason that they are not going to be calculated in this work.

However, regarding the environmental effects, first estimations can be made and the KPIs calculated. The ship will have four accumulators and three fuel cells for hydrogen and be used to cover the distance between Hamburg and Berlin, which amounts to 395 km one way. Covering this distance defines the process boundaries, excluding any handling at departure or arrival of the ship. According to first tests and analysis of the Technical University Berlin, the demand for energy for propulsion of the ship for those 395 km is at approximately 10,600 kWh. As soon as further data on consumption behaviour during on-load operation is available, the process can be adjusted. For the time being, the reference unit for the KPIs will be “km”, not “tkm”. The ship is assumed to be used 3,600 hours per year at a minimum velocity of 10 km/h, which would mean for a distance of 36,000 km/year and therefore an energy consumption of 954,000 kWh/year. Currently, there are different scenarios on how this demand can be covered, varying in the proportions of each, electricity and hydrogen: Scenario A assumes a supply out of 10% electricity and 90% hydrogen, whereas Scenario C assumes 40% out of electricity and 60% out of hydrogen. For the first calculation of the KPIs, the middle course of scenario B has been chosen with a 25% electricity supply and 75% hydrogen usage. A diesel-powered engine for comparison is assumed to have a similar energy demand as the Elektra (Cf. Loewe 2020). Converting the kilowatt hours to litres of diesel equates to a consumption of 96,121 l diesel. Diesel-engines usually have a lower efficiency than electricity-powered engines, what can be seen in the example of the electric truck. In that example the diesel truck has a consumption of 0.76 l/km amounting to 7.543 kWh/km, whereas the E-truck needs 4.64 kWh per km. From this increase, the factor of 1.625 can be derived, by which the energy consumption of the diesel truck in kWh is higher than the one of the E-truck. Due to the lack of common factors that could be used for the conversion of kWh to the consumption of the diesel ship, the factor of the BEHALA E-truck is used in this case as well. Thus, the diesel ship is assumed to have a consumption of 156,196 l diesel per year for a distance of 36,000 km. Important for the calculations of the KPIs are also the energy and emission factors. Currently, the EN 16258 does not include energy and emission factors for hydrogen. A study conducted by the European Commission Joint Research Centre provides factors for the GHG-emissions for different pathways of hydrogen production, however only well-to-tank. As other reliable sources providing also WTW-factors are not available, it has been decided to calculate the GHG-emissions for the ELEKTRA with an average of those factors for the hydrogen consumption. The type of hydrogen has a huge impact on emissions, with hydrogen made from coal having, for example, a significantly higher level of emission than hydrogen made from wind power (Cf. Edwards et al. 2014, p. 134). It is not clear yet, which type of hydrogen will be used for the ELEKTRA. Therefore, an average has been built from nine production pathways. Concerning the factor for electricity, the one for the German electricity mix has been chosen. Although the ship belongs to the BEHALA, having a more environmentally friendly mix than the German average (Cf. table 5), it cannot be assured that the ship will only be charged at the BEHALA port when covering the distance between Berlin and Hamburg. Local emissions of hydrogen and electricity usage are considered to be close to zero, therefore calculating with a WTT-emission factor is acceptable for the first calculations (Cf. Holbach 2020). Emissions of the diesel-ship for comparison are still going to be computed with the WTW-factor for the reason mentioned before with the factor for marine diesel oil of the EN 16258. At the current state of research, factors for standardising the energy consumption of hydrogen in a comparable way to diesel and electricity are not available. The calculation of the KPI "Standardised energy consumption" is therefore omitted for the time being.

GHG-emissions in kgCO_2e/km			
Before		**After**	
2020	15,32	**2020**	14,95
Difference 1:		-0,36 kgCO_2e/km	
Difference 2:		-2%	

TAKING **COOPERATION** FORWARD

Interreg
CENTRAL EUROPE
European Union
European Regional Development Fund

InterGreen-Nodes