Interreg North-West Europe
H2SHIPS
European Regional Development Fund

TU Delft hydrogen shipping activities

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Baggernet webinar

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Maritime application of Hydrogen as a fuel

- The case for using fuel cells in shipping
  - Elimination of emissions
  - Silent operation
  - No single-point-of-failure
  - High efficiency
  - Decreased maintenance.

Criteria for H2 as shipping fuel:

- -safety and certification for use on board of ships
- -volumetric energy density
- -transportability and logistic distribution to ports

a. Liquefied Hydrogen and compressed Hydrogen have constraints!

b. Development of LOHC liquids and boron-hydride solids

Source: U.S. Department of Energy

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Solid Hydrogen: a circular fuel

- Hydrolysis reaction
  - Catalytic reaction
  - Spent fuel of $NaBO_2$

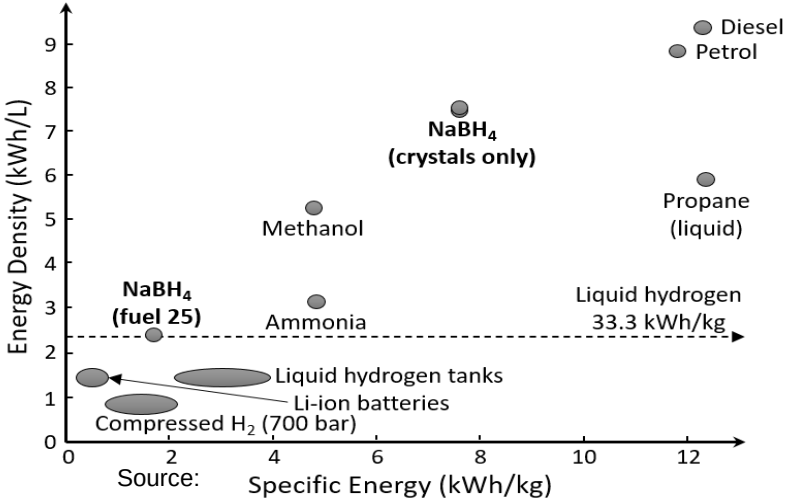
regeneration

$$NaBH_4 + 2H_2O \rightarrow 4H_2 + NaBO_2$$

$$NaBH_4 + (2+y)H_2O \rightarrow 4H_2 + NaBO_2 + yH_2O$$

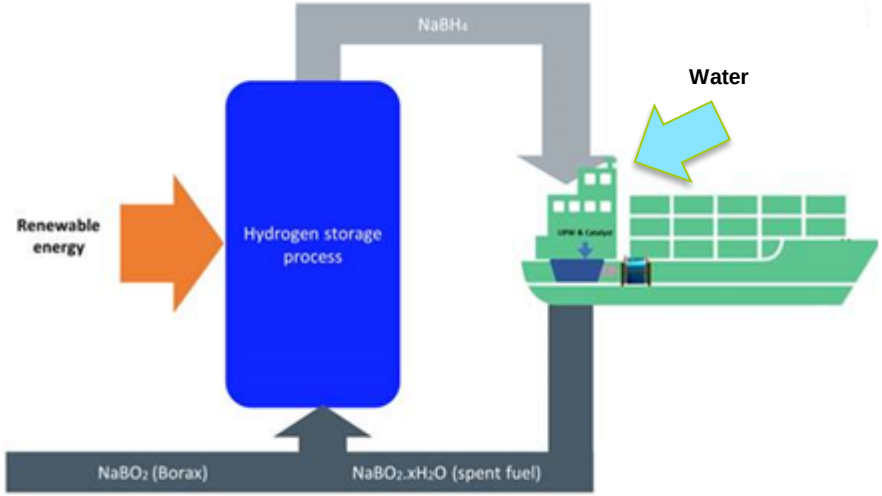
- Energy densities
  - Dry fuel: 7.1 kWh/kg
  - Dry fuel: 7.6 kWh/L

- Regeneration
  - The spent fuel has to be stored
  - Energy efficiency, electricity price and materials determine cost



$NaBH_4$ Storage Concept

- $NaBH_4$ provides energy-dense hydrogen storage that is stable under atmospheric conditions.
- The $NaBH_4$ is produced by recycling the spent fuel product from the ship.
- Production facilities can be created in ports, using renewable energy produced offshore.



