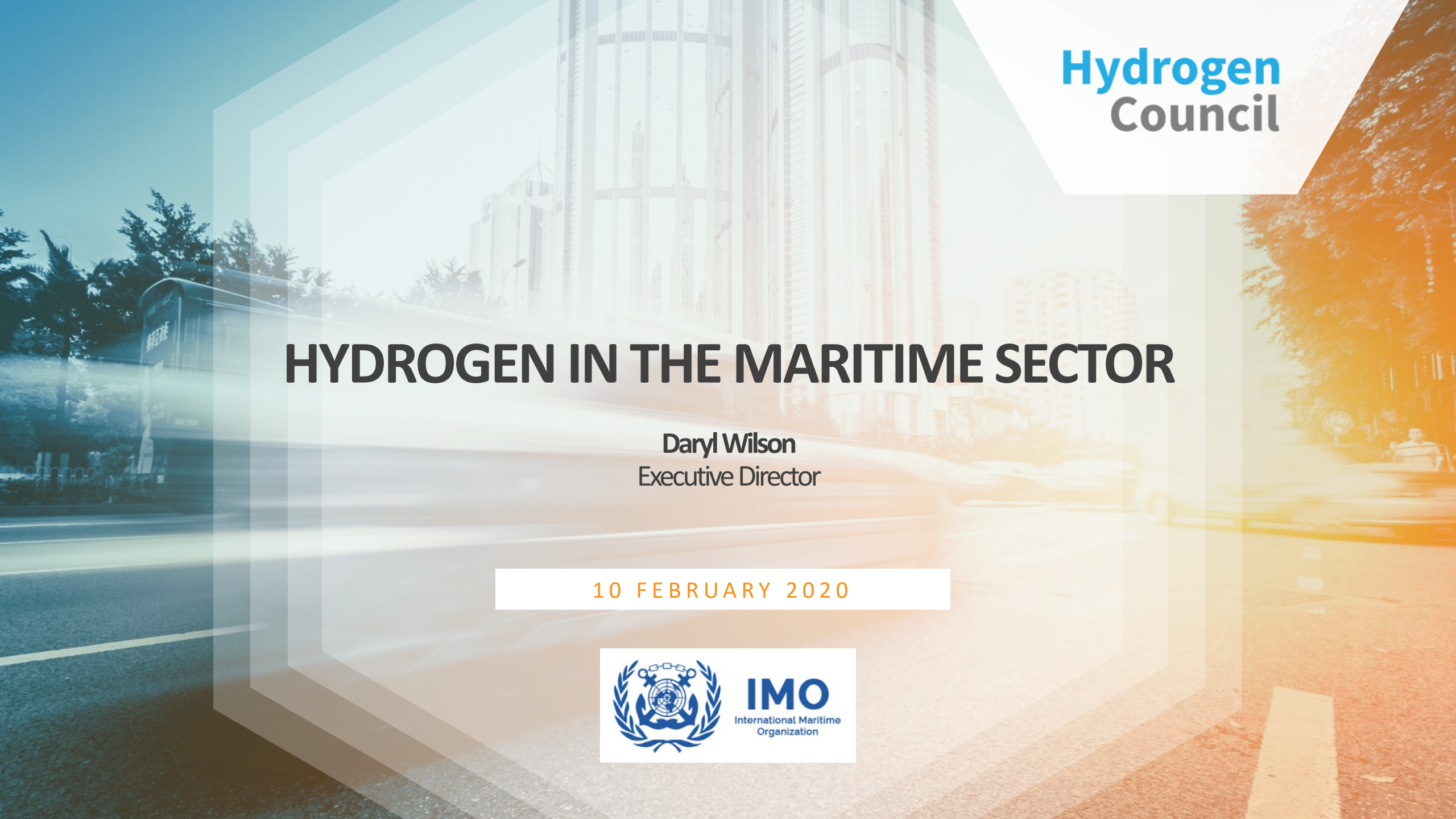


Hydrogen Council

HYDROGEN IN THE MARITIME SECTOR

Daryl Wilson
Executive Director

10 FEBRUARY 2020

IMO
International Maritime Organization

THE HYDROGEN COUNCIL

Introduction

HYDROGEN COUNCIL

A global CEO-led initiative

Founded at WORLD ECONOMIC FORUM Davos 2017

Grown from 13 to **109** companies

Members across **20+** countries

Representing **6.9** MILLION jobs

€19.1 TRILLION in revenues

ONE SHARED VISION

A STRONG & DIVERSE GROUP

Steering Members

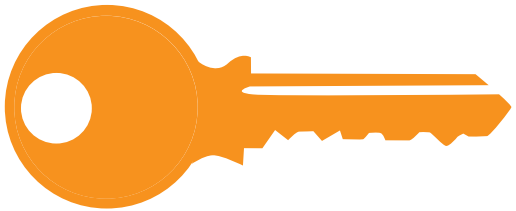
Supporting Members

Investor Group

**Reflects membership as of February 2021*

OUR VISION

Hydrogen has a key role to play in the energy transition



Based on **real industry data**, the Council sees low-carbon and renewable hydrogen as an enabler of the future energy system, growing its role over time and delivering tangible benefits:

By 2030

H_2 scales up to achieve competitiveness

- ✓ Cost falls sharply, making hydrogen a competitive low-carbon option across 22 applications – equivalent to 15% of annual global energy demand

By 2050

H_2 reaches full potential

- ✓ 6 GT of CO_2 abatement annually
- ✓ 30 million jobs
- ✓ $2.5 trillion market

