e4ships
Fuel cells in marine applications

nip

Funded by:
Federal Ministry for Digital and Transport

Coordinated by:
NOW-GMBH.DE

Project management:
PTJ

# Pa-X-ell2

MEYER WERFT GmbH & Co. KG

e4ships & Zero-Emission Shipping Symposium | Hamburg | 08.09.2022

# Pa-X-ell2 - Project consortium

Gefördert durch: Bundesministerium für Digitales und Verkehr
Koordiniert durch: NOW GMBH.DE
Umgesetzt durch: PtJ

MEYER WERFT
PAPENBURG 1795

FREUDENBERG
INNOVATING TOGETHER

LÜRSSEN

CARNIVAL
MARITIME

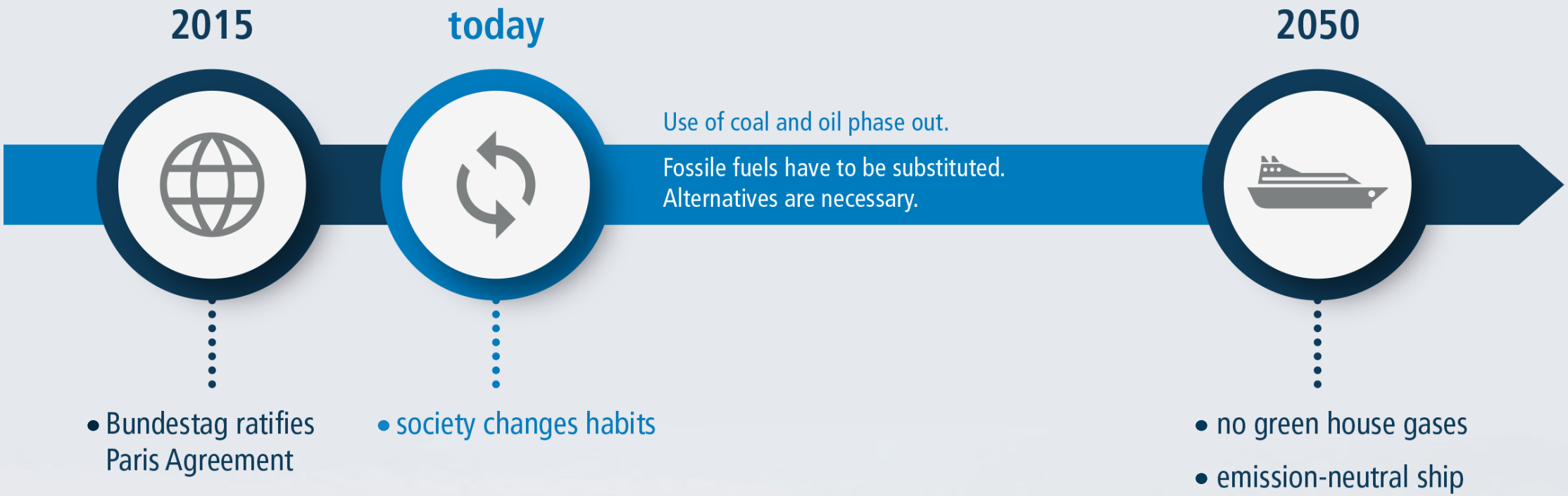
DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

