Let’s Navigate towards Zero - Emission Shipping!
Nedstack First

<table>
<thead>
<tr>
<th>Name</th>
<th>Nedstack Fuel Cell Technology BV</th>
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<tbody>
<tr>
<td>Location</td>
<td>Westervoortsedijk 73, Arnhem, the Netherlands</td>
</tr>
<tr>
<td>Founded</td>
<td>1999</td>
</tr>
<tr>
<td>Ownership</td>
<td>Privately</td>
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</table>

| Website           | www.nedstack.com                 |
| Industry          | PEM Fuel Cells                   |
| Logo              | Nedstack Fuel Cell Technology BV |

High lights

- Leading Global Player in High Power PEM-FC Technology;
  - Longest PEM Power Plant in Operation > 10 years;
  - First MW Sized PEM Power Plant;
  - Largest PEM Power Plant > 2 / 3.6 Mwe.
- > 750 FC Systems installed-base as per 2019;
- > 23,000 Hours in-use Lifetime demonstrated at stack, 65k at Plant;
- In-house Maritime Application Centre;

Specialized in Containerized Power Plants

Nedstack main location
FCS-XXL LT-PEM Stack Label

Nedstack

FCS-XXL LT-PEM Stacks

Highlights

- Portfolio of LT-PEM Fuel Cell stacks intended for extended long-life and high power applications;
- Designed to provide the lowest possible LCOE within boundaries of absolute reliability, availability and safety.
- Proprietary long-life graphite composite bipolar plate technology and proprietary bulk moulding compounds;
- IEC 62282-2 Compliant design, production and Exit factory inspection.
- Integrated safety system by Nedstack CVM Assembly (TI safety µC) and voltage pick up assembly.
Highlights

- PemGen defines our portfolio of power systems around our extended long life (XXL) PEM-FCS stack platform.

- Rationalized over the lowest possible levelized cost of energy (LCOE) within boundaries of absolute reliability, availability and safety.

- The PemGen platform is based on the Nedstack Central BoP philosophy for extreme plant life and superior serviceability;

- Configurable to customer requirements;

1) PemGen is a Nedstack European registered trademark. Registered at EUIPO under NO. 018036949
PemGen: A Portfolio of Maritime FC Power Installations

NFCT MT-FCPP-40
NFCT MT-FCPP-100
NFCT MT-FCPP-500
NFCT/GE Partnership Multi-MWe Partnership

Let’s Navigate towards Zero-Emission Cruising.

Nedstack & GE announce a collaboration to develop marine fuel-cell power and propulsion solutions for passenger vessels. PEM fuel-cell power plants offer a zero-emission propulsion solution as well as auxiliary power for electric power and propulsion applications. Our portfolio of maritime power systems allows for a wide range of use on-ship passenger vessels.

GE and Nedstack Partnership Sets Sights on Zero Emission Cruise Vessels

Mar 21, 2019 / 0 comments

Nedstack already widely deployed at Ports

1) This work was carried out in the framework of the FP7-FCH-JU project “DEMCOPEM-2MW”, cofounded by the FCH JU under grant agreement n° 621256.
Contributing to Regulations and Industrialization

- FELMAR – Dutch industry consortium
  - Nedstack is project coordinator

FELMAR aims at industrializing and marinizing the current state of fuel cell technology for inland navigation and short-sea applications.

- IEA-HIA Task 39;
  - Nedstack is expert group member


- HE – Maritime Working Group;
  - Nedstack is working group member

The HE-Maritime Working Group pursues to facilitate the adoption of hydrogen and fuel cell technologies in the maritime domain by industry-to-policy coordination.

- ZE Shipping Technology Association
  - Nedstack is a founding member

ZESTAs influences regulators and policy makers to introduce legislation that obligates the uptake of zero-emission shipping technologies.
The Maritime Perspective

18-30% 9% 70% 3.5% to 4% 85%

Of all the world's nitrogen oxide (NOx)
of the global sulphur oxide (SOx) pollution.
of all ship emissions are within 400 km of land.
of all climate change emissions
of all ship pollution is in the northern hemisphere.