Sources:

"Hydrogen, Scaling Up" report, 2017
"Path to Hydrogen Competitiveness" report, 2020

STATE OF PLAY

Hydrogen

HYDROGEN DEPLOYMENTS

1-49% increase
50+% increase
FC CHP, MW
Electrolysis, MW
HRS, #
FCEVs, #
Forklifts, #
Commercial vehicles, #

Americas

	Status quo	2030 outlook
Electrolysis, MW	130 ⩓	>25,000 ⩓
HRS, #	60	4,300
FCEVs, #	8,800 ^	3.7 mn
Commercial vehicles, #	32	~300,000
Forklifts, #	30,000	~300,000
FC CHP, MW	500 ⩓	n/a

Europe & Middle East

	Status quo	2030 outlook
Electrolysis, MW	84	>40,000 ⩓
HRS, #	258 ⩓	3,400
FCEVs, #	2,072 ⩓	~4.2 mn
Commercial vehicles, #	531 ⩓	~45,000
Forklifts, #	~300	n/a
FC CHP, MW	108 ⩓	n/a

APAC

	Status quo	2030 outlook
Electrolysis, MW	40 ^	~16,500 ⩓
HRS, #	288 ⩓	2,380
FCEVs, #	11,084 ⩓	~5.1 mn
Commercial vehicles, #	6,270 ⩓	~650,000
Forklifts, #	n/a	n/a
FC CHP, MW	1,583 ⩓	~26,500

GLOBAL

	Status quo	2030 outlook
Electrolysis, MW	**232** ⩓	**>80,000** ⩓
HRS, #	**680** ⩓	**>10,000**
FCEVs, #	**21,973** ^	**~13 mn**
Commercial vehicles, #	**6,833** ⩓	**~1 mn**
Forklifts, #	**30,300**	**n/a**
FC CHP, MW	**2,190** ⩓	**n/a**

SOURCE: McKinsey Hydrogen deployment tracker; EU-, US- and Korea-roadmap studies, national targets, IPHE, press