DNV

EPEA
PART OF DREES & SOMMER

besecke
automation

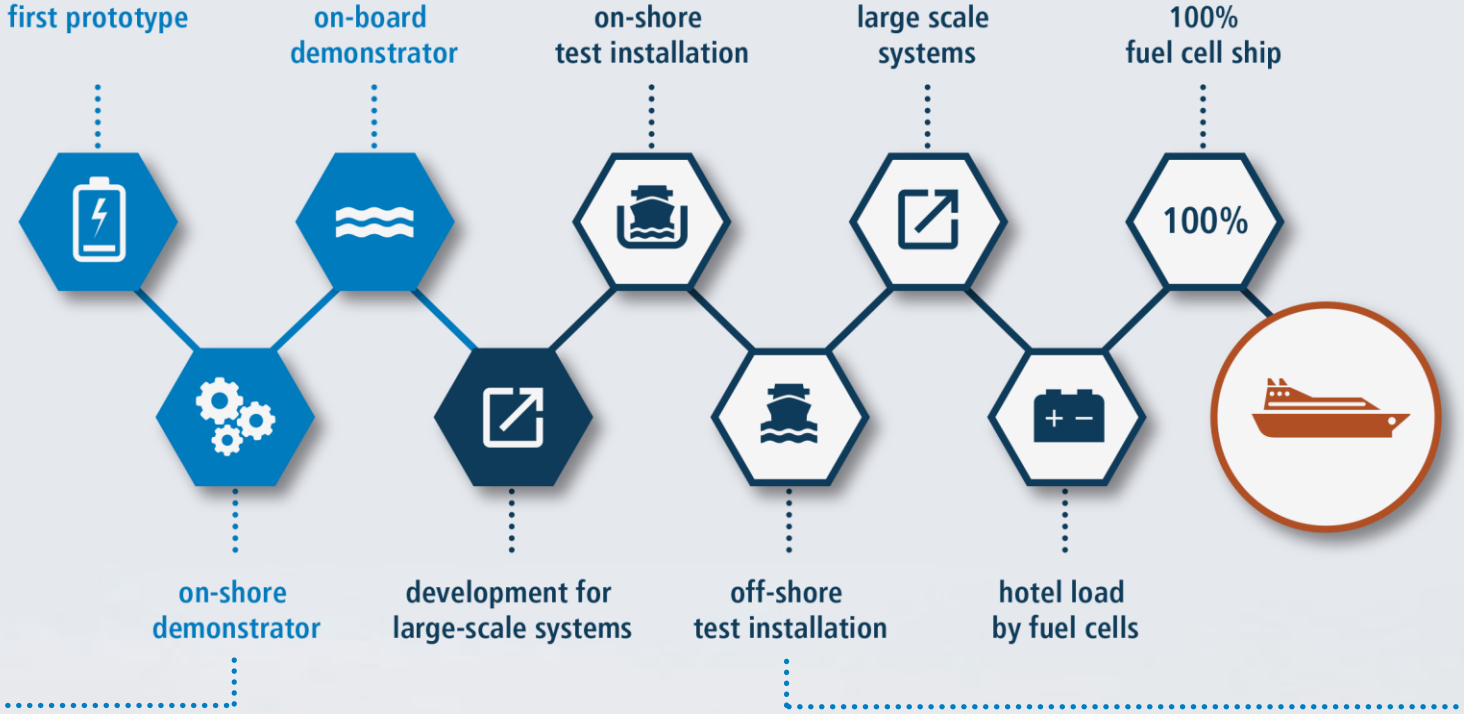
# Pa-X-ell2 Vision




The combination of fuel and systems are the key to success
to reduce the emissions and achieve the climate targets for passenger ships.

# Pa-X-ell2 Development Strategy



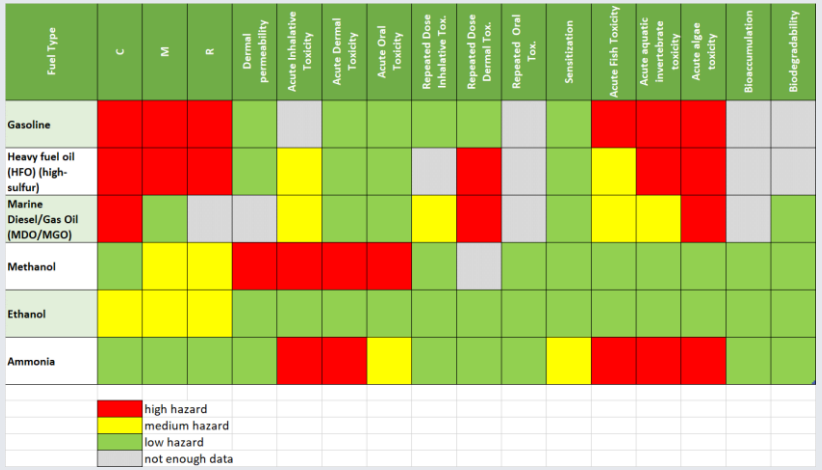




The project Pa-X-ell started in 2009 with the aim to develop new energy grids and fuel cell systems for a “emission-neutral” 100% fuel cell  ship with methanol.

# Hydrogen reformed from Methanol for Fuel Cell Systems

- Methanol can be used as hydrogen carrier
- Methanol is one of the most-produced organic chemicals with about 100 million tons per year
- Green Methanol can be produced based on renewable energy
- Methanol can be stored at ambient temperature with smaller tank space than liquefied or compressed hydrogen
- acute hazards are manageable via safety equipment and procedures
- low toxicity to fish, marine invertebrates, algae
- EPEA investigates with the project partners the ecological aspects of methanol as hydrogen carrier for fuel cells




