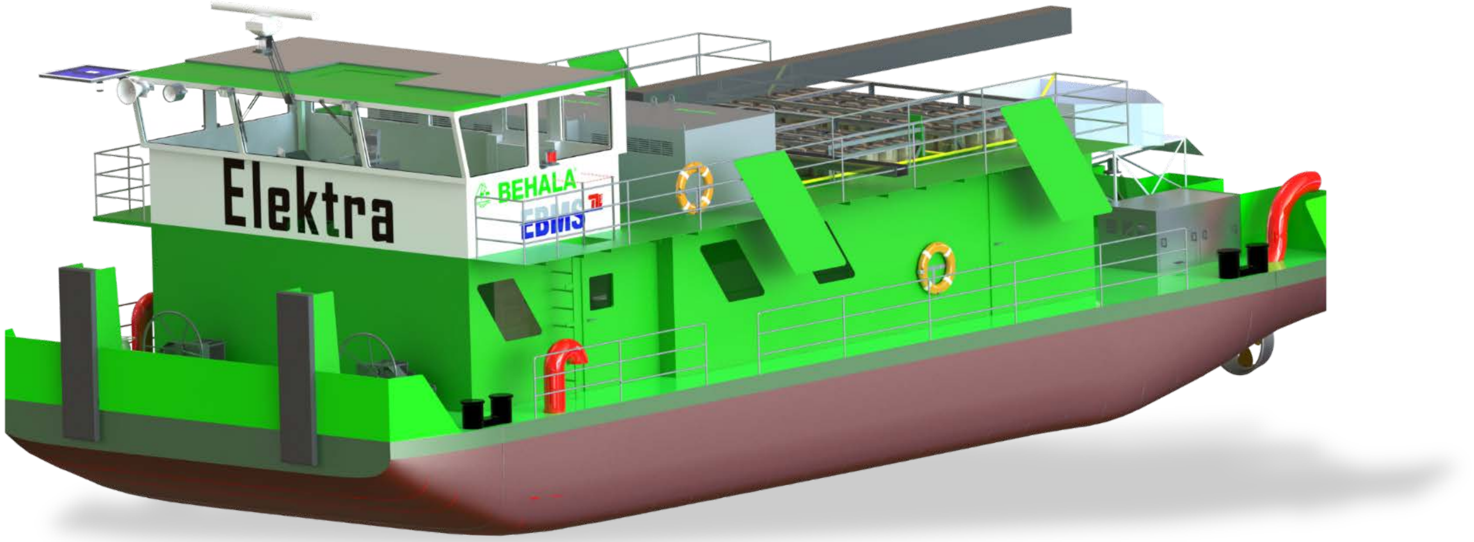
ELEKTRA

Design and realization of a hybrid inland push boat

powered by hydrogen fuel cells and Li-ion NMC batteries
and
the challenge of providing a bunkering infrastructure



Prof. Dr.-Ing. Gerd Holbach

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NOW nip
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PtJ
Projektträger Jülich
Forschungszentrum Jülich

ANLEG Advanced Technology
BEHALA
BALLARD
Schiffswerft Hermann Barthel GmbH
EST-Floattech Intelligent Energy Storage Solutions
Imperial logistics
SER
EBMS

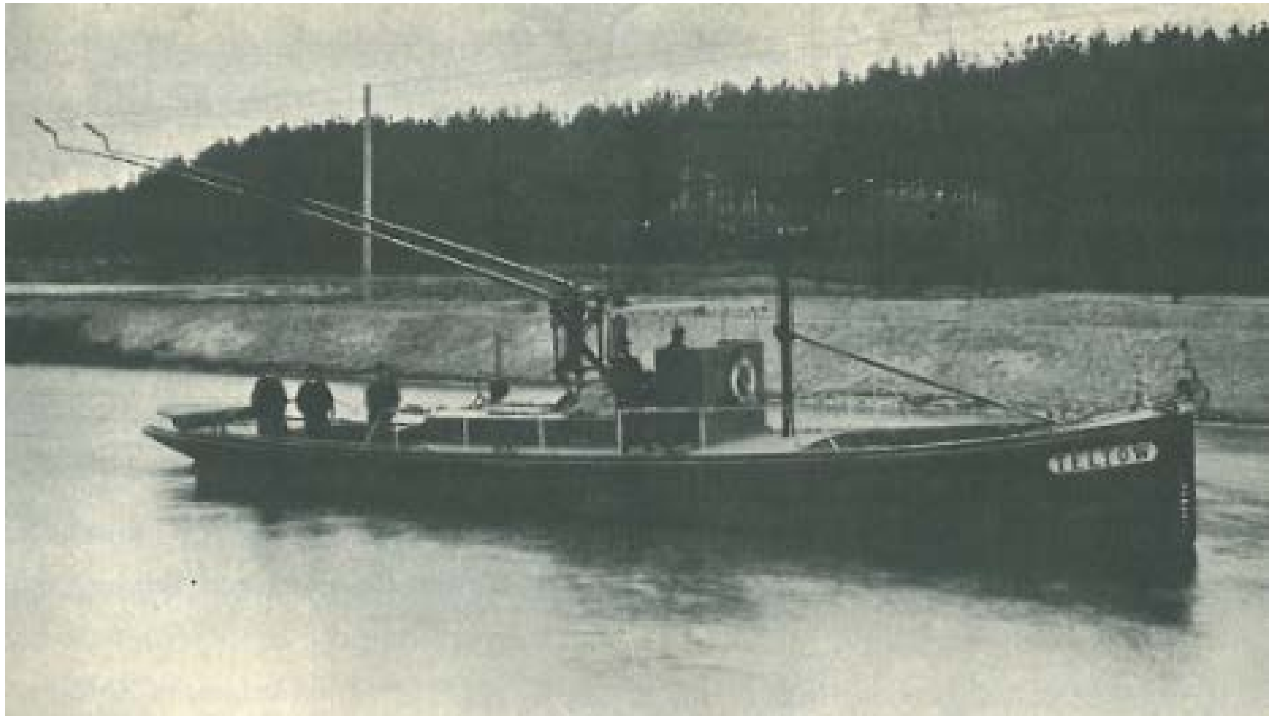
Agenda

1. **Local history**
2. **Requirements and constraints**
3. **Layout**
4. **Supply of energy**
5. **Summary**

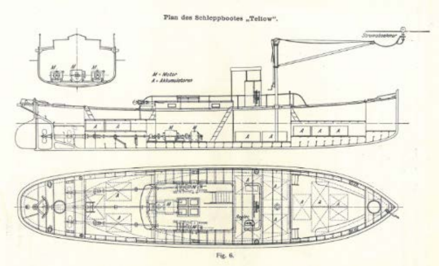
1. Local history

***1886: first electrical ship by Siemens at the river** at Spree*
„ELECTRA" 25 passenger at 14 km/h.

Quelle: Siemens



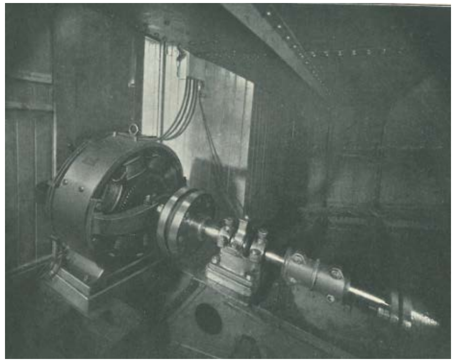
Tug boat „ Teltow" 1906
- Tug convay up to 250 m length
- Trolley wire system
- Experimental vessel (Data lost)



