Interreg North-West Europe H2SHIPS

Pilot Ship Port of Amsterdam on NaBH4 as hydrogen carrier

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PARIS DISSEMINATION EVENT H2SHIPS

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The maritime challenge of hydrogen (storage)

- The case for using fuel cells in shipping
  - Elimination of emisions.
  - 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
- Liquefied Hydrogen and compressed Hydrogen have constraints!

Source: U.S. Department of Energy

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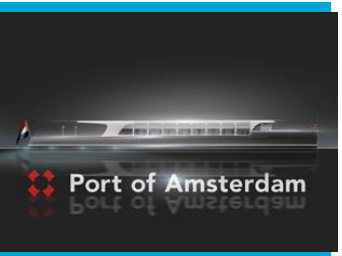
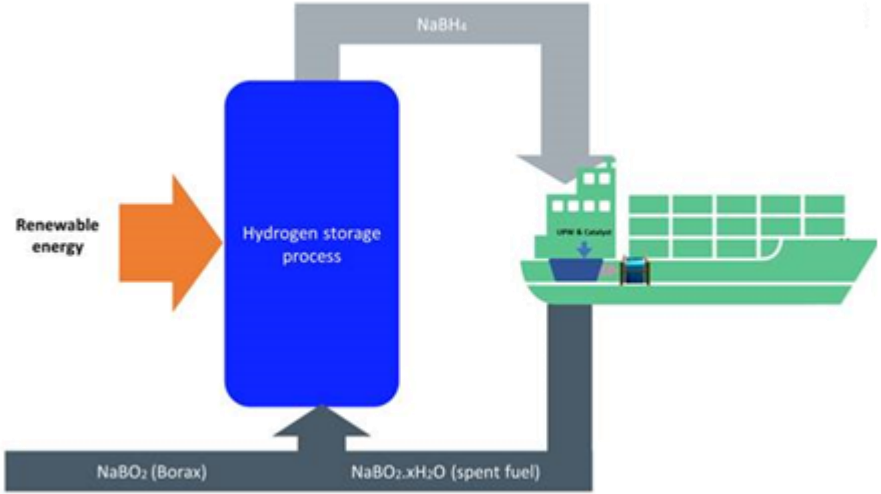
Solid Hydro. Re.Gen



$NaBH_4$ Storage Concept

- $NaBH_4$ provides energy-dense hydrogen storage that is stable and safe under atmospheric conditions.
- The hydrogen is released by mixing it with ultra pure water.
- New $NaBH_4$ is produced by recycling the spent fuel product from the ship by renewable energy
- Production facilities can be created in ports, using renewable energy produced offshore.



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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 sodiumborohydrid 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 **10 hours**

-propeller power: 220 hp (162 kW), expected for this vessel a maximum of **200 kW**