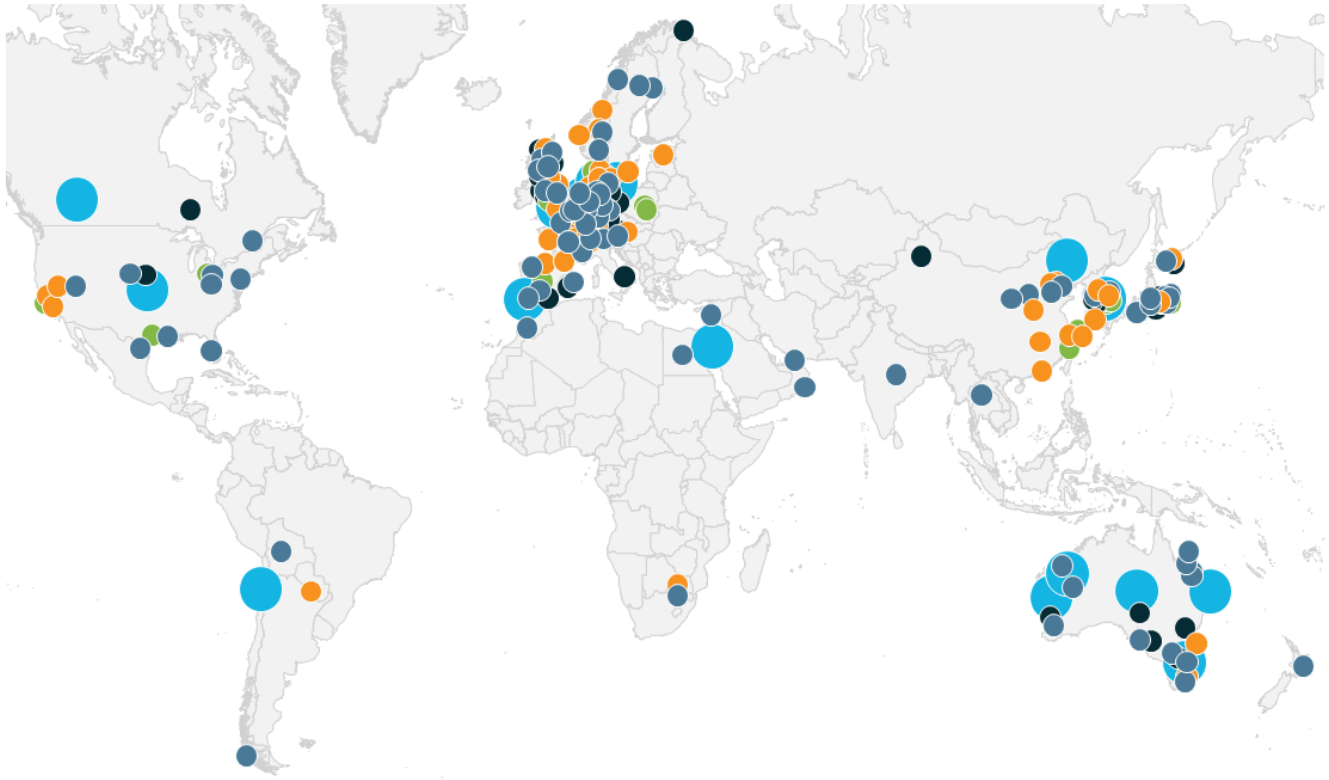
HYDROGEN PROJECTS

Around the world hydrogen projects of unprecedented scale are being announced across the entire value chain, with 85% located in Europe, Asia and Australia

228 announced projects [1]

Projects per region:

- **126** Europe
- **24** Oceania
- **46** Asia and China
- **19** North America
- **5** Latin America