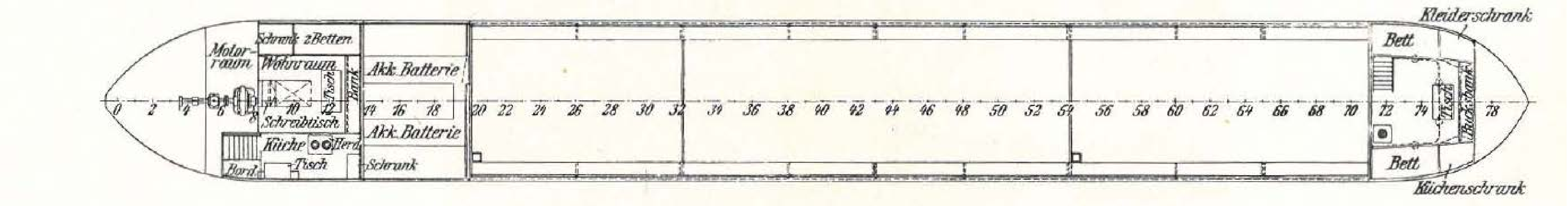
Quelle: Jahrbuch der Schiffbautechnischen Gesellschaft 1908

1. Local history

- **Transport idea:** brick transport from Zehdenick *(northern of Berlin) to* Berlin
- **Basis:** Finow-Maßkahn 40,0 x 4,6 x 1,3 m, 150 dwt
- **Power unit:** direct current 7 kW
- **Akkuweight:** 9,5 t (**6%!** from dwt, lead battery)
- **Range**: 90 km
- **Quantity**: app. 100 ships *1908*



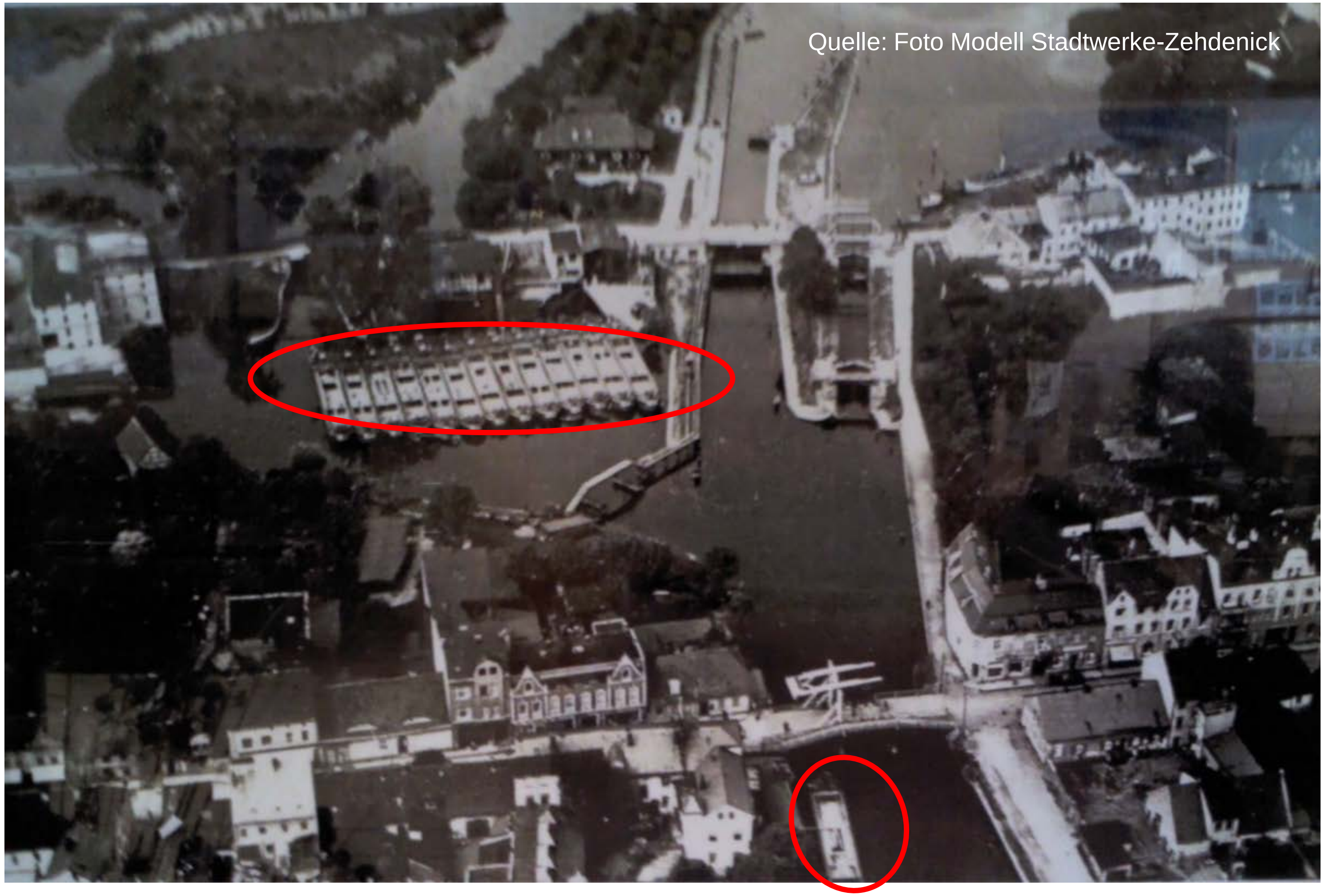
Germany 1908, Power up to app. 500 PS



Source: Jahrbuch der Schiffbautechnischen Gesellschaft 1908

1. Local history

„Renewable“ electrical chargingstation at Zehdenick about 1910



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2. Requirements and constraints – local an global emission-free

Main task „ELEKTRA“ in connection with „URSUS“:

- RoRo – project loads and regional / supra-regional transport of heavy duty gas turbines from the Siemens AG / Berlin plant

Heavy Cargo RoRo-Barge „URSUS“
length 64.50 m / width 9.50 m
displacement 1,400 t / draught 1.30 m – 3.06 m

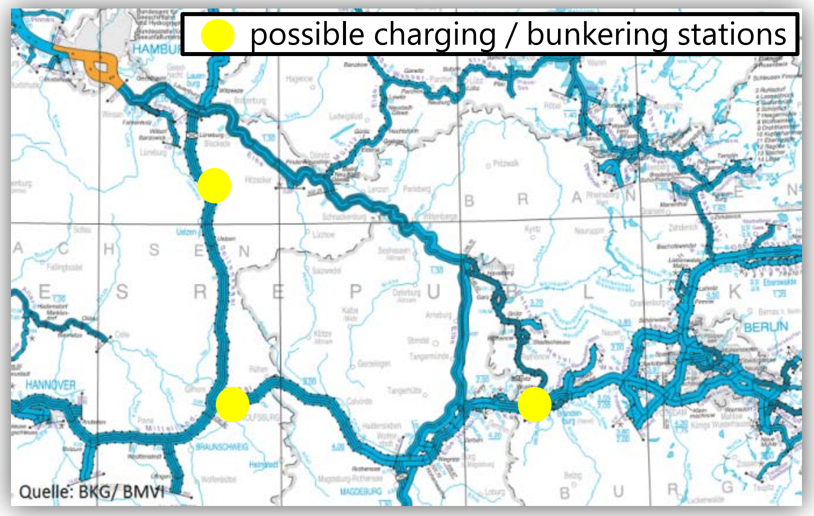
Ramp
length 265 m

2. Requirements and constraints - local and global emission-free

Regional operation

- Max. push load of 1.400 t
- Approx. range of 65 km
- Area of operation: zone 4
- Operational time of 8 h
- Average speed 8 km/h, up to 10 km/h
- Drive: battery or hybrid electric

