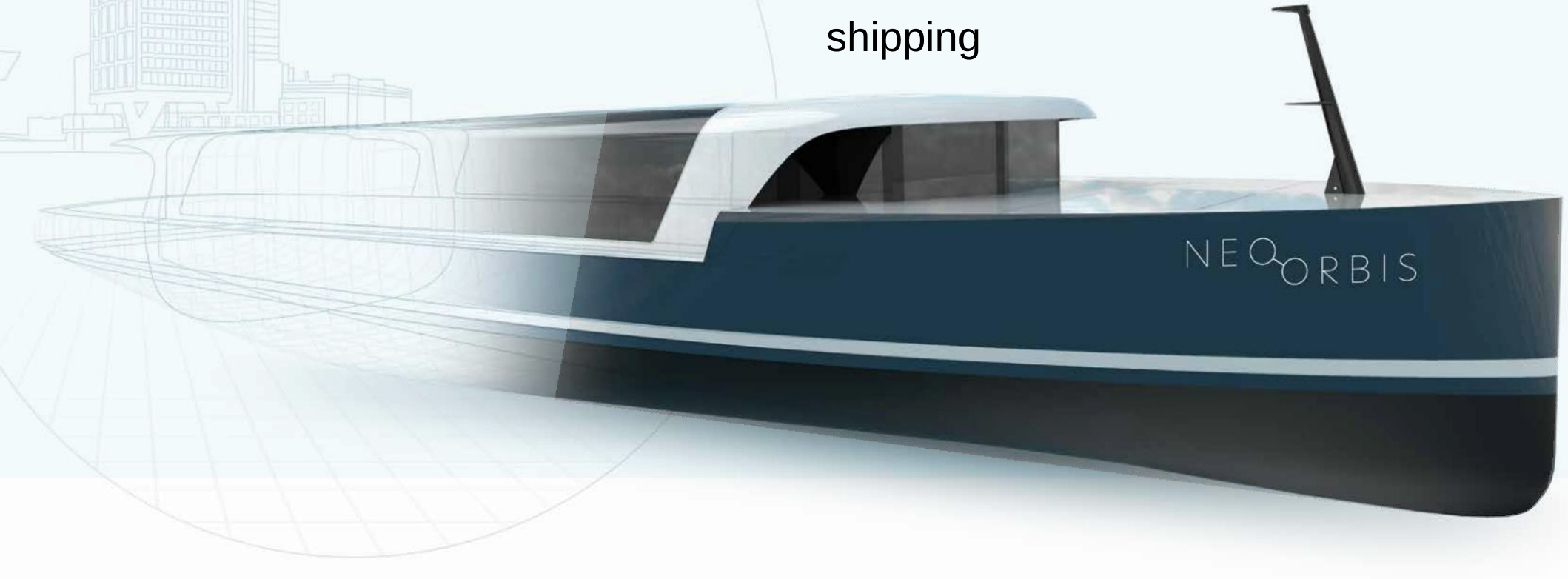
HS Neo Orbis

On course for circular, emission-free shipping



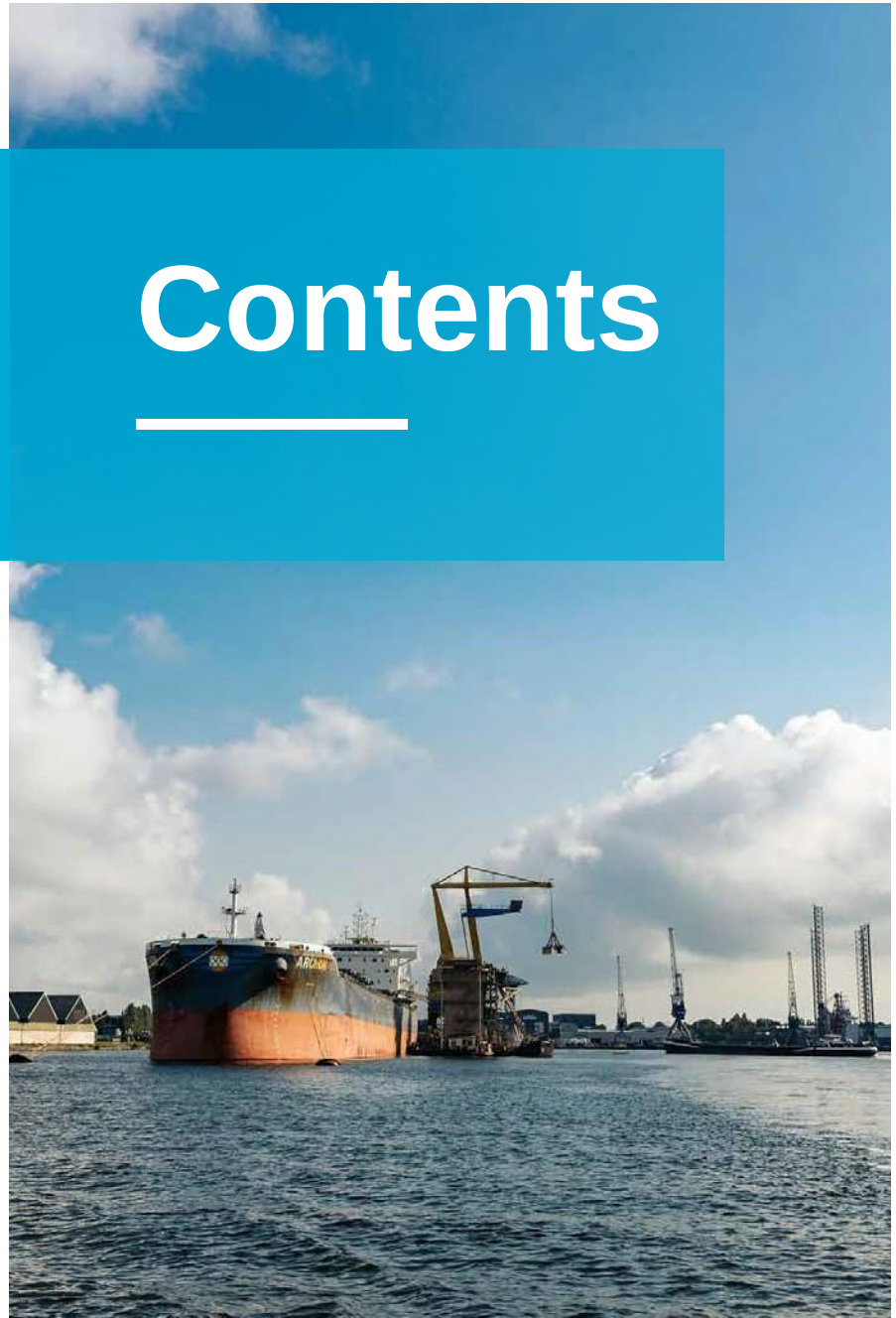
Foreword

It is time to set power to full speed ahead for the energy transition. Port of Amsterdam is doing this in many ways, including the construction of a new saloon boat, as a pilot project marking a breakthrough innovation in renewable energy.

The vessel will be called Neo Orbis: *neo* (new) comes from Latin and *orbis* (world) from Greek. It will sail using hydrogen in a solid form: sodium borohydride. This opens up a world of