BIO-METHANOL FACILITIES ESTABLISHED/ UNDER CONSTRUCTION

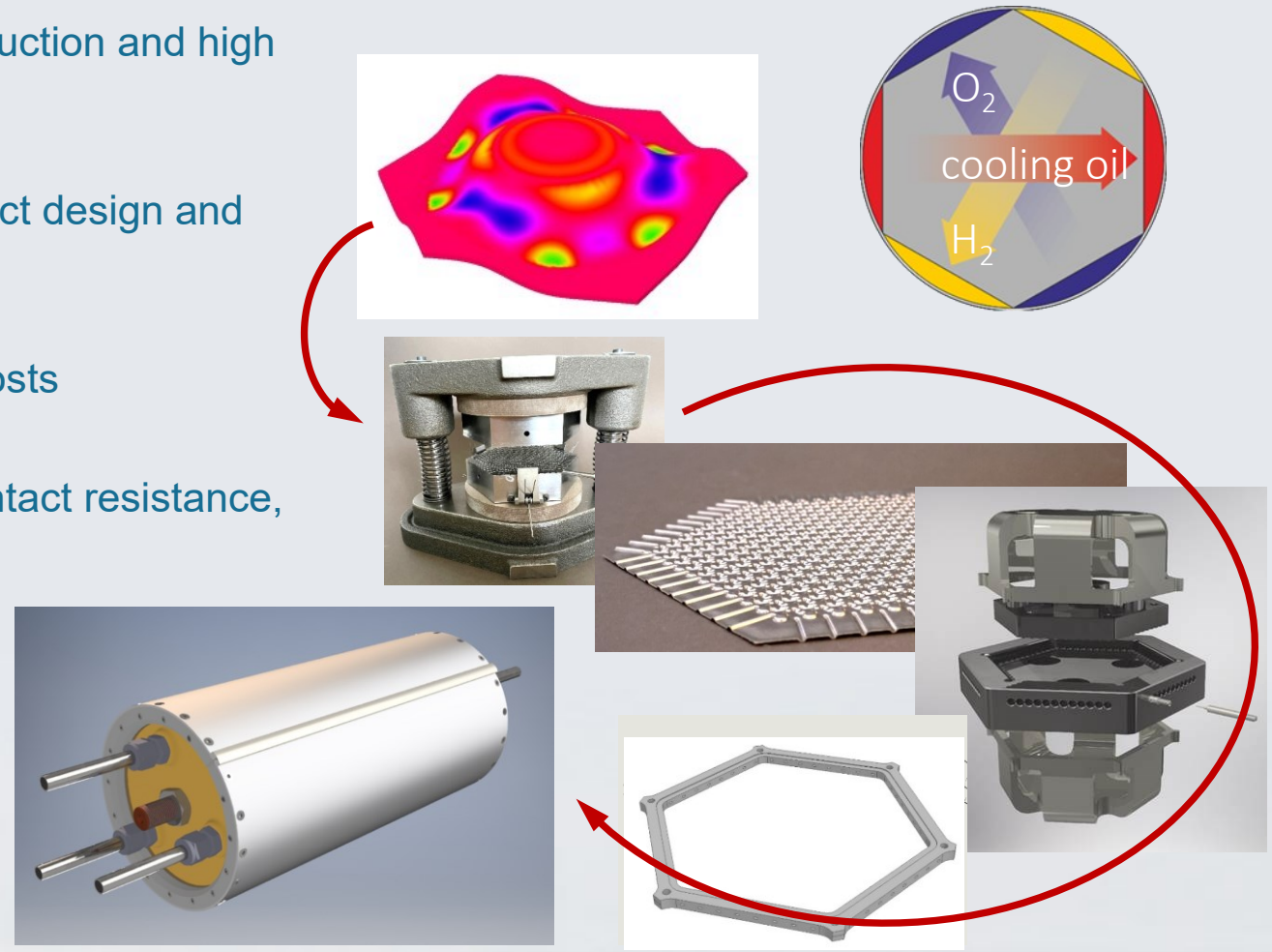
In Pa-X-ell 2: Phase 1 and Phase 2

| Location | Company | Material Input | Source | Renewable Energy | Renewable? | |
|---|---|---|---|---|---|---|
| | | | | | Material Input | Energy |
| Sweden Luleå | Carbon Recycling International (CRI) | Residual blast furnace gases ($CO_2$) Hydrogen ($H_2$) | Steel manufacturing plant | No (Non disclosed 20% surcharge from renewables) | | |
| Iceland Grindavik | Carbon Recycling International (CRI) | Gaseous emissions ($CO_2$) Hydrogen ($H_2$) | Geothermal power plant (steam emissions) | Hydropower Geothermal | | |
| Canada Varennes | Enerkem | Municipal solid waste | Waste disposal (post sorting, after recycling, composting) | No | | |
| Netherlands Rotterdam | Enerkem | Non-recyclabe mix waste (incl. Plastics) | Waste disposal | No | | |
| Sweden Mönsterås | Södra | Raw forest material | Pulp mill | No | | |
| Sweden Hagfors | Värmlands Methanol | Forest residue | Saw mill | No | | |

Green methanol is a efficient hydrogen carrier, less dangerous than conventional fuels and can be produced based on regenerative energy sources.