-Sodiumborohydride as Hydrogen Carrier

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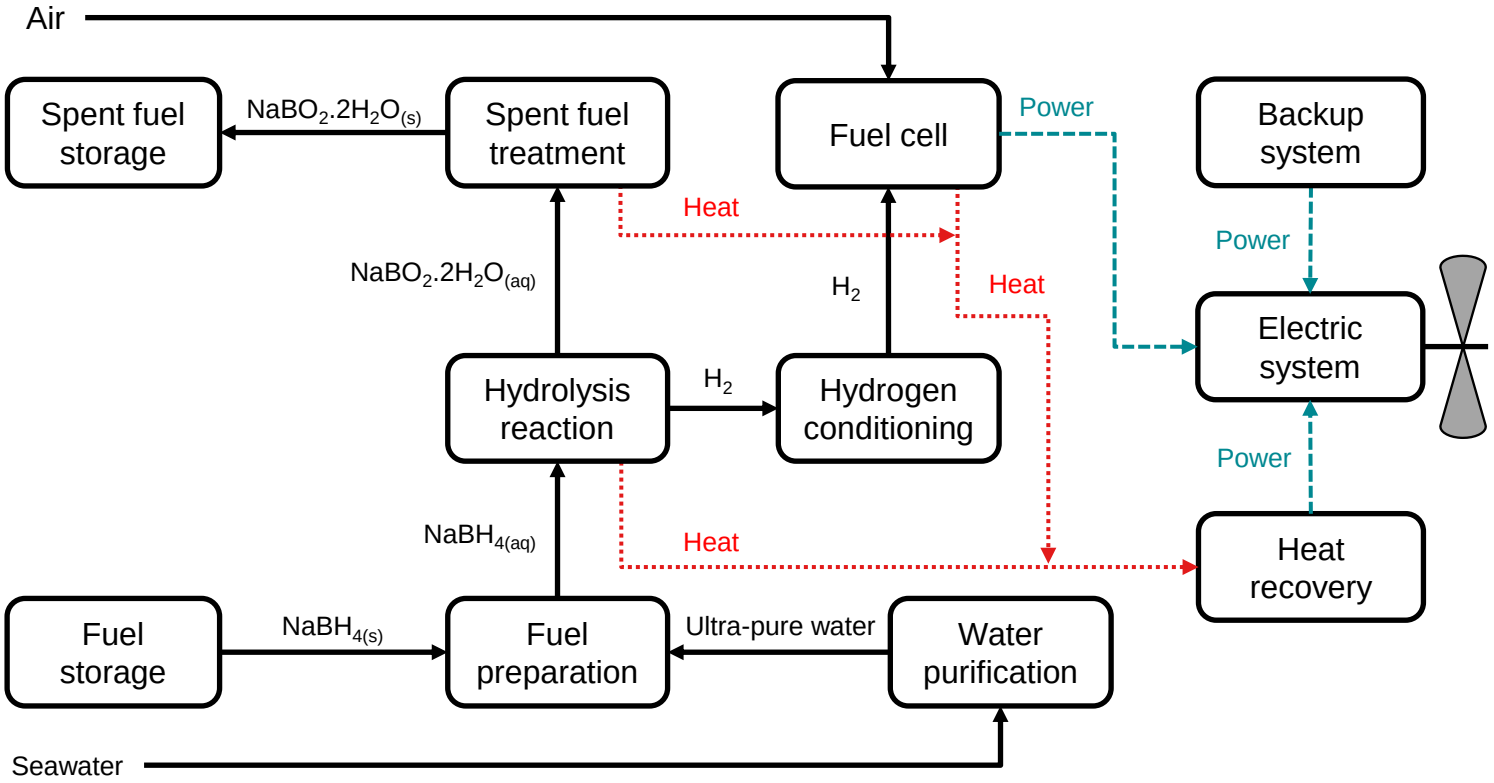
Concept NaBH4 system principle