possibilities for the safe and compact use of hydrogen. So compact that vessels are expected to take to sea using this fuel in the future. We are conducting this pilot with the European project H2SHIPS.

Together, we ensure that more hydrogen-powered vessels will soon sail in north-west Europe. Let’s discover the new world of emission-free shipping using hydrogen.

Port of Amsterdam is heading towards a new world of emission-free shipping, powered by circular energy.



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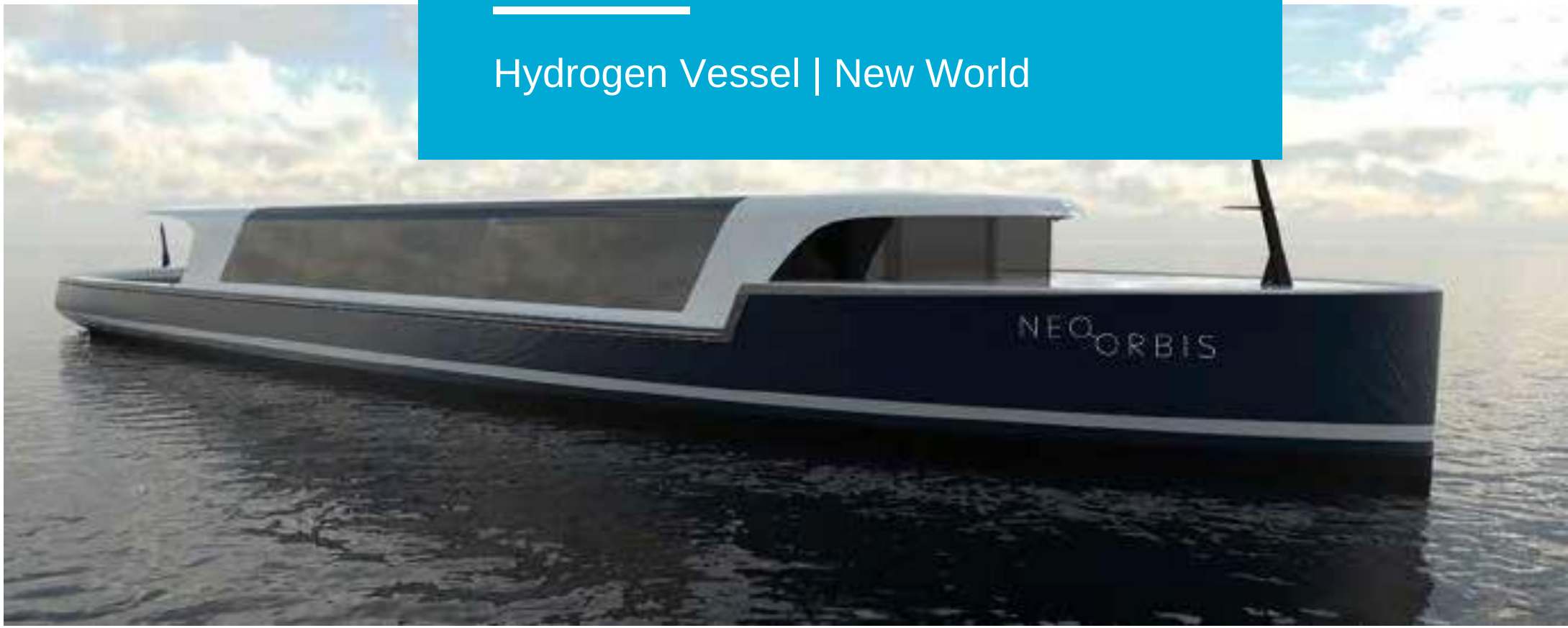
01 HS Neo Orbis