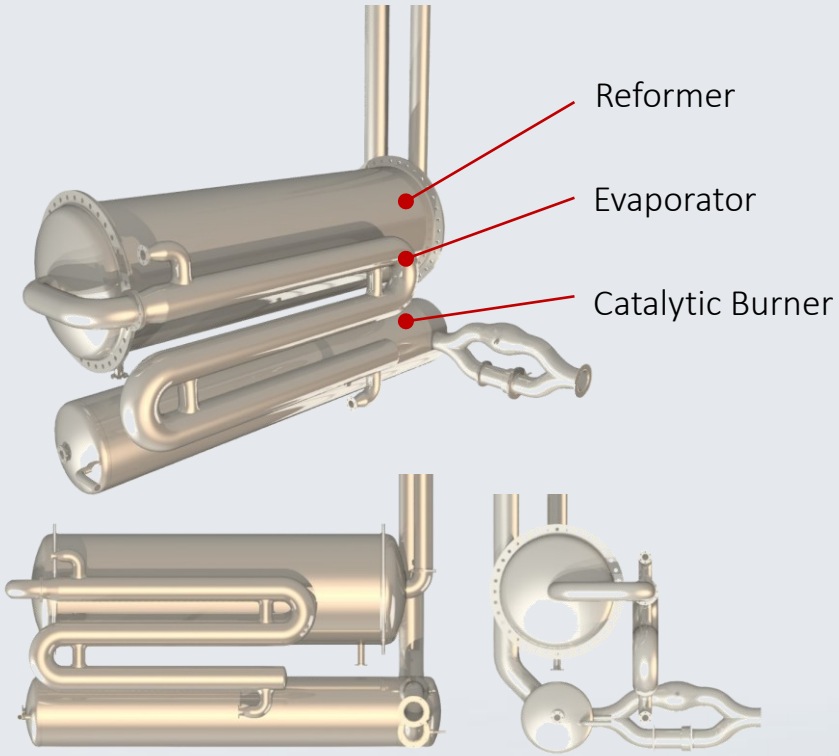
# DLR HT-PEM Fuel Cell Development

- New hexagonal fuel cell design aiming for low cost production and high power density
- Bipolar plates with integrated gasket allowing for compact design and low tolerance requirements
- Sheet metal die forming as a basis for low production costs
- Geometrical optimization in the conflict between low contact resistance, defined flow characteristics and sheet forming limits



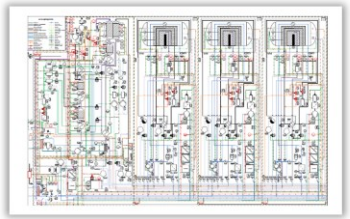
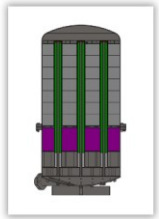
# DLR Methanol Steam Reforming Unit

- Heat supply for methanol decomposition and reforming realized via combustion of anode off gases in a catalytic burner and an integrated liquid heating loop for equal heat distribution
- Heat supply for fuel and water evaporation realized via the liquid cooling loop of the HT-PEM fuel cell
- Reformate drying upstream the fuel cell
- Experimental basis for testing e.g. increased steam to carbon ratios at elevated pressures with different control strategies in order to optimize power density, reformate purity and efficiency




**Technology development in large scale HT-PEM systems needed to realize the potential of heat recovery and utilization.**

# Freudenberg Engineering Demonstrator LT-PEM MeOH 100







- **Uniform Cell Parameters** – Temperature range <5K and extremely low pressure drop => Basis to achieve true heavy-duty lifetimes
- **Freudenberg Catalyst** Development shows **better degradation results** than leading market players

- Successful **validation of recovery cycles** to keep high efficiency level
- **Endurance Tests >15,000h** of our FC stacks with Reformate has confirmed our design strategy for true heavy-duty segments
- **Stack** design **ready for high-volume assembly**

- Concept of **SHIFT-SELOX DESIGN** to enable high lifetimes @ FC
- Besides **AIP approval** major agenda points incl. **SAFETY MATRIX** for **class statement** were already approved by DNV

Next step: Transfer of all technical gains of the MeOH 100 System to a power class 500kW with a significant upscaling potential for the maritime market.