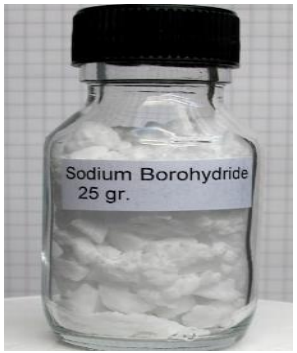
Safety & Health

- Safety consideration for Dry $NaBH_4$ storage:
  - Flashpoint = 70 degree Celsius
  - Autoignition temperature = 220 degree Celsius
  - Reaction with (unfiltered) water in case of total tank failure is slow due to impure water, however, more research is required to properly assess the risks

Less flammable than conventional diesel!

- Safety considerations for spent fuel storage:
  - Non-flammable
  - Non-corrosive

- Non-toxic, non-explosive powder



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Port Oostende

UNIVERSITY OF BIRMINGHAM

+ 2 Sub-partners
+ 15 Associated Partners

NAVALU

hynamics EDF GROUP

syctom

HAROPA Ports de Paris Seine Normandie

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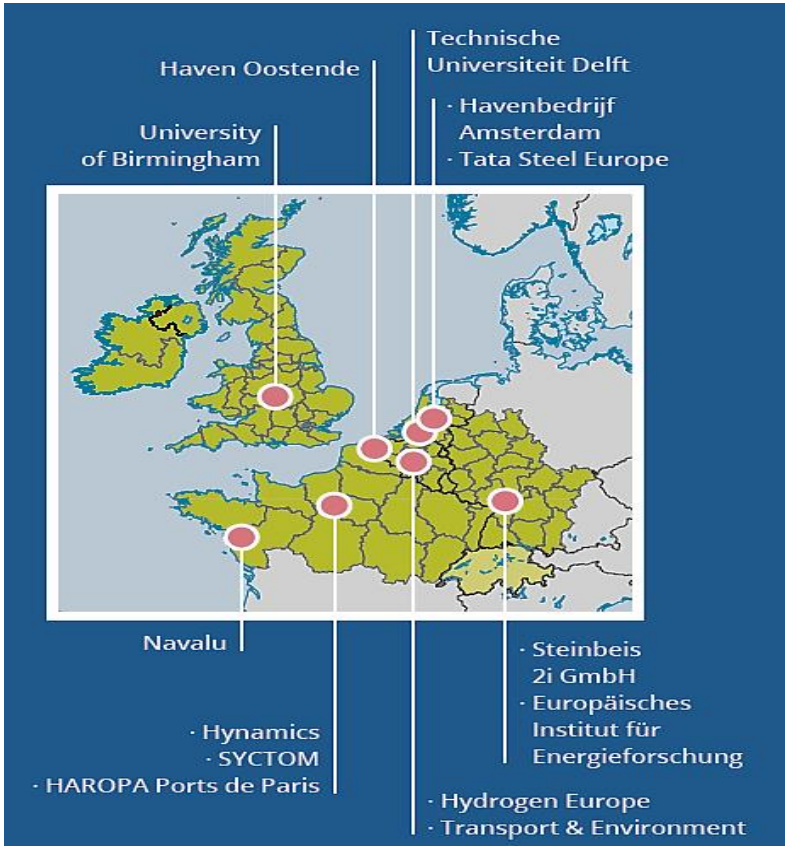

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Port of Amsterdam

TATA STEEL

EIFER
EUROPEAN INSTITUTE FOR ENERGY RESEARCH

STEINBEIS 2i

Hydrogen Europe

TRANSPORT & ENVIRONMENT

The Amsterdam Demonstrator in H2SHIPS

The NL demo will take place on a new Port Authority Vessel of Port of Amsterdam. The vessel will have a zero emission propulsion and will sail in the Amsterdam urban and port area.

- The configuration will be battery-electric, with a maritime fuel cell as range extender and sodiumborohydride as hydrogen carrier.
- NL partners: Port of Amsterdam, Tata Steel and Delft University of Technology.
- Port of Amsterdam and TATA find it very important, that existing small inland ships with small destinations at the end of inland waterway logistical lines towards the Netherlands, Belgium and France can be sustained by a retrofit modification of zero-emission propulsion power. This demo enables this process.