Hydrogen Vessel | New World



The new vessel replaces our current saloon boat, which we use to show clients around the port and the city.

We will use this new vessel to show possible port locations to potential clients, hold meetings and host trade missions. We will also welcome government ministers and members of the Dutch royal family aboard regularly. We will sail around the harbour, Amsterdam city centre and the North Sea Canal up to IJmuiden.

Port of Amsterdam will replace its old vessel, *De Havenbeheer*. The new vessel will be powered using hydrogen as an emission-free fuel, a technology developed in the Netherlands.

HS Neo Orbis will show off not only the development of the port area, but also the major steps the port is taking in the energy transition.

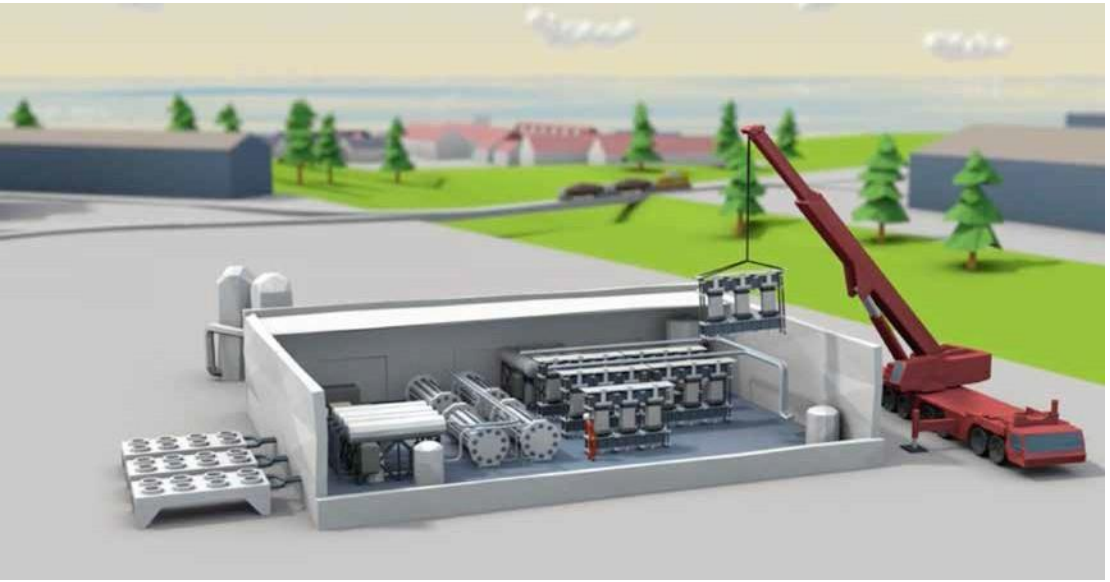
02 Mission

Port of Amsterdam

All hands on deck for emission-free shipping. We are taking the lead by investing, developing and bringing stakeholders together.

There are few places where the energy transition is so tangible as at the port. As the largest petroleum port in the world, Port of Amsterdam is leading the way in exploring and developing alternative energy sources itself for shipping.

One of these energy sources is hydrogen. We are investing in the construction of a 100 MW electrolyser – a hydrogen production plant.



Artist's impression of the electrolyser under construction in Velsen

Biodiesel installation

We also serve as a matchmaker for several innovation projects. These include a hydrogen district in Hoogeveen, a self-powered sailing hydrogen laboratory that travels the world and an energy hub in Emmen that will run on fuels including hydrogen. The construction of our new saloon boat was an ideal opportunity for us to take an important next step: to demonstrate that vessels can sail emission-free, powered by renewable hydrogen energy.

03 Pilot

with H2SHIPS

We demonstrate through the HS Neo Orbis that vessels can sail on circular energy.

We are doing this in cooperation with H2SHIPS.

We follow the process from design to construction and certification to find solutions that benefit commercial vessels on the whole. We have received a grant for this from H2SHIPS. This European project aims to develop hydrogen for maritime use in north-west Europe to significantly reduce emissions.