Supra-regional operation



- Berlin ↔ Hamburg
- Max. push load of 1.400 t
- Approx. range of 100 km/d
- Area of operation: zone 3+4 (exc. Rhine)
- Operation time of 16 h
- Average Speed 8,5 km/h, max. 10 km/h
- Drive: hybrid electric (FC/accumulator)

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3. Layout

Main dimensions

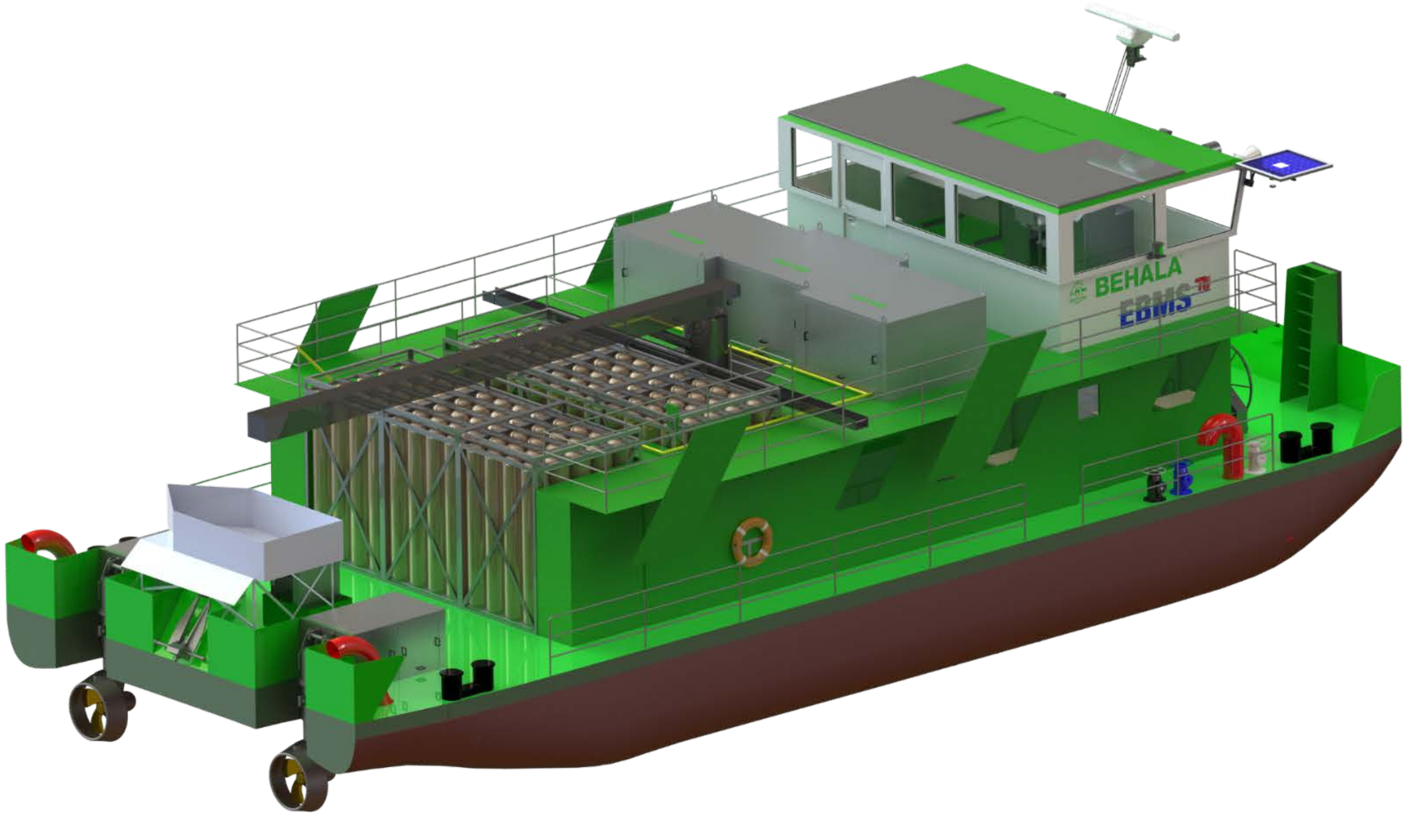
- length 20.00 m
- width 8.20 m
- draught 1.25 m
- displacement 150 t

Operation

- Batterie-elektrisch 8 h / 65 km
- Hybrid-elektrisch 16 h / 100 km

Powertrain

- power 2 x 200 kW



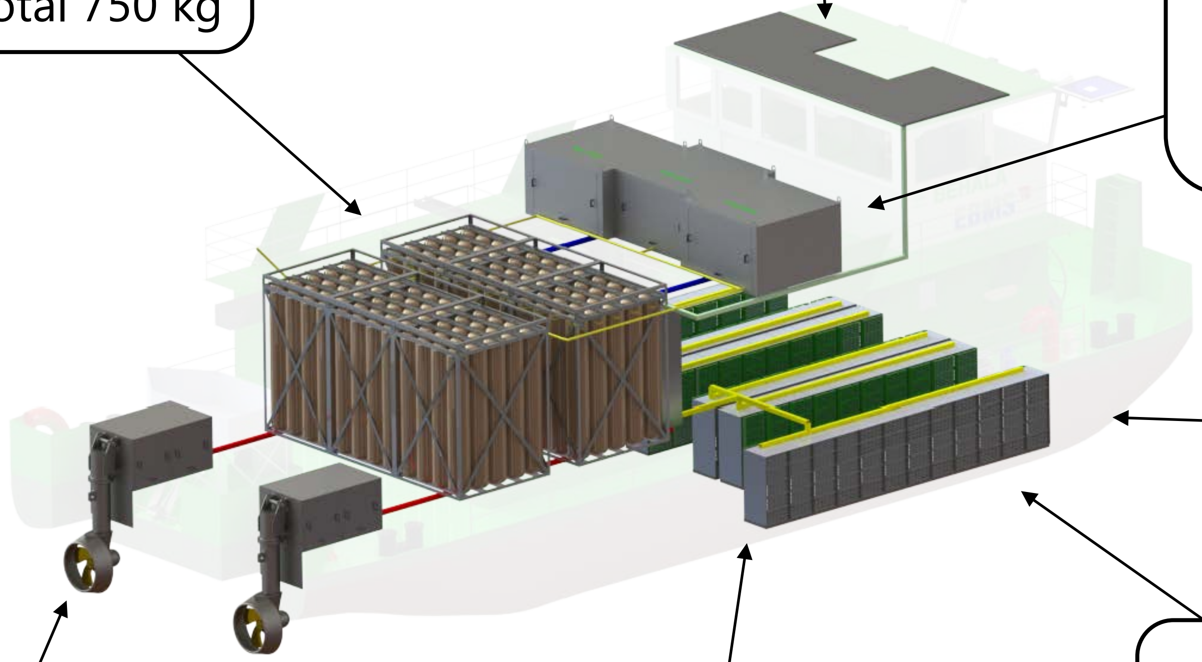
3. Layout – technical specifications

Hydrogen storage system
6 bundles with 125 kg
Total 750 kg

Photovoltaik module
2.7 kWp

Fuel cell system
NT-PEMFC 3 x 100 kW

Max. power: 300 kW
Operating power: 200 kW



Shore connection
~ 250 kVA
7 - 8 h

Drive system
regional: 8.0 km/h – 165 kW
supra-regional: 8.5 km/h – 210 kW
Max. speed: 10.0 km/h – 400 kW