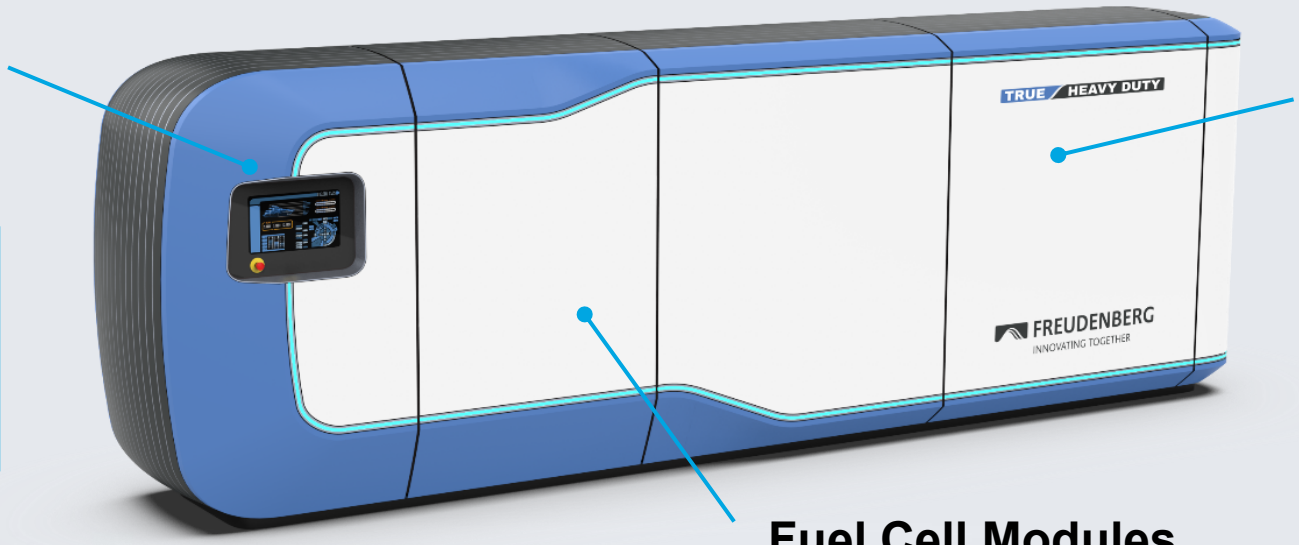
# Outlook: A true heavy-duty FC system with lifetimes >35.000 hours

**Electronic Module**

Electrical Infrastructure
+ Control System

**FUEL REFORMING**

METHANOL or LNG




**Hydrogen Supply Module**
**- High thermal and mechanical integration Level**

Fuel Reformer + Media Interfaces

**Fuel Cell Modules**
**- True heavy-duty**

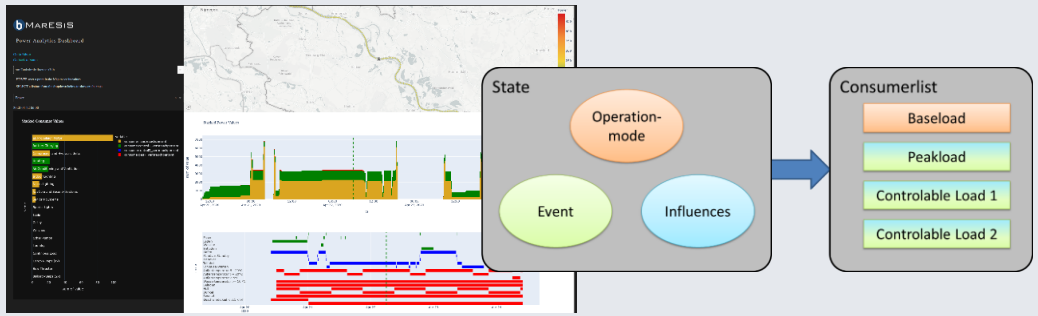
Stack + Balance of Plant Components

Illustrative image

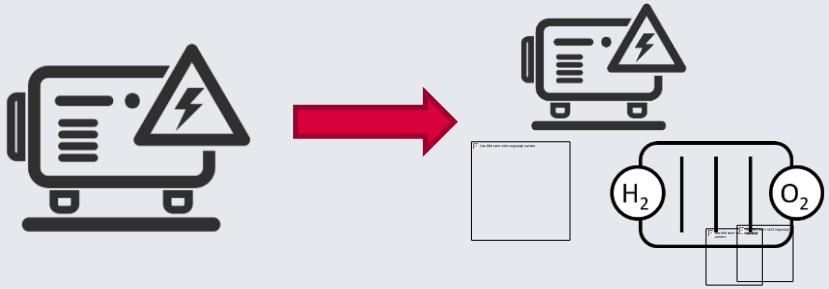
Our Ambition: A maritime FC system 500kW with integrated fuel reforming to enable carbon-neutral shipping in large scale