The power of collaboration

We believe in engaging the partners we need early on, so we can make this project a success. This is why we brought several parties on board at an early stage, including the designer, system integrator, inventor and certification partner.

Delft University of Technology

Researches the regeneration of the fuel used and the system design, together with the University of Amsterdam.

H2 Circular Fuel

The inventor and builder of the sodium borohydride unit that we will use.

MARIN

A research institute that advises us on maritime technology.

Wijk Yacht Creation

The partner designing the vessel for us.

Lloyd's Register

This company that issues the vessel's certification and safety approval.

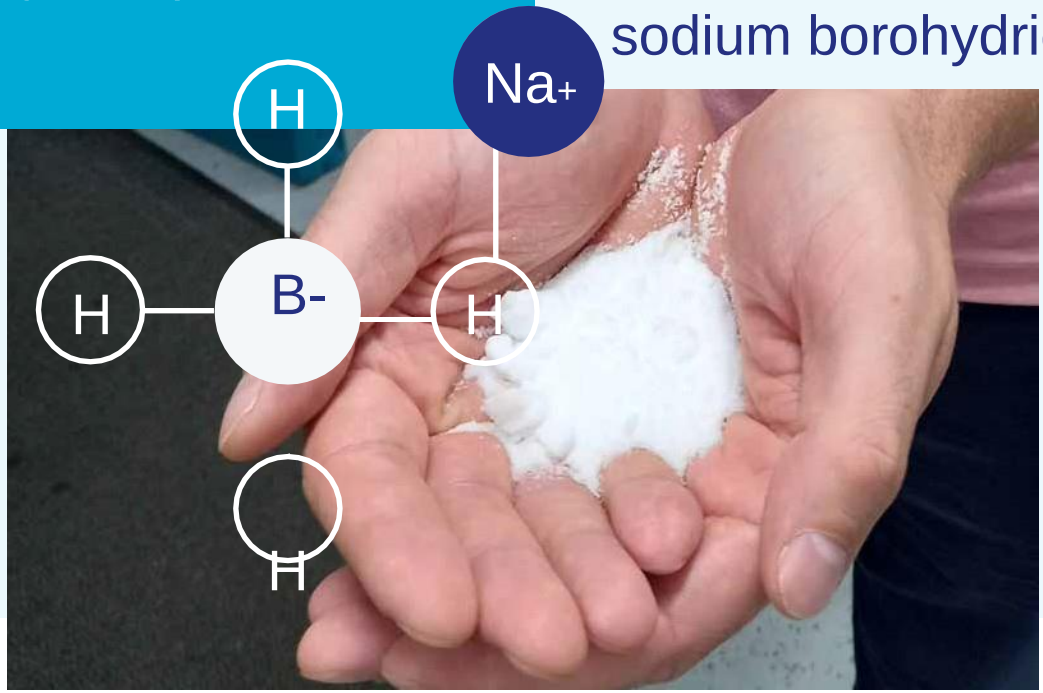
Baumüller

A systems integrator advising us during the design phase.

04 $NaBH_4$

(Sodium borohydride)

Hydrogen has been making advances as an energy source for years.
What is new is its solid form: sodium borohydride.



The molecule consists of one boron and one sodium ion, and four hydrogen atoms.

Sodium borohydride

The vessel is powered by electricity, which we generate using hydrogen. Because hydrogen is difficult to store on board in gas form, we will use a new solid form of hydrogen: sodium borohydride (NaBH4). This substance reacts with water, producing hydrogen. It is much more compact and safer to store than hydrogen gas, which is highly flammable.

Several factors are important to ensure sodium borohydride can compete with a fossil fuel as a fuel source. The substance must be compact enough to be stored on board (bunkering). We measure this by energy density. It must be economically competitive with gas oil (with a low sulphur content). It must also be at least as safe.

Sodium borohydride can already compete with diesel in two of these areas. Its volumetric energy density in its pure, dry form is much higher than other hydrogen sources and is close to that of diesel. It is also much safer than gas or liquid hydrogen.