17
Giga-scale production: Green H2 projects > 1GW and blue H2 projects > 200 kt p.a

90
Larger-scale industrial usage: refinery; ammonia, methanol. Steel, and industry feedstock

53
Transport : transportation applications and hydrogen and synfuel production for mobility

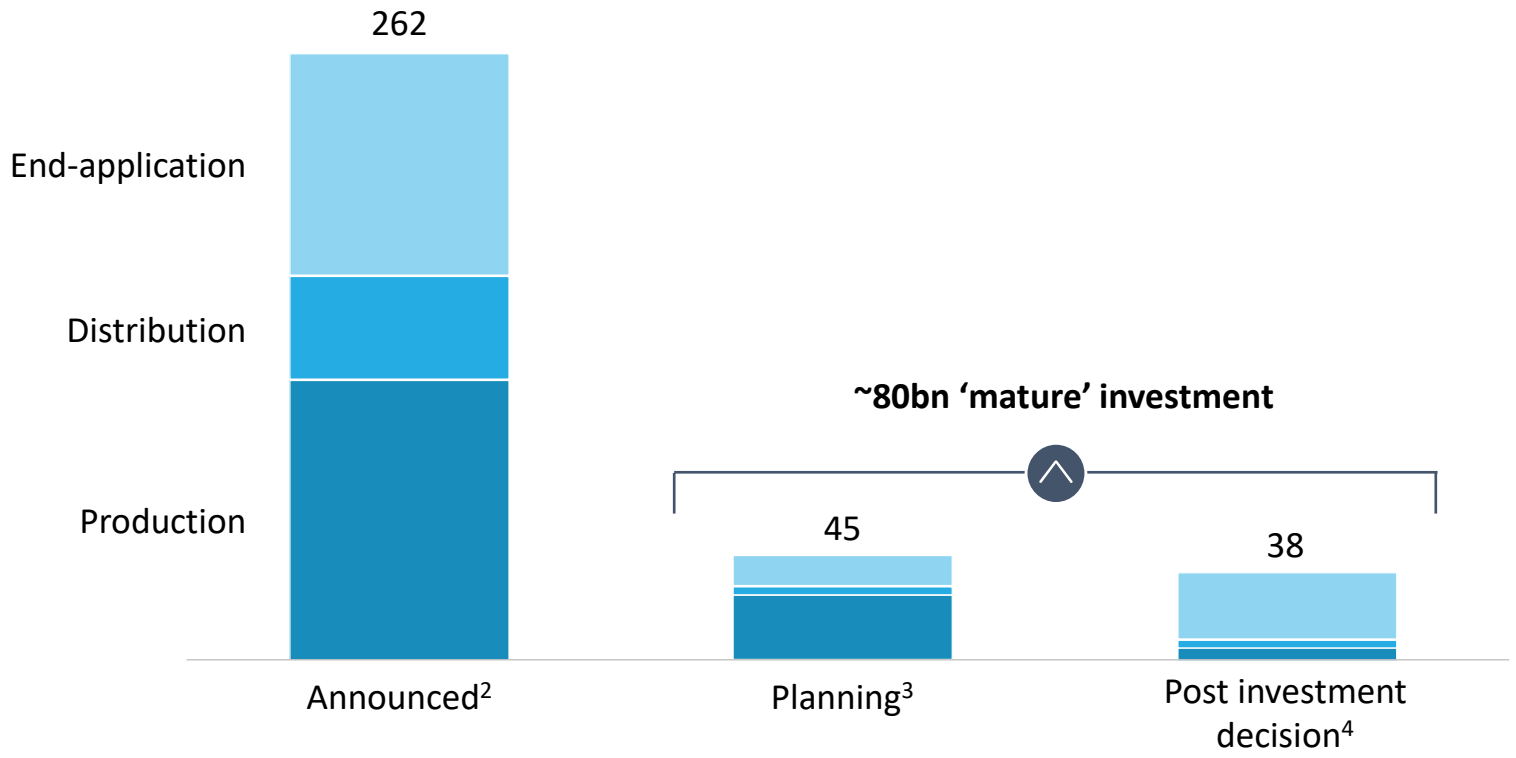
45
Integrated H_2 economy: cross-industry, and projects with different types of end-uses

23
Infrastructure projects: H_2 distribution, transportation, conversion, and storage

HYDROGEN INVESTMENTS

Around 80bn of announced investments are considered mature, either in planning stages or post FID1