Propulsion batteries Li-NMC
Max. power: 2,050 kWh
Usable power: 1,950 kWh
EoL: 1,550 kWh

On-board power supply batteries Li-NMC
Max. power: 137 kWh

3. Layout – accumulators

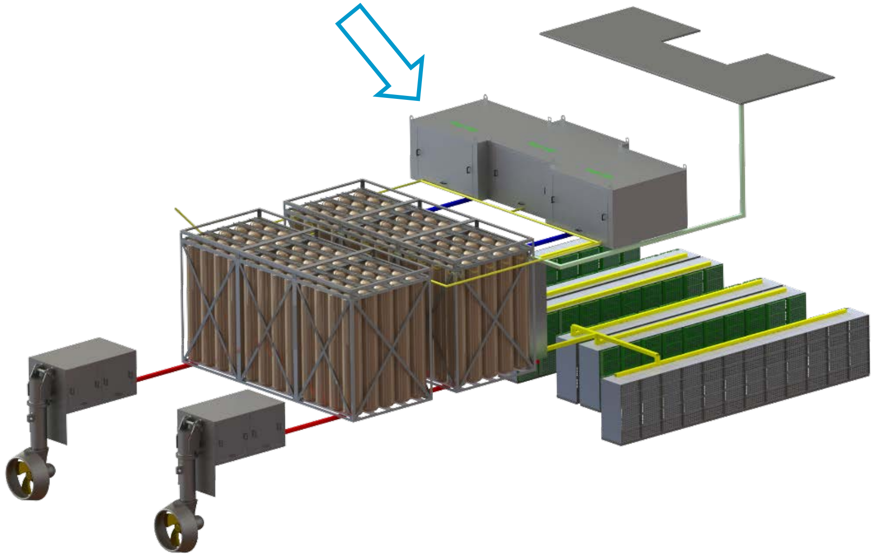
EST-Floattech
Intelligent Energy Storage Solutions

Battery energy storage system

- cell chemistry: NMC (nickel manganese cobalt oxide)
- total capacity:
  - approximately 2,250 kWh (usable)
  - approximately 1,800 kWh @EOL (theoretically ~15-20 years)
- total system weight: about 25 tonnes (15 % of the ELEKTRA overall weight)
- incl. thermo management
- integrated fire protection system
- fully charged via shore connection in 7 to 8 hours

Fuel cell system

- approximately 200 kW base load
  - ~ stationary behaviour
- Small window of operation
  - ~16 h continuous operation



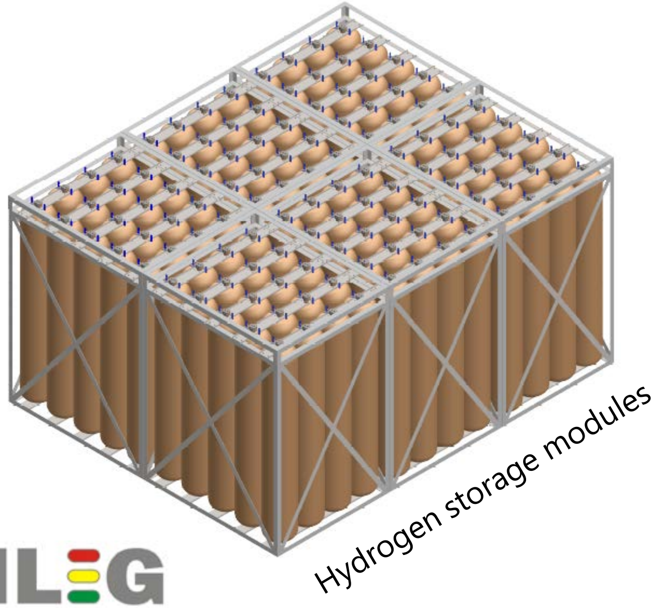
Arrangement of fuel cells system and hydrogen storage on board of ELEKTRA

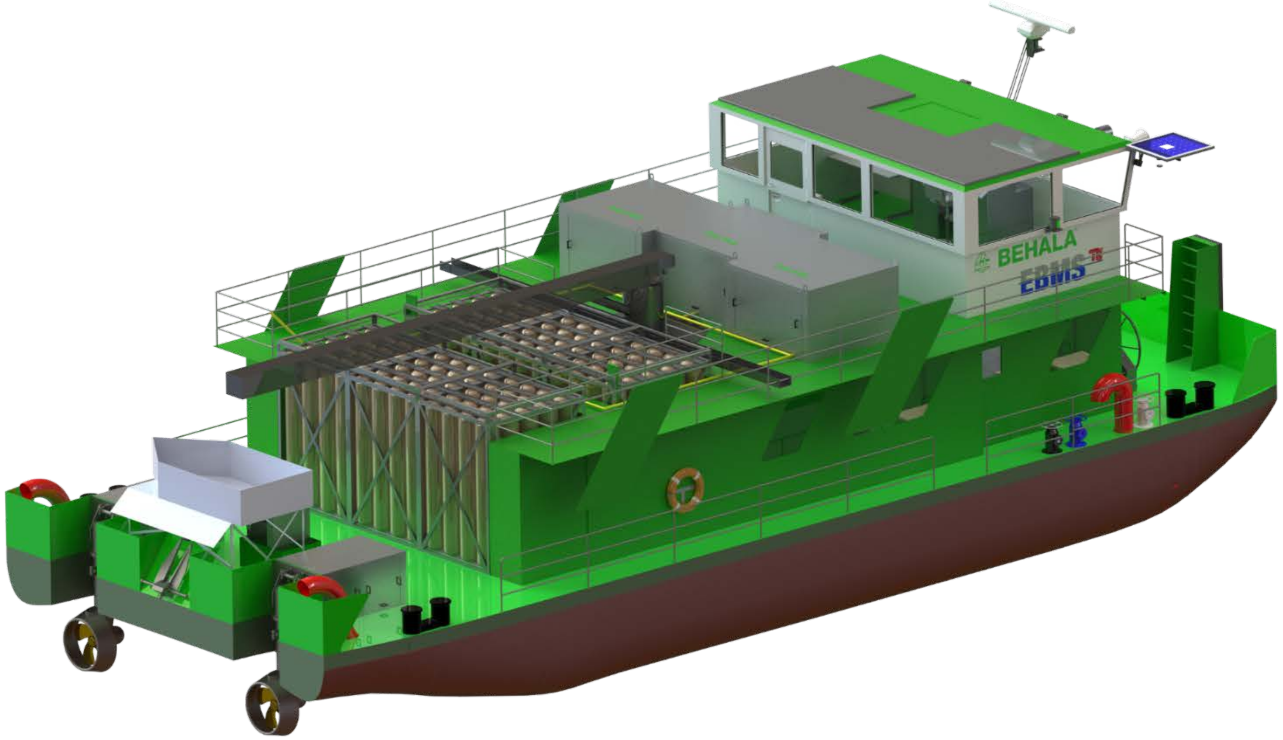
FCveloCity®-HD 100

- NT-PEM incl. cooling and compression system
- 3 x 100 kW units installed
- individually operable
- „freezable“
- remote diagnostics
- H_2-sensor integrated
- Durability approximately 15 years