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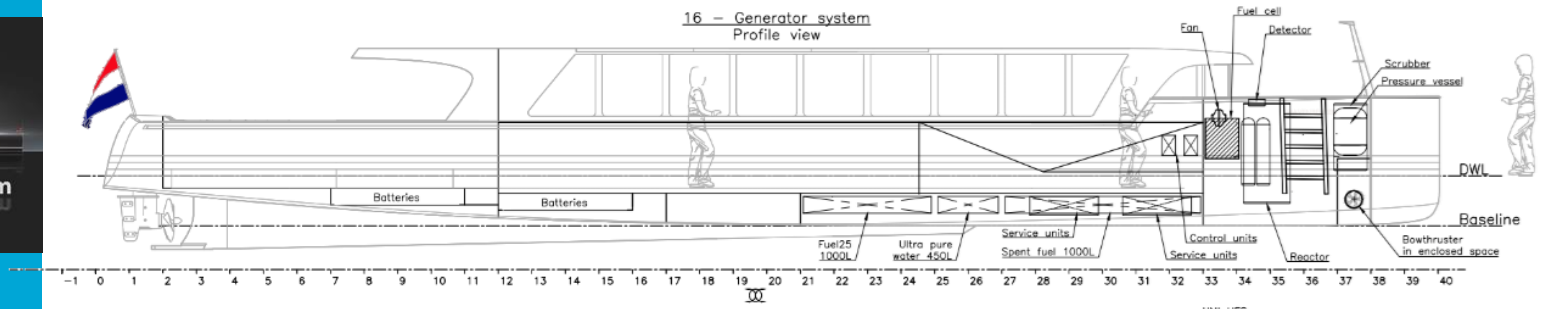
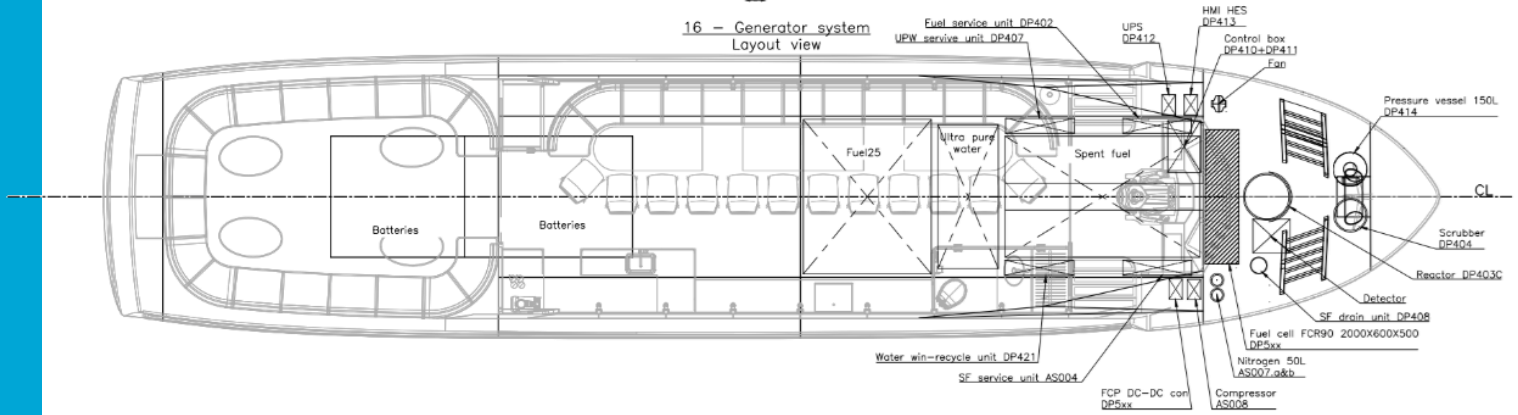
Hydrogen Configuration Demonstrator





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	

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Intermediate successes of the Amsterdam demo project

- 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).

  – https://www.portofamsterdam.com/nl/nieuws/h2ships-varen-op-waterstof

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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
Equipment selection, shipbuilder acquisition	2021
Build and equipment test	2022
Ship acceptance tests and sail	2022, first halfyear 2023

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Follow-up after Amsterdam demo

TATA STEEL

ptc
Particuliere Transport Cooperatie

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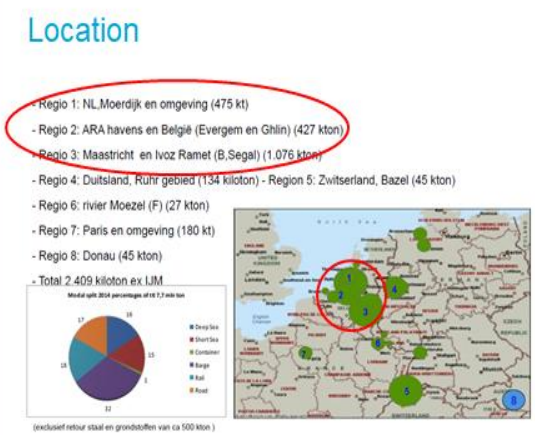
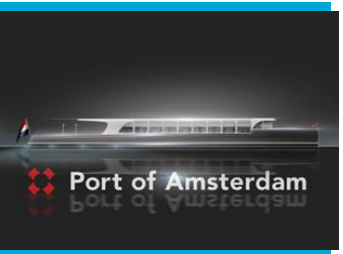


-Small inland ship, operated by PTC, chartered by Tata
-2 propeller shafts, 250 kW, 1 H2-electric, 1 conventional
-Retrofit of existing ship, commercial cargo test
-Modular hydrogen power pack with Sodiumborohydrid fuel and PEM fuel cells