USD bn



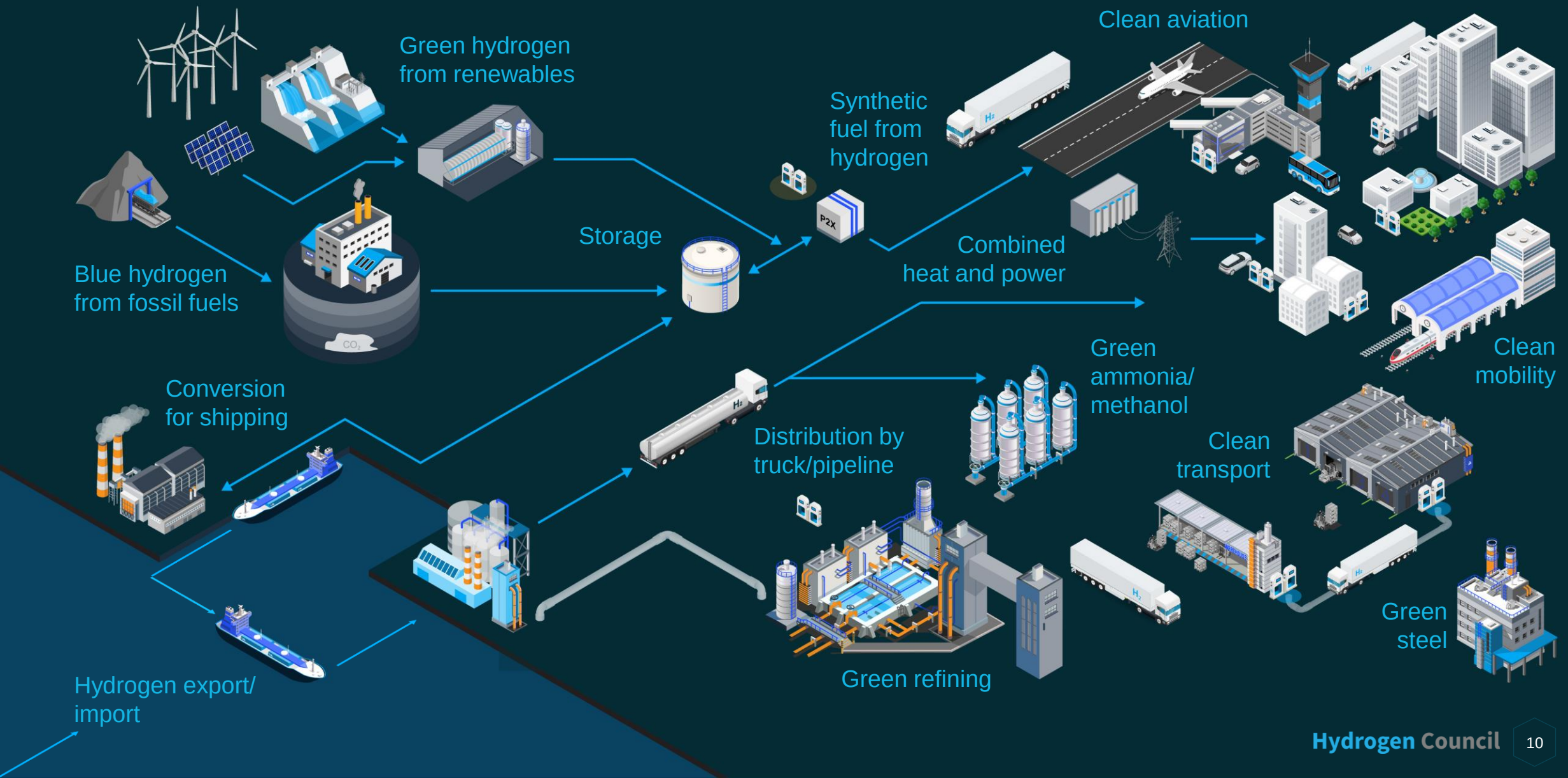
70bn of government funding has been announced to support project and technology development

