WIC MEETING SEPTEMBER 16 2020

Welcome to the WIC meeting!

@ABC

WATERSTOF INDUSTRIE CLUSTER

AGENDA

9.30 - 10.00 AM: Reception with coffee

10.00 – 10.30 AM: Presentation new cluster members + round table

10.30 – 11.00 AM: News from the WIC/WaterstofNet: Flemish H2 strategic vision

11.00 – 11.25 AM: Belgian federal hydrogen developments by FOD Economie

11.25 – 11.45 AM: Vision maritime applications by Hydrogen Europe

11.45 AM – 1PM: H2 developments at ABC/CMB/BeHydro and tour at ABC

1 PM – 2 PM: Sandwich lunch

PRESENTATIONS NEW MEMBERS

WATERSTOF INDUSTRIE CLUSTER

BESIX

von KARMAN INSTITUTE FOR FLUID DYNAMICS

PRESENTATIONS NEW MEMBERS

WATERSTOF INDUSTRIE CLUSTER

Tessenderlo Group
EVERY MOLECULE COUNTS

GASCOMPONENTEN

Ballast Nedam
Industriebouw

NIPPON GASES

De Vlaamse Waterweg nv

HOLTHAUSEN
CLEAN TECHNOLOGY

➔ Presentations in November

Excel in creating sustainable solutions for a better world

BESIX - Green Hydrogen Market

1. What is BESIX Group ?
2. Concession & Asset expertise
3. Environment & Industry expertise
4. BESIX in the Green Hydrogen market

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N°48

BESIX

N°1
in Belgium

TOP 250
International
Contractors

65%
activities abroad

25 countries

+95 years
international activity

+55 years
experience
in the Middle East

Privately Owned
50% MIC with casting vote
50% OC

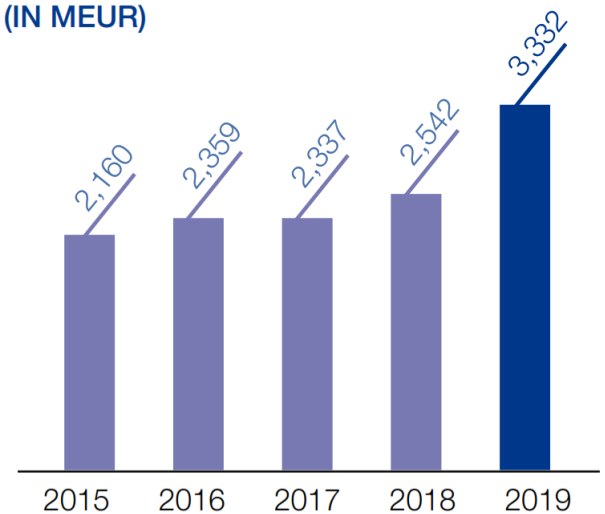
+4,500
white collars

+10,000
blue collars

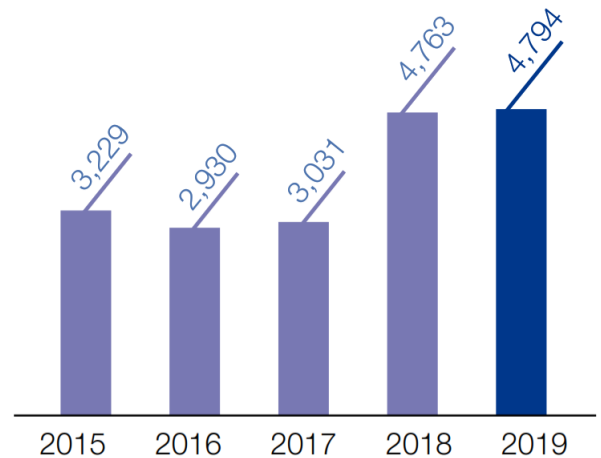
A strategy of diversification

Our large activity scope reinforce our service offerings and mitigate risk

EVOLUTION OF REVENUES
(IN MEUR)

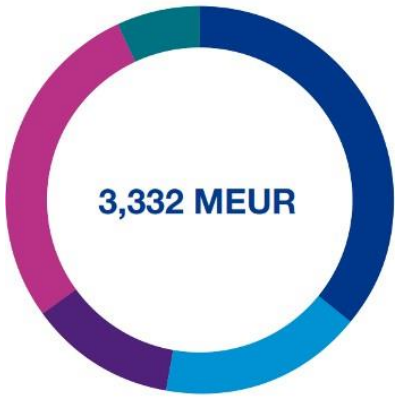


EVOLUTION OF ORDER BOOK
(IN MEUR)



REVENUES BY REGION

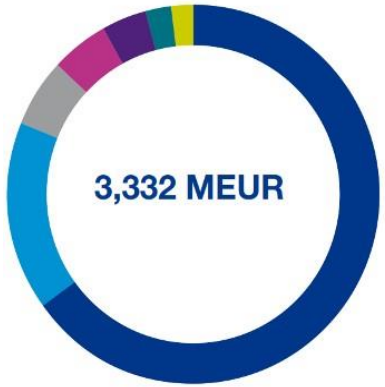
(2019)



- BELGIUM // 36%
- MIDDLE EAST // 17%
- THE NETHERLANDS, LUXEMBOURG & FRANCE // 12%
- AUSTRALIA // 28%
- REST OF THE WORLD // 7%

REVENUES BY AREA OF EXPERTISE

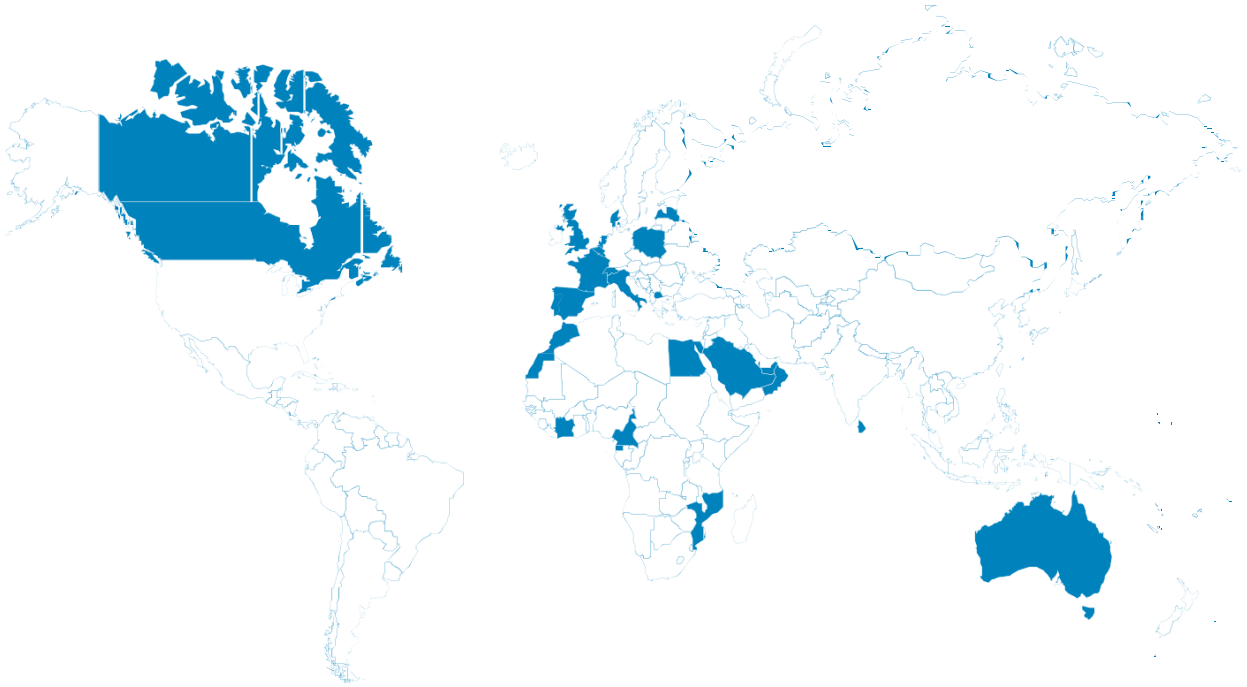
(2019)



- BUILDINGS // 65%
- CIVIL WORKS // 16%
- MARINE WORKS // 4%
- FOUNDATIONS // 5%
- ENVIRONMENTAL WORKS // 2%
- OTHER (CABLING AND INFRA) // 6%
- QUARRIES / CONCRETE // 2%

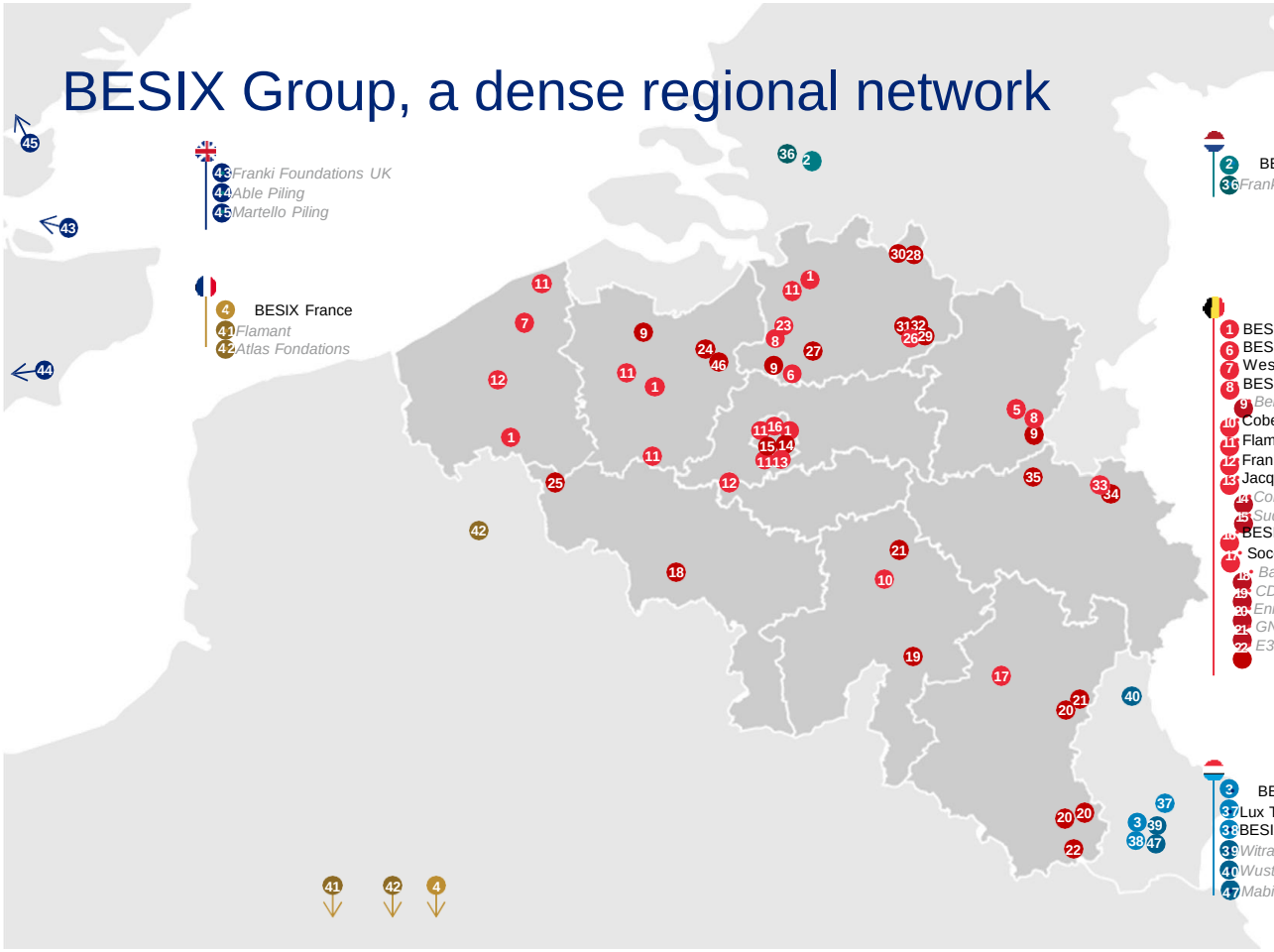
A strategy of diversification

Our geographical spread reinforce our service offerings and mitigate risk



Australia
Bahrein
Belgium
Cameroon
Canada
Denmark
Egypt
Equatorial Guinea
France
Ivory Coast
Italy
Lativa
Luxemburg
Montenegro
Morocco
Mozambique
Oman
Poland
Portugal
Qatar
Saudi Arabia
Spain
Sri Lanka
Switzerland
The Netherlands
United Arab Emirates
United Kingdom

BESIX Group, a dense regional network



43 Franki Foundations UK
44 Able Piling
45 Martello Piling

4 BESIX France
41 Flamant
42 Atlas Fondations

2 BESIX Nederland
36 Franki Grondtechnieken

1 BESIX Belgique
6 BESIX Stay
7 WestConstruct
8 BESIX Infra
9 Belasco
10 Cobelba
11 Flamant
12 Franki Foundations Belgium
13 Jacques Delens
14 Corebat
15 Sud Construct
16 BESIX RED
17 Socogetra
18 Bagetra
19 CDL
20 Enrobage Stockem
21 GNB
22 E3F

23 Van den Berg
24 Larabo
25 De Beukelaer
46 Uniconnect
26 Vanhout
5 Belemco
27 De Bie-Veba
28 Energieconcepten
29 HBS
30 Isofoam-Isochape
31 Vanhout Facilities
32 Vanhout Projects
33 Wust
34 ACMP
35 SDW

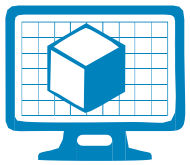
2 BESIX Luxembourg
37 Lux TP
38 BESIX RED Luxembourg
39 Witraloc
40 Wust Luxembourg
47 Mabilux

BESIX

Expertise along the whole value chain

REAL ESTATE | **CONTRACTING** | **CONCESSIONS & ASSETS**

01 Project Development



02 Design

03 Build

04 Finance

05 Maintain & Operate

BESIX - Green Hydrogen Market

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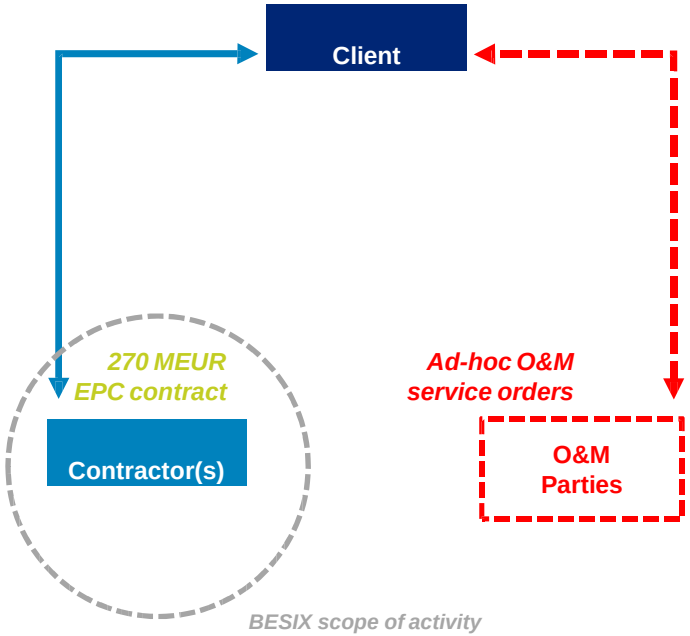
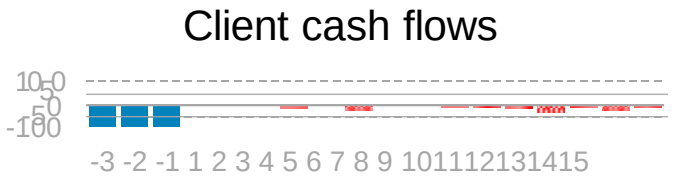
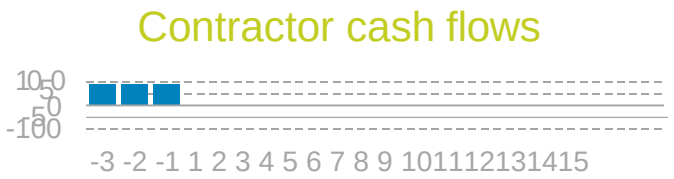
The classical D&B / EPC contract

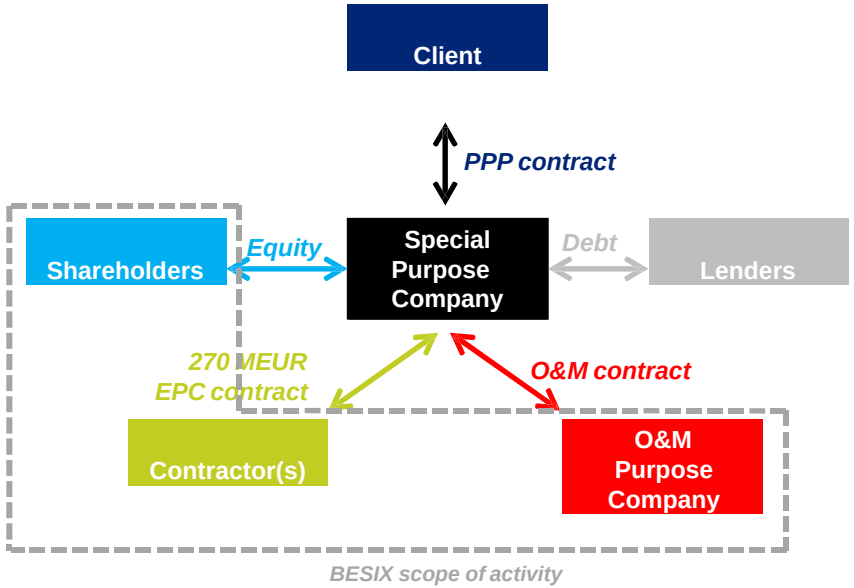




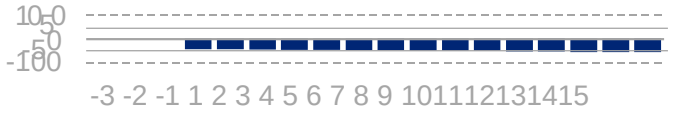


The PPP / DBFM / BOOT setup

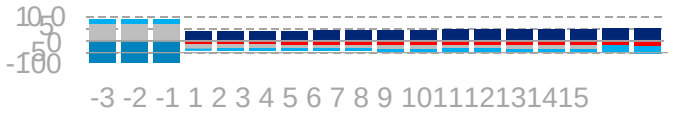
***P**ublic **P**rivate **P**artnership*
***D**esign **B**uild **F**inance **M**aintain*
***B**uild **O**wn **O**perate **T**ransfer*



Client cash flows



SPC cash flows



Contractor cash flows

BESIX

C&A Europe

Very large civil & infra projects BEISX NL

Coen Tunnel (2009)

Limmel Lock (2015)

Beatrix Lock (2016)

A16 Rotterdam (2018)

Municipal PPPs Vanhout

BESIX

C&A Middle East

Municipal water treatment projects (UAE)

ASPCL Ajman (2005)

ISTP2 (2009)

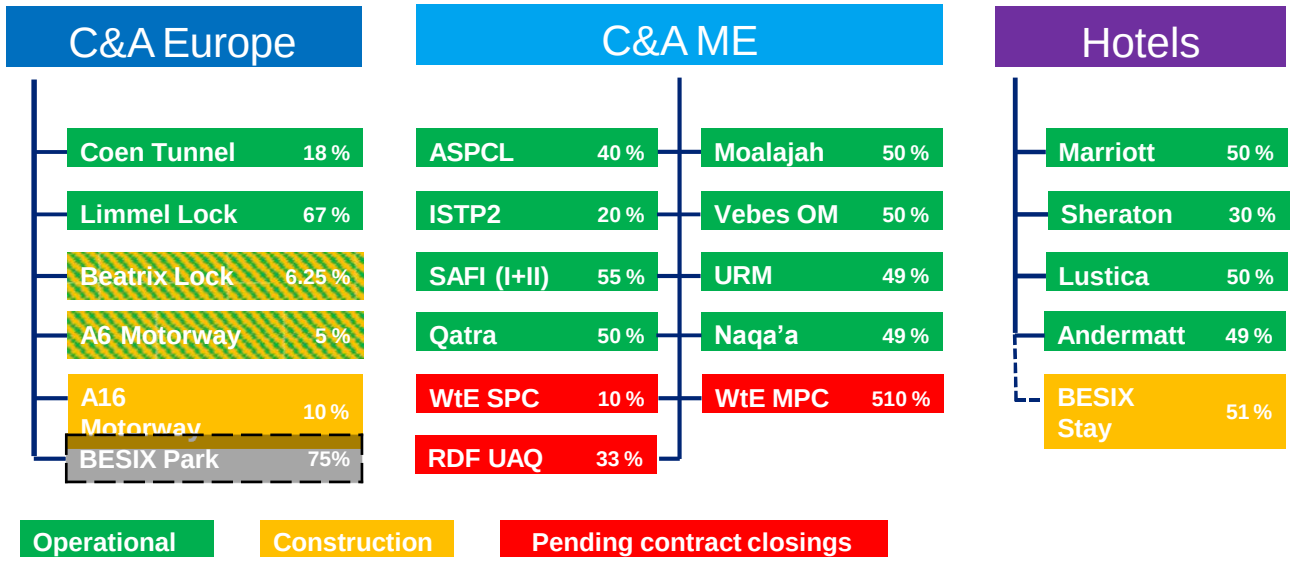
Safi Ajman (2011)

Al Saja'a STP (2018)

Moving to solid waste projects (UAE)

BESIX

A portfolio of diversified SPC/MPCs



Remark. DBM projects in BeNeLux not shown on this picture (i.e. R4 Gent, Brabo 1 Tram, Leopold II Tunnel, Parking Graanmarkt, Parking Lammermarkt, Leidsche Rijn Tunnel)

BESIX

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BESIX – Environment & Industry

Expertise

Municipal WWTP
- Conventional
- N/P removal
- SBR / MBR

Water production plants
- Conventional
- Desalination
- Re-Use

Industrial WWTP
- Breweries
- Petrochemical
- Pharmaceutical

Pumping stations & hydropower
- Pumping stations
- MEP of locks
- Small hydro power plants

Sludge to Energy / Biogas
- Mesophilic digestion
- Thermophilic digestion
- CHPs or Bio-Methane

Waste to Energy
- Waste pre-treatment
- Waste combustion
- Energy recovery

Sludge Treatment Plant – ZERO ENERGY

Tiel – The Netherlands

Wastewater Treatment Plant & Biogas/Biofuel Plant

S'Hertogenbosch – The Netherlands

Heat Network

ISVAG Incineration Plant – Belgium

Electromechanical & Hydropower generation

3 locks – Viesville-Gosselies-Marchienne – Belgium

Combined Gas Power station - Emile Huchet

Saint-Avold, France

Electric Power Plant

Pont-Sur-Sambre, France

Wastewater Treatment Plant

Jebel Ali Phase 2 – U.A.E

Desalination Plant

Jebel Ali Desalination plant – U.A.E

Waste to Energy

Dubai - United Arab Emirates

LNG Jetty

South Hook - UK

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BESIX in the Green Hydrogen Market

Role

- Co-Developer
- Integrator
- EPC
- O&M

BESIX in the Green Hydrogen Market

Sectors

- Hydrogen production plant
- Hydrogen network pipes
- Import/Export facilities
- Integration into smart building / smart cities

BESIX in the Green Hydrogen Market

Technical in-house know-how

- Balance of plant
  - Demineralised water
  - Dry cooling
  - Nitrogen
- Electromechanical
  - High Voltage – Medium Voltage
  - Automatisation – Instrumentation
  - HVAC / Plumbing
- Structures, building & civil works
- Undergrounds services
- Marine works

BESIX in the Green Hydrogen Market

Geography

- Belgium – The Netherlands – France - Luxembourg
- Northern Europe Countries (Norway, Denmark, Poland, Lituania)
- Australia
- Middle East (UAE, Qatar, Oman)
- Northern Africa (Moroco, Egypt)
- Canada

Cluster POWER-to-GAS – value chain

WHAT TO REMEMBER ?