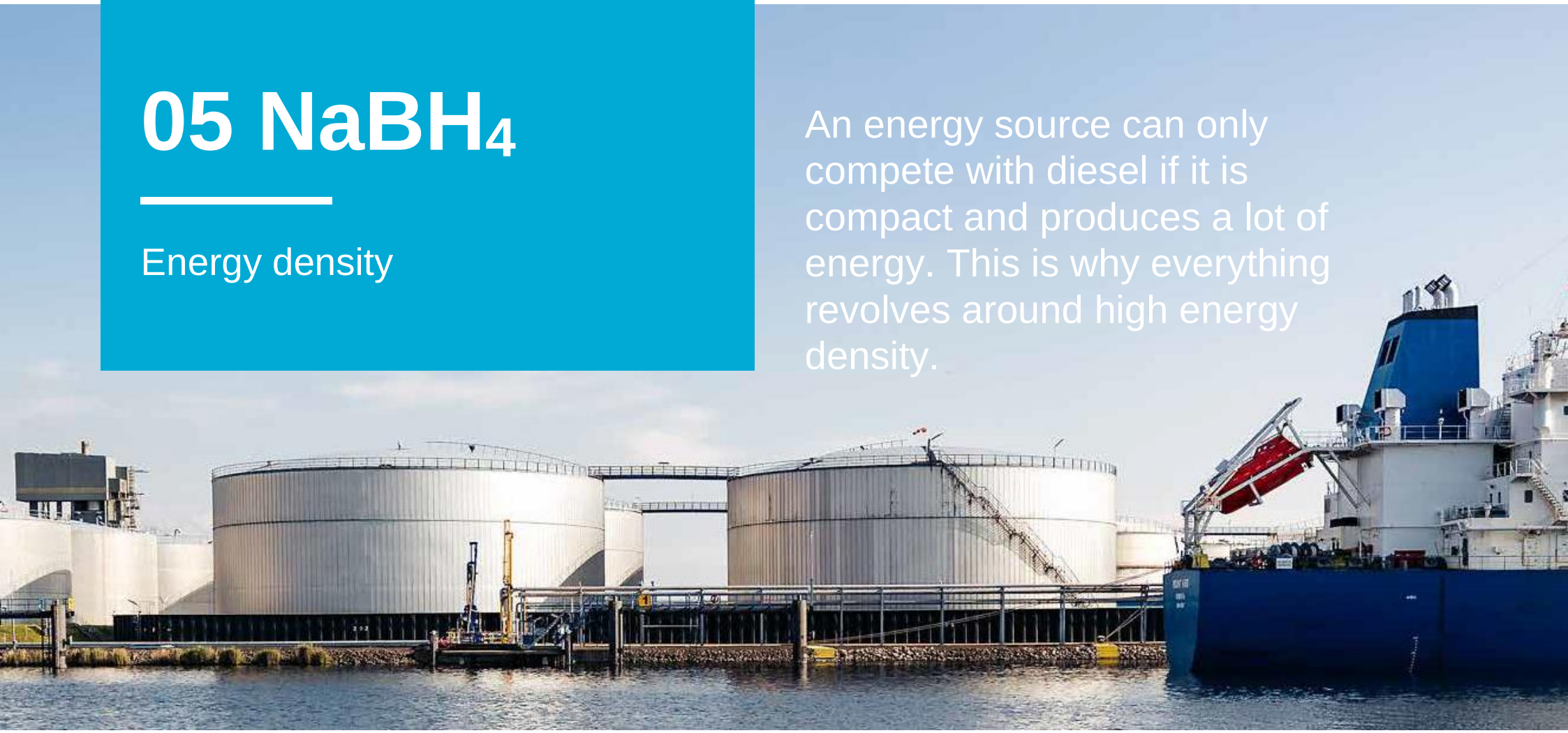
A residual product must be stored on board, known as the spent fuel. We process this on shore into new sodium borohydride.

The economic side is a challenge, as the infrastructure is not ready yet. It still costs energy to generate hydrogen, and we want to do so using green energy – but that also costs money. These issues are not yet part of this pilot. We will continue to work on this if the vessel takes to water. We first want to show that we can use this solid form of hydrogen, not only reduce CO_2 emissions (and other air pollutants, soot, sulphur oxide and nitrogen oxide), but to even reduce them to zero.

05 $NaBH_4$

Energy density

An energy source can only compete with diesel if it is compact and produces a lot of energy. This is why everything revolves around high energy density.