Development Solid H2 carrier



H2 Regeneration

H2 Generation

Present interest: Inland vessels, fishing vessels, dredging, ferries, short sea ships

2022

State-of-the-art Small scale regenerator

2022: H2CARGOSHIP: Follow up Amsterdam Demonstrator with Tata and PTC

2021

2021

2020

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

2020

2019

2019

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NaBH4 has superior characteristics

Actually, a crystal structure in the form of NaBO2.2H2O is formed

regeneration

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

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

- Hydrolysis reaction
  - Catalytic reaction
  - Spent fuel of $NaBO_2$
  - Excess water ratio (y) → Fuel 25

Excess water promotes the reaction and cleans the spent fuel out of the reactor

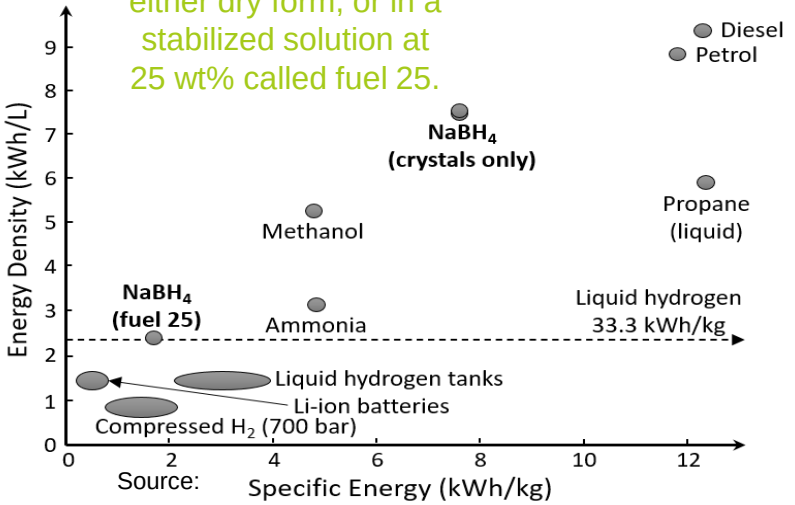
- Energy densities
  - Dry fuel: 7.1 kWh/kg
  - Dry fuel: 7.6 kWh/L

LHV of H_2 equivalent

Including efficiencies, the kWh/L (effective) is comparable to diesel

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

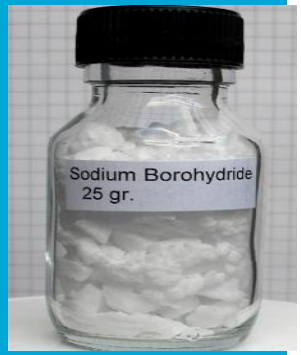
$NaBH_4$ can be used in either dry form, or in a stabilized solution at 25 wt% called fuel 25.