1. BESIX is a multisector group with solid anchorage in Europe, Middle East & Australia

2. BESIX can take different roles from EPC contractor to co-developper

3. BESIX has in-house electromechanical expertise

4. Excel in creating sustainable solution for a better world

www.besix.com

von Karman Institute for Fluid Dynamics

Introduction

History

Under the impulse of Theodore von Kármán, the **USA and Belgium** decided in 1956 to create an institution devoted to **training and research in aerodynamics,** open to young engineers and scientists of the **NATO member nations**.

The objective was to foster fruitful exchanges and understanding between the participating nations in the well-defined technical field of aerodynamics (later extended to fluid dynamics).

Theodore von Kármán receiving the National Medal of Science from President Kennedy in 1963

Education

Research Master Programme in Fluid Dynamics (Master-after-Master)
9 months

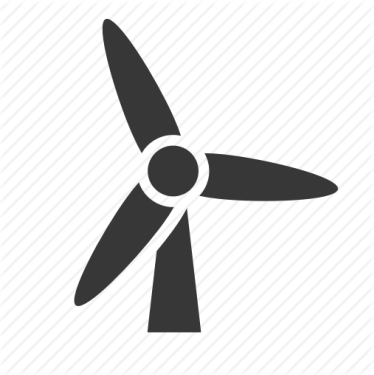
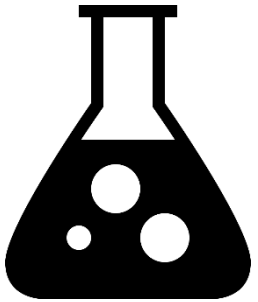
Doctoral Programme in Fluid Dynamics (PhD)
1-4 years

Short Training Programme
2-6 months

Lecture Series
1 week

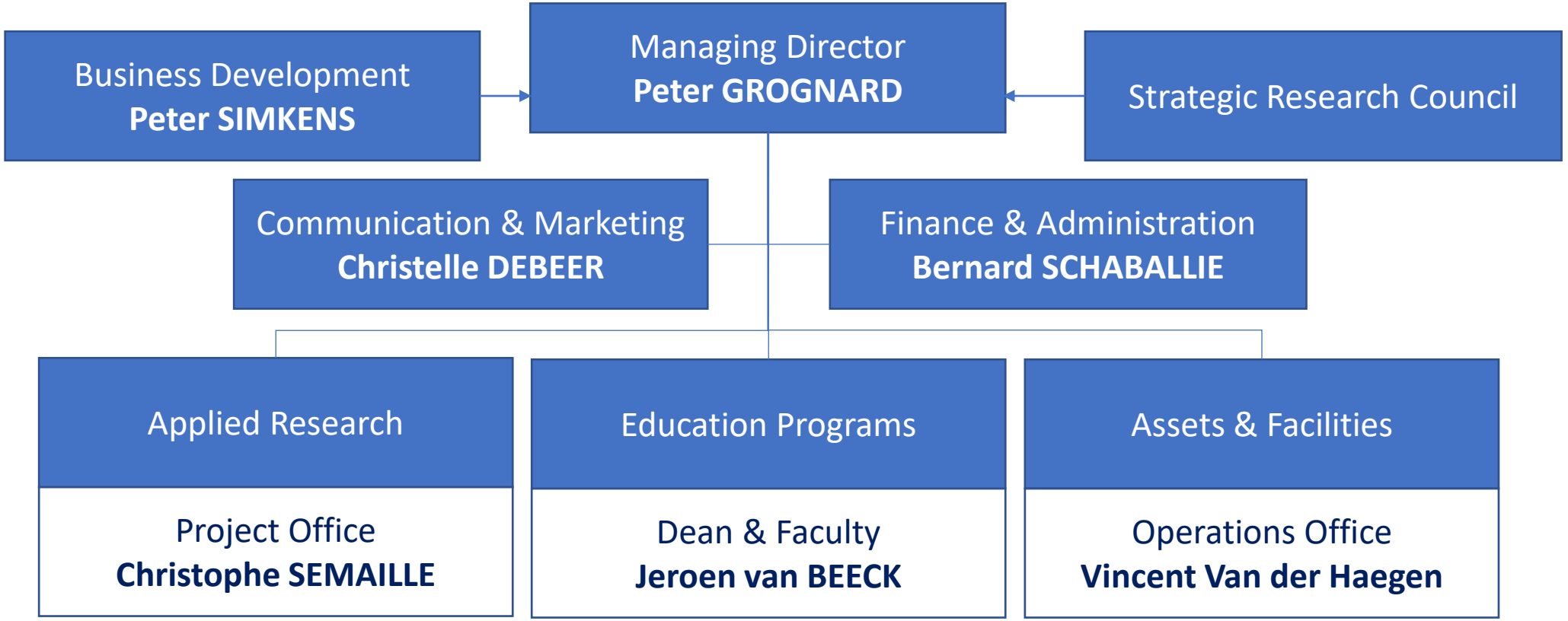
Research



AEROSPACE FLUID DYNAMICS	TURBOMACHINERY FLUID DYNAMICS	INDUSTRIAL PROCESSES FLUID DYNAMICS	ENVIRONMENT FLUID DYNAMICS	FLUID ENGINEERING & MEASUREMENT
1. Space debris & exploration 2. Re-entry 3. Hypersonics 4. Aeronautics	1. Turbines aerodynamics & heat transfer 2. Compressor aerodynamics & heat transfer	1. Multiphase flows 2. Liquid metal flows 3. Cryogenic flows	1. Atmospheric flows 2. Renewable energy 3. Pollution & explosions	1. Non-intrusive measurements 2. Calibration 3. Custom instrumentation

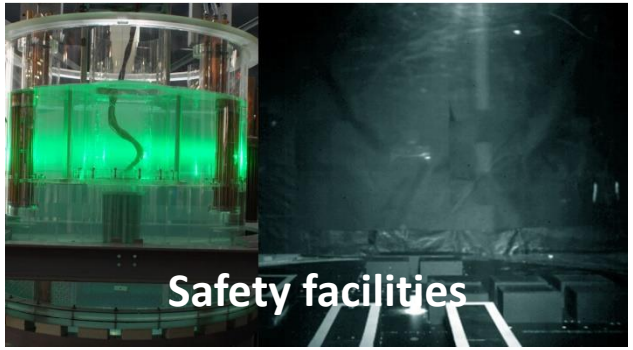
Organisation



Research Expertise Groups

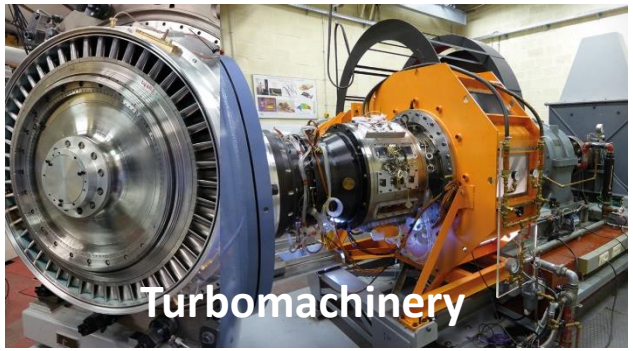
Aerodynamics & Aeronautics	Liquid & Solid Propulsion	Turbine Aerodynamics & Heat Transfer	Aerochemistry	Liquid Metals & Industrial Flows	Shape Optimisation
Aeroacoustics	Aerothermodynamics	Compressor Aerodynamics & Heat Transfer	Rerefied & Plasma Flows	Environment Flows & Safety	Instrumentation & Measurement Techniques

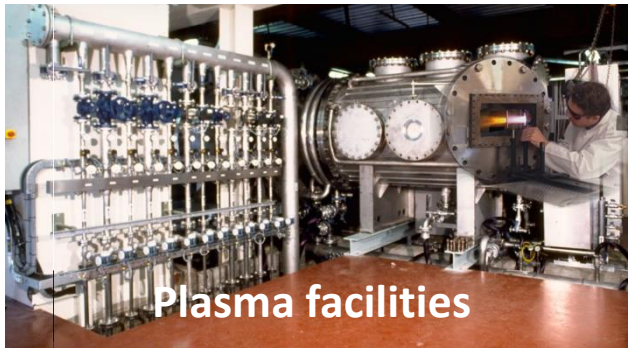
Facilities


Safety facilities


High Performance Computing


High Speed Wind Tunnels


Turbomachinery


Plasma facilities


Cryogenic facilities


Low Speed Wind Tunnels


Acoustic facilities


2 Phase Flow facilities


von Karman Institute
in Hydrogen
for Propellant Management
in Space

Flows in Liquid Propellant Management: Roadmap

TRL 1...4

2012 | 2016 | 2018 | 2020 | 2022 | 2024

Multiphase Fluid Hammer

- Water hammer in liquid propulsion systems (satellites, cryogenic upper-stage) (1xGTSP, 1xTRP)
- Adiabatic Decomposition of Propellants (1xTRP)

Cavitation

- Cavitation / flashing in components (e.g. valves, metering orifices, inducers...) (2xGSTP, 1xNPI)
- Cavitation /flashing in propellant-assisted valves (1xGSTP)

Flow Boiling

- Chilldown in cryogenic upper-stages (1xGSTP)
- Liquid film cooling in small scale thrusters (1xTRP, 1xGSTP)
- Nucleate boiling in ALM regenerative cooling channel (GSTP)

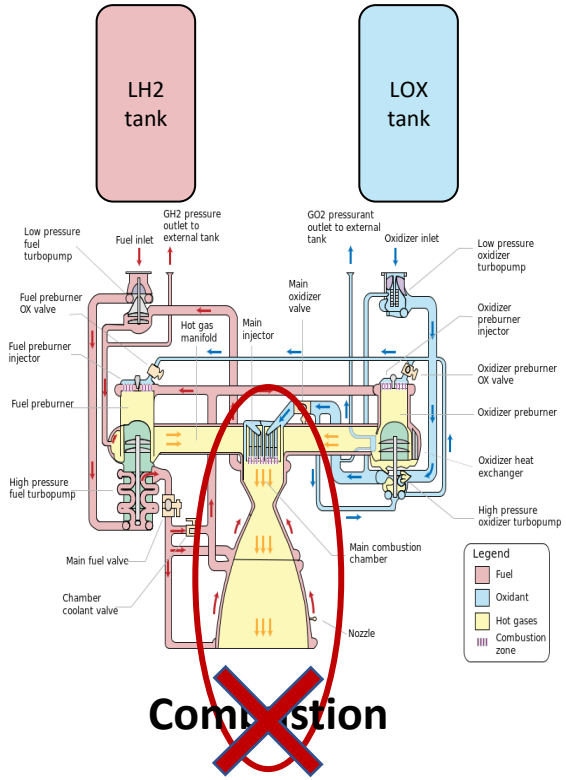
Propellant Management in Tanks

- Isothermal sloshing (prediction methods for Propellant Management Devices) (GTSP, PRODEX)
- Non-isothermal sloshing (Physical and numerical modelling of cryogenic sloshing) (GTSP, PRODEX)
- High-Fidelity Validated Lattice-Boltzmann Simulation Tool for sloshing (GSTP)
- Prototyping of Spacecraft Refueling (TRP)
- Topical Team Propellant Management Physics
- Microgravity experiments (ISS, sounding rocket...)

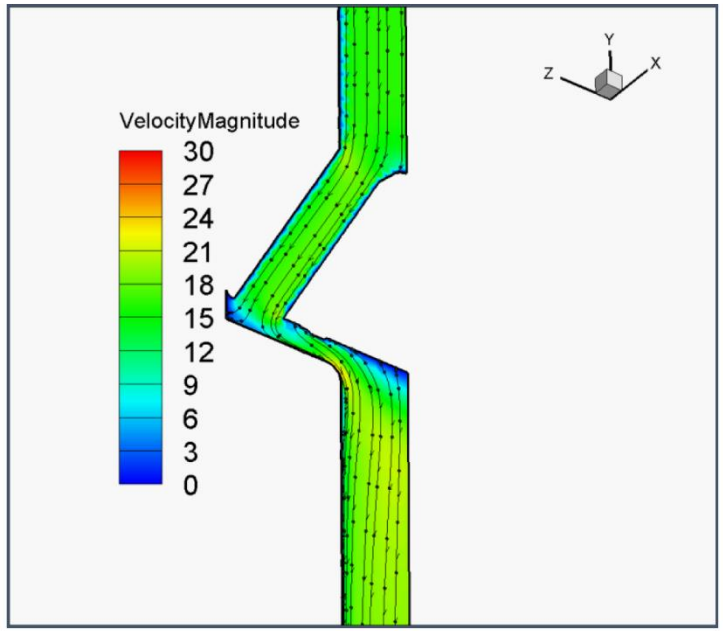
New propellants

- Densified cryogenic propellants (slush) (1xTRP, 1xNPI)
- New test capabilities in Methane (De-Risk, GSTP)

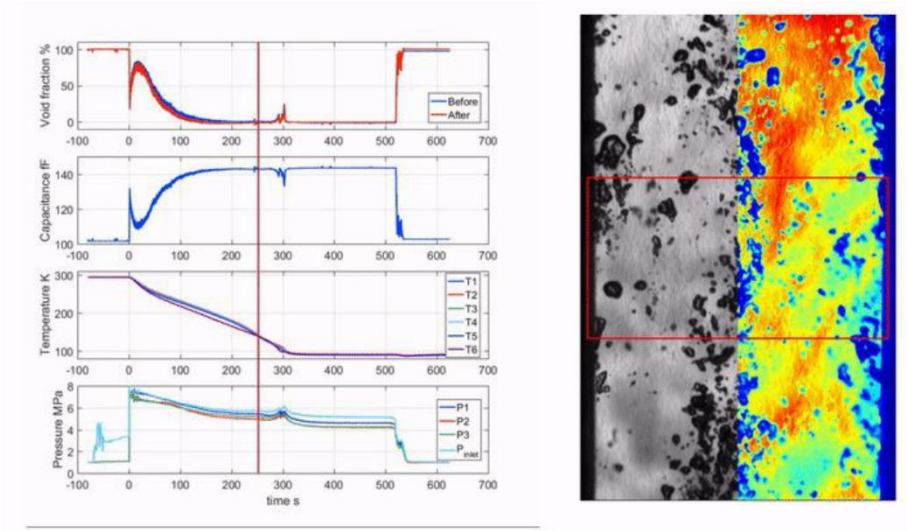
Substitute fluids for experiments: **H2O, HFE** | **LN2** | **+ LCH4**



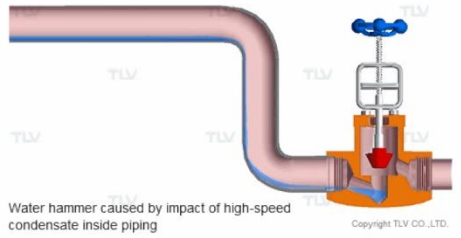
Liquid Hydrogen Flows in Pipes (Experimental)

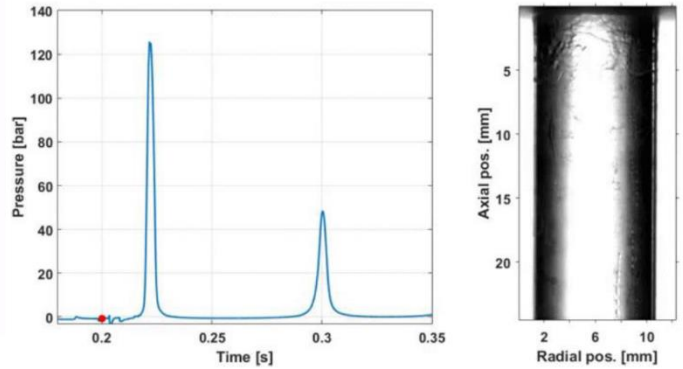


Velocity magnitude and streamlines along a 2D section



void fraction, capacitance, temperature, pressure evolution





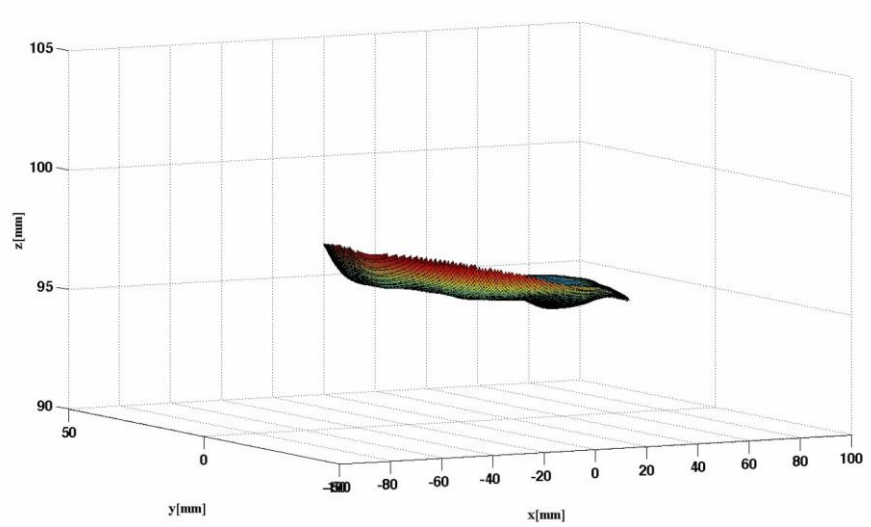
Cavitation:
hydraulic characterization
of feedline valves

Flow Boiling &
Chill-down at Injection

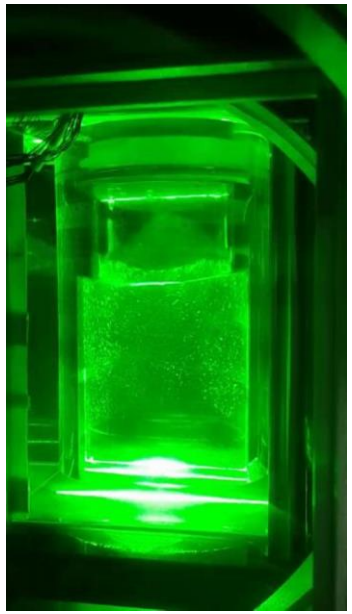
Multiphase Fluid Hammer:
What happens when a (cryogenic) fluid comes into a vacuum line?

Better Energy Efficiency, less Corrosion

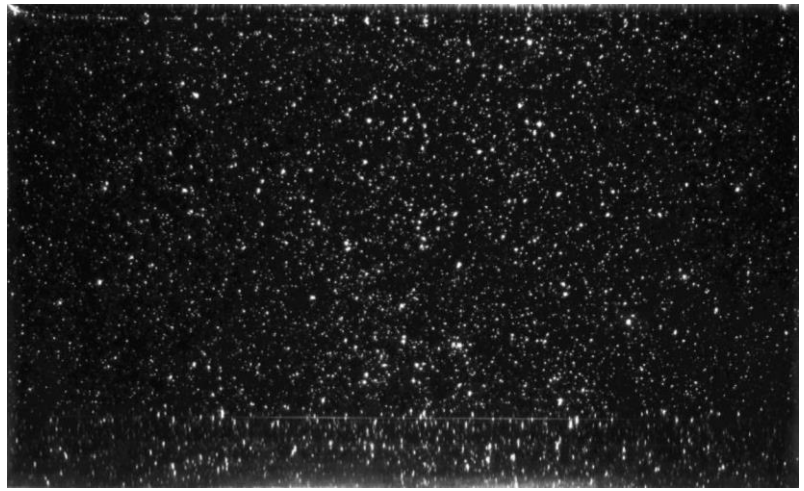
Liquid Hydrogen Storage and Sloshing (Experimental & Numerical)



3D free surface detection water sloshing

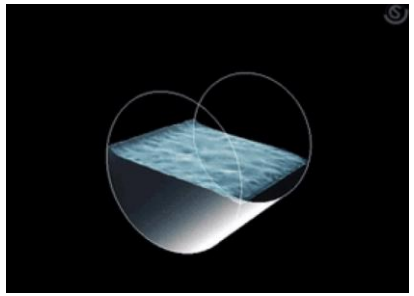


2D Particle Image Velocimetry sloshing test



2D Particle Image Velocimetry natural convection test

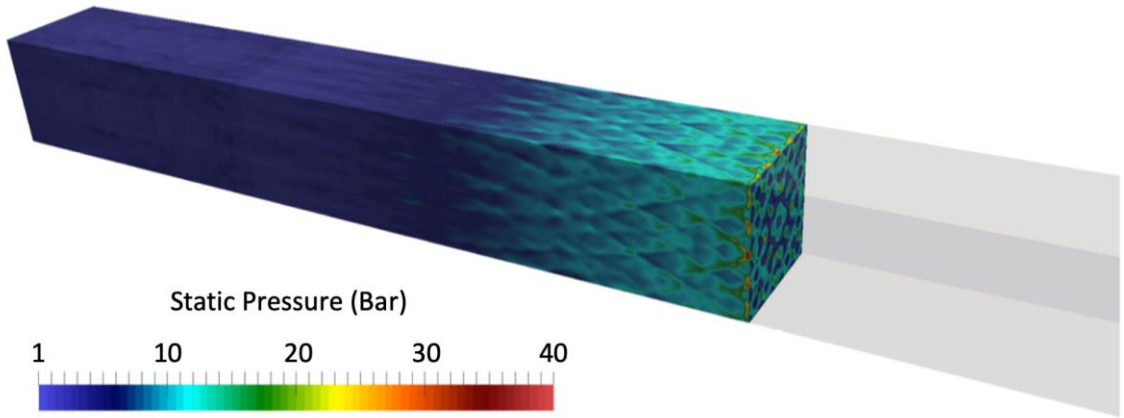
Sloshing in a Moving Tank



Fluid / Propellant Management in a Tank

Better Gravitational Control, less Energy Losses

Pulsed Detonation Thrusters (2020 – 2021)