Hydrogen storage (exchangeable)

- Type IV high-pressure vessels, GH_2 500
- 6 modules, individually cranable
  - transport by truck and trailer
  - Total weight: about 20 tonnes
- 750 kg GH_2 useable





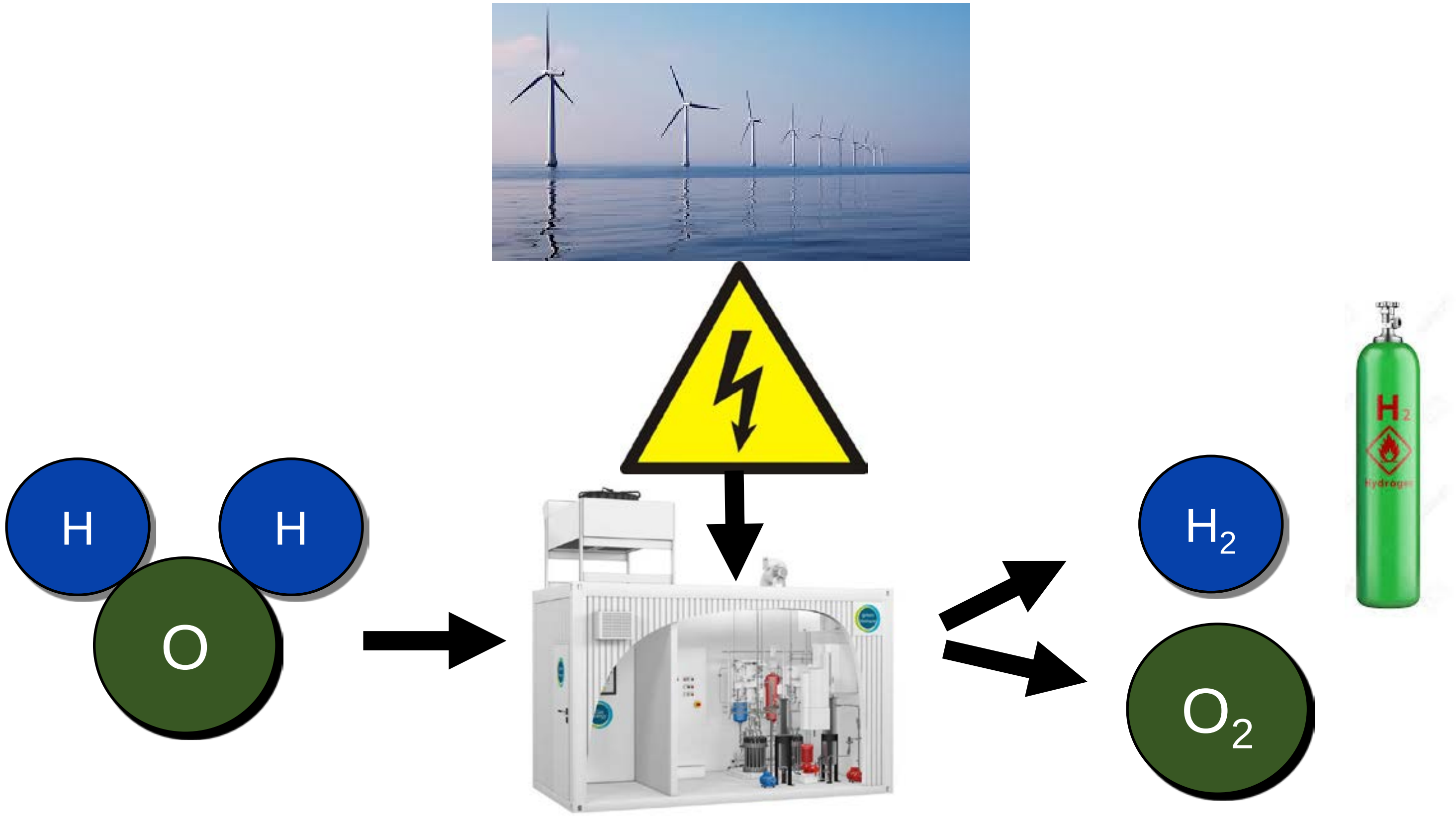
ANLEG

Hydrogen

- **Black hydrogen**
  - produced by electrical power from emission-related energy sources
- **Grey hydrogen**
  - by-product of chemical industry
- **Green hydrogen**
  - produced by electrical power from regenerative and sustainable energy sources

- Intention to use green hydrogen
- Steady increase of proportion of regenerative and sustainable energy sources can lead to higher production rates of green hydrogen and lower prices

3. Layout – hydrogen production



elektrolyzer

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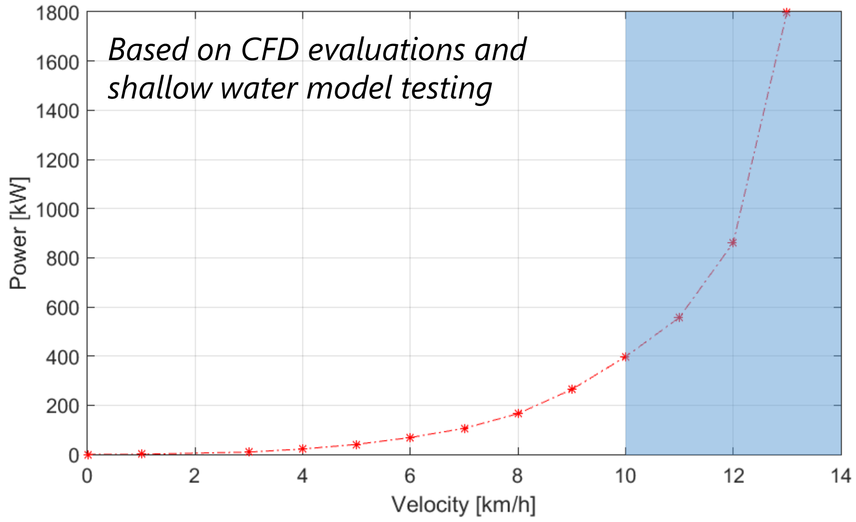
4. Supply of energy – examination of the route

Examination of

- Distances
- Operating ground speeds
- Optional maximum speed of 10 km/h
- Operating times
- Influence of the flow velocities
- Field measured energy demands (in locks)