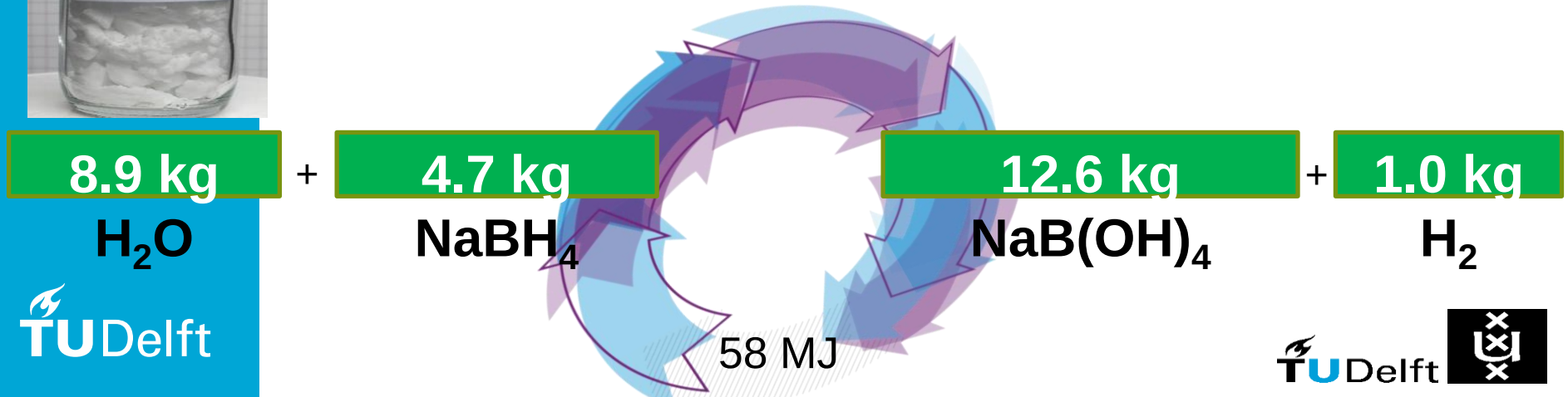
NaBH4 is a circular fuel

Grav. E-density: **25** ($NaBH_4$), **23** (NH_3), **120** (H_2), **42.7** (Diesel) **MJ/kg**

Vol. E-density: **27.1** ($NaBH_4$), **15.2** (NH_3), **5.1** (H_2,700 bar), **8.5** (H_2, –255 °C), **36** (Diesel) **MJ/L**



- Non-toxic, non-explosive powder
- $NaBH_4 + 4\ H_2O \rightarrow$ **4 H_2** + spent fuel ($NaB(OH)_4$)
- 2020: recycling of spent fuel *and* borax possible on large scale!



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Port Oostende

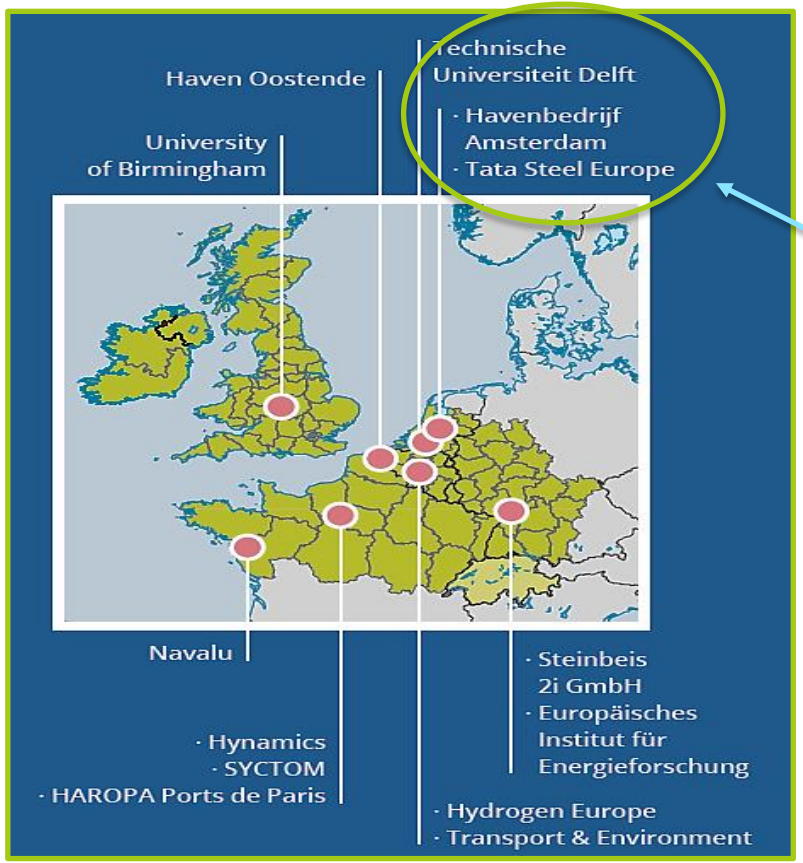
UNIVERSITY OF BIRMINGHAM

+ 2 Sub-partners
+ 15 Associated Partners

hynamics EDF GROUP

syctom

HAROPA PORT Le Havre Rouen Paris



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by EDF and KIT

STEINBEIS 2i

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TRANSPORT & ENVIRONMENT

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