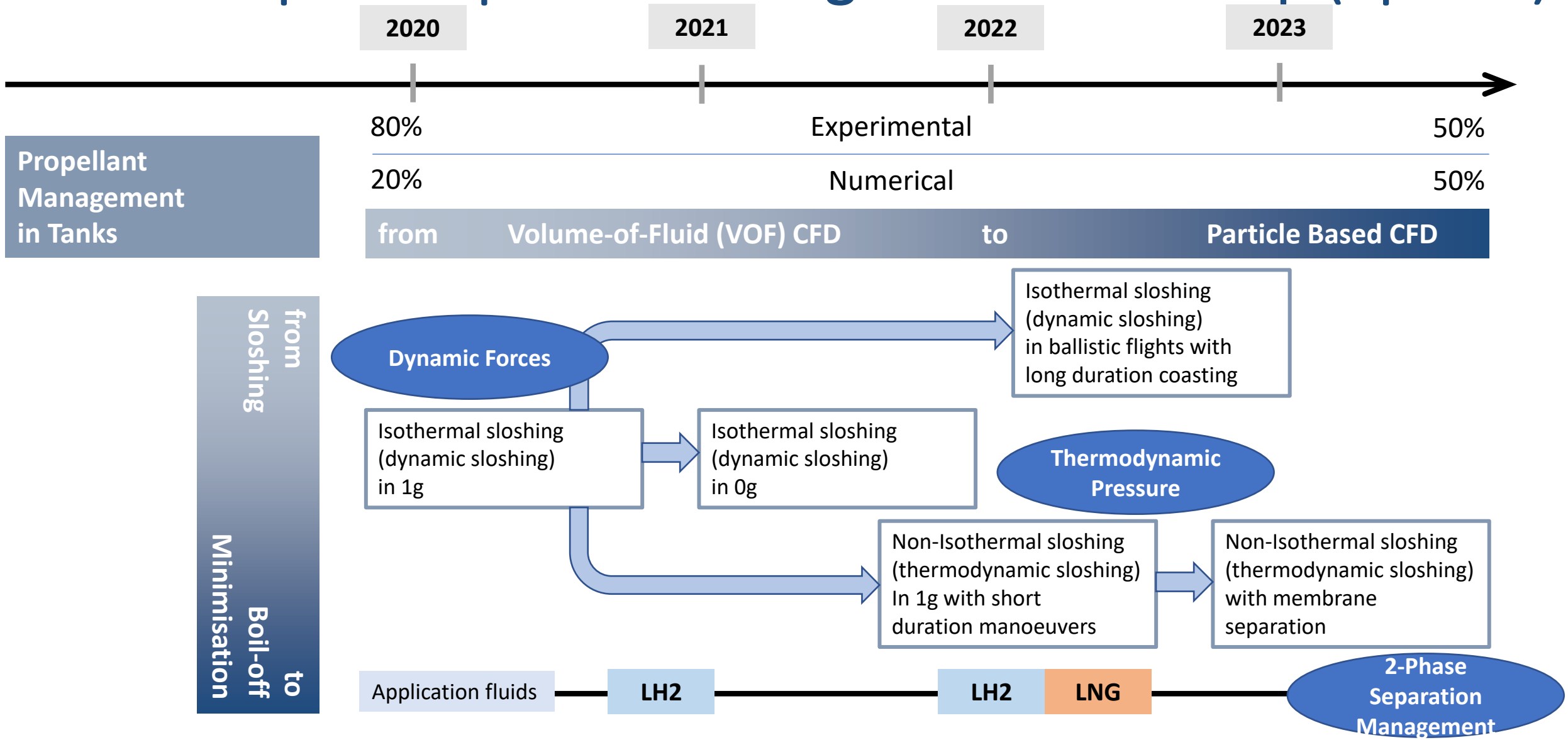


3D detonation cell structures of stoichiometric H2/Air mixture
Predicted by zndFOAM

- numerically and experimental prove/disprove pulse-detonation thruster as viable option for spacecraft propulsion
- thorough requirement review for a space mission & propulsion system
- 1D simulations to reach a number viable solutions
- reduced number of 3D CFD simulations to come to 2 PDT candidates
- trade-off analysis to consolidate final PDT design for testing
- **H2-O2** detonation experiments under vacuum conditions, providing a vast amount of data to validate our numerical tools
- system requirements reassessment and consolidation with PDT results
- design, development & verification plan for future PDT systems

von Karman Institute in Hydrogen for Transport Applications

Flows in Liquid Propellant Management: Roadmap (update)



Hydrogen-powered aviation

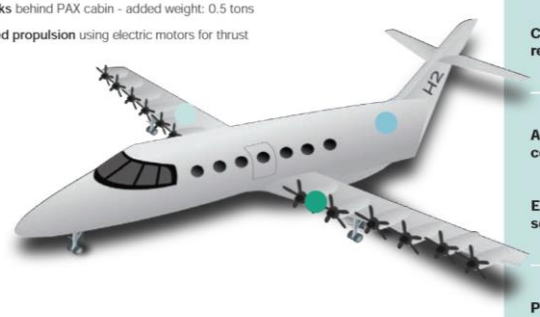
Exhibit 6

Commuter aircraft powered by fuel cells

Revolutionary aircraft

Design mission: 19 PAX, 500 km range, cruise speed 500 km/h

- **Highly efficient** wing
- **2 LH_2 tanks** behind PAX cabin - added weight: 0.5 tons
- **Distributed propulsion** using electric motors for thrust



Energy demand[1]	-10%
CO_2 reduction	100%
Climate impact reduction	80-90%
Additional cost	0-5% CASK[2]
Entry into service	<10 years
Propulsion power	Fuel cell system
MTOW[3]	+15%

1. Major assumptions: 25% gravimetric index of LH_2 tank, 90% useable LH_2 fuel, FCS mass 1.5 kW/kg (incl. cooling) and 58% peak efficiency (LHV), e-motors and PMAD with 97% efficiency, battery with 0.6 kWh/kg
2. Cost per available seat kilometer
3. Maximum take off weight

Exhibit 7

Regional aircraft powered by fuel cells

Revolutionary aircraft

Design mission: 80 PAX, 1,000 km range, cruise speed Mach 0.44

- **Highly efficient** wing
- **2 LH_2 tanks** behind PAX cabin - added weight: 2 tons
- **Distributed propulsion** using electric motors for thrust

Energy demand[1]	-8%
CO_2 reduction	100%
Climate impact reduction	80-90%
Additional cost	5-15% CASK[2]
Entry into service	10-15 years
Propulsion power	Fuel cell system
MTOW[3]	+10%

1. Major assumptions: 30% gravimetric index of LH_2 tank, 90% useable LH_2 fuel, FCS mass **1.75 kW/kg** (incl. cooling) and 59% peak efficiency (LHV), e-motors and PMAD with 97%
2. Cost per available seat kilometer
3. Maximum take off weight

Exhibit 10

Long-range aircraft powered by H_2 turbines

Evolutionary aircraft

Design mission: 325 PAX, 10,000 km range, cruise speed Mach 0.85

- **2 LH_2 tanks** in front and back of PAX cabin - added weight: 52 tons
- **H_2 turbines** generating propulsion power

Energy demand[1]	+42%
CO_2 reduction	100%
Climate impact reduction	40-50%
Additional cost	40-50% CASK[2]
Entry into service	20-25 years
Propulsion power	H_2 turbine
MTOW[3]	+23%

1. Major assumptions: 38% gravimetric index of LH_2 tank, 92% useable LH_2 fuel, 50% H_2 turbine cruise efficiency, 80% fan efficiency
2. Cost per available seat kilometer
3. Maximum take off weight

Exhibit 8

Short-range aircraft powered by hybrid H_2 propulsion

Revolutionary aircraft

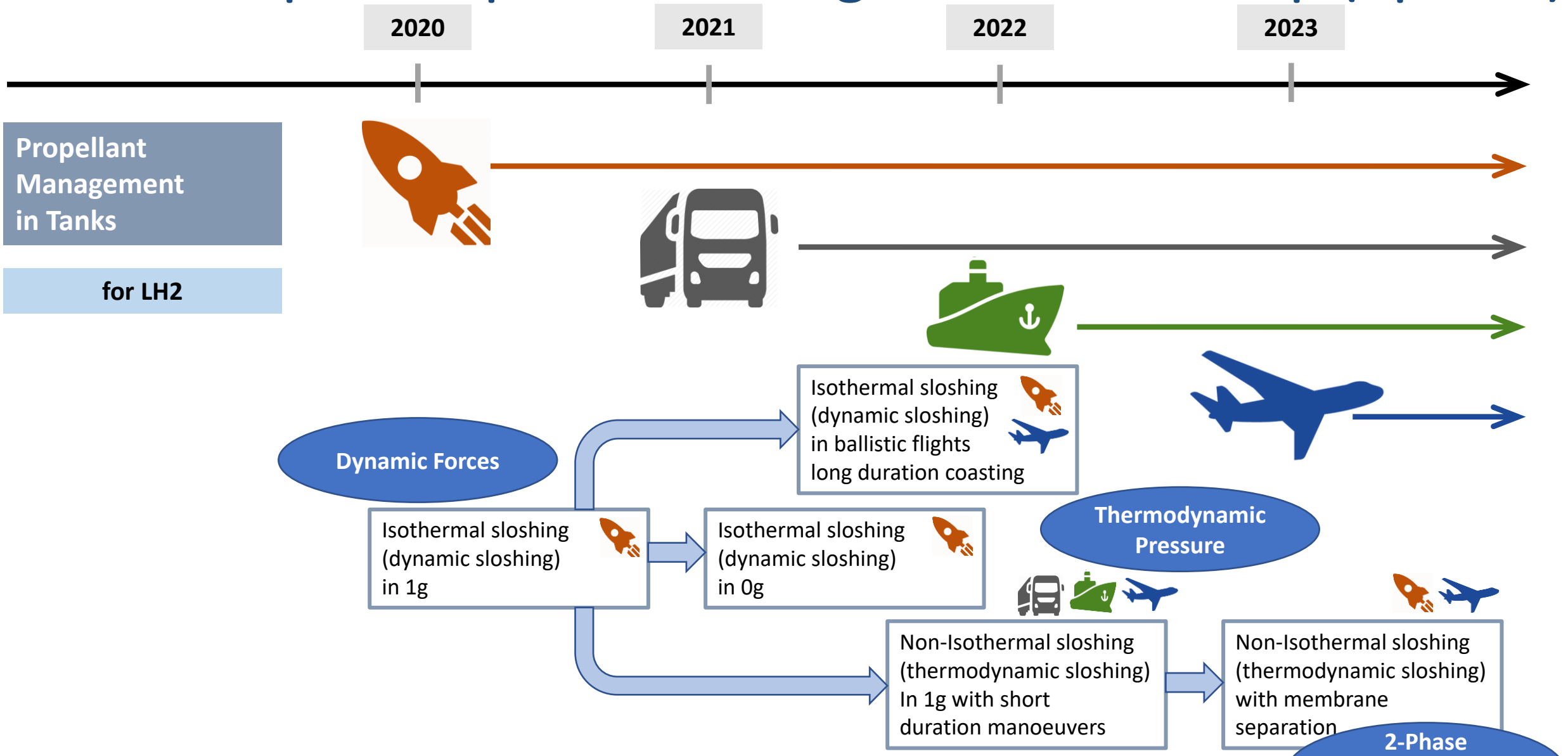
Design mission: 165 PAX, 2,000 km range, cruise speed Mach 0.72

- **2 LH_2 tanks** behind PAX cabin -added weight: 4 tons
- **Fuel cell system (11 MW)** powering electric motors
- **Electric motor** driving main turbine fan shaft during cruise, while H_2 turbine is turned off

Energy demand[1]	-4%
CO_2 reduction	100%
Climate impact reduction	70-80%
Additional cost	20-30% CASK[2]
Entry into service	15 years
Propulsion power	Hybrid
MTOW[3]	+14%

1. Major assumptions: 35% gravimetric index of LH_2 tank, 91% useable LH_2 fuel, FCS mass 2 kW/kg (incl. cooling) and 60% peak efficiency (LHV), e-motors and PMAD with 97% efficiency, battery with 0.6 kWh/kg, H_2-turbine with 45% cruise efficiency
2. Cost per available seat kilometer
3. Maximum take off weight

Flows in Liquid Propellant Management: Roadmap (update)



Hydrogen vs. bio-fuels (SAFs) for hypersonic airplanes

- Configuration & performance analysis for mach 2 and mach 5 aircraft
- Aerodynamics & aeroacoustics: jet noise modeling & testing, and sonic boom propagation
- Propulsion and pollutant emissions: propulsive system modeling, and combustion modeling for bio-fuels and **hydrogen**
- Impact prediction on air quality, ozone layer and climate

Clean Sky 2

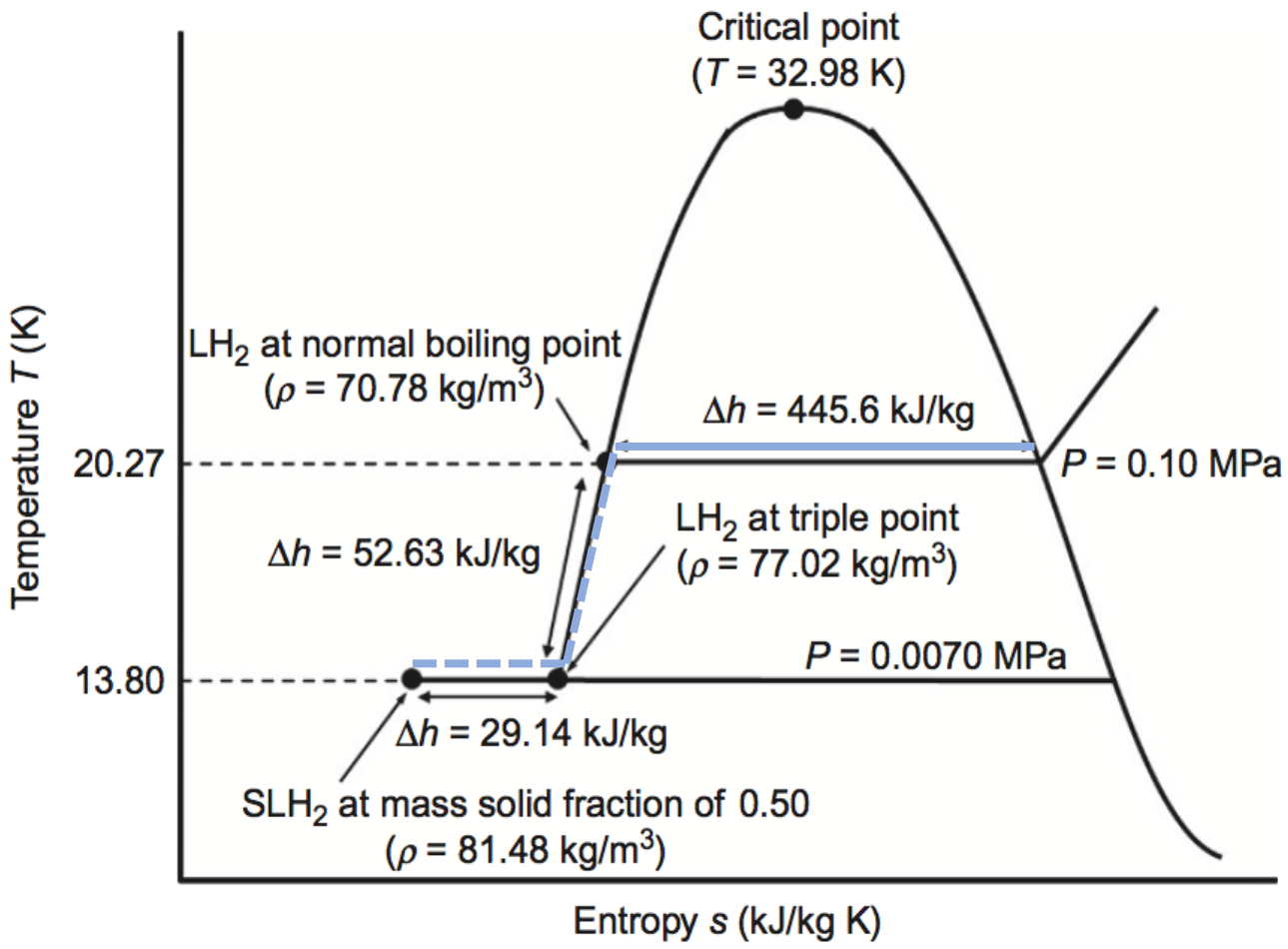

von Karman Institute
in Hydrogen
for Energy Applications

Slush (Densified Cryogenic Fluids)

WHY?

- Reduced sensibility to sloshing
- Higher density → Larger stored mass
- Increased specific enthalpy → Higher holding time
- Improvement of performances → Gross Mass reduction

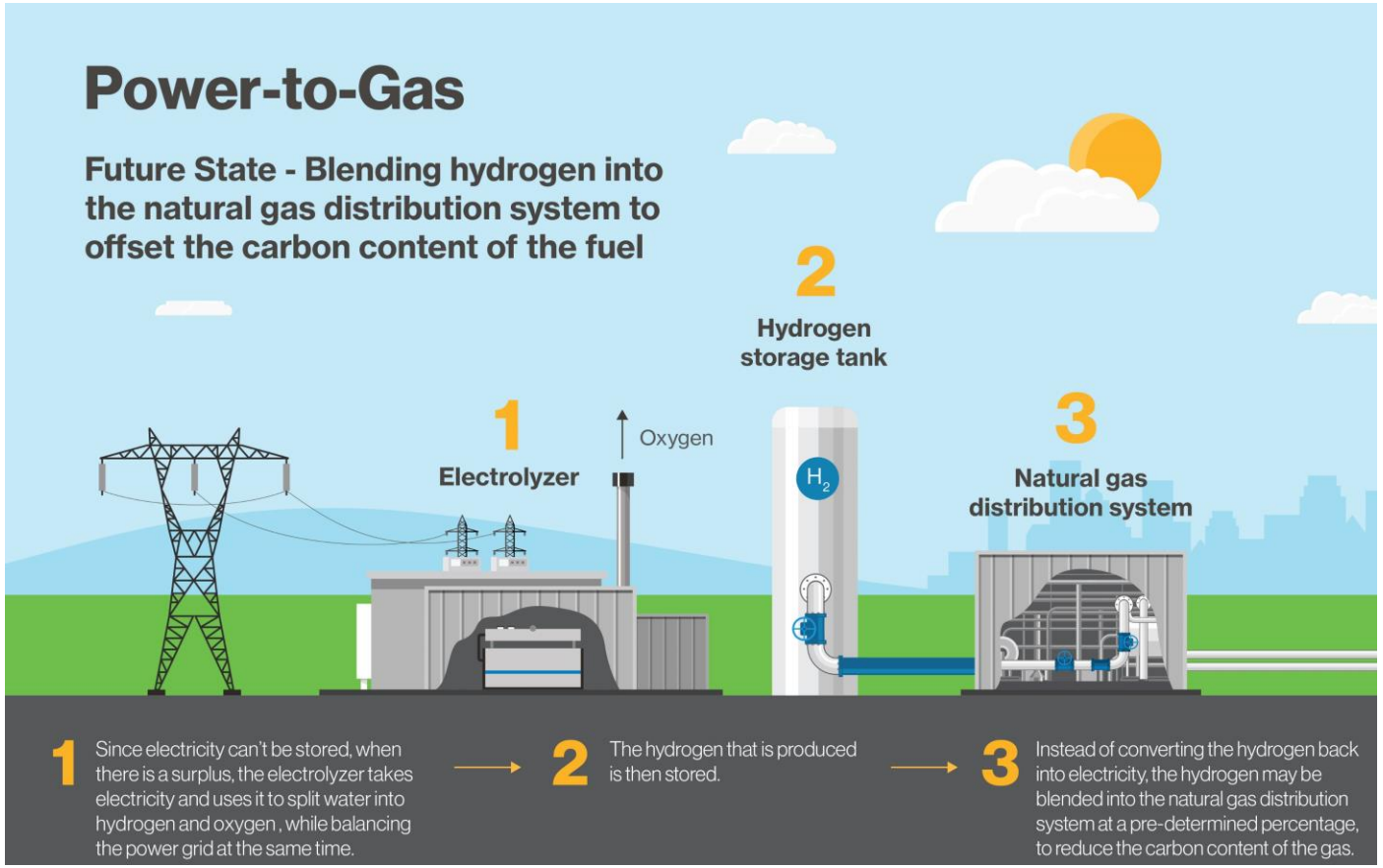
Slush (Densified Cryogenic Fluids)



<u>Enthalpy gain</u>:

- Heat capacity through the gaseous state increases with 18%
- Longer holding time in fuel storage (as well as in transport)
- Reduced insulation requirement

Slush (Densified Cryogenic Fluids)



Application (with H2, LNG…) -> Energy Storage for Wind Energy

News from the cluster

NEW MEMBERS SINCE JUNE

WATERSTOF INDUSTRIE CLUSTER

BESIX + HOLTHAUSEN CLEAN TECHNOLOGY


storm
Polders Investeringsfonds nv
BERKMAN
Ballast Nedam
UTRECHT
Nedstack
Port of Antwerp
CMB
BLUEGATE
ANTWERP
Oiltanking
sue2
ROTTERDAM
ARNHEM
BEHYDRO
TOTAL
DEME
PORT OF ZEEBRUGGE
AGFA
remeha
NEDERLAND
Q8
Shipit
SOLENCO POWER
www.vanwingen.be
EINDHOVEN
trucks
DENYS
BRUGGE
ANTWERPEN
NIPPON GASES
umicore
borit
GENT
BELGIË
HASSELT
HYDROGENICS
POM
BRUSSEL
PLASTIC OMNIUM
Tessenderlo Group
EVERY MOLECULE COUNTS
VDL
BUS & COACH
fluvius
TOYOTA
VANHOOL
Eneco
pom
Limburg economisch versnellen
De Vlaamse Waterweg
Aspiravi
SAMEN GEDREVEN DOOR DE WIND
ANGLO BELGIAN CORPORATION
We power your future
Atlas Copco
DELHAIZE
Air Liquide
von KARMAN INSTITUTE FOR FLUID DYNAMICS
HYUNDAI
NEW THINKING. NEW POSSIBILITIES.
COCAS
COLRUYT GROUP
luminus
fluxys
PMV
FARYS
BESIX
SIEMENS
Ingenuity for life
INFRABEL
TRACTEBEL
ENGIE
COOSAT
renewi
WATERSTOF INDUSTRIE CLUSTER

WATERSTOF INDUSTRIE CLUSTER

VALUE CHAIN

STRATEGIC PLAN H2 FLANDERS

- Strategic hydrogen plan for Flanders 2030
- Bottom-up vision (questionnaire)
- To be presented to Flemish government
- Meeting of minister presidents FL – NL November 4

STRATEGIC PLAN H2 FLANDERS

1. Key messages
2. H2 roadmap: goals and targets 2025/2030
3. Flemish H2 research program
4. Policy
5. Timing and check goals/targets