Amsterdam Demo Design Data

Dimensions:

Max length: 20 meters

Max. beam: 4.25 meters

Max. draft: 1.50 meters

Max height above waterline: 1.90 meters

Accommodation: 25 persons.

Map Courtesy Waternet Amsterdam

Operational profile and propulsion data:

-the requirement to sail with an average speed of **12.5 km/h** (3.5 m/sec) for a period of **9 hours** and for **1 hour** at max speed of **15 km/h**.

-propeller power: 110 kW

-Li-ion battery pack of 100 kWh

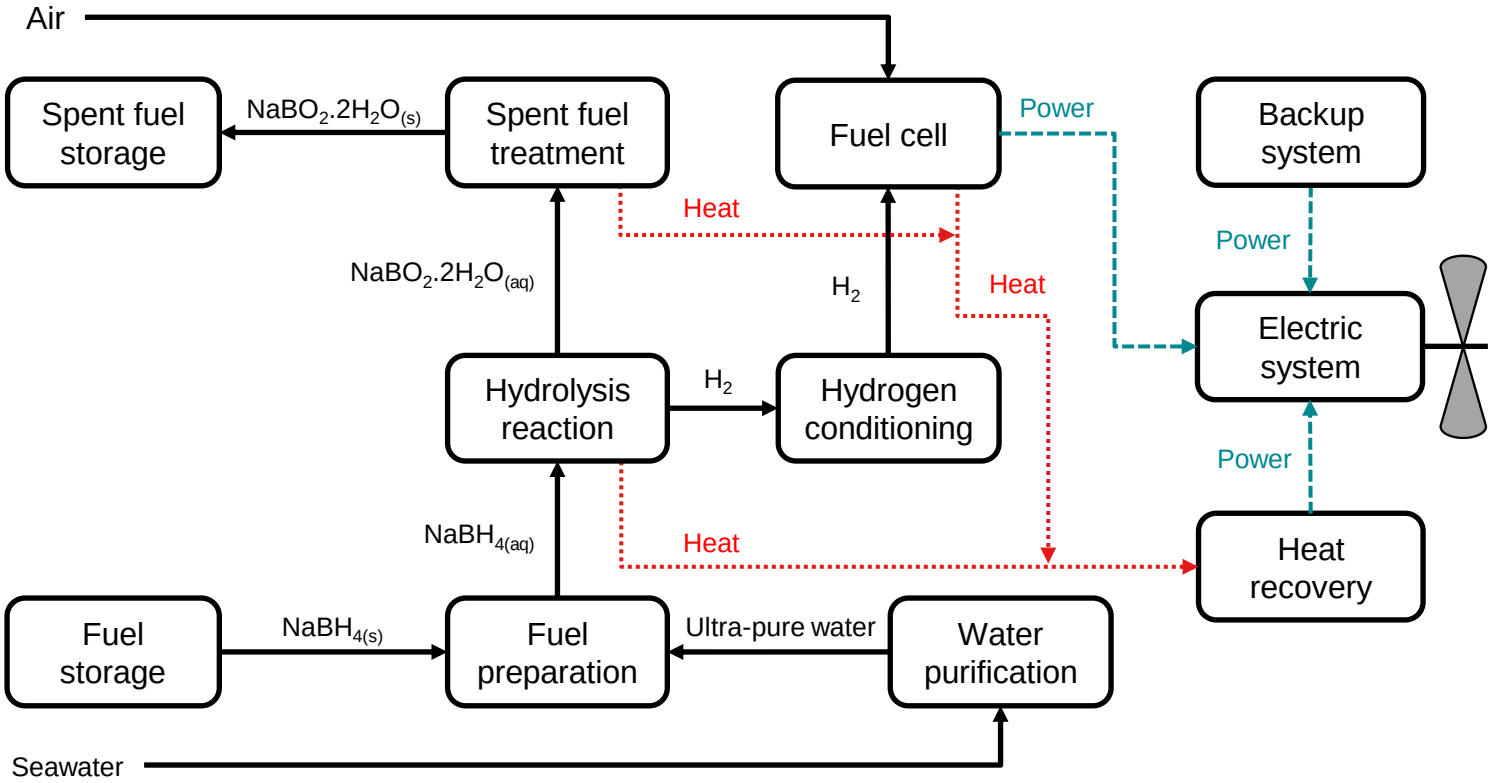
