DELIVERABLE D.T3.3.2
ELECTRIC SHIP PILOT IN BERLIN
(INCLUDES D.T3.2.3 AND.T3.3.1)

Final assessment of greening transport measures for Electric ship Pilot in Berlin

Version 2

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1. Introduction

The Electric ship Pilot in Berlin is one of 7 pilot actions of the InterGreen-Nodes project. To demonstrate the infrastructure and technological possibilities for the application of clean fuels at the local level, meaning the last mile, and at the terminal, measures to make transport greener have been assessed and validated through stakeholder inputs.

This concluding report is the final assessment report for the pilot activity (D.T3.2.3 + D.T3.3.2) and includes the evaluation of technical performance and environmental impact measurements, as well as lessons already learned from the mid-term evaluation D.T3.3.1).

In this pilot activity, an electric ship for inland waterway transport of heavy goods was tested at the Westhafen of Berlin. At the start of the project, the ship was under development. In the meantime, the vessel is undergoing extensive testing and inspection in Berlin.

2. 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. 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.

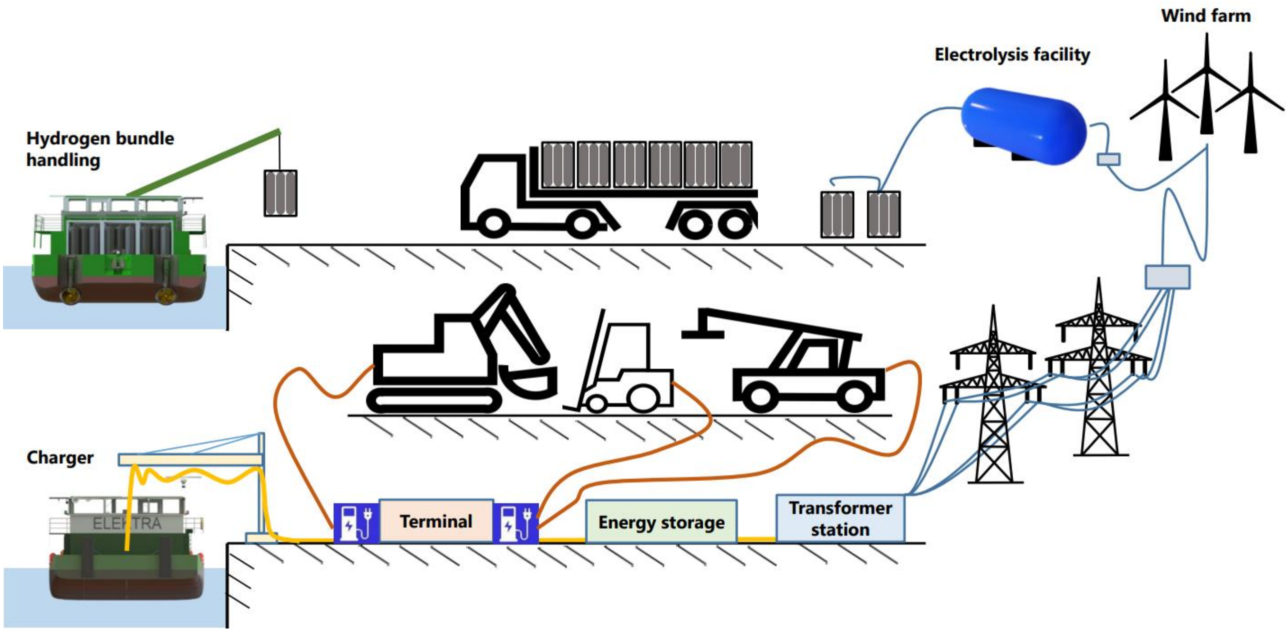

Figure 1: The ELEKTRA and its energy infrastructure (source: © TU Berlin)

4. 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 kgCO2e/km			
Before		**After**	
2020	15,32	**2020**	14,95
Difference 1:		-0,36 kgCO2e/km	
Difference 2:		-2%	

5. Lessons Learned and Experiences

There was a first test block between March 9 and March 22, 2022. In the Berlin and Brandenburg trade area, ELEKTRA covered a total of 9 days of approx. 420 km in solo operation purely battery-electric. In addition, the hybrid operation was tested during the transfer from the shipyard across the Elbe to Berlin over 3 days with approx. 165 km. Furthermore, a test drive took place in a 150-m formation in hybrid operation, during which approx. 15 km were covered. The following insights were gained from this first test phase:

- After a few adjustments, ELEKTRA shows excellent handling in solo operation;
- The interaction of the energy sources basically works very well and stably;
- Pure battery operation has largely been tested to complete satisfaction;

- The energy consumption for propulsion when driving solo has so far been below the forecast, i.e. longer ranges are currently possible;
- Very extensive sensor technology installed on board has recorded a wide variety of data - extensive data is currently still being evaluated with new self-made tools;
- Pier (standby) operation can still be significantly improved in terms of energy consumption.

In summary, it can be stated that local and global low-emission waterborne transport in metropolitan regions and supra-regional is feasible today. Furthermore, efficient inland waterway vessels with H2 fuel cells and battery energy storage systems are considered feasible. In addition, further development needs in the area of charging and hydrogen infrastructure are considered necessary. The cost of green hydrogen and green electricity must be reduced. It is necessary to create rules and regulations that enable economic use of the technology.