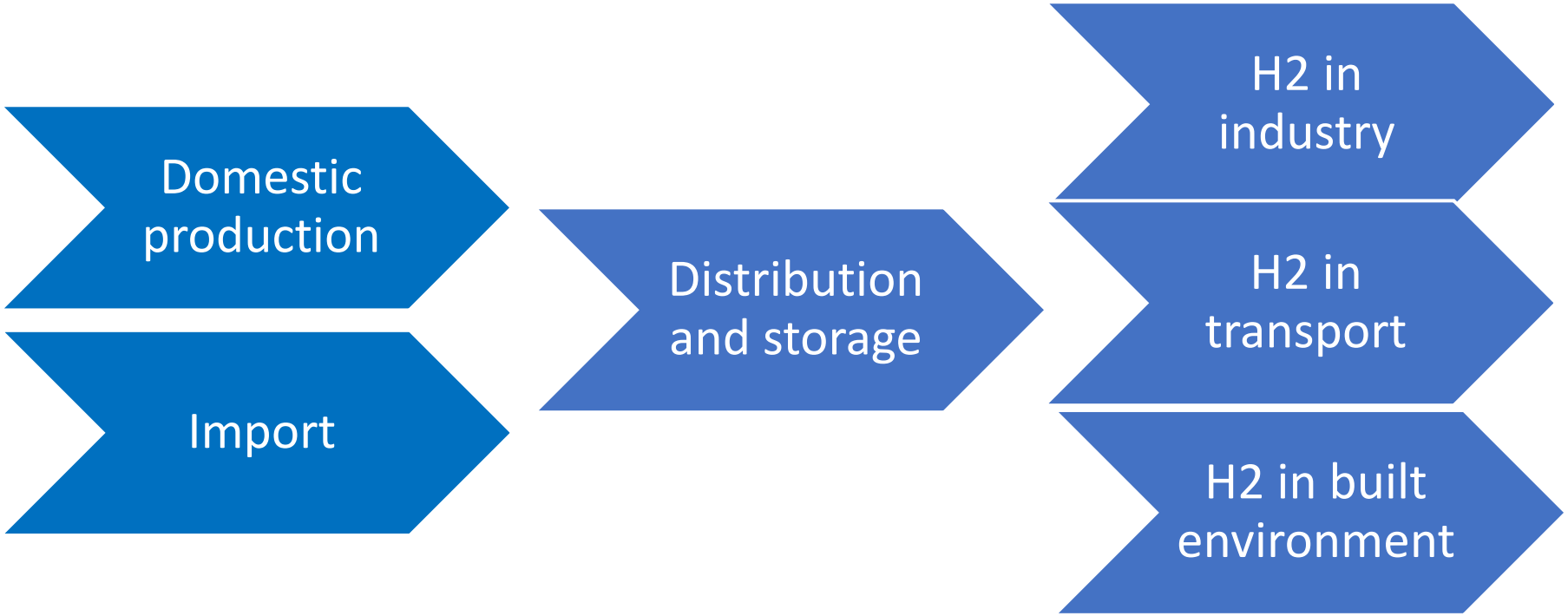
KEY MESSAGES FOR FLANDERS

- Ambitious EU hydrogen strategy ➔ leading position for FL
- Strong starting position + important assets to roll out H2 market
- Important technology players that can expand and be in pole position in EU ➔ increasing local employment
- FL should promote hydrogen technology by showcases and the development of a home market

KEY MESSAGES FOR FLANDERS

- Focus areas for FL
  - ✓ Major hub for importing hydrogen to EU + need for strategic partnerships
  - ✓ Connection of H2 backbone with surrounding countries
  - ✓ Frontrunner in sustainable chemical/steel industry by H2
  - ✓ Application and supply of heavy duty solutions
- Need for well coordinated and focused hydrogen research program
- Early adopter of EU H2 policy and proactive attitude regarding national H2 policy

H2 ROADMAP: GOALS AND TARGETS 2025/2030



H2 ROADMAP: FEEDBACK FROM CLUSTER MEMBERS

WATERSTOF INDUSTRIE CLUSTER

Domestic production

Medium scale electrolysis pilot projects
CAPEX down and efficiency up
Decentralised production important
Level playing field green carriers needed
Low carbon strategy needed

Distribution and storage

Transnational storage needed
Studies/projects other carriers
Open acces network needed
Roadmap conversion natural gas grid

H2 in transport

Focus on long range/heavy duty
HRS network
Other H2 carriers/e-fuels for inland shipping or aviation
Level playing field needed

Import

Need for pilot projects
Other carriers have to be studied
Will need fitting infrastructure
Roadmap

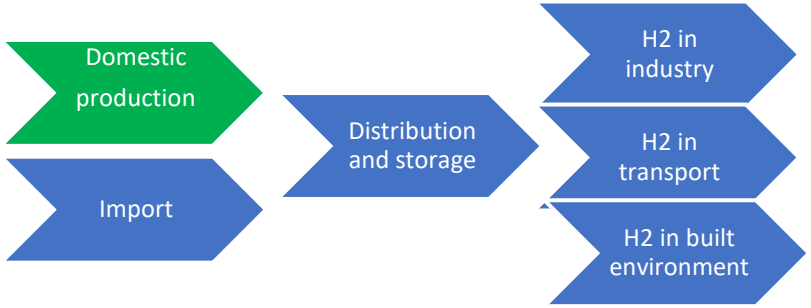
H2 in industry

Challenge grey H2 as feedstock
Platform molecules
Support needed production e-fuels
Need to close gap between clean and grey H2

H2 in built environment

Need thorough study/roadmap
Net balancing opportunities
Need for level playing field
Pilot projects

GOALS & TARGETS

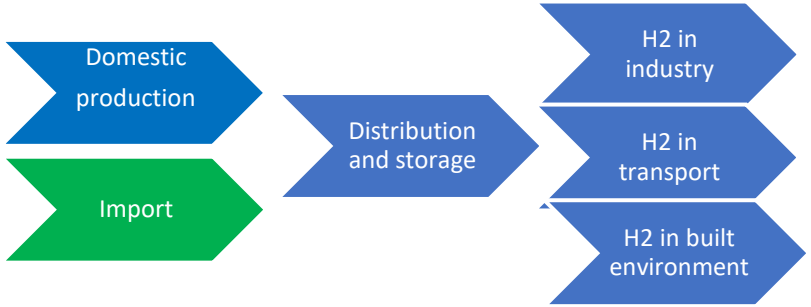


WATERSTOF INDUSTRIE CLUSTER

Domestic production	Targets/goals 2025	Targets/goals 2030
Centralised:		
Large scale electrolysis in port environments + industrial clusters		
SMR + CCS/CCU		
Decentralised:		
Regional/local electrolysis		
Alternative production technologies		

COMING SOON

GOALS & TARGETS

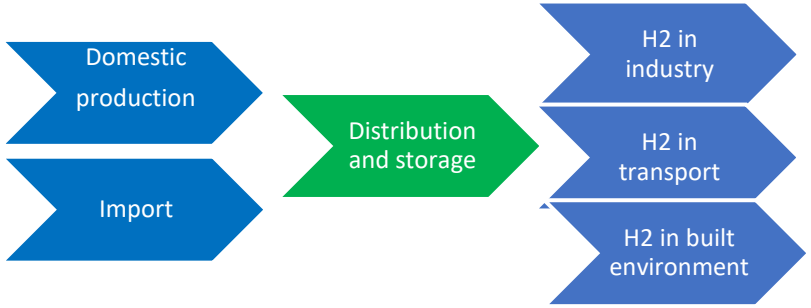


WATERSTOF INDUSTRIE CLUSTER

Import	Targets/goals 2025	Targets/goals 2030
Building infrastructure in Flanders/Belgium		
Establish import routes with partner countries		

COMING SOON

GOALS & TARGETS

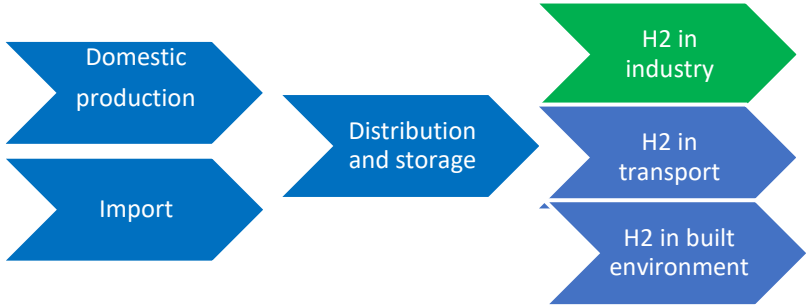


WATERSTOF INDUSTRIE CLUSTER

Distribution and storage	Targets/goals 2025	Targets/goals 2030
Natural gas grid		
New H2 infrastructure		

COMING SOON

GOALS & TARGETS

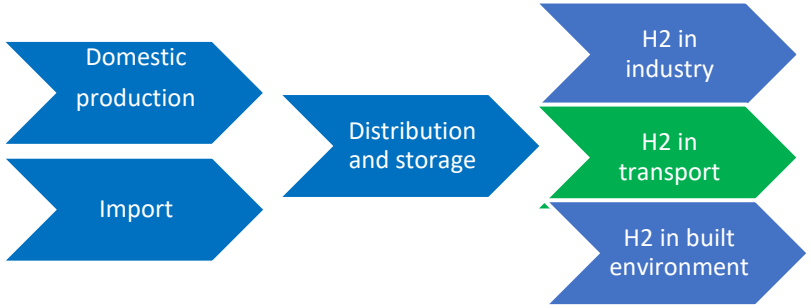


WATERSTOF INDUSTRIE CLUSTER

H2 in industry	Targets/goals 2025	Targets/goals 2030
Current H2 as feedstock for industry		
New applications		
Heating for industry		
Power for industry		

COMING SOON

GOALS & TARGETS



H2 in transport	Targets/goals 2025	Targets/goals 2030
Infrastructure		
Heavy duty		
Passenger cars		

COMING SOON

GOALS & TARGETS

WATERSTOF INDUSTRIE CLUSTER

H2 in built environment	Targets/goals 2025	Targets/goals 2030
Replacement natural gas and local storage		

COMING SOON

FLEMISH H2 RESEARCH PROGRAM

- Expertise at companies and research institutes
  - ✓ Limited alignment
  - ✓ Scattered research activities
- EU hydrogen strategy: R&D priorities
  - ✓ Large scale electrolysis and fuel cells
  - ✓ H2 distribution and storage ➔ EU H2 network
  - ✓ Large scale use of H2 in industry and transport
  - ✓ Need for framework: policy and standards

➔ In order to play a key role in EU there is a need for coordinated H2 R&D

POSSIBLE FOCUS AREAS R&D FLANDERS

Field/application	Topics	R&D expertise Flanders
Production H2		
Distribution and storage		
Heavy duty transport inland shipping		
Power & heat (CHP)		
Industry		
General		

FLEMISH AND FEDERAL POLICY

- WIC Policy team:
  - ✓ Inventory of main bottlenecks for H2 deployment
  - ✓ Policy recommendations (FL, B)
  - ✓ Link with EU policy

- Main bottlenecks:
  - ✓ H2 production → High CAPEX & electricity price
  - ✓ Difference in cost green/blue hydrogen versus grey hydrogen
  - ✓ No legislative framework for transport of H2 in natural gas network
  - ✓ Industry → No incentives to produce or buy green hydrogen
  - ✓ Transport → Limited infrastructure (HRS) ⇔ no vehicles
  - ✓ H2 and E-fuels not recognised as a fuel in NCEP (focus on biofuels) ⇒ no incentive
  - ✓ No legislative framework for H2-ships

FLEMISH AND FEDERAL POLICY

Political level	Production	Distribution & storage	Industry	Transport	Buildings
	REDII	EU Strategy for Energy System Integration	REDII ETS IED	REDII AFID EU regulations on CO2 reduction	Energy Performance of Buildings Directive
	GO's for clean H2 Taxation of energy carriers	Framework for open access H2 network		Fuels legislation	
	Tax & Levies exemptions electricity for green H2.		OPEX support for H2 projects. Targets for industry	Public transport. H2 refuelling infrastructure. Road taxes.	EP/EPC legislation. H2 distribution network

TIMING AND CHECK GOALS/TARGETS

- First draft: now
- Meeting Flemish government 17/09
- Check goals/targets with most relevant members: mid September – mid October
- Check text with all cluster members: mid October
- Final version: end of October

IMPORTANT: H2 STRATEGY FROM FL GOV

- Flemish government also working on H2 strategy
- Initiative from cabinet Crevits + EWI/VLAIO

  ➔ Focus on economics, innovation and R&D

  ➔ Other departments will be contacted

- Goal = Statement Flemish government early October
- Close cooperation!

SAVE THE DATES

- Next cluster meeting November 18 AM
  - Replaced by webinar (?): TBC

- Hydrogen conference: December 7 AM + PM
  - Location: Lamot, Mechelen
  - Minister Crevits confirmed

VARIA

- Launch working group on shipping
- Listing possible needs for education colleges/universities

➔ support H2 industry

IPCEI-status

WaterstofNet

Belgium

- June 2020: deadline for submission IPCEI-expressions of interest
- July 2020: regional financial framework
- All submitters were invited for ‘match-making’ event on 31st of August in Brussels:
  - 12 presentations
  - Most fit within Green Octopus projects
- 1 October : deadline submission adapted proposal

Netherlands:

- Information sessions by Dutch government, submission before 22/9

Germany

- strong hydrogen vision, growing interest for IPCEI/Green Octopus

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Federale waterstofactiviteiten

AD Energie

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Overzicht

- IPCEI
- ETF
- Politieke verklaring (Penta)
- Waterstof en offshore energie
- ENOVER waterstof & energieopslag
- Brandstoffenbeleid

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IPCEI (1/3)

- Oproep tot indiening van blijken van belangstelling (OIB)
- Doel: actoren identificeren die zouden kunnen deelnemen aan een Important Project of Common European Interest rond waterstof

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IPCEI (2/3)

- Time line:
  - 06/03: publicatie OIB op website FOD Economie
  - 05/05: deadline indiening samenvattende beschrijving project + fiscale dossier
  - 05/06: deadline indiening Project Portfolio, Funding Gap en Prodcom Analysis
  - Nu: 20 projecten onder revisie

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IPCEI (3/3)

- Regionale financierende overheden
- Federaal:
  - Project leader
  - Evaluatiecomité (expertise)
  - Onderzoeken van proces- en financieringsmogelijkheden

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Energietransitiefonds (ETF) (1/3)

- Doel: ondersteunen van onderzoek, ontwikkeling en innovatie op het vlak van energie (binnen federale energiebevoegdheden)
- Subsidies
- Beschikbaar budget 2020: €25 miljoen

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ETF (2/3)

- Time line:
  - 10/2019: oproep tot voorstellen
  - 31/01/2020: afsluiting oproep
  - 30/04: advies van AD Energie
  - 06/06: beslissing tot steuntoekenning per KB

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ETF (3/3)

- 15 van de 42 projectvoorstellen ontvingen subsidies
  - Waterstofgerelateerd: 2 (H2FC-SoSvector en H2GridLab)

- Uiterlijk **01/11/2020** nieuwe projectoproep

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Joint Declaration of the Pentalateral Energy Forum on Hydrogen (1/2)

- Mei 2020: ondertekening door energieministers van het Pentalateraal energieforum:
- Doel: inzet uitdrukken om samenwerking op het gebied van waterstof te versterken
- Nadruk op moeilijk te decarboniseren sectoren

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Joint Declaration of the Pentalateral Energy Forum on Hydrogen (2/2)

- Link: https://www.benelux.int/files/1615/9077/7640/jointpoliticaldeclaration.pdf
- Federale rol:
  - Faciliterende, coördinerende rol voor BE
  - Toekomstige rollen?
  - Cross-border samenwerking cruciaal

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Waterstof en offshore energie (1/2)

- Offshore energie op de Noordzee BE: federale bevoegdheid
- NSEC: Delivering 2050 → discussion paper “Hydrogen en Offshore wind”:
  - Faciliterende rol
  - Discussieonderwerpen om mogelijke rollen voor waterstof in de offshore-context te identificeren

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Waterstof en offshore energie (2/2)

– Basis voor expert workshop eind 2020

- In kustregio enkele private ambities aangekondigd op het gebied van waterstofproductie met elektriciteit uit offshore wind

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ENOVER werkgroep waterstof & energieopslag (1/2)

- Leden: SPOCs BE entiteiten + externen op uitnodiging
- Doelstelling/werking:
  - Opvolgen ontwikkelingen binnen BE
  - Opvolgen buitenlandse ontwikkelingen
  - Coördinatie BE posities

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ENOVER werkgroep waterstof & energieopslag (2/2)

- Toekomstige agenda:
  - Topics uit politieke verklaring inzake waterstof van het PLEF
  - Waterstofstrategie in kader van Green Deal
  - …

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Brandstoffenbeleid (1/2)

- RED II: **14 %** hernieuwbare energie in vervoersector tegen 2030
- NEKP: **13,9 %** biobrandstoffen tegen 2030
- Oktober 2020: NEKP-evaluatie Europese Commissie
- Tegen eind dit jaar: haalbaarheidsstudie biobrandstoffen
- 30 juni 2021: termijn omzetting artikel 25

=> Beperkte marge voor andere vectoren (0,1 %)

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Brandstoffenbeleid (2/2)

- Link met artikel 25 van de RED II => RFNBO's: hernieuwbare vloeibare en gasvormige transportbrandstoffen van niet-biologische oorsprong
- Nog niet duidelijk welk aandeel voorzien zal worden op federaal/nationaal niveau
- Europees kader voor evaluatie van duurzaamheid RFNBO's: 2021-…

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Bedankt!

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- Algemeen biofuels: e2.biofuels@economie.fgov.be

Hydrogen Europe

MARITIME working group

Clustermeeting Waterstofnet – 16/09/20

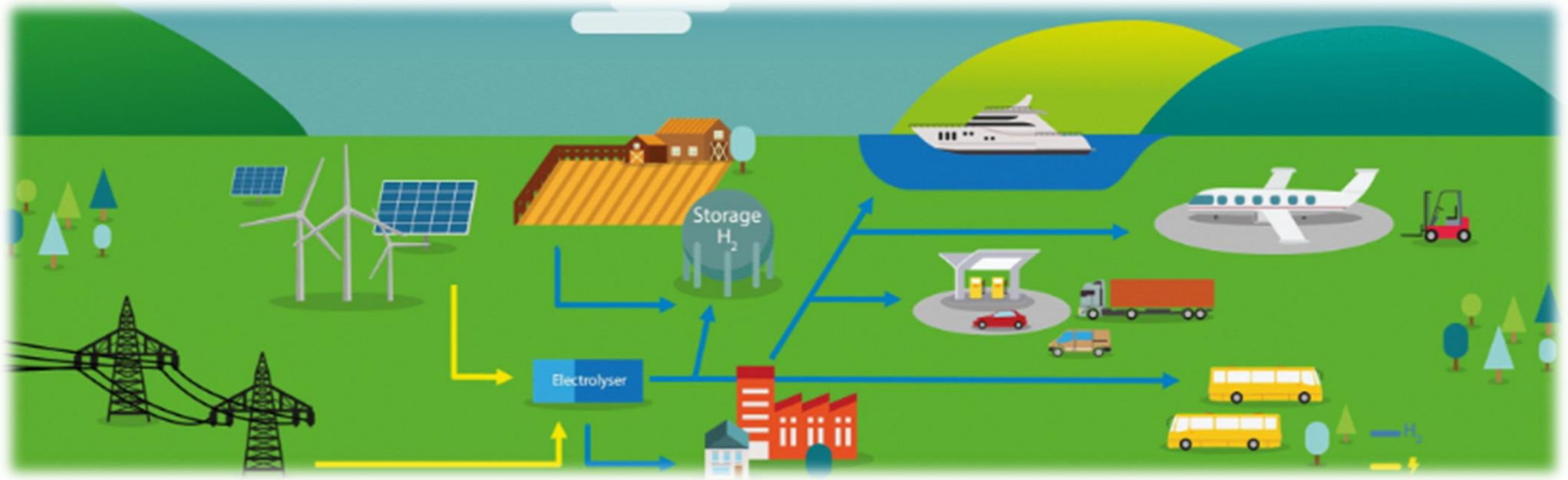
HYDROGEN EUROPE: who we are

Our Vision

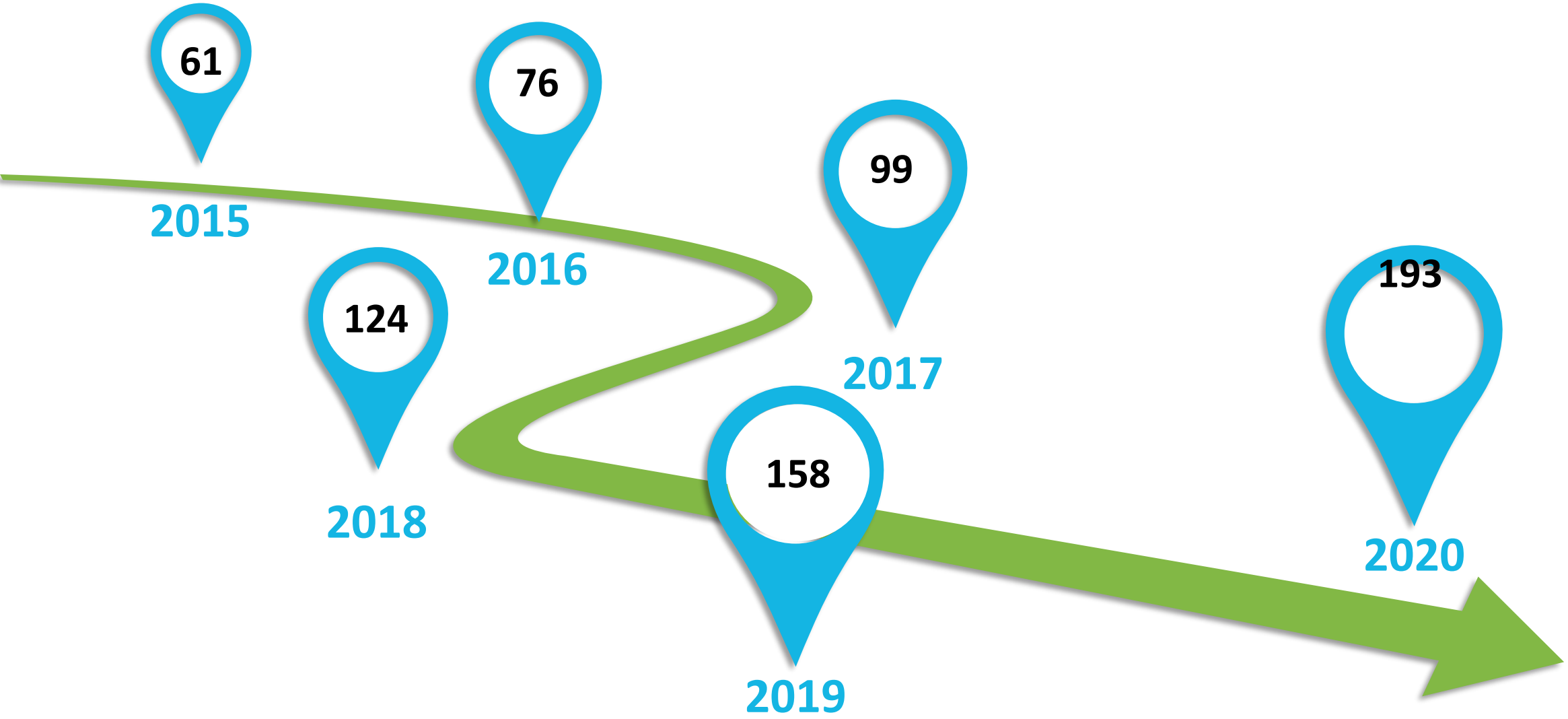
Hydrogen enabling a zero emission society

Our Mission

We bring together diverse industry players, large companies and SMEs, who support the delivery of hydrogen and fuel cells technologies. We do this to **enable the adoption of an abundant and reliable energy which efficiently fuels Europe's low carbon economy.**