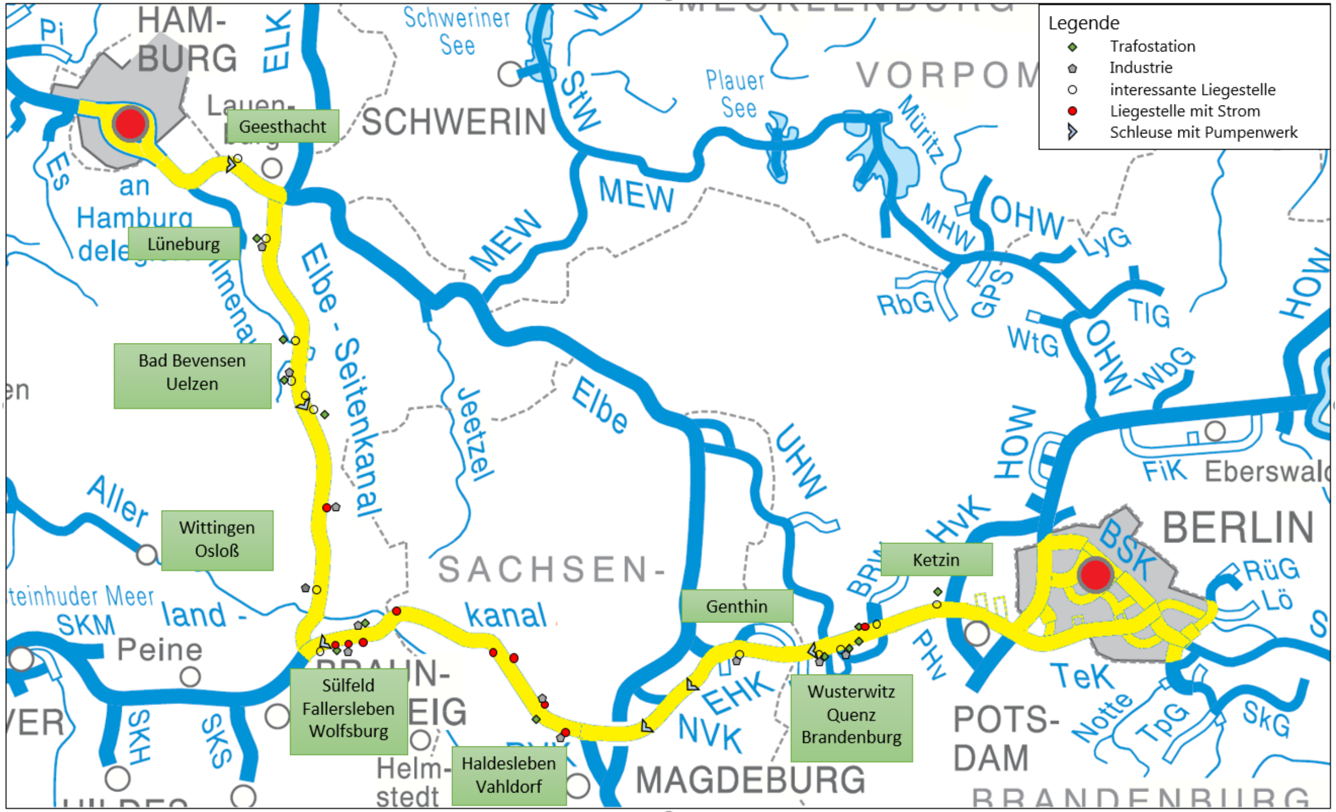
Energy demand round trip	
Demand driving energy (round trip)	**~ 21.200 kWh**
Demand driving energy (one-way)	~ 10.600 kWh



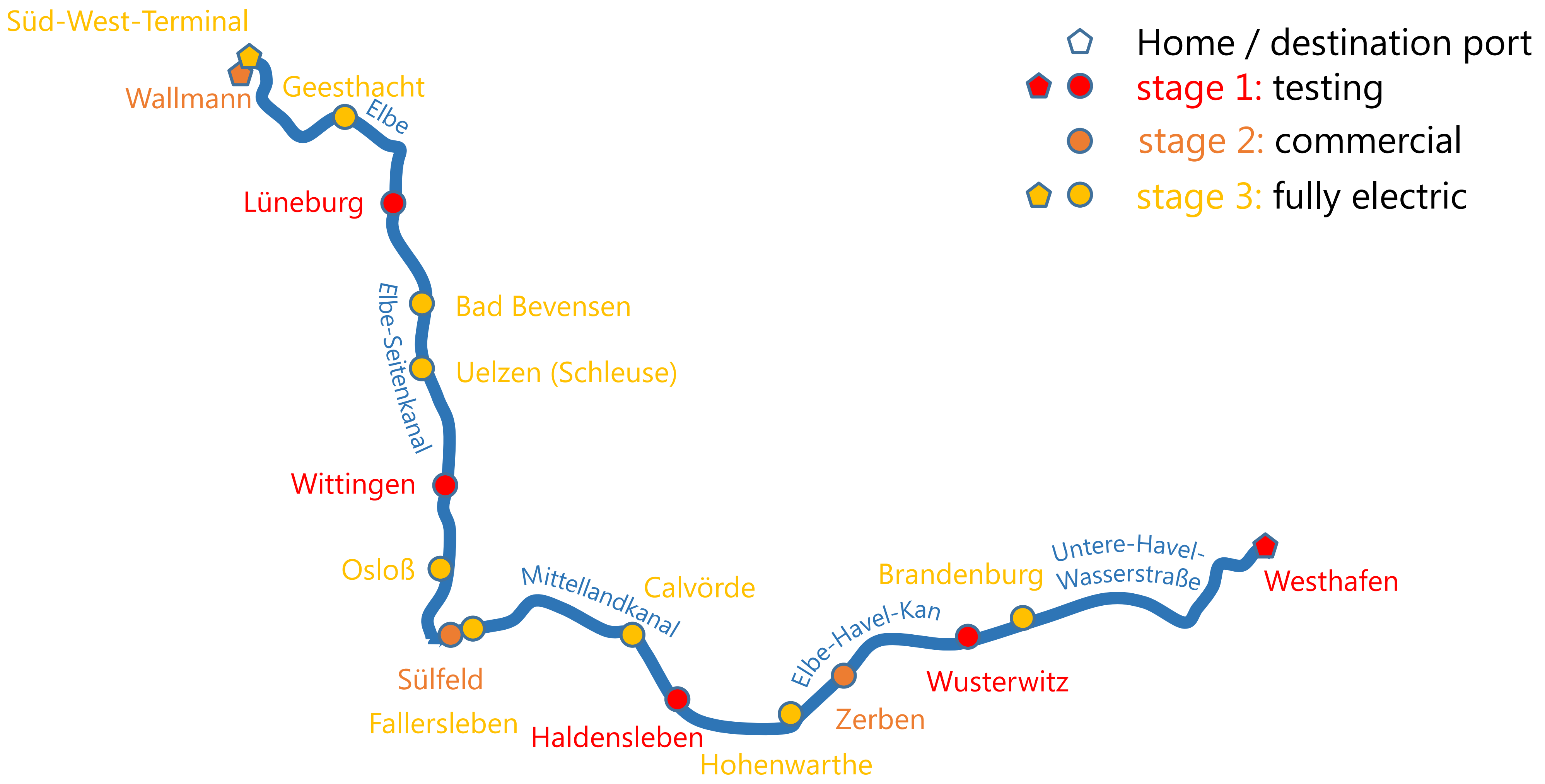
4. Supply of energy – infrastructure

Required

- Shore-based charging station able to fully charge accumulators in 7 to 8 hours
- Access for unit transporting hydrogen modules and handling space for the crane