# Energy and Consumer Management for higher efficiency

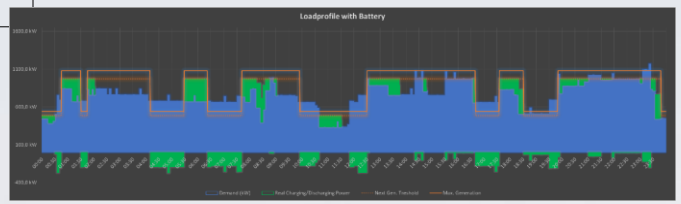
## Analysis & Simulation




## Optimal combination and sizing of power Generator- and Storagesystems




## Powersaving by Storage Systems

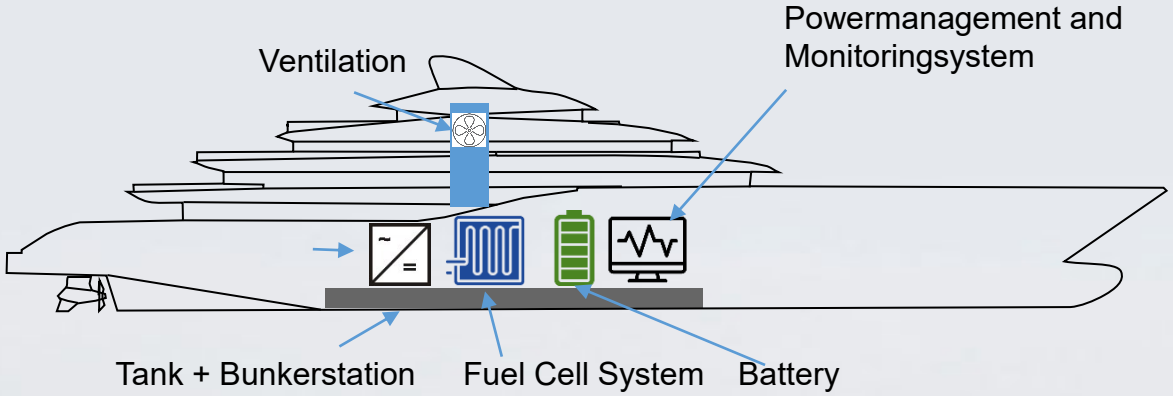


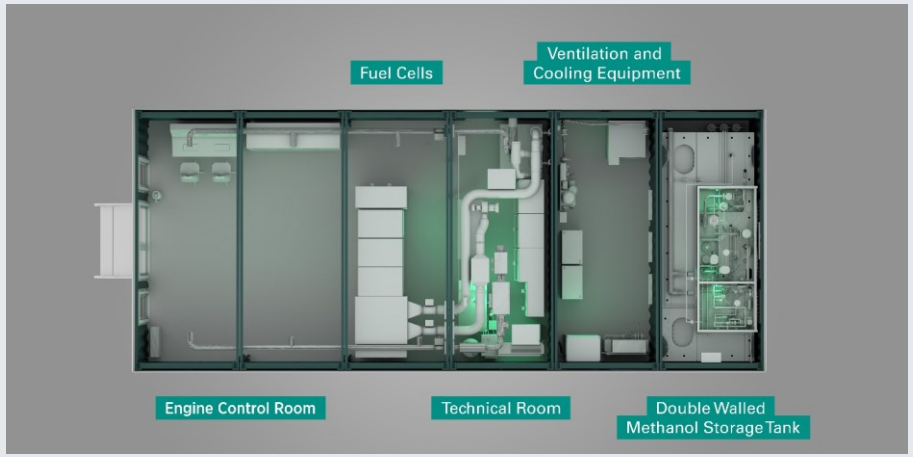

## Powersaving by Consumer Management

Project Partner besecke developes an Energy Management System to optimize energy flows, increase efficiency and to reduce installed power.