1) The Guardian, 2017
H2@Ports perspective

Ports are Climate Change Engines

1) GHG emissions (tCO2e/capita) Source: Hoornweg et al (2011)

- Rotterdam 29.8 tCO2e/capita
- Denver 21.5
- Minneapolis 18.3
- Houston 14.1
- Los Angeles 13.0
- Chicago 12.0
- Portland 12.4
- Shanghai 11.7
- Cape Town 11.6
- New York City 10.5
- Hamburg 9.7
- London 9.6
- Singapore 7.9
- Barcelona 4.2

Ports are Air Quality Issue Zone

Most Ports are Urban Ports

90% of European ports are urban ports
### NemoH2 – 2nd FC pax. vessel with Class Approval

<table>
<thead>
<tr>
<th>Spec</th>
<th>Value</th>
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<tbody>
<tr>
<td>Length oa</td>
<td>21.95 m</td>
</tr>
<tr>
<td>Beam oa</td>
<td>4.25 m</td>
</tr>
<tr>
<td>Draught</td>
<td>1.1 m</td>
</tr>
<tr>
<td>Displacement</td>
<td>45 tons</td>
</tr>
<tr>
<td>Payload &amp; Crew</td>
<td>88</td>
</tr>
<tr>
<td>Mission</td>
<td>Canal Boat</td>
</tr>
<tr>
<td>Max Speed</td>
<td>8.5 Kn</td>
</tr>
<tr>
<td>Cruising Speed</td>
<td>7 kn</td>
</tr>
<tr>
<td>E-Propulsion</td>
<td>Sern thruster 75 kWe Bow thruster 11 kWe</td>
</tr>
<tr>
<td>Battery pack</td>
<td>70 kWh</td>
</tr>
<tr>
<td>H2 storage</td>
<td>24 kg @ 35 Mpa</td>
</tr>
<tr>
<td>FC Engine</td>
<td>2 x 40 kWe</td>
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Challenge 1: SUPPLY CHAIN GAP

Maritime is not automotive.

Automotive components and supply chains are not compatible with the maritime domain. Not with their duty cycles and not with their environmental conditions and safety requirements.

Maritime fuel cell power installations require more robust, longer lasting and Class approved hydrogen related components.
Regulatory Development Summary (in scope)

1. UN
   - All Current vessels approved under alternative design process.
   - IGF Code on Low Flashpoint Fuels Chapter E. Ready in Concept.
   - Class rules to be established after Chapter E approval.

2. Supernational
   - CCR (Rhine States) have no hydrogen rules;
   - Current demonstrators based on ROSR waivers;
   - Hydrogen rules being formulated (no release date)

3. Flag States
   - Awaiting IMO level approval;
   - Currently most flags provide waivers under class approval (RBD) only;
   - Additional Health and Safety codes and documentation requirements apply;

4. Port Authorities
   - Port Management Bye-laws are not in favor of hydrogen and fuel cell demonstrators as far as we know them.
   - Waiver programs are depending on personal motivation and support of administrators and are more depending on personality rather than policy.

IMO
- National Port
- Regional
- IMO
- Port Management Bye-laws are not in favor of hydrogen and fuel cell demonstrators as far as we know them.
- Waiver programs are depending on personal motivation and support of administrators and are more depending on personality rather than policy.
Challenge 2: THE REGULATORY GAP

Port Authorities are law makers.

Any maritime fuel cell project should also aim at creating institutional freedom to act.

Such institutional engineering involves obtaining Port Management Byelaw waivers, Class approval (by alternative design) and commitment from the flag state.
Nedstack Main Sponsor of European Hydrogen Ports and Maritime Conference 2018 and 2019
Challenge 3: THE WAITING GAME

There is a strong need to change, but hydrogen fuel cell technology is widely considered to be experimental, to be unregulated and uncertain.

Shipowners are waiting for ports to provide infrastructure and the other way around. There is a waiting game at play where the imperative to act is being passed around from ship to shore and back.

For any demo to emerge a coordinating mechanism is needed to align the ecosystem and coordinate action.
Block Flow Diagram of Pre-Switchboard Flows & Conv.

Energy Source → Energy Carrier → Reformer → Conversion → Recovery → Distribution

- Compressed H2
- Liquified H2
- Organic H2-Carriers
- Inorganic H2-Carriers
- Synthetic Fuels
- Biofuels
- Methanol
- Ethanol
- LNG
- CNG
- Diesel

PemGen™ PEM FC

Reforming & Cleaning

ICE

- Recovery
- Generator

Main Switchboard

Heat Grid
Challenge 4: THE ENERGY VECTOR & INFRA CHALLENGE

There are a diversity of routes from the energy source to the main switchboard, each requiring their own infrastructures and technology solutions.

Automotive grade hydrogen quality and by extension automotive stacks are not feasible.

However there is no clear view on what energy source / energy carrier route is most promising.
Fuel Cell Power Installations or Systems?