Membership growth



Growing portfolio of services

FCH JU (CHE)

- Production
- Distribution
- Mobility
- Heat power, industry
- Cross-cutting
- H2 valleys
- Value chain

ADVOCACY

- Energy WG
- Production SubG
- Infrastructure SubG
- Mobility WG
- Trucks WG
- **Maritime WG**
- Aviation WG

OPERATIONS

- Communications
- Events
- Membership
- Admin & Finance

INTELLIGENCE

- **Technology**
- **Market**
- **National regulations standards**

INDUSTRIAL POLICY

- IPCEI on hydrogen
- Clean Hydrogen Alliance WG
- Funding & Financing WG

Maritime

working group

4 pillars

1. Technico-economic assessment (HE comparison tool)
2. Policy
3. R&I and funding Technical regulation
4. Technical regulation

MAWG 4 PILLARS

1. **TECHNICO-ECONOMIC ASSESSMENT** (open – members + non-members)
   - Many different ship types, sizes and trades with a lot of unknows. **HE comparison tool** to bring structure and clarity.
   - Result feeds into the policy debate. Gives credibility to HE.
   - Focus of the maritime work of HE until June 2020 (09/07/20 first MAWG with broad focus on policy)
   - Continuous improvement trough **dialogue with stakeholders and roundtable discussions**
2. **POLICY** (closed - members only)
   - EU–policy on decarbonisation of ships through energy-efficiency improvements and direct carbon-pricing: MRV and ETS
   - broader regulation to facilitate uptake of low carbon fuels for maritime e.g. Fuel EUMaritime
   - Revision of the energy taxation directive → **maritime is excluded (mobile entities – taxing evasion)**
3. **R&I AND FUNDING** (closed – members only)

   SRIA (RM12) focus on small ships to trigger development of supply chains in ports, develop building blocks for larger ships
4. **TECHNICAL REGULATION**

   IMO regulation, standardization)
   (closed – members only)

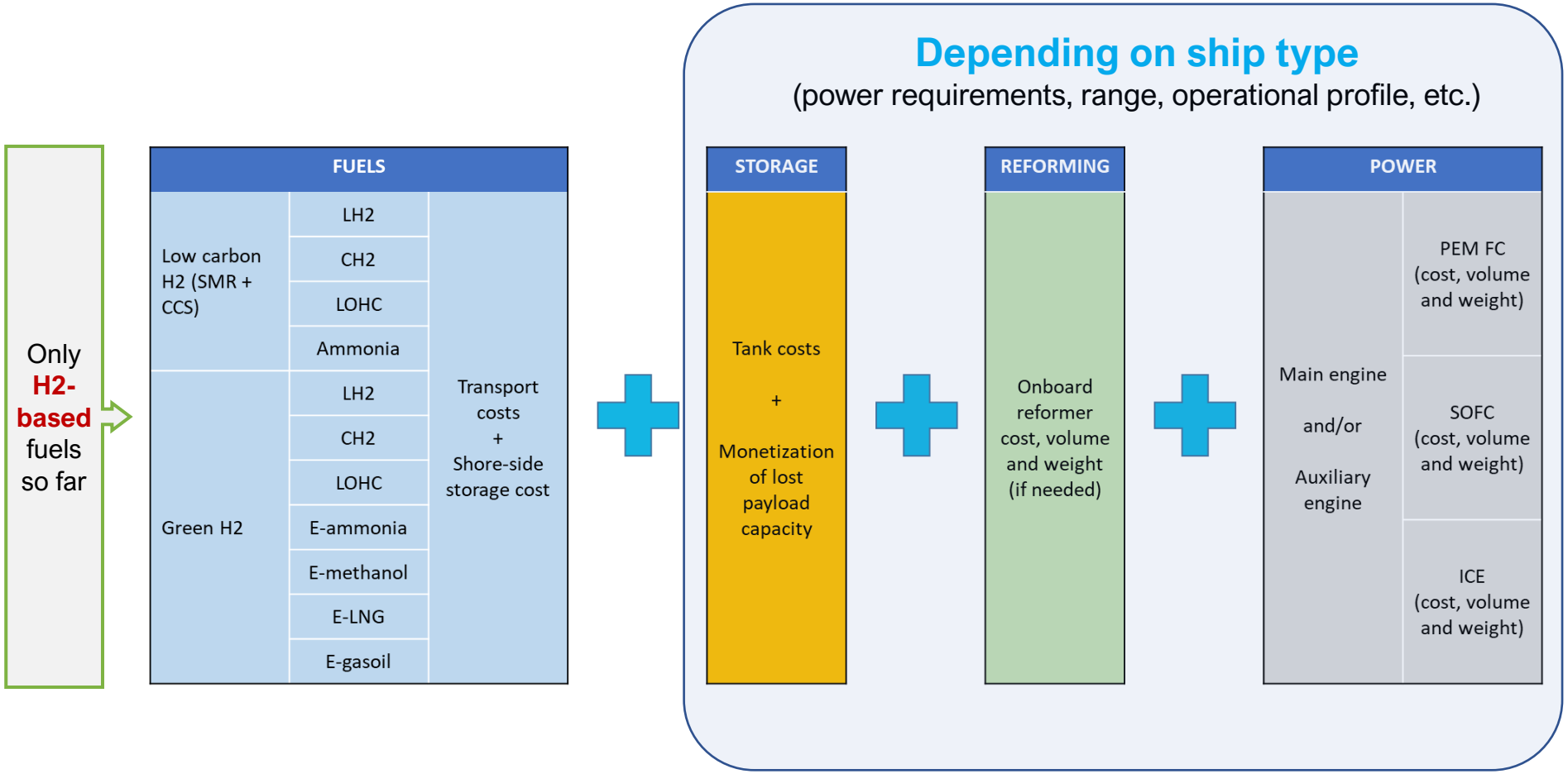
Port policy (AFID, local regulation for storage, …), hydrogen import, ….

PORTS

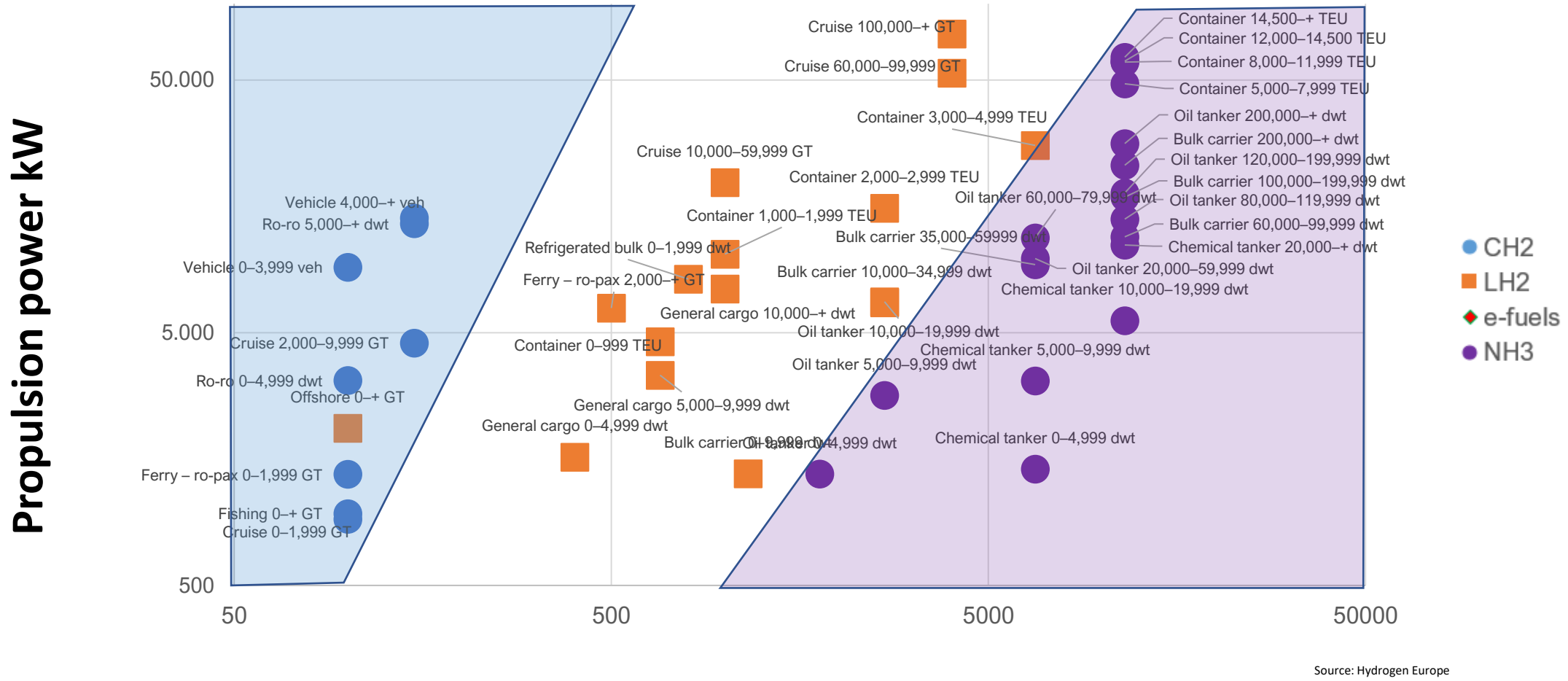
PROJECT H2 SHIPS

H2SHIPS: demonstrate the technical and economic feasibility of **hydrogen bunkering and propulsion** for **shipping** and identify the conditions for **successful market entry** for the technology for ports across North-West Europe.

Pillar 1: Techno-comparison tool

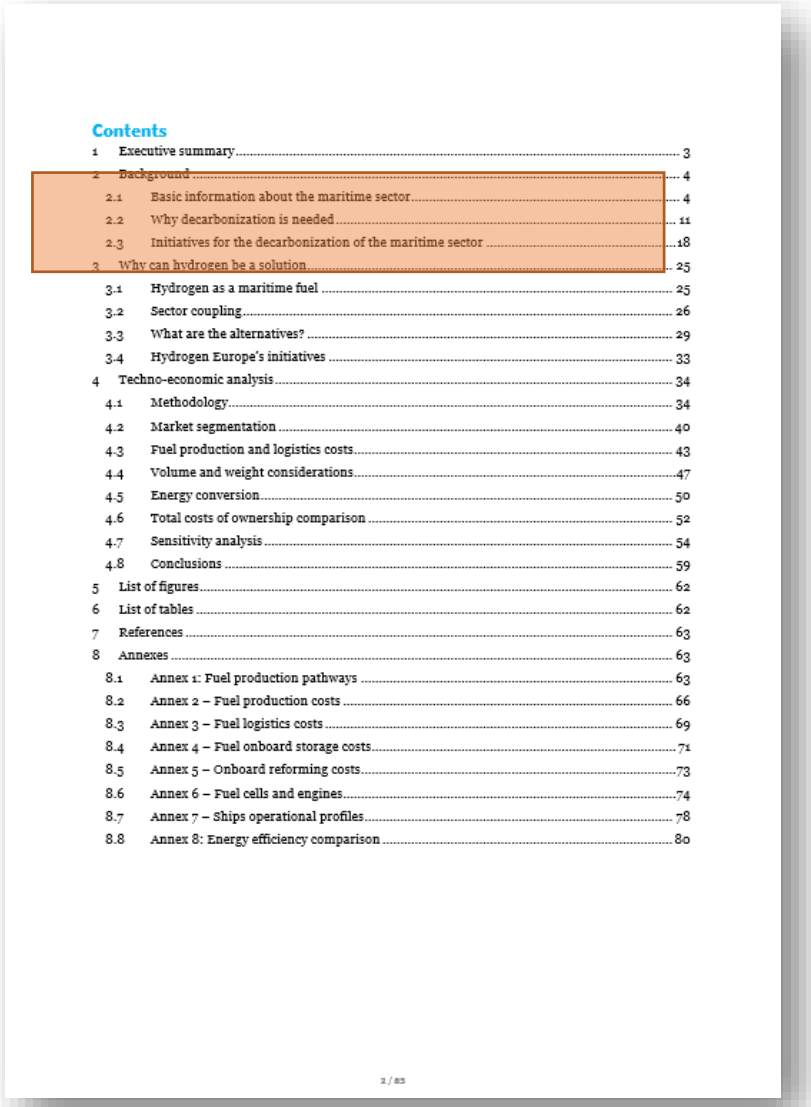


Pillar 1: Techno-comparison tool - Emerging conclusions



Source: Hydrogen Europe

Pillar 1: Techno-comparison tool – report



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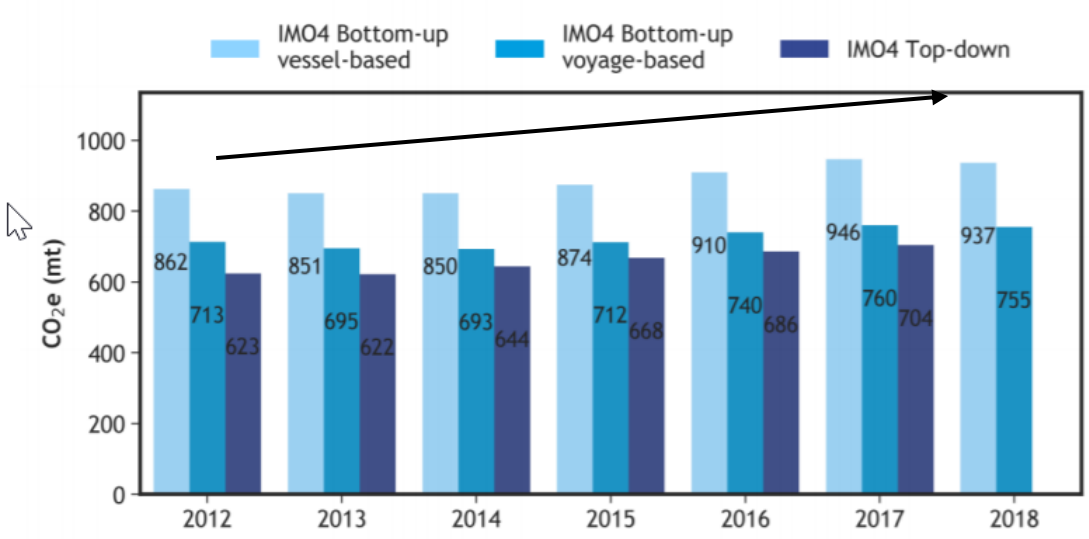
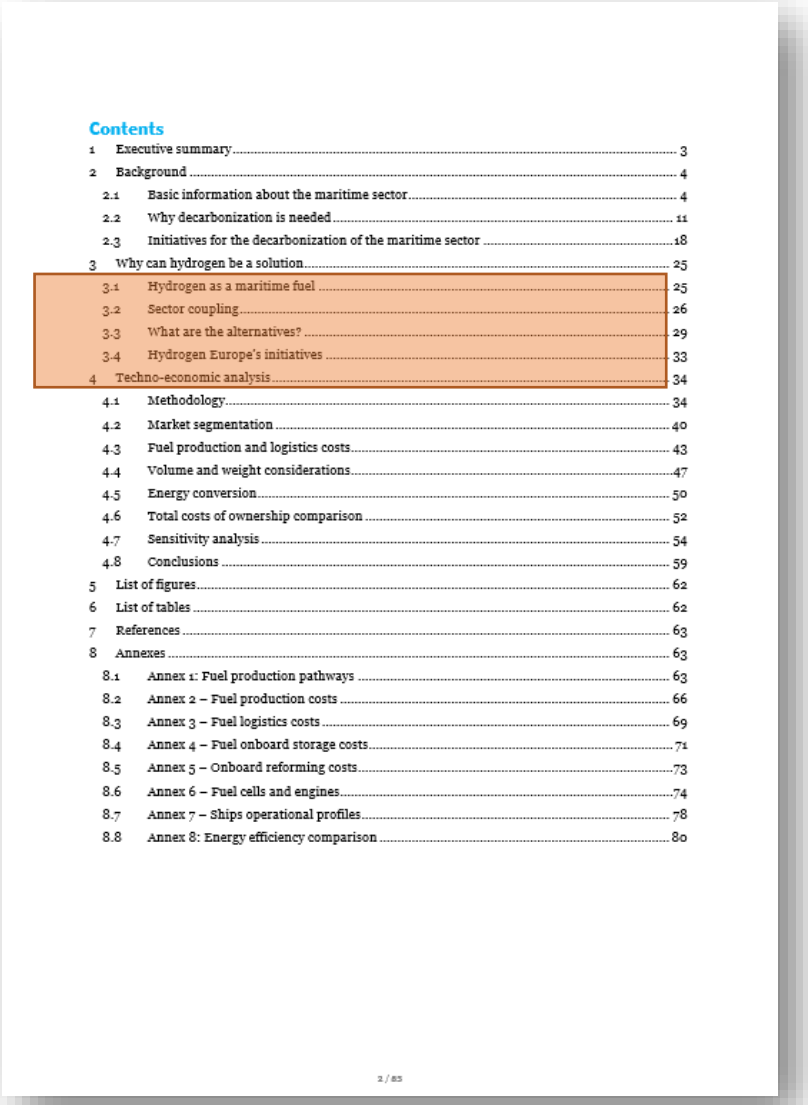
- Correlation between the maritime sector and international trade
- Sector's GHG emissions



- Policies and initiatives in place to tackle the GHG emissions problem

Pillar 1: Techno-comparison tool – report



Contents

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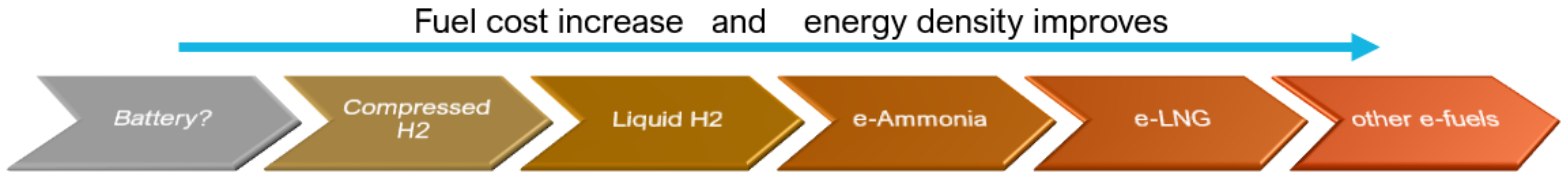
- Qualitative analysis of hydrogen as fuel for shipping
- Current supply of hydrogen
- Synergies with other sectors of the economy:
  - Sector coupling
  - Decarbonisation of port operations
  - Decarbonisation of port industrial hinterland
- Qualitative assessment of possible alternatives:
  - Biofuels
  - Batteries
  - LNG

DELIVERABLE: publication of the report end of October
+ Maritime Vision Paper (2024 – 2030 – 2040)

Pilar 1: tool conclusions…

- The lifetime of ships (on average 30 years) highlights the urgency of enrolling hydrogen as a fuel as soon as possible, to avoid that the fleet renewal of the next years will include too many fossil fuelled ships (and fossil fuel infrastructure) which will then still service global trade and EU-trade for decades to come.
- Hydrogen Europe has looked at the available technology, their strengths and weaknesses, and their technology readiness levels (TRL), to **propose deployment scenarios for ships and the infrastructure**
- When it comes to fuel production costs alone, **pure hydrogen** options are always cheaper than fuels that require further ‘transformation’ – regardless of electricity price
- We found that for the large ship **Ammonia** is the cheapest synthetic fuel (based on renewable hydrogen) - more research on Ammonia slip, N2O emissions



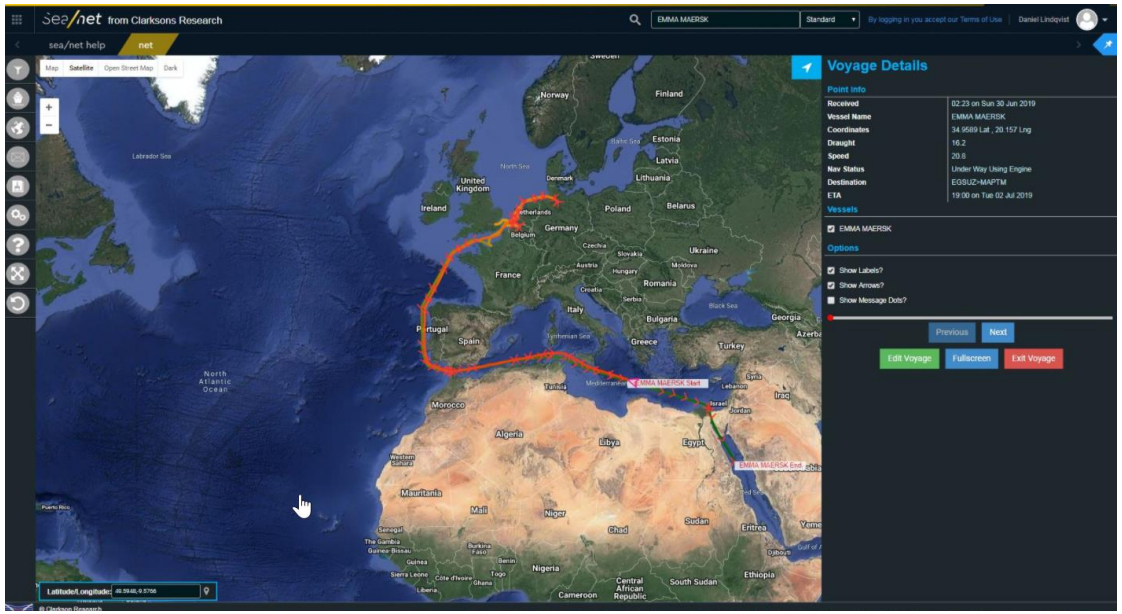
Pillar 1: Techno-comparison tool – further steps

- The tool is not the main focus of the MAWG anymore
  updating and improving….
  e.g. Currently we are in contact with 3 groups of researchers working on two different metal hydrides solution and looking into cryo-compressed form of hydrogen storage

- Future development: **fuel bunkering supply chain costs** and infrastructure needs

- Potential future development: **small targeted reports concerning** single specific application (ship or ship type), e.g. RO-PAX ferry connecting Poland and Sweden or a feeder vessel, a cruise ship…

- Clarkssons database most comprehensive regarding technical specification, ship movements, …



Clarksons Research

Pillar 1: next steps - Roundtable discussions

✓ **Timing**: app. every month starting September 2020

✓ **Who**: members and non-members.