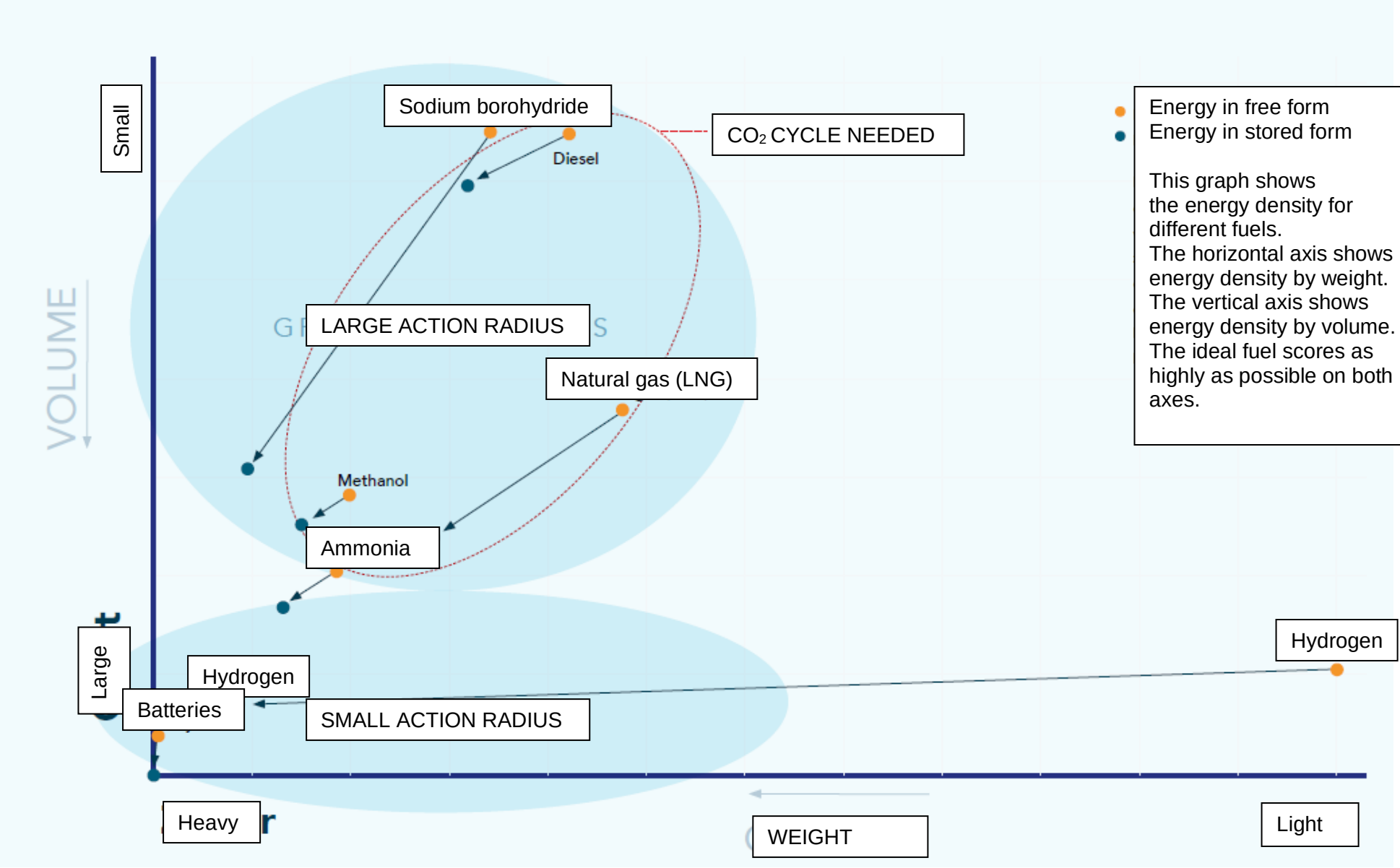
Energy density

Vessels require a lot of power and are often underway for a long time. That is why it is so important that the fuel is compact enough for storage on board.

Sodium borohydride ($NaBH_4$) scores very highly on volumetric energy density, almost as high as diesel. This makes storage and transport relatively inexpensive. However, a lot of volume is required for the additional systems on board. There is also a residual substance – the spent fuel – which must also be stored on board.

This project is still under development, so we can likely optimise these systems further. We also don't end up with an empty tank. The conversion results in a residual product, which can be converted to new sodium borohydride on shore with green energy.

With these additional systems, $NaBH_4$ scores better than other emission-free energy sources on volume and is comparable on weight. In addition, $NaBH_4$ is generally a lot safer than other emission-free sources. Its residual product can be recycled to make new fuel again. This makes $NaBH_4$ circular and emission-free.


Small
VOLUME
Large
Sodium borohydride
Diesel
CO_2 CYCLE NEEDED
LARGE ACTION RADIUS
Natural gas (LNG)
Methanol
Ammonia
Hydrogen
Batteries
Hydrogen
SMALL ACTION RADIUS
Heavy
WEIGHT
Light
Energy in free form
Energy in stored form
This graph shows the energy density for different fuels.
The horizontal axis shows energy density by weight.
The vertical axis shows energy density by volume.
The ideal fuel scores as highly as possible on both axes.