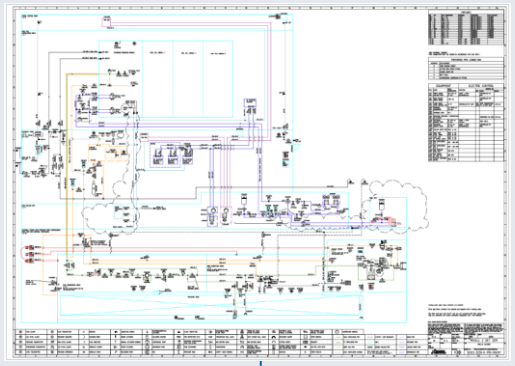
# Yacht Demonstrator Lürssen Werft - Idea and concept

- Integration of the newly developed 100kW fuel cell system from Freudenberg in a real yacht environment with all relevant ship systems and components
- Implementation of applicable IMO and class regulations
- Permanent available for carrying out extensive tests under defined conditions
- Simulation of all operating parameters in a hybrid energy grid




# Yacht Demonstrator Lürssen Werft – Design and Production



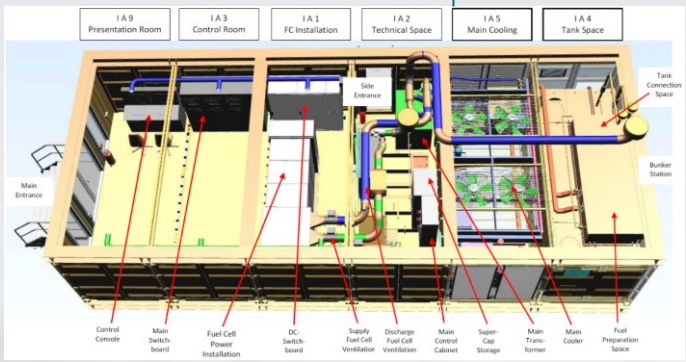
Concept

Outfitting of the containers

Construction on site

2018 2019 2020 2021

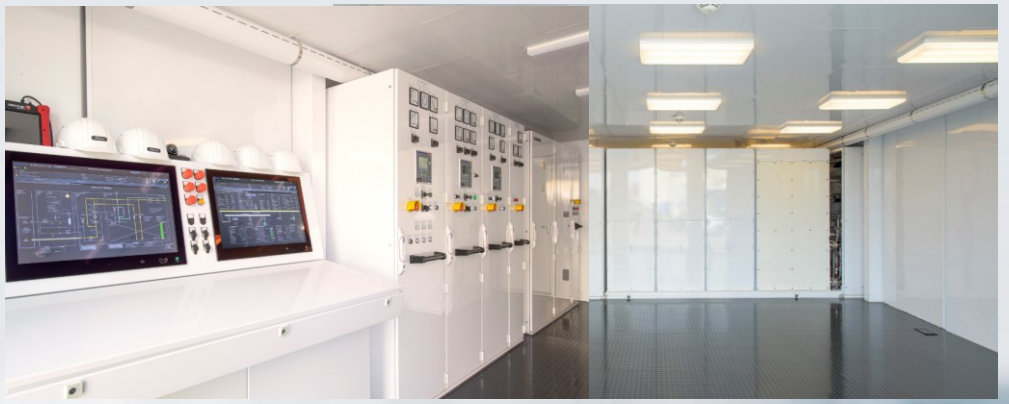
Design




Building of tank

# Yacht Demonstrator Lürssen Werft – Commissioning

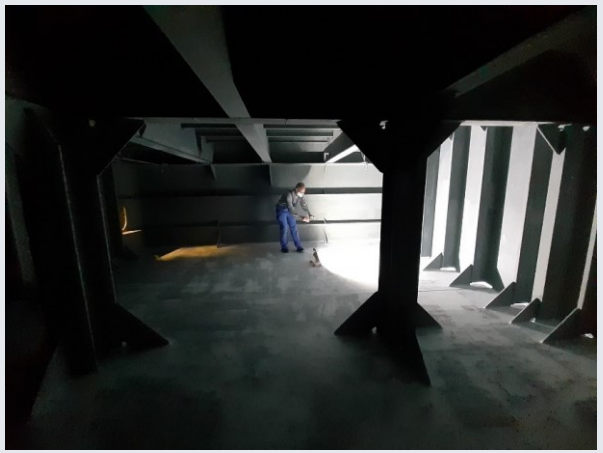
- Summer 2022: first bunkering of methanol
- Parameterization of the fuel cell and optimization of the system interfaces
- July 2022: Plant produces electricity for the first time
- Further optimization of the system interfaces
- Generation of significant learnings

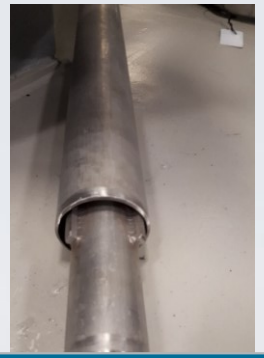
# Overview of the integrated fuel cell test installation on board of AIDAnova