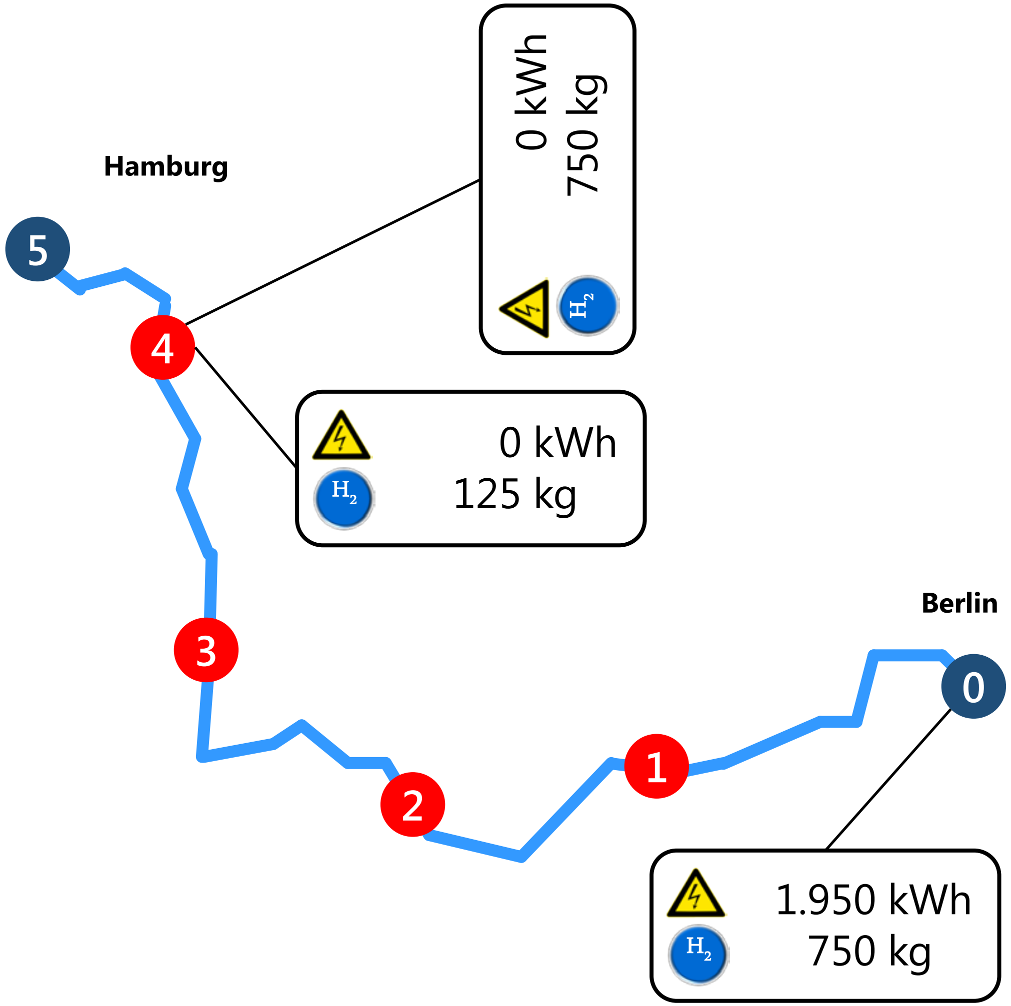


4. Supply of energy – infrastructure – charging stations



4. Supply of energy – scenarios for charging and bunkering

Scenario A	⚡	~ 10 %	H_2	~ 90 %
Scenario B	⚡	~ 25 %	H_2	~ 75 %
Scenario C	⚡	~ 40 %	H_2	~ 60 %



The flexibility to react on prices and availability of the resources (electric current and hydrogen) rises with the expansion stages.

4. Supply of energy – electrical connectors

Currently in use by inland navigation (mainly river cruise ships)

- PowerLock connectors
  - Voltage of 400 V_{AC}
  - Currents up to 400 A
  - Power transmission up to 277 kVA

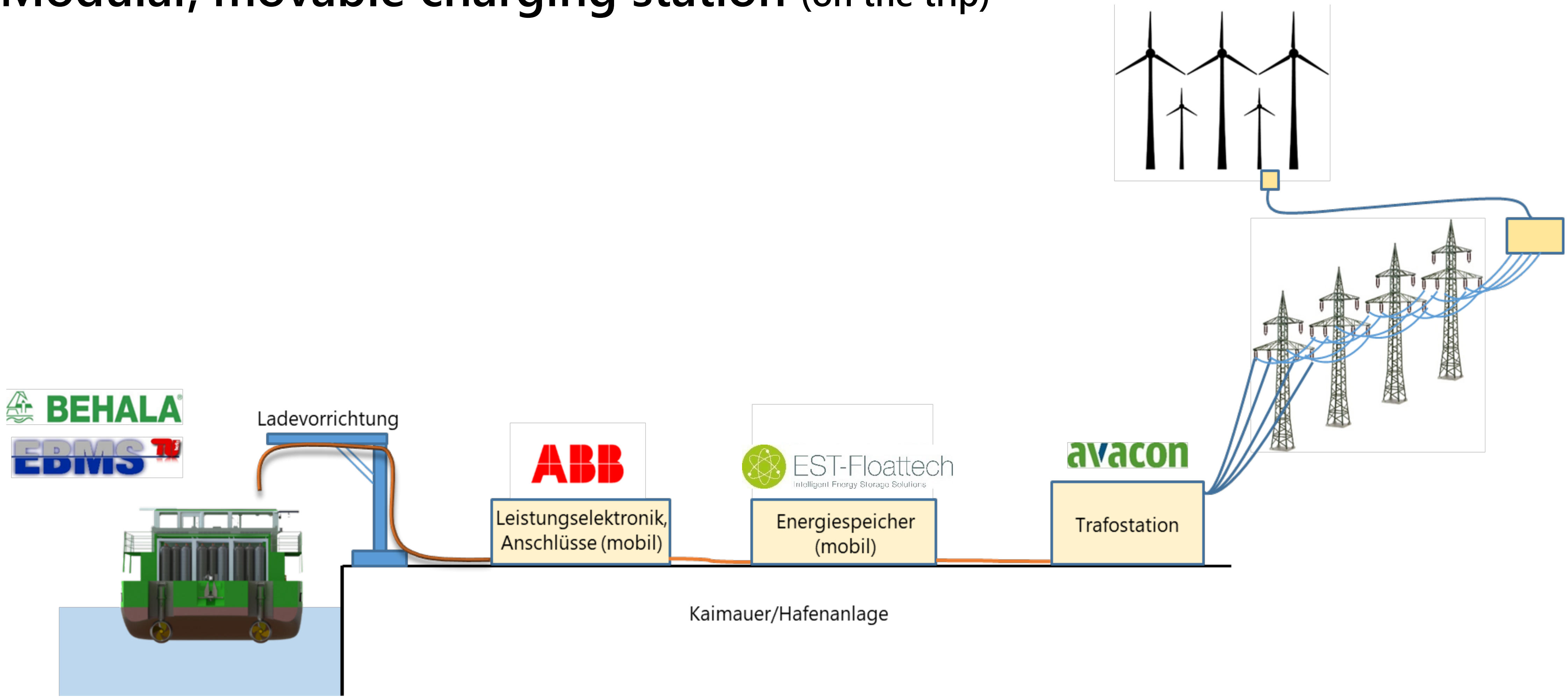
Source: ittcannon.com

DS2 250 A von Marechal Electric

- Voltage of 400 V_{DC}
- 250 A each contact
- total 1.000 A

Source: Marechal

Modular, movable charging station (on the trip)



4. Supply of energy – mobile charging station

Shore based power supply with a high power battery storage

- Up to 2 or 3 MWh useable energy content in a 40“ container
  (lead-acid or lithium-ion batteries)