-PEM Fuel Cell 60-90 kW

-Sodiumborohydride as Hydrogen Carrier

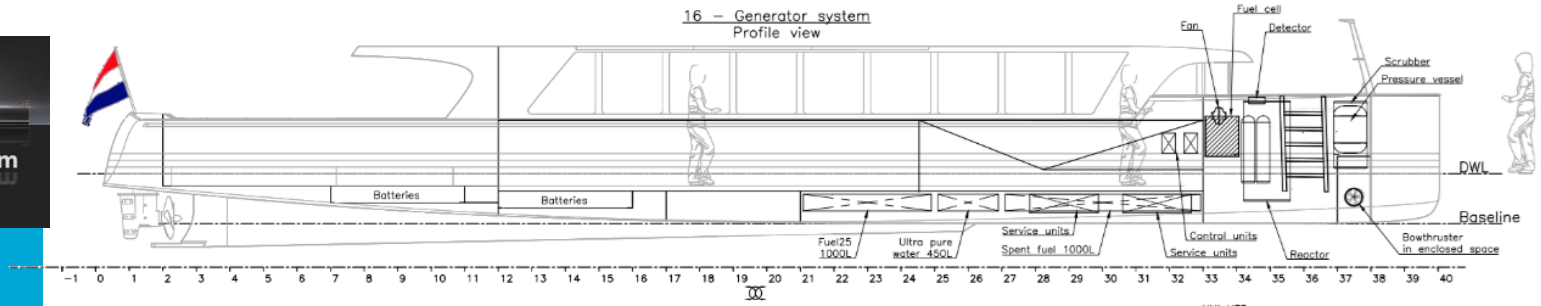
Intermediate successes

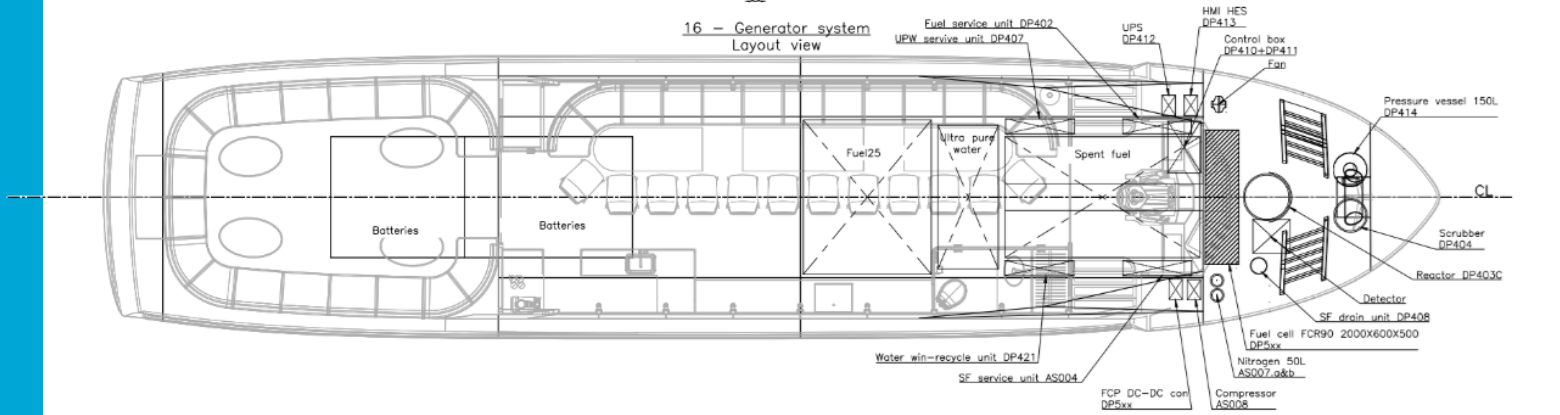
- No show-stoppers in design and certification process (HAZIP and other) (Lloyd's register)
- Amsterdam Milieudienst: NaBH4 can be bunkered without additional safety legislation, no safety area around the ship required
- Successful conclusions of safety report that the ship may pass covered area's (especially under bridges).