1) IMO CCC-5-3 ANNEX 4 – relevant to the Pending IMO IGF Code on Low Flashpoint Fuels - Chapter E
Challenge 5: THE DEFINITION CHALLENGE

IMO and by extension the maritime industry administer different system definitions than we are used to in the IEC 62282 series of international standards.

There is a definition problem on how we define scope, power ratings and so on. Supplier solutions are not cross-comparable and maritime industry actors have difficulties understanding the different BoP strategies and built levels.
Dutch Zero-Emission-Shipping consortium

Integration

Simulation, Verification and Validation

Compliance and Approval

Fuel Cell Ship

Fuel Cell System
Power Pack
- Flow Controllers
- Exahusts
- Blowers
- Humidifiers

Fuel Cell stacks

Secondary Energy System
- Batteries
- Super/Ultra Caps
- DC/DC

Power Management System
- DC/DC-Grids
- Power Distribution Unit

Propulsion System
- Propulsion Control
- Drive Motor Inverters(s)
- Drive Motor(s)

E-Auxiliary System
- HVAC
- Air Compressor
- Hydraulics

H2 Supply / Bunkering

Hydrogen Fueling
Fueling Apparatus

Hydrogen Delivery
- Regulator

H2 Storage
- Tank Valve
- Shutoff Valve
Challenge 6: THE INTERFACE AND SAFETY GOAL ATTRIBUTION CHALLENGE

Ongoing demonstrators and engineering programs bring to light a challenge on the exact attribution of safety goals and interfaces between the gas storage, gas distribution and fuel cell power installation system.

A standardized safety concept with attributed safety goals to sub systems would be highly preferable.
Zero-Emission Lab @ MARIN

Test Capabilities for Zero-Emission Shipping:

World wide unique test-bed for zero-emission shipping technology.

- Cavitation effects resilience;
- Duty cycle simulation;
- Dynamic response tests;
- Power Split optimization;
- Advanced Control Functionalities;
- ...
Challenge 7: THE VERIFICATION CHALLENGE

Already published Class Rules assume the IEC 62282-3 as a reference for technology verification and requires complementary verification for ‘Maritime use’.

However, no convention for sea-worthiness verification has been codified so far, leaving shipowners in doubt whether FCPI’s can withstand cavitation effects, rough sea dynamics and so on.
Coopetition Opportunities
Coopetition Opportunity. We Should Jointly....

<table>
<thead>
<tr>
<th>#</th>
<th>Challenge</th>
<th>Action</th>
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<tbody>
<tr>
<td>1</td>
<td>The Supply Chain Gap</td>
<td>• Quantify the maritime hydrogen and fuel cell market potential to move suppliers;</td>
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<tr>
<td></td>
<td></td>
<td>• Communicate the opportunity widely in the maritime technology market.</td>
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<td>2</td>
<td>The Regulatory Gap</td>
<td>• Continue lobbying at IMO level;</td>
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<td></td>
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<td>• Develop a Flag state recommended policy for hydrogen / fuel cell waivers;</td>
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<td></td>
<td>• Develop a Port Management Byelaw kit for creating an innovation space;</td>
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<td>3</td>
<td>The Waiting Game</td>
<td>• Install a Ship-to-Shore coordination mechanism for aligning all actors in the eco system</td>
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<td></td>
<td></td>
<td>to facilitate the transition;</td>
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<td>4</td>
<td>The Energy Vector and Infra</td>
<td>• Develop a joint view on promising and less promising maritime energy vector and</td>
</tr>
<tr>
<td></td>
<td>Challenge</td>
<td>bunkering routes to facilitate port authority decision making and infra planning;</td>
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<tr>
<td>5</td>
<td>The Definition Challenge</td>
<td>• Define our maritime solutions as Fuel Cell Power Installations and specify at End-of-</td>
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<td></td>
<td></td>
<td>Life rates at system level (or jointly embrace a different convention).</td>
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<tr>
<td>6</td>
<td>The Challenge of Interfacing and</td>
<td>• Establish an industry benchmark as a safety concept or at least an attribution of safety</td>
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<td></td>
<td>Safety Goal Attribution</td>
<td>goals to sub systems. Such pro-forma safety concept would be the base case for any</td>
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<td>shipowner or shipyard looking for an off the shelf solution.</td>
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<td>7</td>
<td>The Verification Challenge</td>
<td>• Establish a set of sea-worthiness test cases and scenario’s for maritime fuel cell power</td>
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<td>installations that compliment the IEC test requirements.</td>
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Let’s Stay in Touch!

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