✓ **How**: webinar with speakers invited to the HE office

TOPICS

1. **Fuel Cells – Internal combustion engines (will be the 1st roundtable September 2020)**
2. **Potential for small and large ships**
3. **Bunkering and storage, … with involvement of ports**
4. **Liquid and compressed hydrogen - hydrogen carriers (chemical commodities e.g. ammonia and methanol)**

OVERLAPS

- Not one technology versus the other. Open and transparent technology debate.
- **Discussion will feed into technical papers and the maritime vision paper**

ROUNDTABLE DISCUSSION on e.g. Fuel Cells

FCH techno providers and/or pure players

H2 Production & distribution

AREVA H_2Gen · AsahiKASEI · atawey · H2B2 · HYDROGENICS · iht · ITM POWER · nel · McPhy · SIEMENS · John Cockerill · thyssenkrupp · sunfire · Air Liquide · Linde · WOIKOSKI · HYGEAR · hydrogenious LOHC TECHNOLOGIES · HyET Hydrogen · Advent · metacon · Wystrach · INEA · HYSYTECH · Haskel · Swagelok · WORTHINGTON INDUSTRIES · Everfuel

FC Transport

BALLARD · elringklinger · FUEL CELL POWERTRAIN · HyMove · PM PROTON MOTOR · Mercedes-Benz FuelCell · POWERCELL · PLUG POWER · SYMBIO · FREUDENBERG · MICHELIN · faurecia · PLASTIC OMNIUM

FC Stationary

AFCEnergy · CeresPower · Danish Power Systems · elcogen · GENCELL · SOLID POWER · Nedstack · SAINT-GOBAIN · ENGIE · IRD · m-FIELD · MTSA TECHNOPOWER · Helion · BOSCH · convion · SOLENCO POWER · VIESMANN

Others

Fronius · Hinicio · arcola energy · SEIYA consulting · CCS GLOBAL · Persee · EFCF EUROPEAN FUEL CELL FORUM · TÜV SÜD · MAYFAIRMARINE · Sumitomo Benelux s.a./n.v. · Worley · sfice · kiwa · Horizon Educational · TOMO GROUP · JM Johnson Matthey · 'TORAY' · EMEC · hypion · umicore · H2energy

Pillar 2: Policy

CENTRAL OBSERVATION

Except for biofuels (and batteries), all zero-emission and carbon neutral fuels that are envisaged (hydrogen, ammonia, E-LNG, E-diesel, E-methanol) are made from hydrogen.

CONSEQUENCE 1:

- **Regulating GHG emissions and change of fuel will create a demand for H2.**
- Hence shipping regulation becomes one of the short-term end-users regulation triggering the H2 economy
- It is in the interest of the Hydrogen sector:
  - **Push EU to be ambitious**
  - ensure that the regulation is not used to favour LNG as fuel and/or biofuels as short-term solutions postponing all the rest.

CONSEQUENCE 2:

- we need to demonstrate we are able to provide H2 in sufficient quantity and at affordable price
- **We need to cooperate not only with ships but also ports which are key H2 hubs**.

Pillar 2: Policy – EU MRV and ETS

EU Emission Trading System directive

(2003/87/EC)

EU regulation on the Monitoring Reporting and Verification of CO2 emissions from ships
(EU) 2015/757

European parliament and some DGs of the European commission inspired by what was done for aviation:

CO_2 emissions from **aviation** have been included in the **EU emissions trading** system (**EU ETS**) since 2012. Under the **EU ETS**, all **airlines** operating in Europe, **European** and non-**European** alike, are required to monitor, report and verify their emissions, and to surrender allowances against those emissions

ENVIRONMENT CTTEE OF EP VOTED IN FAVOR OF INCLUDING SHIPPING IN THE ETS (July 2020)

Vote in plenary 16/09/20

FuelEU Maritime: European Commission initiative

About this initiative

Type of act

Proposal for a directive to encourage the use of low carbon fuels

New Initiative

FuelEUMaritime

(EC proposal Q4 2020?)

Summary

- Ship traffic to or from ports in the European Economic Area accounts for some 11% of all EU CO2 emissions from transport and 3-4% of total EU CO2 emissions.
- This initiative – **FuelEU Maritime** – aims to increase the use of sustainable alternative fuels in European shipping and ports by addressing:

  - market barriers that hamper their use
  - uncertainty about which technical options are market-ready
  - It is part of a package to bring the sector in line with the EU's ambition of climate-neutrality by 2050.

Pillar 2: Policy – Fuel EUMaritime

Roadmap

Feedback period

27 March 2020 - 24 April 2020

FEEDBACK: CLOSED

→ Hydrogen Europe feedback on the Inception impact assessment for FuelEUmaritime send on 24th of April

Public consultation

Feedback period

02 July 2020 - 10 September 2020

FEEDBACK: OPEN

→ Hydrogen Europe response on the public consultation for FuelEUMaritime. Deadline **10 September**! Input from the Maritime Working Group (**members only**). Hydrogen Europe sent a proposed response (31/07) for members to comment on.

UPCOMING

Commission adoption

Planned for

Fourth quarter 2020

FEEDBACK: UPCOMING

New Initiative

FuelEUMaritime

(EC proposal Q4 2020?)

Pillar 2: Fuel EU Maritime – lessons to be learned

- The development of national regulation has proven to be a barrier to the uptake of alternative fuels.
- Especially for short sea shipping harmonization of regulation/guidelines on e.g. bunkering (the ship-shore interface) needs to start now.
- A robust and sound alternative fuel framework both at IMO, European, national and local level is a prerequisite for the uptake of hydrogen in shipping.

Many lessons can be learned from introduction of LNG as a fuel for ships prior to the implementation of the 0.1% Sulphur limit in the Emission Control Areas (ECAs) in 2015.

- IMO focused on developing a code (IGF-code) allowing ships to burn LNG safely but could not consider the ship-shore interface (bunkering) and issues such as safe loading and unloading of ships while bunkering, standardization of connectors, methane slip, etc...
- EU published EU bunkering guidelines for LNG-fuelled ships in 2018.
- **Port authorities have welcomed this but are bound by own local stricter regulations**. Uncertainty about the availability of LNG in ports led to more uncertainty.

Pillar 4

Hydrogen Europe would welcome the EU to learn from those experience in developing faster new and effective harmonized framework (e.g. on standardization, harmonization of local rules) and robust regulation on SAF-infrastructure for alternative fuels where hydrogen is given a prominent role. We would very much welcome as well IMO to start developing technical regulations for ships powered by hydrogen and hydrogen based fuels such as ammonia.

Pillar 2: Policy – directive on alternative fuel infrastructure

Ports needs to look more broadly at becoming H2 hubs or “H2 Valleys” where hydrogen can be produced or imported, stored and distributed for use in different applications such as:

- **H2 for trucks and rail (e.g. in port areas where electrification of the railway is not possible)**
- **H2 for inland waterways (for inland ports)**
- **H2 for onshore power**
- **H2 for the decarbonisation of terminal and cargo handling equipment**
- **H2 for the industrial hinterland (refineries, chemicals…)**
- …

The revision of the directive on alternative fuels infrastructure will play a crucial role in this regard.

8. **To cover the need for maritime application, ports should provide hydrogen infra structure for ships as a first step.** As we speak, large bunkering ports in the ARA (Antwerp-Rotterdam-Amsterdam) region are building hydrogen-fuelled tugboats. These projects will trigger the design, deployment, and operation of a hydrogen supply chain and the decarbonisation of ports. Hydrogen will be produced from low-carbon sources, whether in ports or elsewhere (e.g. offshore wind) and then delivered to ports via pipelines and/or ships. Hydrogen can then be used as a shipping fuel (but also as a fuel for the other mobility usages within the port) and to decarbonise the ports industrial areas - either as a source of clean energy or as a feedstock for industry (e.g. for ammonia production or refining).

Pillar 2: Policy - Offshore Renewable Strategy (maritime dimension)

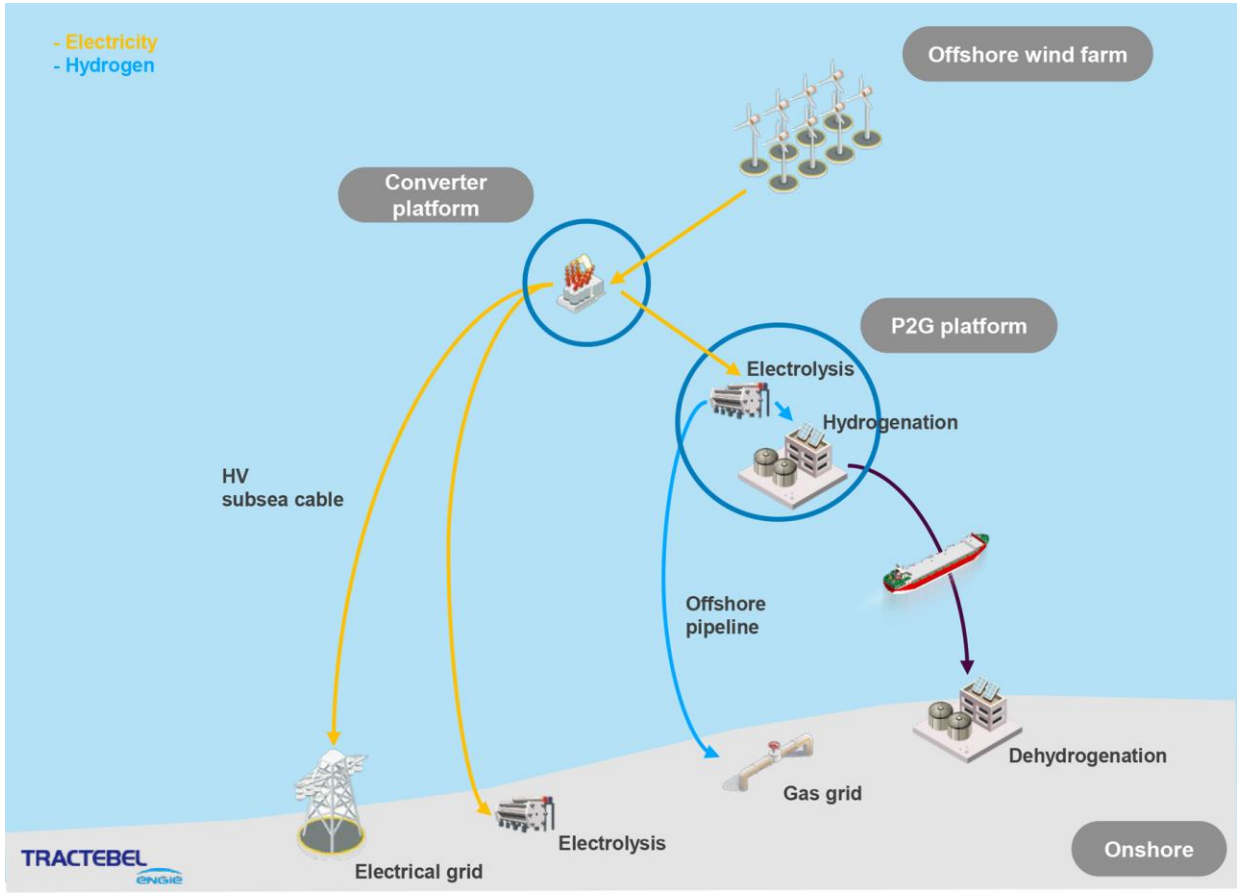
H2 produced on existing and new offshore infrastructure will need to be transported by ship or pipeline to land. Ships will not only transport H2 but also hydrogen fuelled ships will bring crew to work on the platforms and windturbine (for maintenance). Also the platforms could be used as a way to supply hydrogen to any hydrogen fuelled merchant ships in transit.

Intelligence team input

- Potential production capacity of H2 trough electrolysers on offshore platforms
- Investment cost of transporting H2 produced on offshore platform through ships or pipeline

Actions/deliverables (link to comms)

- Policy team: Develop position paper with interested parties in Energy/Maritime WGs with a view to publication.
  Timeline for completion: September/October
- Identify maritime stakeholders (e.g. DEME, CMB, ….)

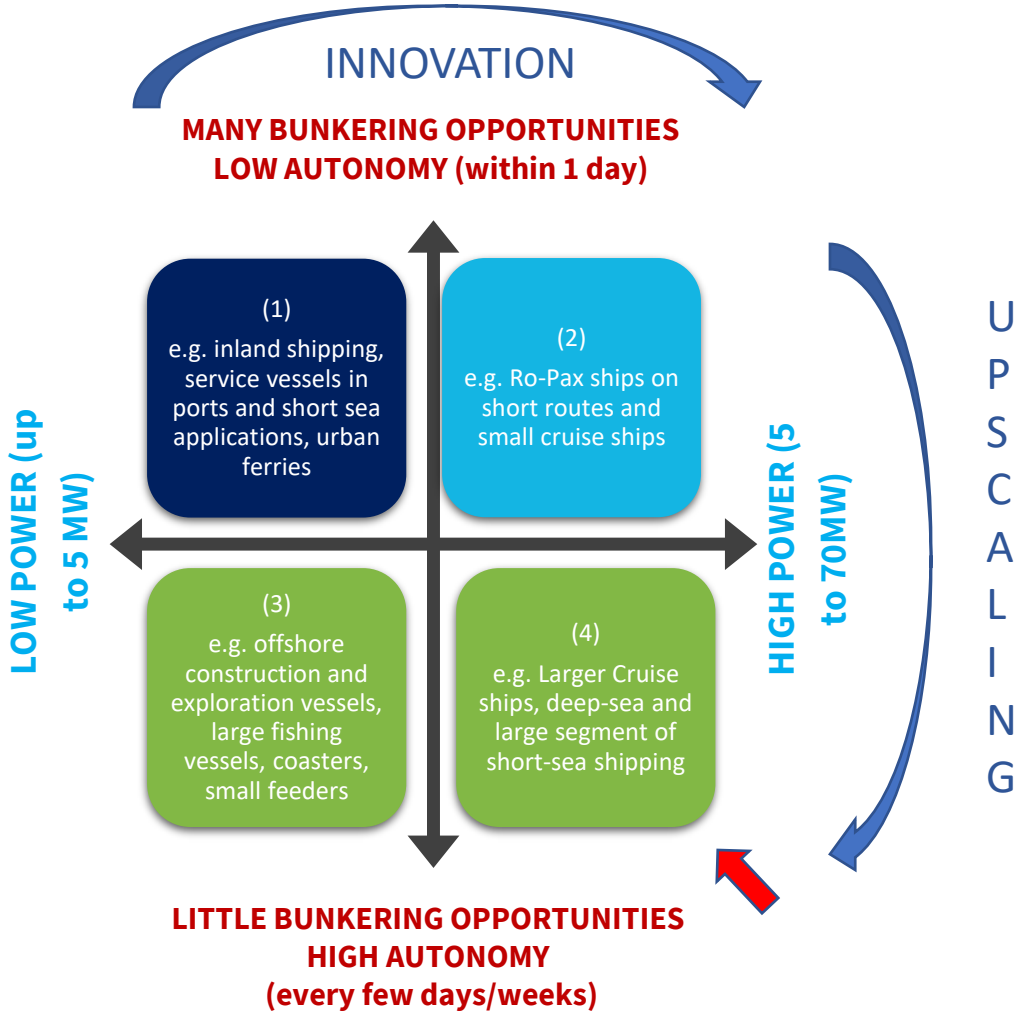


Pillar 3: R&I and Funding - **UPSCALING THROUGH INNOVATION**

Hydrogen Europe will focus on synergizing certain ship types active in ports with fuel cell (and internal combustion engine) technology and **infrastructure in ports**

Ports as Hydrogen valleys

EU ports face same challenges (production and import, storage and distribution)



CATEGORIZATION OF SHIPS TYPES based on power and autonomy will not only bring more structure in the debate but it will also help to scale up technology

PORTS AS HYDROGEN VALLEYS

As we speak large bunkering ports in the ARA (Antwerp-Rotterdam-Amsterdam) region are building hydrogen fuelled ships. Such projects which will trigger the design, deployment and operation of a hydrogen supply chains and the decarbonisation of ports

In Denmark a partnership has been formed between port, airports, shipowners, …the first of its kind to develop an industrial-scale production facility to produce sustainable fuels for road, maritime and air transport in the Copenhagen area. The partnership brings together the demand and supply side of sustainable fuels

- Sustainability
- Scalability
- Storablity

ANGLO BELGIAN CORPORATION

We power your future

BeHydro

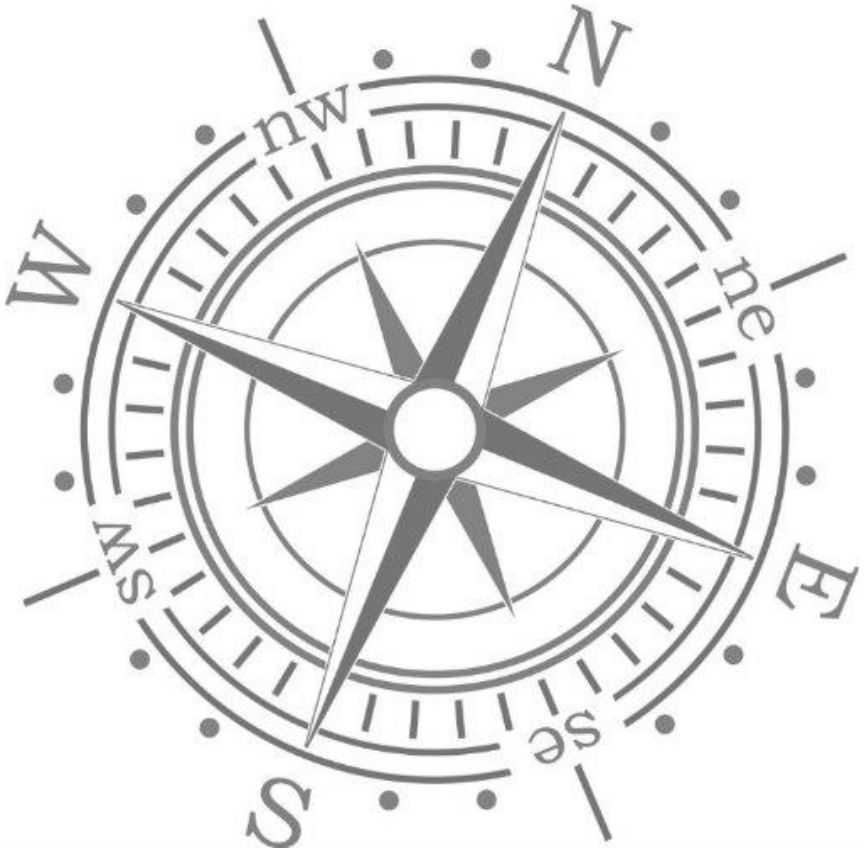
Hydrogen Powered Combustion Engines

September 2020, Koen Christianen (ABC) & Roy Campe (CMB)

CMB.TECH

Table of contents

- Who is BeHydro (ABC & CMB)
- Why Hydrogen?
- Why combustion engines?
- BeHydro engines
- Some H_2 reference projects
- Q&A



ANGLO BELGIAN CORPORATION
We power your future

Company of ABC
ABC today…

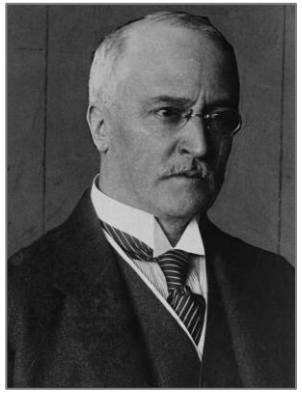
- HQ & production facility in Gent (B)
- 330 people
- 2019 T/O: € 100 Mio.
- > 90 % T/O = export

ANGLO BELGIAN CORPORATION
We power your future

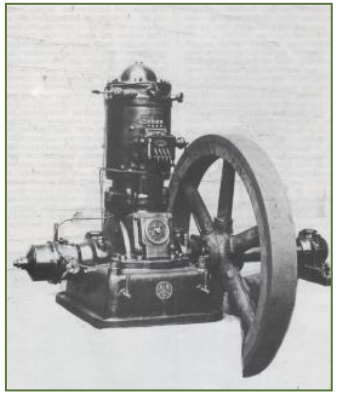
Company of ABC
History

- Founded in 1912
- Patent of Rudolf diesel
- Core business : medium speed 4-stroke engines

Ateliers Onghena



Rudolf Diesel



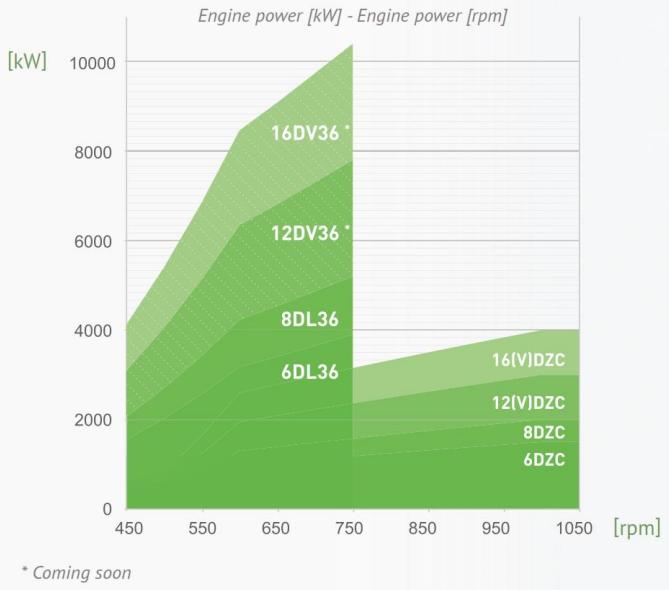
Type: 1D (14 HP)

World Expo in Ghent

ANGLO BELGIAN CORPORATION
We power your future

Company of ABC
From 0,8 to 10,5 MW

Power range



* Coming soon

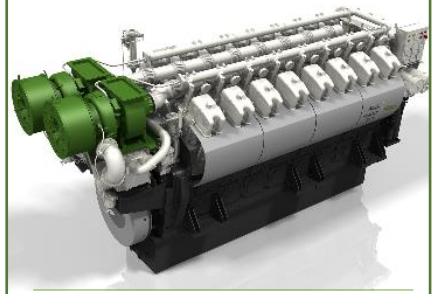
DZC series

Bore: 256 mm
Stroke: 310 mm

6 & 8 cylinders in line

Up to 1,000 rpm
Up to 2,000 kW

(V)DZC series



Bore: 256 mm
Stroke: 310 mm

12 & 16 cylinders in V

Up to 1,000 rpm
Up to 4,000 kW

DL36 series

Bore: 365 mm
Stroke: 420 mm

6 & 8 cylinders in line

Up to 750 rpm
Up to 5,200 kW

DV36 series

Bore: 365 mm
Stroke: 420 mm

12 & 16 cylinders in V

Up to 750 rpm
Up to 10,500 kW

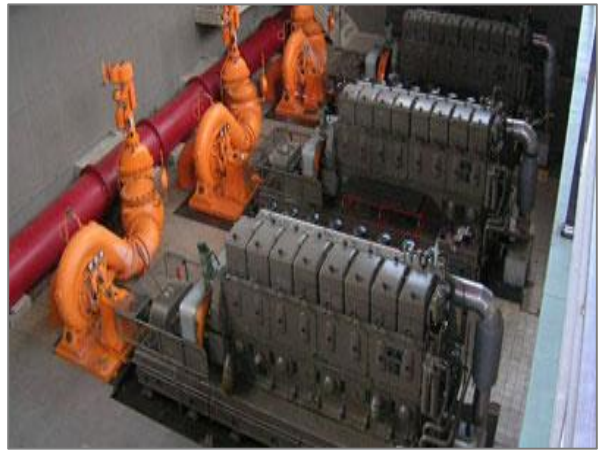
ANGLO BELGIAN CORPORATION
We power your future