06 How it works

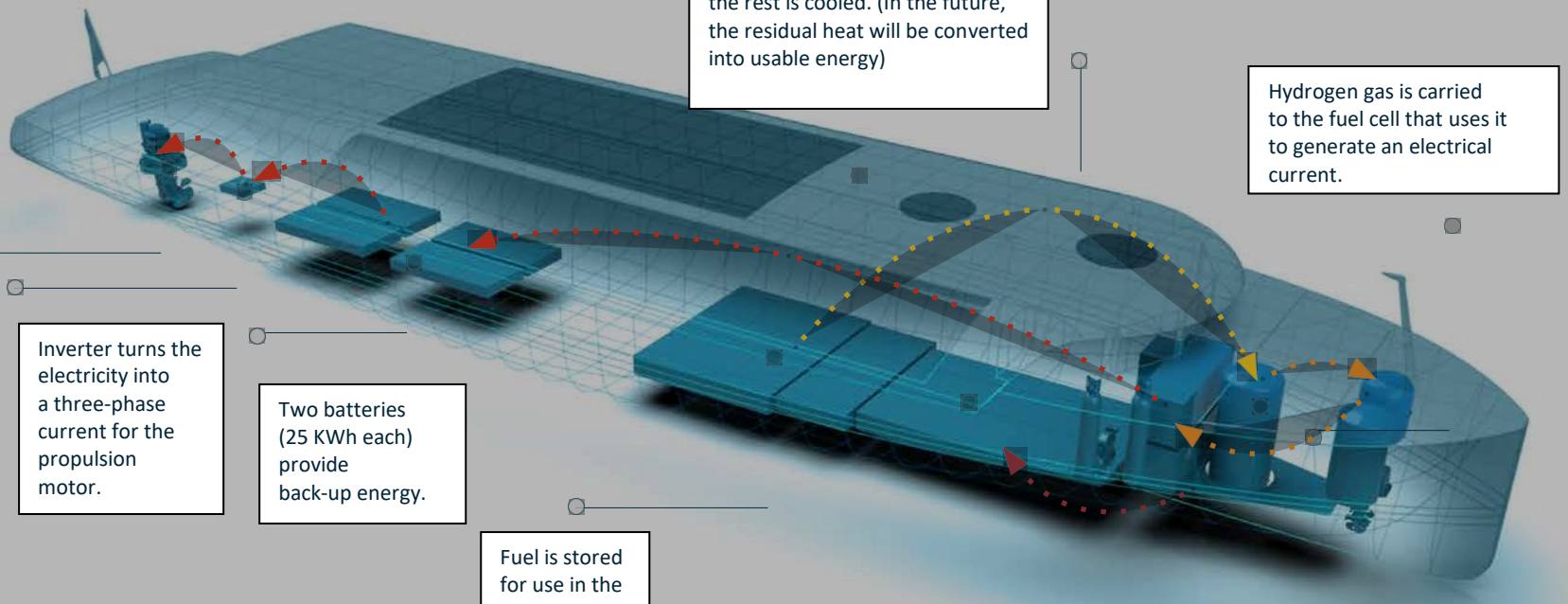
There is a fuel cell on board the HS Neo Orbis, which produces a current from hydrogen and oxygen.
A battery captures that current and drives the vessel's propeller.

The vessel is electrically powered using hydrogen as a primary energy source, in combination with a battery.

The fuel cell makes electricity from hydrogen as well as oxygen taken from the air. Water and heat are released, both of which we re-use: we use the heat for on-board heating, and we use the water in the extractor to release the hydrogen.

We use the electricity produced to drive an electric motor. This motor turns the propeller and powers the systems on board, such as the bow thruster, radar, lighting and kitchen equipment.

How it works



The heat produced is used on board the vessel and the rest is cooled. (In the future, the residual heat will be converted into usable energy)

Hydrogen gas is carried to the fuel cell that uses it to generate an electrical current.

Electric motor drives the propeller.

Inverter turns the electricity into a three-phase current for the propulsion motor.

Two batteries (25 KWh each) provide back-up energy.

Fuel is stored for use in the extractor

Spent fuel is stored for re-use.

H_2 Extractor
Dissolved sodium borohydride reacts with a catalyst, producing hydrogen.