Concept NaBH4 system configuration



Hydrogen Configuration Demonstrator





GENERAL PARTICULARS:

LENGTH O.A.	19.96	M
BREADTH O.A.	4.25	M
DISPLACEMENT FULL	42	TON
SPEED	9	KNOTS
FLAG STATE:	Dutch, zone 3 Amsterdams grachten type	
CREW	1	
PASSENGERS	24	
HULL / DECKHOUSE MATERIAL	STEEL	

Progress of the Amsterdam demo

Item	
Ship Design	End of 2019
Propulsion System Design	First half 2020
Detailed Design	Second half 2020
Hazip H2 safety classification	Ready, november 2020. No safety zones around bunker location foreseen
Build and equipment (FAT) test	2021/2022
Ship acceptance tests (HAT/SAT) and sail	2022

Integrated Design Project for a Short Sea Vessel

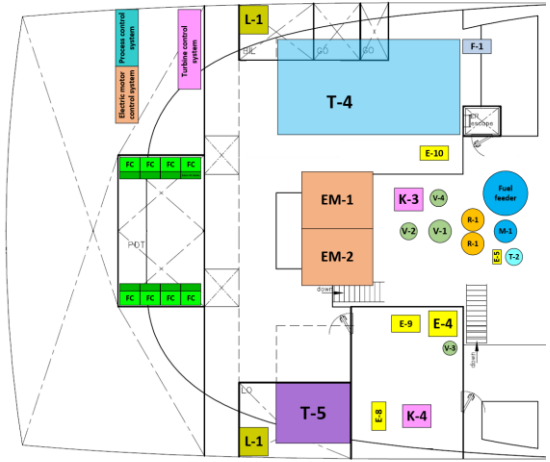
- **Input data:**

Parameter	Unit	Value
Deadweight	tonne	11000
Cargo capacity	TEU[1]	380
Length	m	132
Fuel type	-	Diesel fuel
Engine rated power	MW	4
Average power consumption	**MW**	**2.5**
Rated speed	kn	14
Average speed	kn	11
Maximum sailing time	**days**	**14**

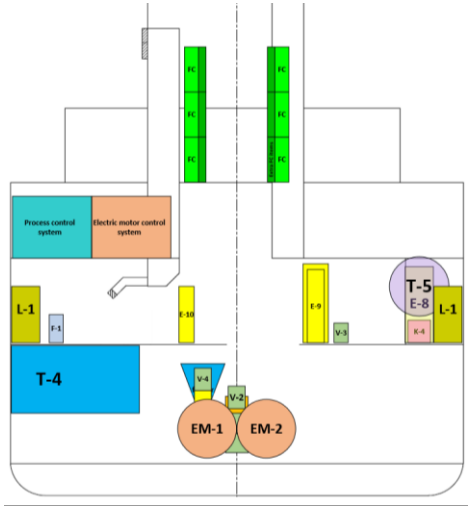
Note 1: TEU=Twenty-Foot Equivalent Unit

Summary of Short Sea ship design

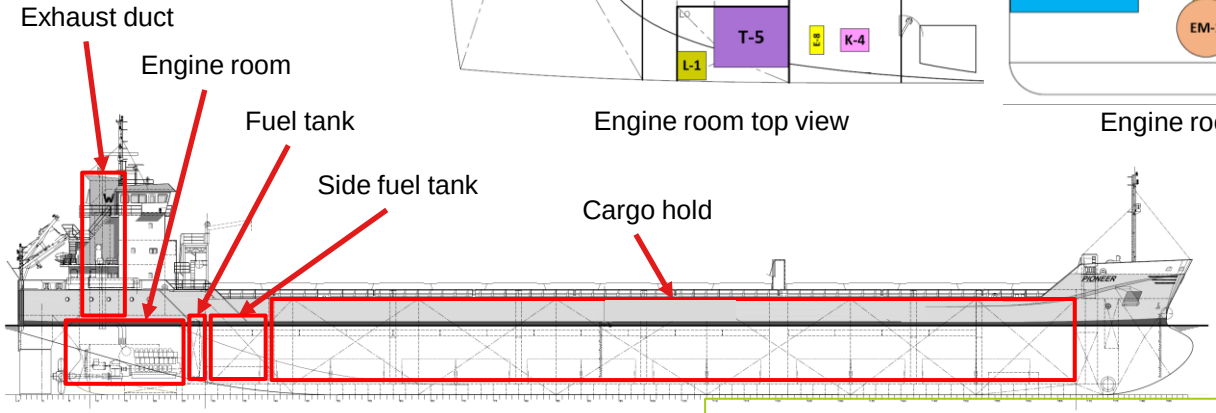
- **Plant layout:**
  - Equipment sizing