Company of ABC
Market overview

Marine propulsion

Power generation

Traction

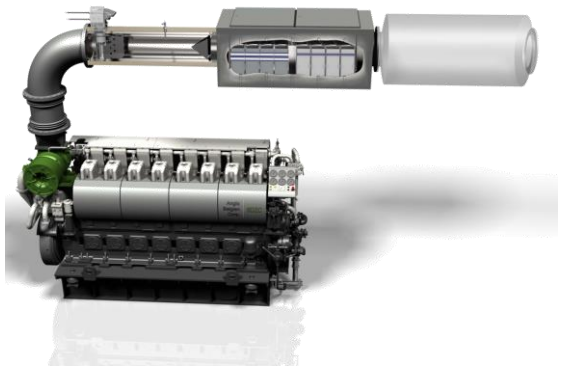


Industrial application

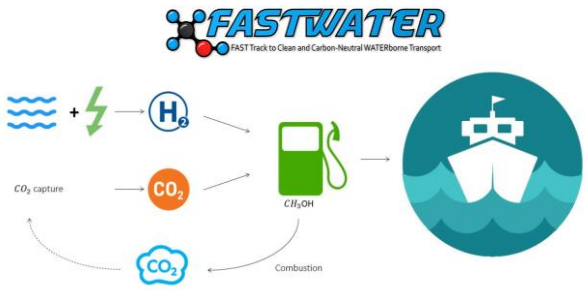
ANGLO BELGIAN CORPORATION
We power your future

Company of ABC
Developments

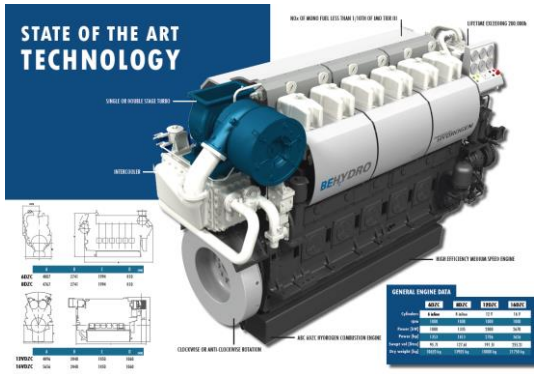
Exhaust aftertreatment



Methanol



Hydrogen

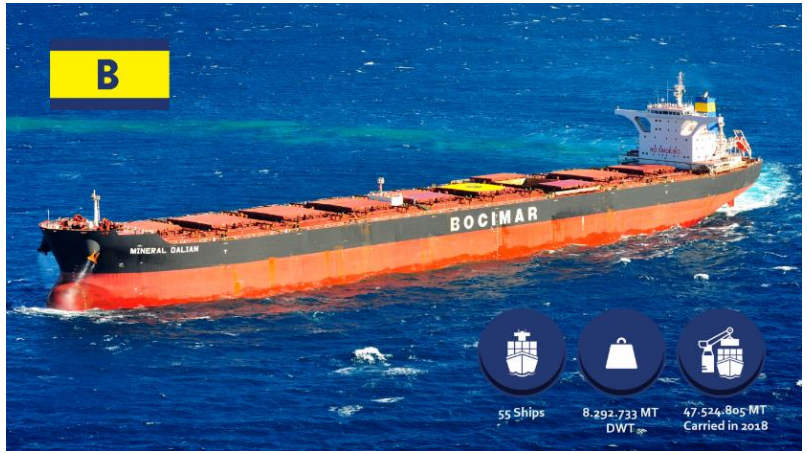


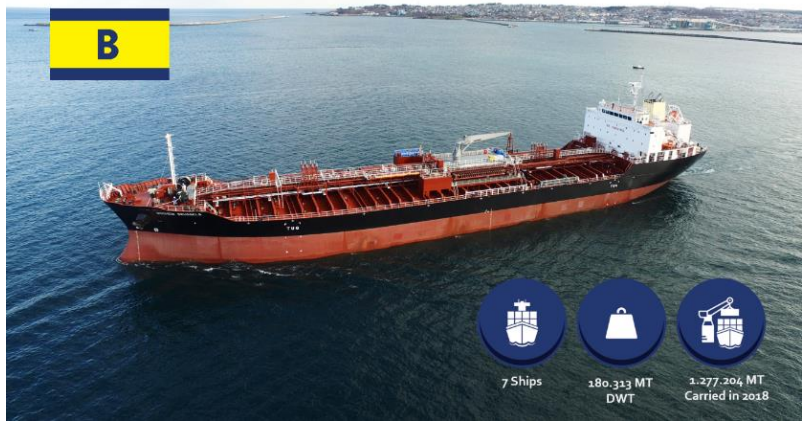
Digital Twins

CMB (Compagnie Maritime Belge) owns/operates 80 ships

- CMB is a maritime group with its registered office in Antwerp and was founded in 1895.
- 100% privately owned by Saverys family.
- 130 shore-based staff and about 3000 seafarers.
- The group consists of 5 divisions:
  - **Bocimar**: Active in dry bulk shipping
  - **Delphis**: Container fleet, mainly ice classed
  - **Bochem**: Chemical tanker fleet
  - **CMB.TECH**: Development of new technologies
  - **Reslea**: Maritime Campus Antwerp

CMB BOCIMAR BOCHEM DELPHIS CMB.TECH MCA MARITIME CAMPUS ANTWERP

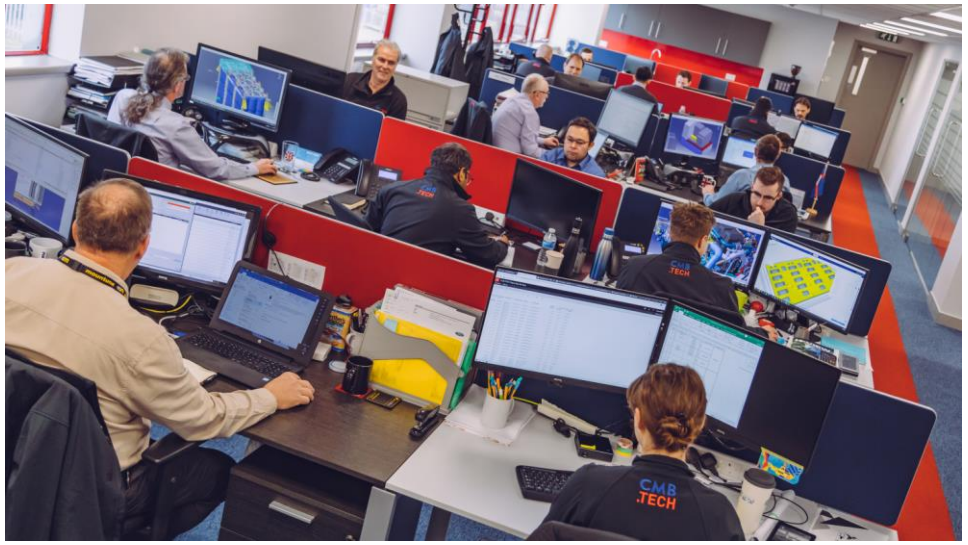


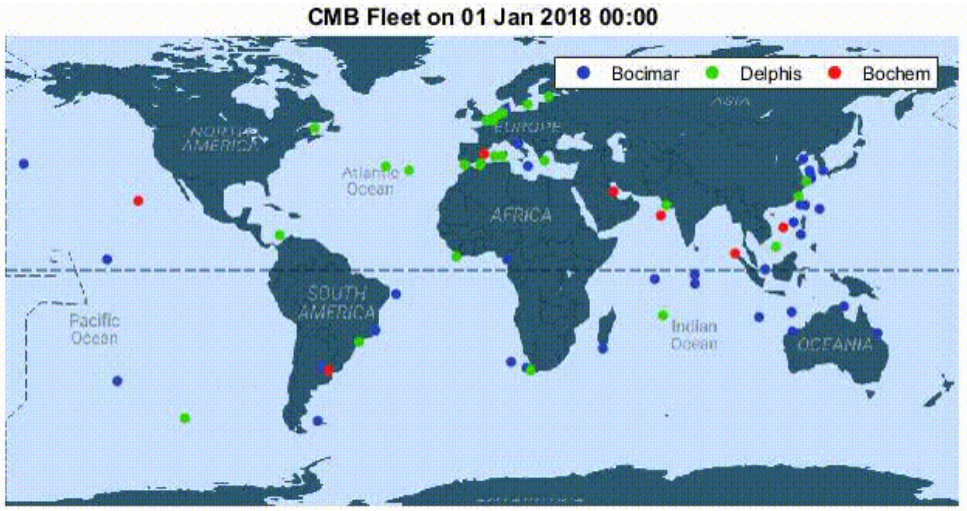


CMB BOCIMAR BOCHEM DELPHIS CMB.TECH RESLEA

CMB.TECH: the Innovation & Development division of CMB

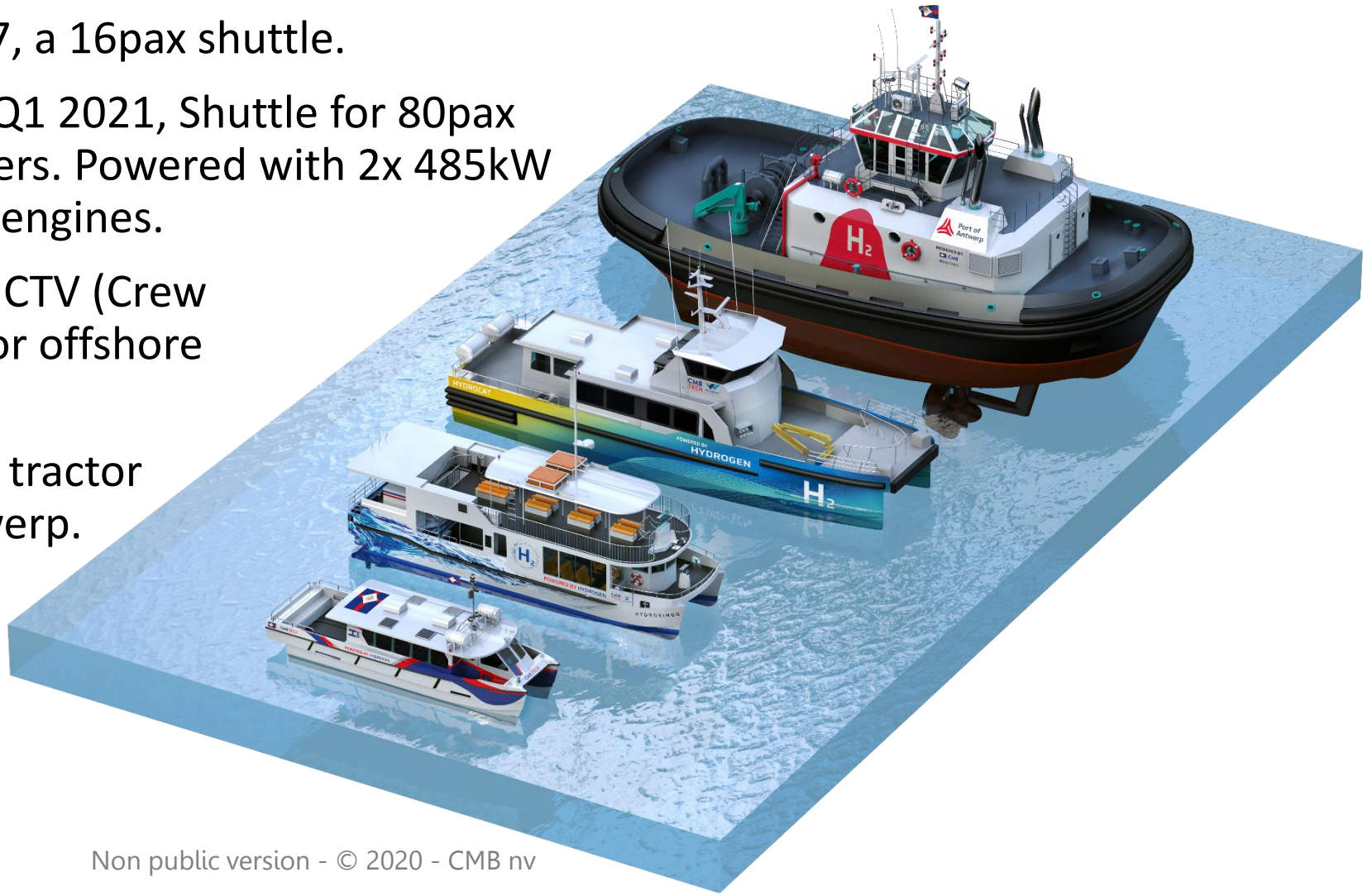
- CMB.TECH focuses on:
  - Hydrogen technology;
  - Fleet performance monitoring;
  - Weather routing software;
  - On-board battery pack to reduce emissions for redundancy power;
  - Energy saving technologies.
- Goals:
  - Reduction of emissions;
  - Implementation of cost saving technologies;
  - Improvement of the operational performance;
  - Assure that newbuildings are future-proof.



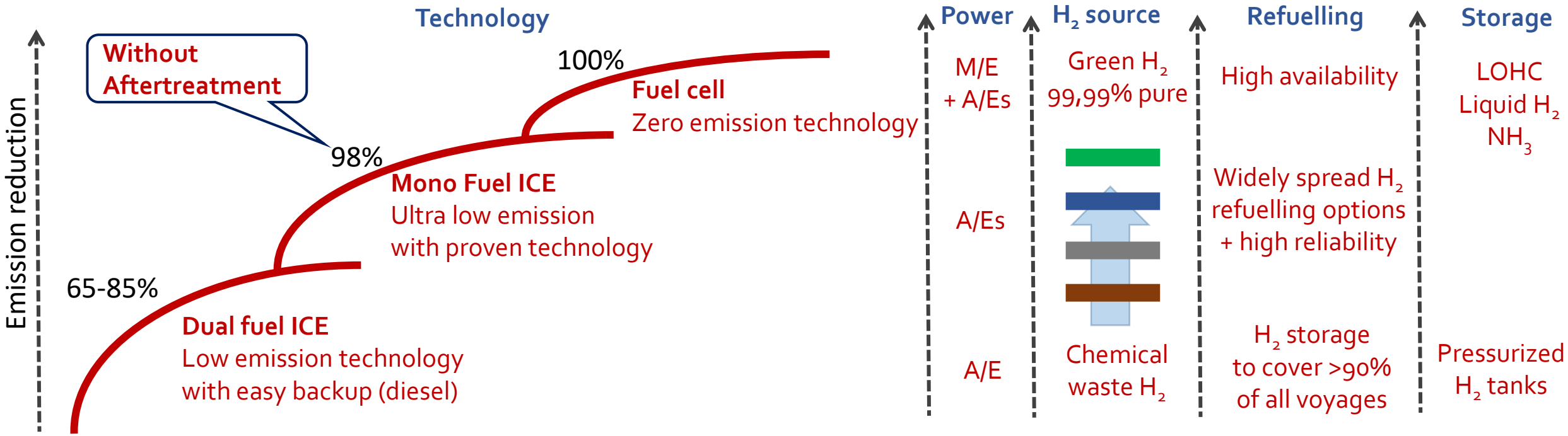


CMB is pioneering with Hydrogen powered vessels

- **Hydroville:** Launched in 2017, a 16pax shuttle.
- **Hydrobingo:** Delivery Japan Q1 2021, Shuttle for 80pax for the Japanese coastal waters. Powered with 2x 485kW hydrogen diesel combustion engines.
- **Hydrocat:** Delivery Q2 2021, CTV (Crew Transfer Vessel) to be used for offshore wind parks in the North Sea.
- **Hydrotug:** Delivery Q1 2022, tractor tug built for the Port of Antwerp. The vessel has 2x 2MW H_2-diesel engines and 400kg of H_2 storage for daily use.

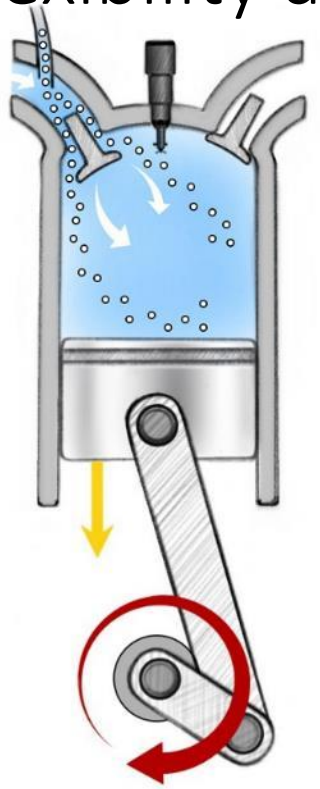


Heavy industries (such as shipping) require incremental innovation instead of disruptive innovation

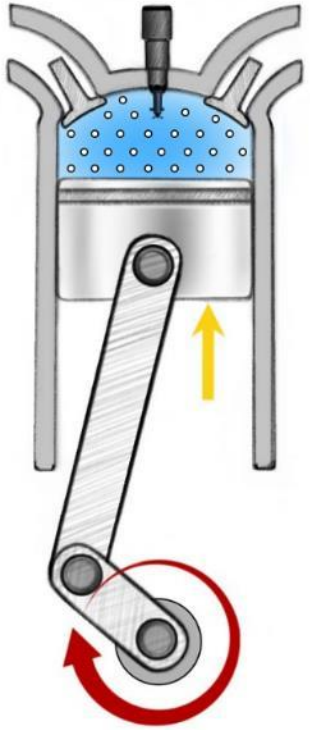


➔Dual fuel technology is the first step towards the zero emission goal, while the service can be guaranteed as one always can rely on diesel

Hydrogen-Diesel co-combustion: ability to combine fuel flexibility and efficiency with environmental performance



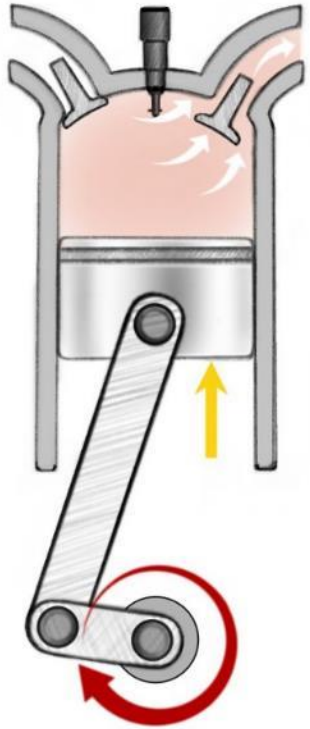
Hydrogen is injected at the port and aspirated in the cylinder during intake stroke



Hydrogen mixes further into a uniform and homogeneous mixture during the compression stroke

A small amount of pilot fuel (diesel) is injected into the chamber just before top dead centre

Diesel auto-ignites (due to high temperature and pressure) and co-combusts with all the H_2, forcing the piston down during the power stroke

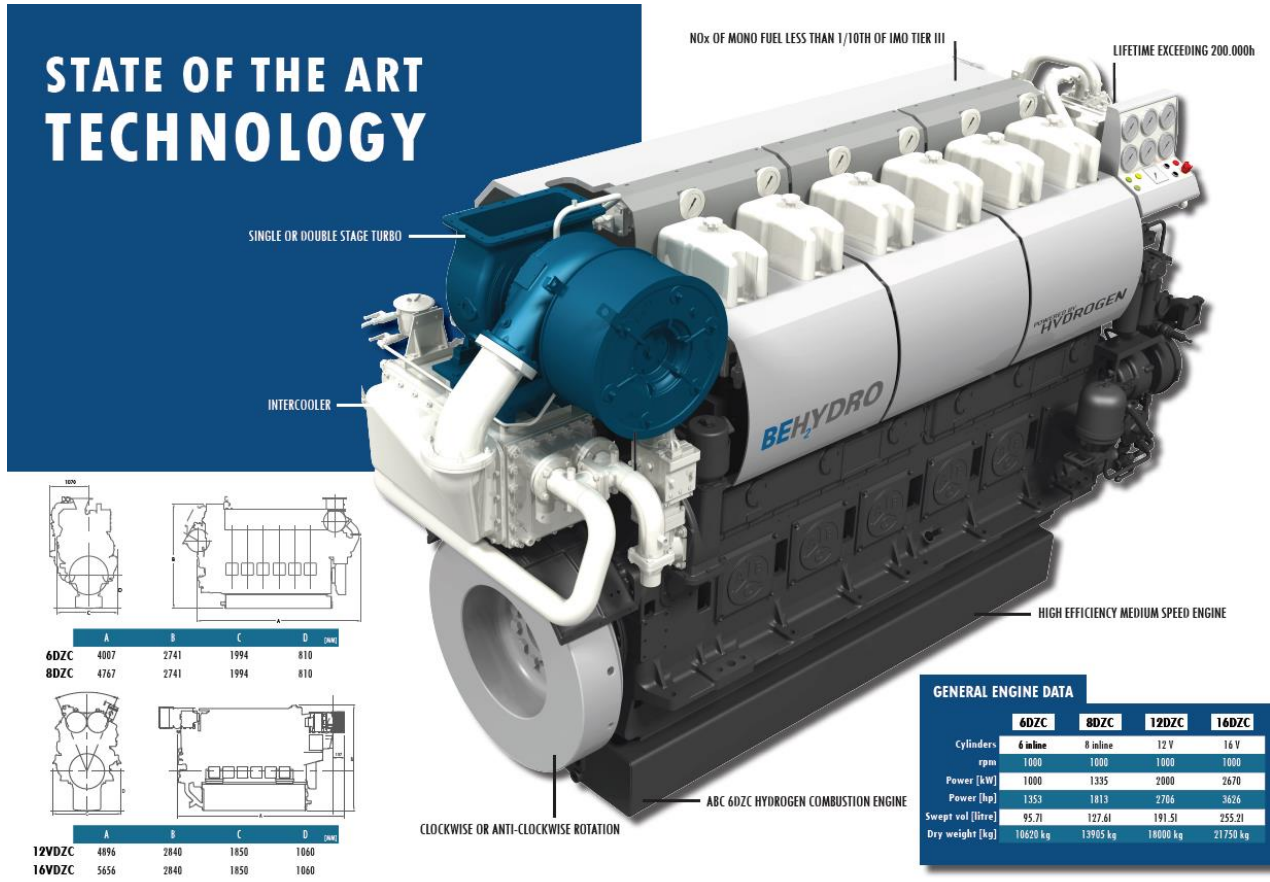


The cylinder is cleaned during the exhaust stroke, having lower NO_x and CO_2 emission in the exhaust gas

Medium speed H_2 engines (both mono a- dual fuel) are being developed and build

BEH$_2$YDRO

- BeHydro medium speed engines have a power range from 1-2.7MW.
- The engines are based on the DZ series of ABC Engines. These engines have a proven track record for more than 30y. The dual fuel methane-diesel is also available for many years and has a successful history.
- Both mono fuel (with spark ignition) as well as dual fuel (with diesel for the compression ignition) engines have been developed.
- Efficiency is expected to be about 42%. If one reuses the waste heat (for CHP usage), the total efficiency will be about 70%.