- Development and integration of two fuel cell systems and a methanol system on board of AIDAnova for testing under real conditions by MEYER WERFT and Carnival Maritime
- Installation of all required infrastructure and sub systems
- Development according to interim guideline
- Safety concept approved by RINA

# Integrated fuel cell test installation on board of AIDAnova



Methanol tank and equipment in machinery space

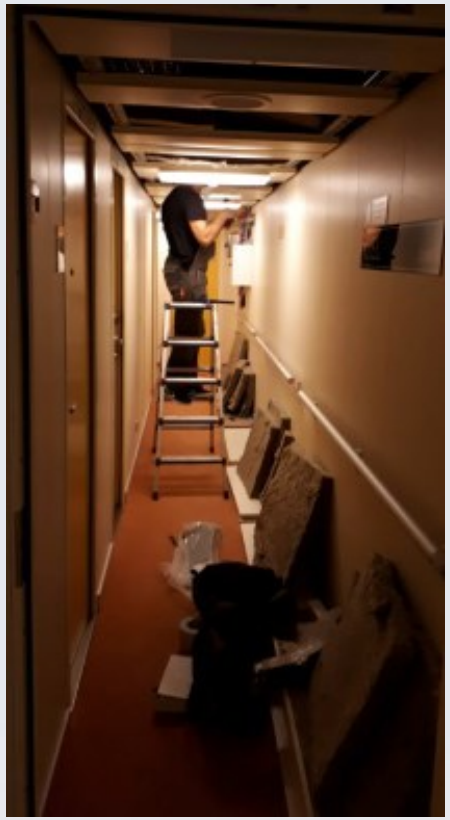
Sub Systems (e.g. Nitrogen)

Fuel Cell Room

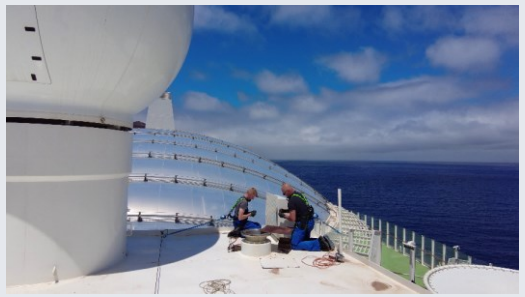
Double walled methanol piping system

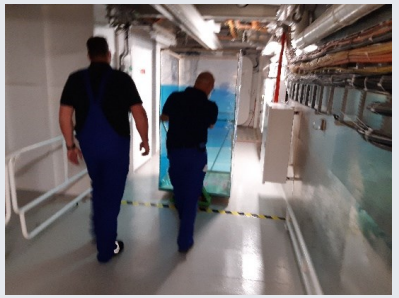
Preparation of ship structure during building process; installation of fuel cell plant in the last year.

# Integrated fuel cell test installation on board of AIDAnova



Electrical equipment and cabling

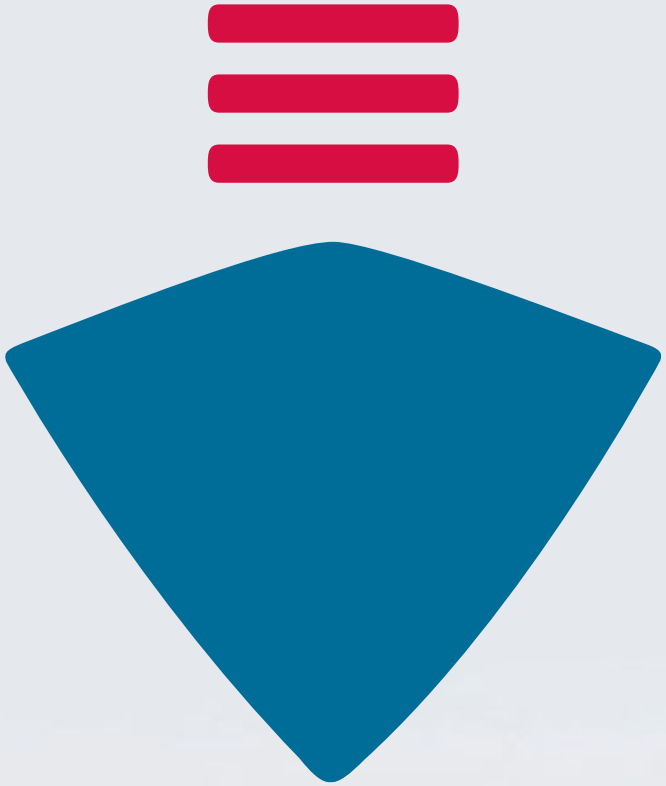




Bunker Test together with Bunker One



Installation of fuel cell systems in the upcoming weeks.
Testing can start this year.



## Thank you!

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