Engine room top view



Engine room aft view



Adding to Short Sea conclusions

- No extreme pure water requirements, neutral possible with recycling of FC-output water
- Component sizing comparable or lower volume irt ICE-sizing
- Spent fuel drying possible with neutral energy balance (use of waste heat)

Development Solid H2 carrier

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H2 Regeneration

H2 Generation

Present interest:
Inland vessels, fishing vessels, dredging, ferries, short sea ships, (super)yachts, navy, cruise vessels

H2 Cargoship

2022

State-of-the-art Small scale regenerators: Mg-based (TUD) & electrochemical (UVA)

350 kW+ module

2022

2021

2021

2020

PDEng research TU Delft: short sea ship application, regeneration process

2020

2019

2019

Further initiatives

- Regeneration demonstration 2022
- Implementation pilot module on ships (inland, offshore).
- Prepare large scale regeneration and production
- Maritime Masterplan/RVO R&D Mobility Call (5M+ project proposals before 17/8)

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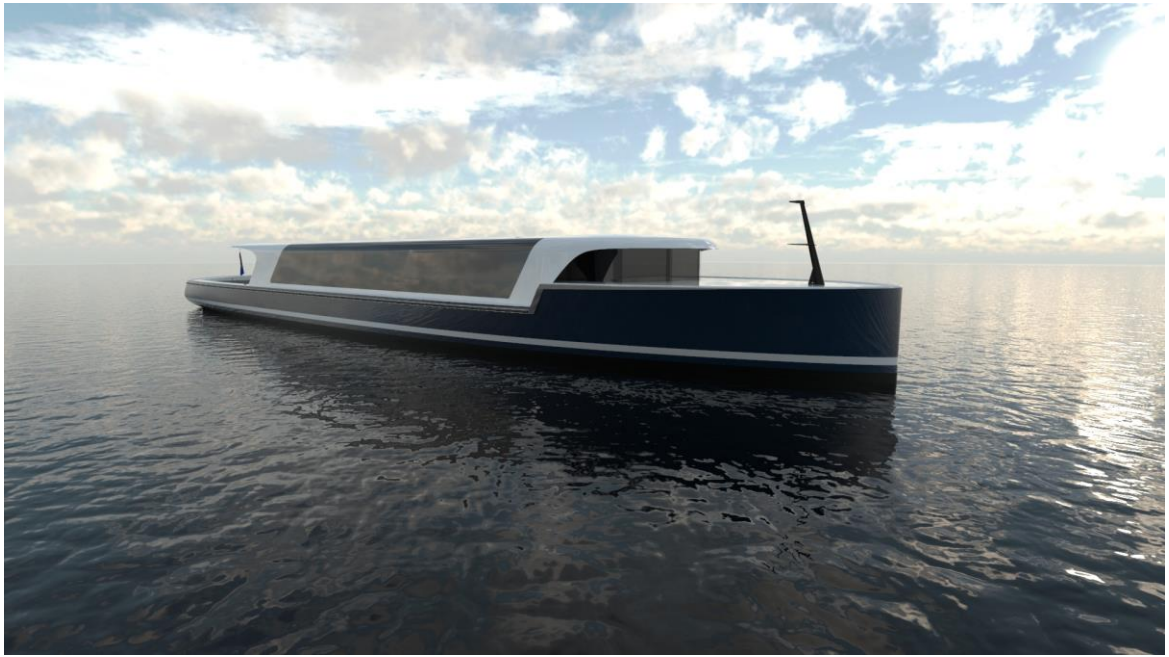

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