- Raw materials for fuel
- Fuel
- Hydrogen
- Electrical current
- Spent fuel

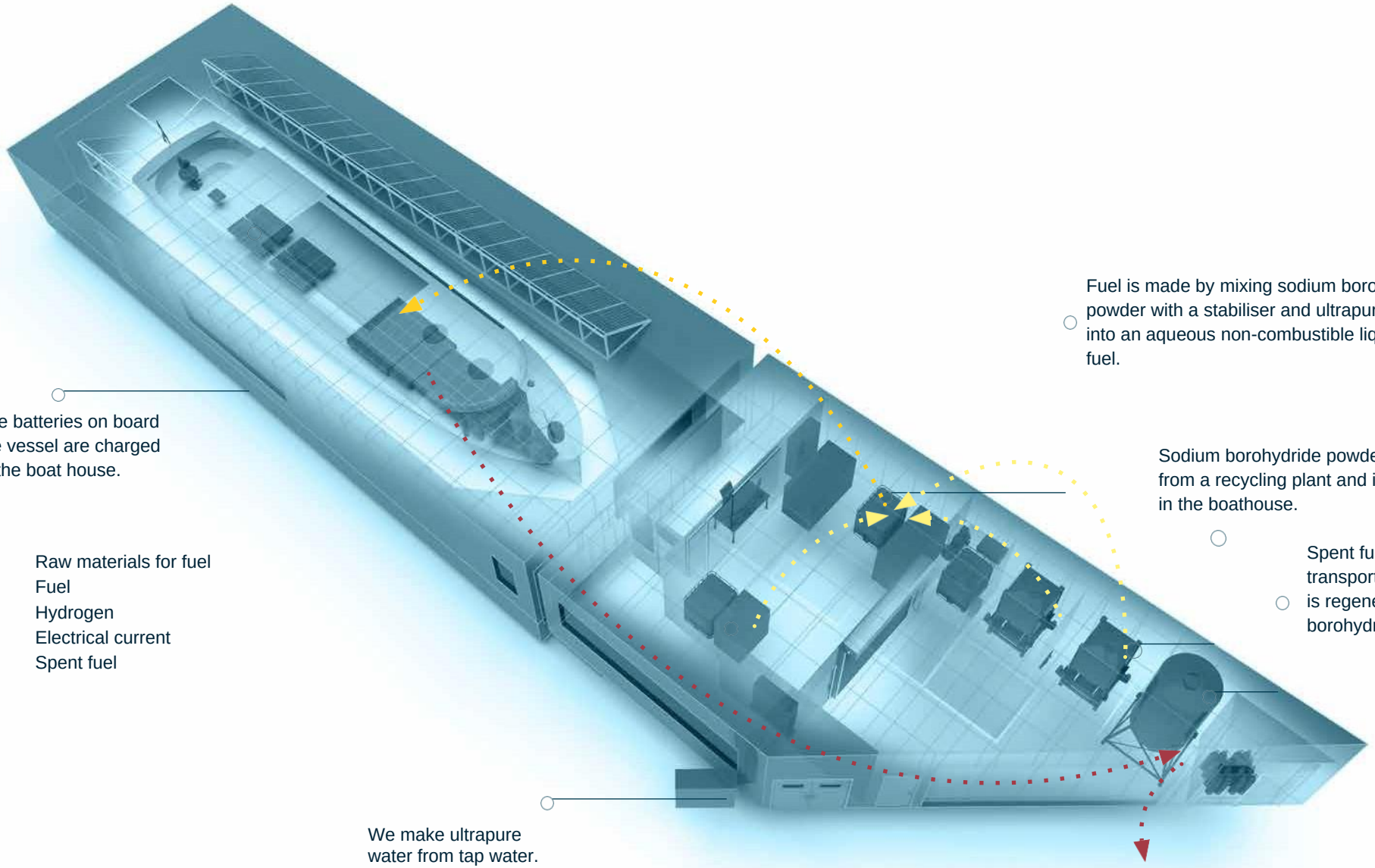
07 Processes

HS Neo Orbis

In the long term, we will create a closed system, by turning the residual materials into new sodium borohydride.
The new world is built on circular energy consumption.

Spent fuel is converted to sodium borohydride within the installation using green energy. This conversion process is called regeneration, or 'packing in' hydrogen.

The packed-in hydrogen can come from various green sources, such as electrolysis or an unpacking process, similar to the extractor on the vessel. Packing-in consist of a separation and coupling process, based on substances such as reusable magnesium.



The batteries on board the vessel are charged in the boat house.

Raw materials for fuel
Fuel
Hydrogen
Electrical current
Spent fuel

We make ultrapure water from tap water.

Fuel is made by mixing sodium borohydride powder with a stabiliser and ultrapure water into an aqueous non-combustible liquid: fuel.

Sodium borohydride powder comes from a recycling plant and is stored in the boathouse.

Spent fuel is stored for transport to the site where it is regenerated into sodium borohydride (packing-in).

Spent fuel is converted to sodium borohydride within the installation using green energy. This conversion process is called regeneration, or 'packing in' hydrogen. The packed-in hydrogen can come from various green sources, such as electrolysis or an unpacking process, similar to the extractor on the vessel. Packing-in consists of a separation and coupling process, based on substances such as reusable magnesium.

08 Safety

Not only does hydrogen as an energy source make shipping emission-free, it is also safer than fuel oil.

While the HS Neo Orbis generates electricity using hydrogen, most energy is stored on board as sodium borohydride, which is much more stable. By contrast, hydrogen gas can ignite at room temperature if there is spark. In diesel, this happens around 55°C. But for sodium borohydride, this occurs at only around 70°C.

In the application room (similar to the engine compartment on a conventional vessel), the sodium borohydride is eventually unpacked as hydrogen gas. This happens as and when it is needed.
The gas concentration is continuously measured in this room. Hydrogen is not hazardous unless there is a concentration in the air of at least 4.0% hydrogen. The safety system on board this vessel will operate even if the hydrogen concentration reaches 0.1%. As soon as that happens, all hydrogen operations are stopped, and the entire application room is ventilated.
All hydrogen is extracted within a few seconds.

Hydrogen

Properties

State:	Gas
Autoignition temperature:	560°C.
Explosion limit:	4-75%
Risks:	Highly flammable; explosive

Sodium borohydride

Properties

State:	Powder
Autoignition temperature:	220°C
Flash point:	70°C
Risks:	Flammable; toxic when ingested Reacts with water to form hydrogen

Diesel

Properties

State:	Liquid
Autoignition temperature:	210°C
Flash point:	55°C
Risks:	Flammable; toxic when ingested Environmentally damaging

As the entire concept of hydrogen shipping is new, we still need to identify and fulfil the many requirements. We are already exploring ways to handle the spent fuel, the batteries on board and the risks. We don't just want to take the vessel to sea, but we want to do so safely. By going through the entire certification process, we are paving the way for new, larger initiatives. That way, we can reach the new world of clean shipping faster together.

09 Contact

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