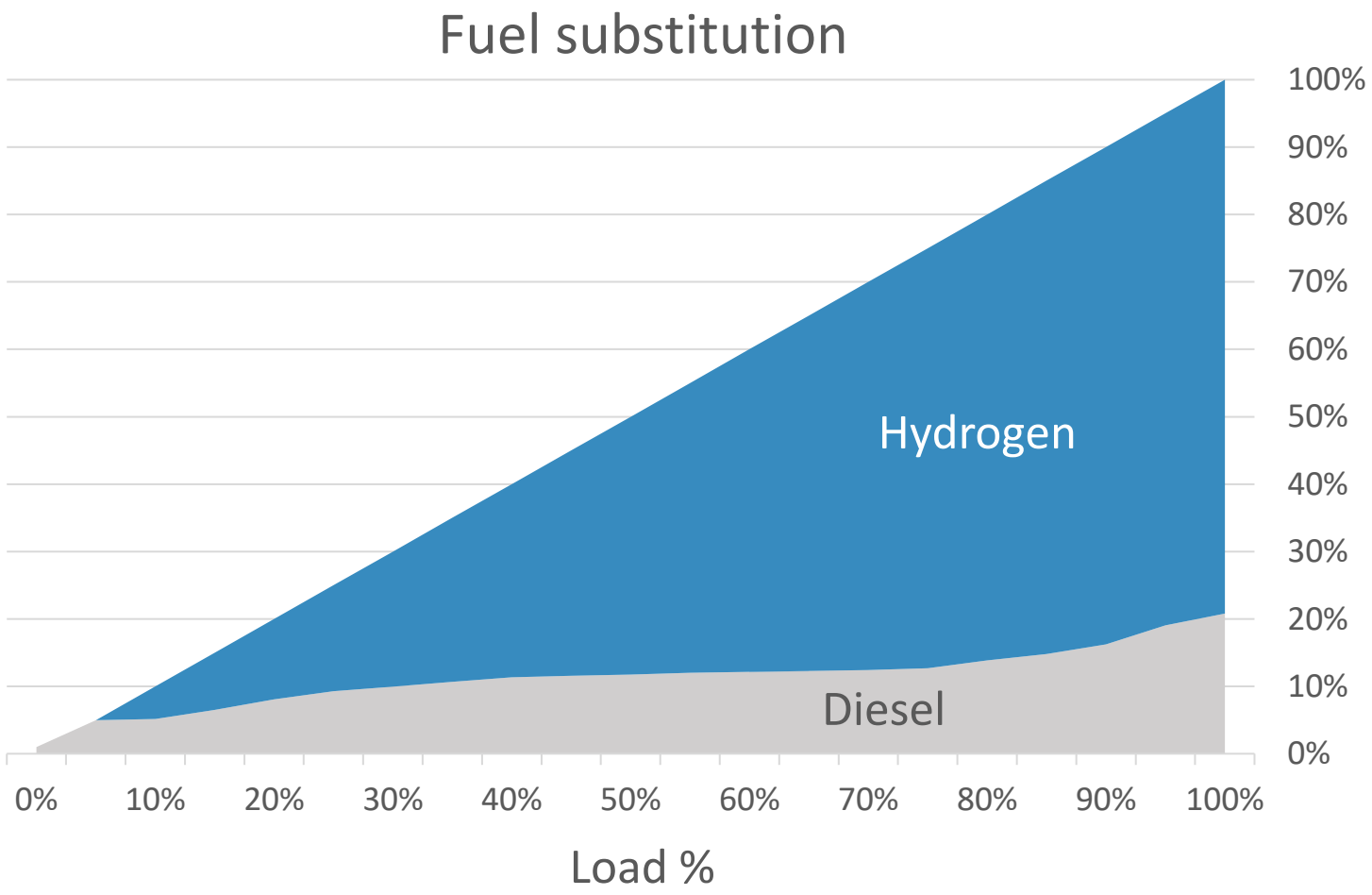


Testing on the full scale 1MW dual fuel engine started in June 2020

The dual fuel engine will be launched to the public on the 17th of September

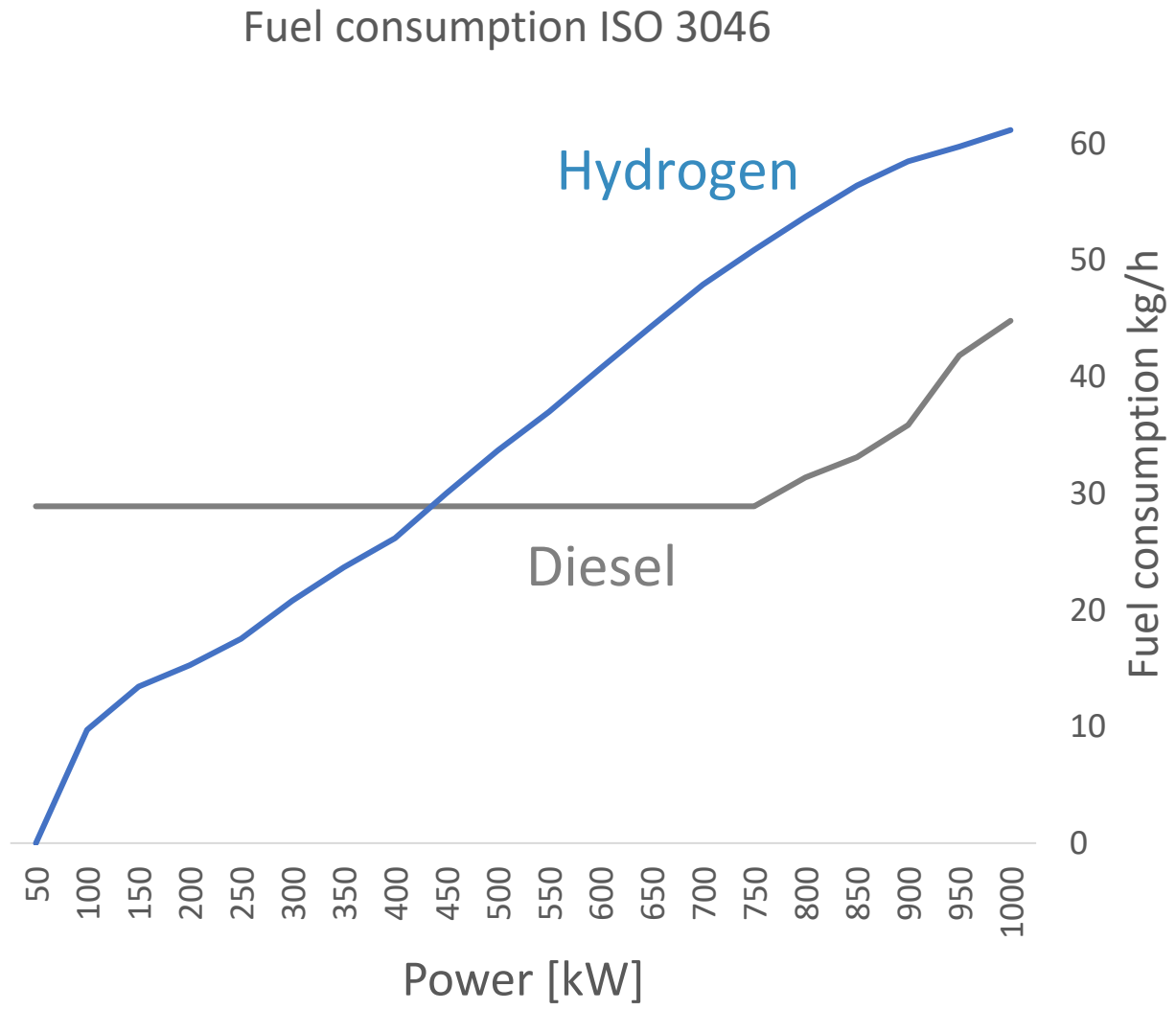
At maximum power output, the carbon footprint of the dual fuel is 80% lower

- 1000kW @ 1000rpm
- Diesel substitution ratio of 80%
- Efficiency up to 42% @ 1000kW
- Emissions on Hydrogen also IMO 2 compliant (<= 8.93 g/kWh NOx)
- The pilot fuel is optimized, but a minimum quantity is still required.



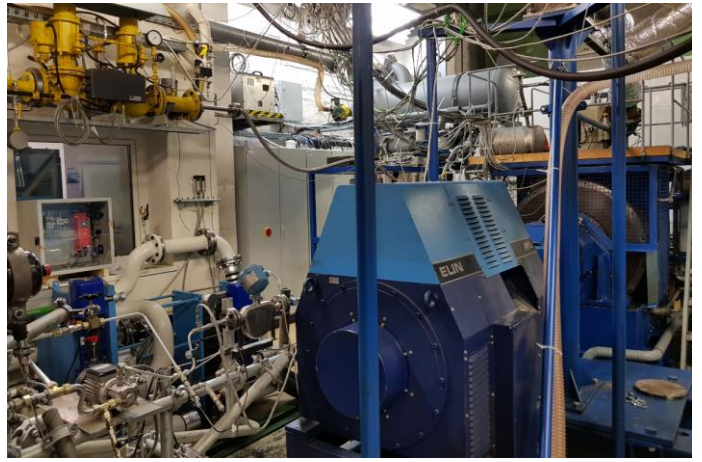
At maximum power output, the carbon footprint of the dual fuel is 80% lower

- Fuel consumption @ 1000kW:
  - Hydrogen: 61kg/h
  - Diesel: 45kg/h
- Up to 75% load, the diesel injection is only the minimum possible for the diesel injectors.

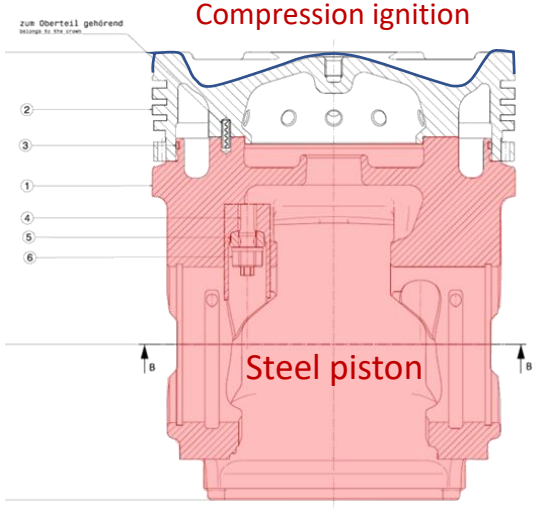


The design of the spark ignition engine is frozen and is based on the 3 extensive test sessions on a mono cylinder setup

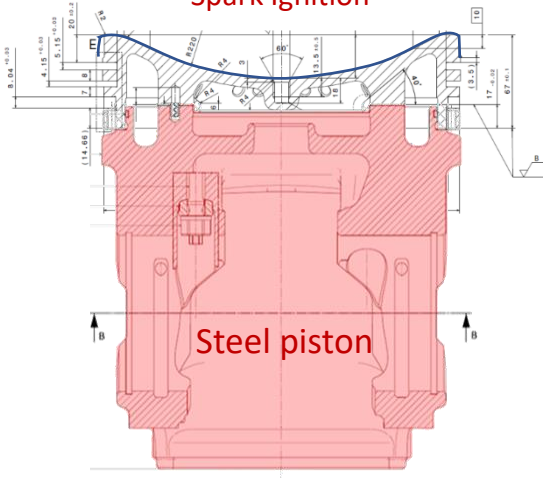
- Replacement of the diesel injector with a spark plug.
- 3-5% higher efficiency is measured with the spark ignition compared to the base diesel version.
- Only pollution measured is the consumption of the lubrication oil, which is in the PPM range.
- NO_x and particle number levels are extremely low indicating that no expensive after treatment is required saving massively on the costs.
- Production of the full scale engine will start once the H_2 system has been validated on the dual fuel engine.
- New ignition coil and with Bosch spark plugs designed to run 1000s of additional hours.



Crown
Compression ignition



Crown
Spark Ignition



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Hydrotug

Delivery Q1 2022

Hydrotug is a tractor tug built for the port of Antwerp. The vessel has 2x 2MW hydrogen diesel engines and 400kg of H_2 storage for daily use.

Mobile shore power solution

In tendering with Port of Rotterdam

A BeHydro medium speed gen-set will be used to supply a large sea going ship with clean shore power.

Hydrogen Power Barge

Concept study ongoing

Mono fuel BeHydro gensets and hydrogen storage are installed on a barge to provide clean energy to ships. The barge can also be used for refuelling.

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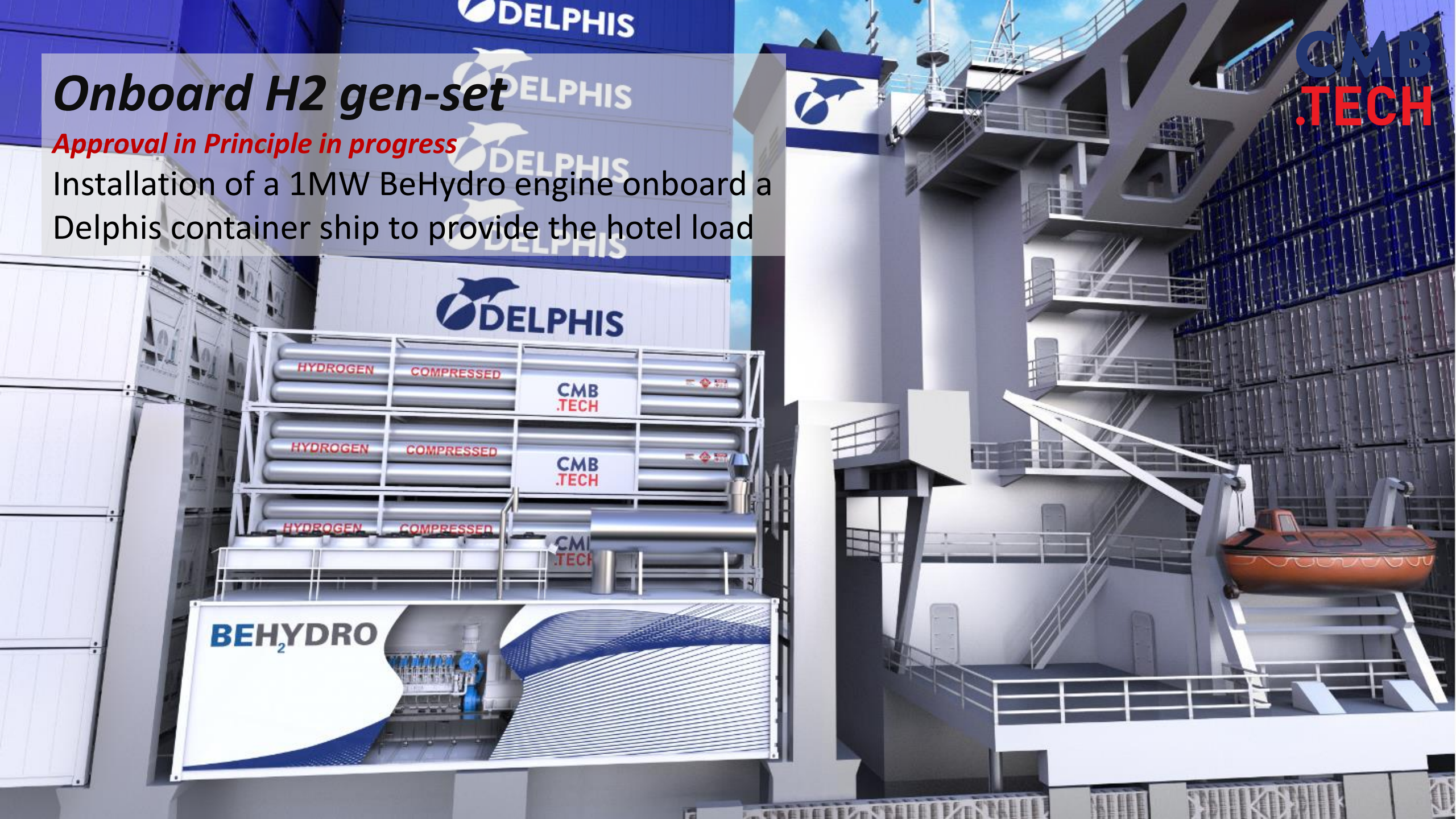
Onboard H2 gen-set

Approval in Principle in progress

Installation of a 1MW BeHydro engine onboard a Delphis container ship to provide the hotel load



H2 freight locomotive

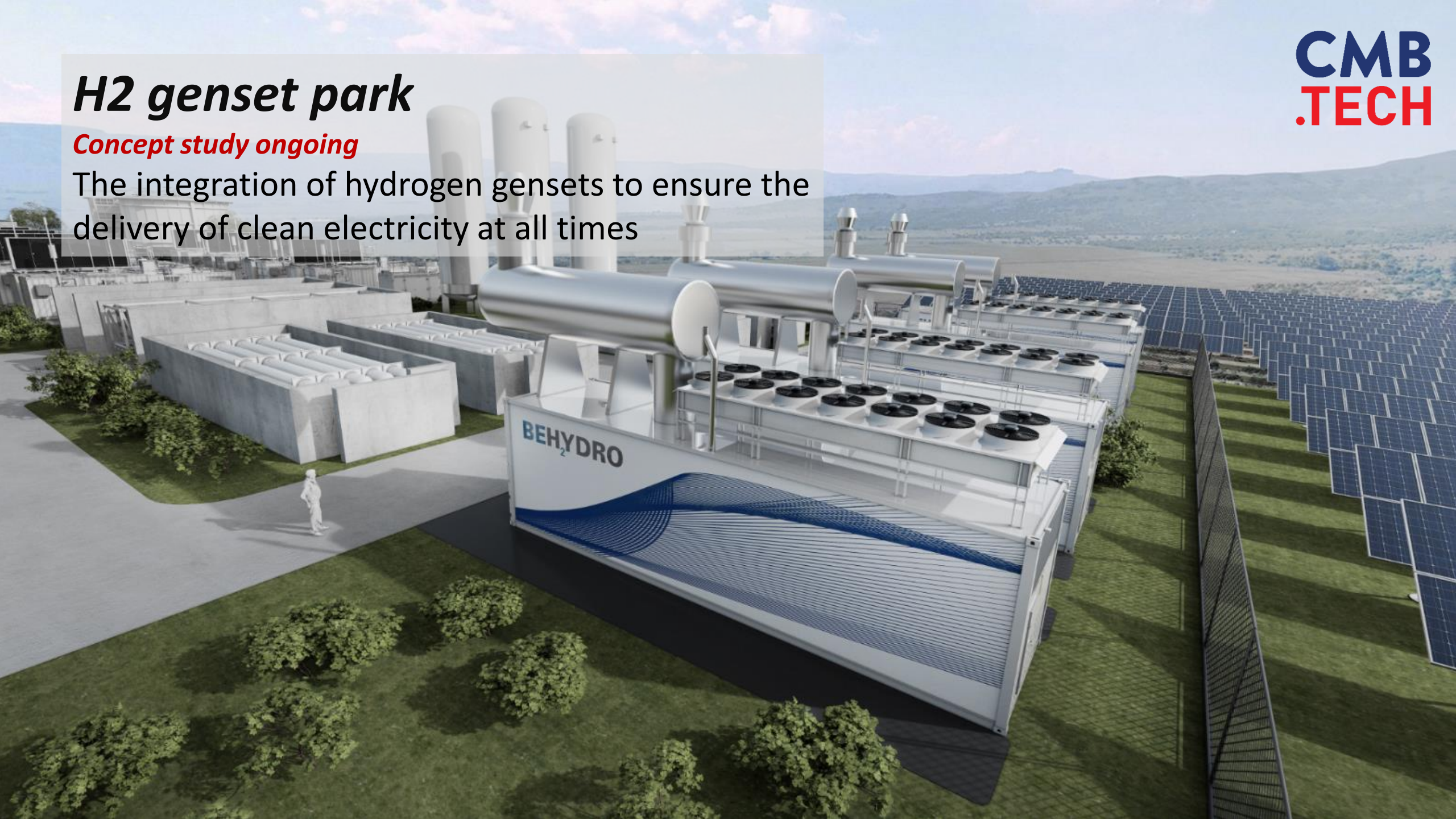
Feasibility phase

A 1MW freight locomotive will be retrofitted with 30kg of hydrogen storage to reduce emissions

H2 genset park

Concept study ongoing

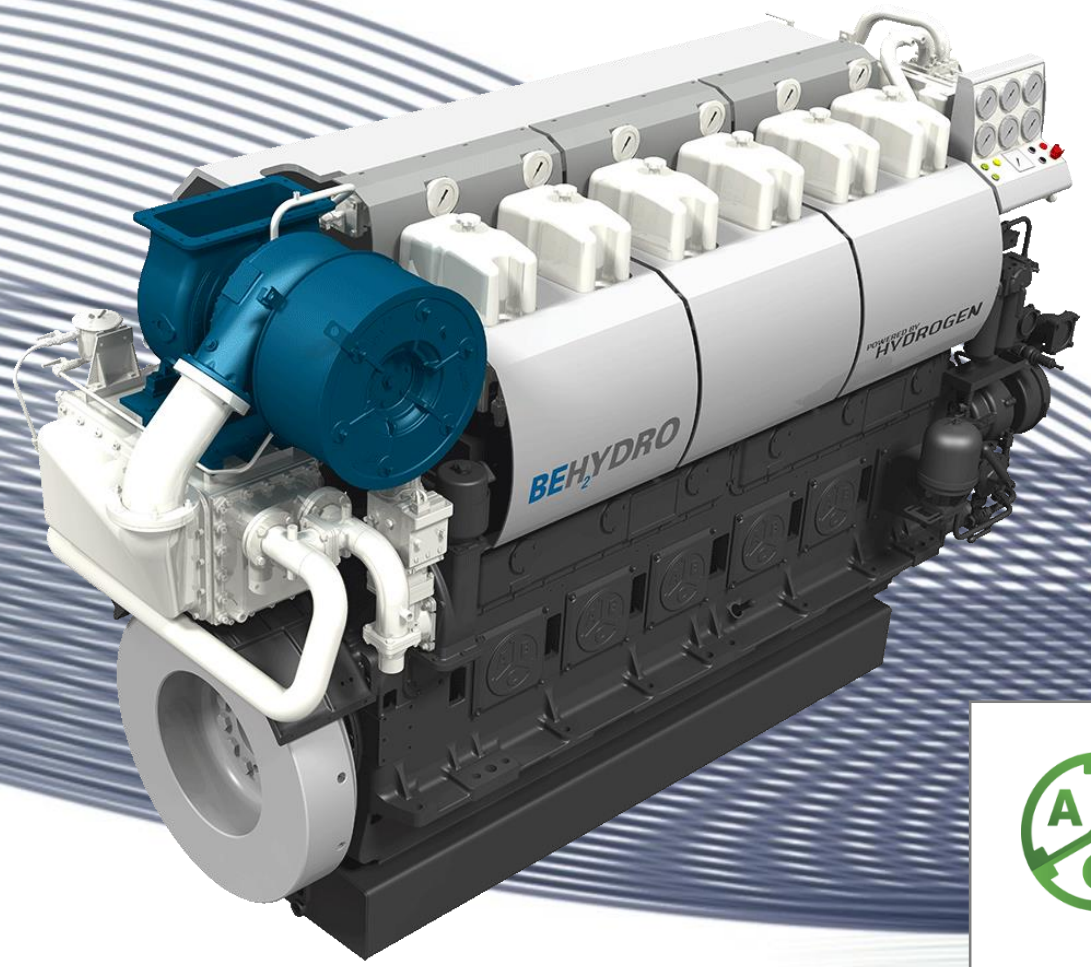
The integration of hydrogen gensets to ensure the delivery of clean electricity at all times



Maritime & public H_2 Refuelling Station

Delivery Q1 2021

CMB is developing the first maritime & public H_2 refuelling station which is equipped with a 1.2 MW PEM electrolyser and 500bar tube trailer filling station



Q&A

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