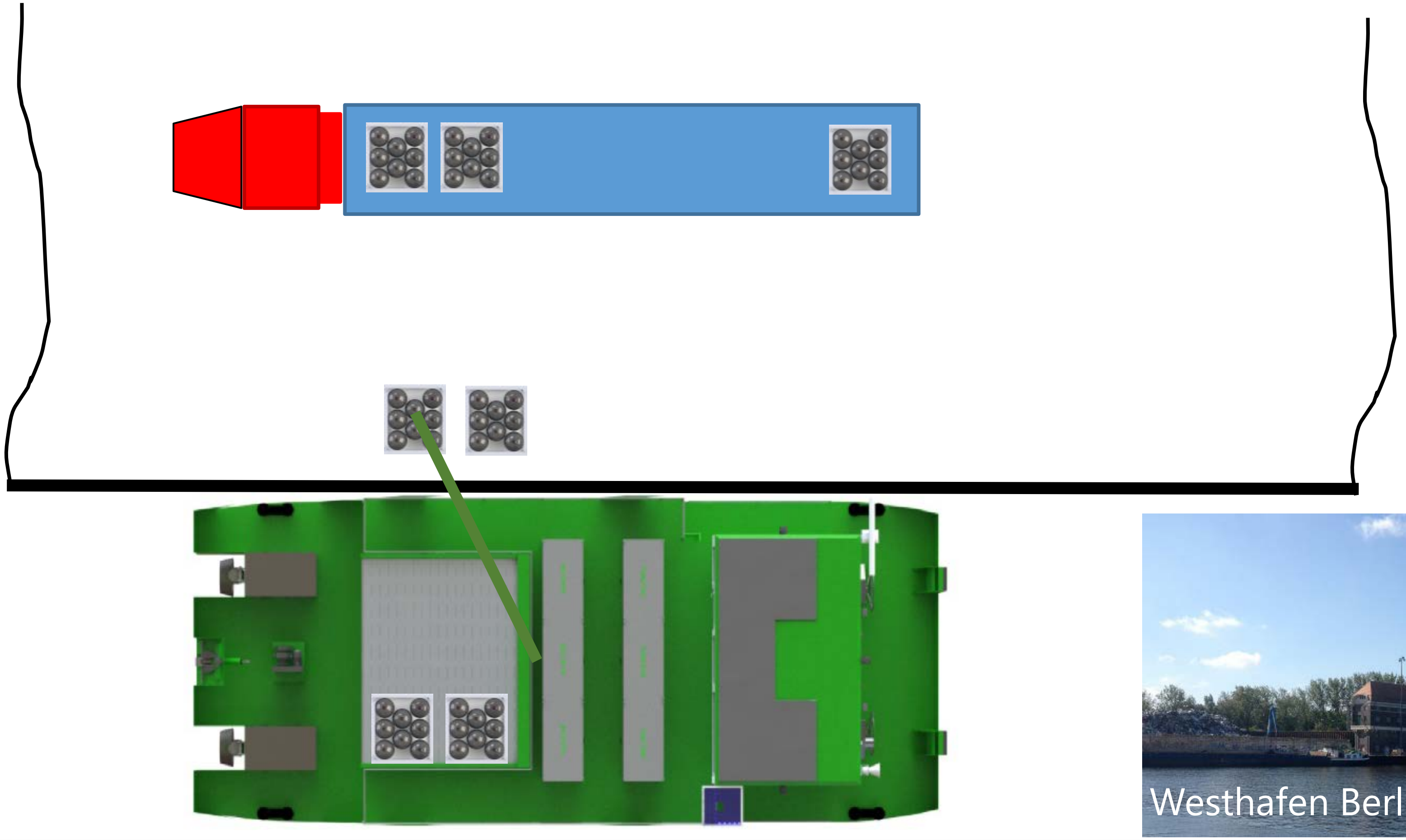
Source: EST-Floattech

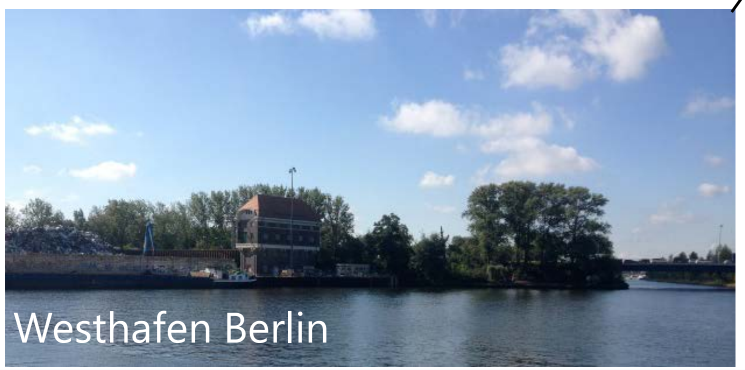
- **Could Absorbs irregular high power peaks from the energy grid**
- **Support the development of non-existent infrastructure**

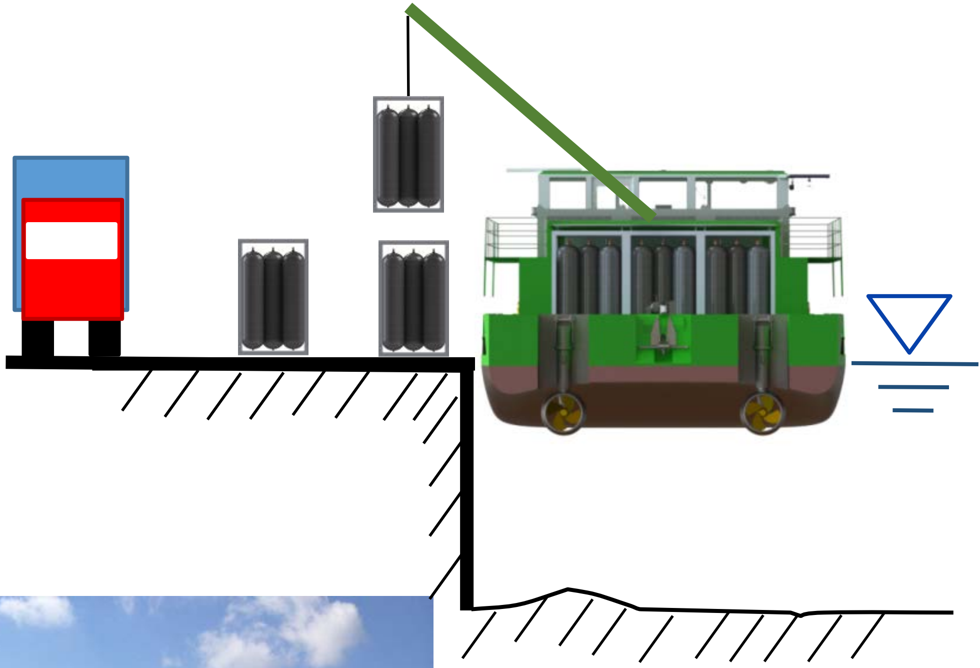
Supply of energy – hydrogen

Exchangeable H_2-Tanks

- H_2-delivery by truck or train from the local area







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Summary

- **Local zero-emission transport in metropolitan areas is today possible**
- **Global zero-emission transport intended (green hydrogen, green electrical power) is possible**
- **Further development of the charging and H_2-infrastructure is necessary**
- **Cost for hydrogen and electricity must decrease**
- **Rules and regulations for reliable investments are necessary**

The ELEKTRA with the heavy cargo barge URSUS in front of the Berlin Westhafen port in 2021

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Outlook:	**2019**	**Beginn of construction**
	2020	**Delivery**
	2021	**Trail period**