6X increase in private investment until 2025 compared to 2019 spending. And x16 until 2030

80% of private investment allocated to capex, while the remaining is into R&D and M&A

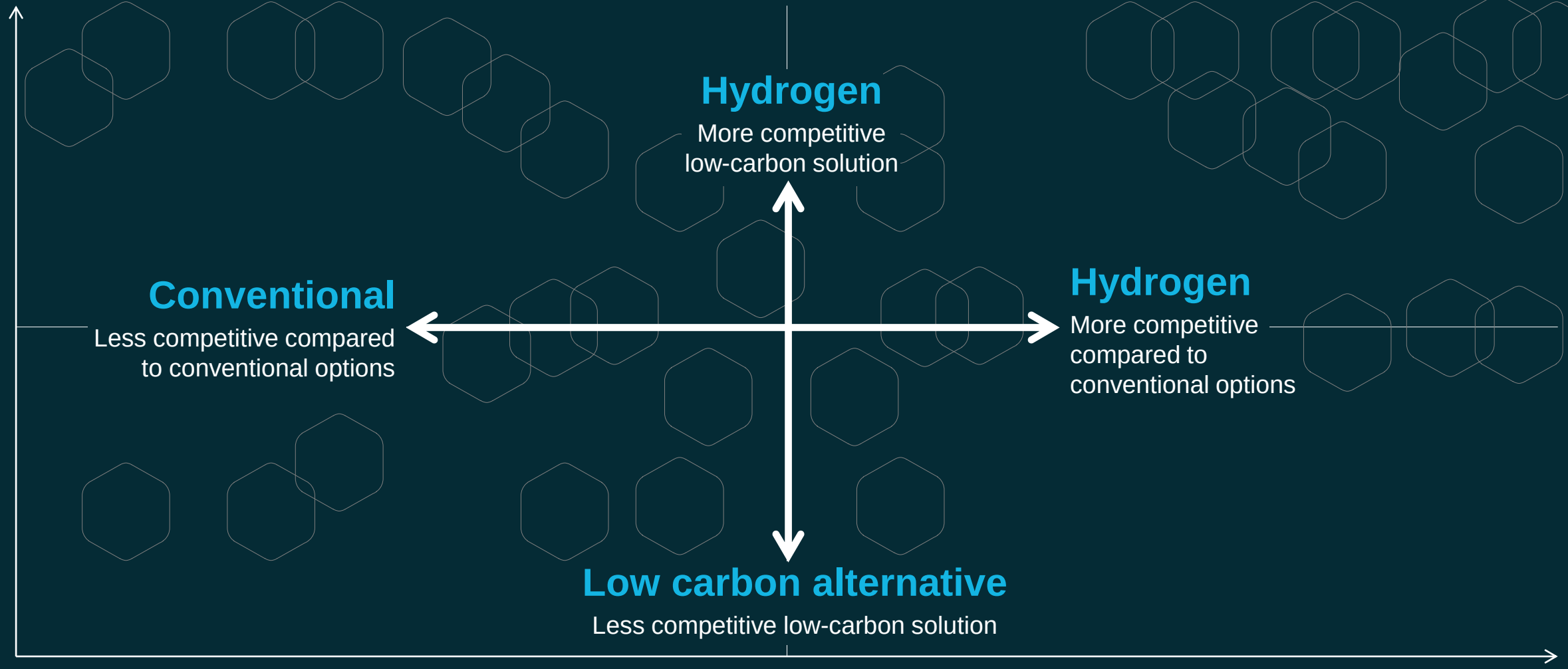
1. Final Investment Decision
2. Includes projects at preliminary studies or at press announced stage. It also includes required investment to reach national targets and governments funding
3. Includes projects that are at the feasibility study or front-end engineering and design stage
4. Includes projects where are a final investment decision (FID) has been taken, under construction, commissioned-and operational

The hydrogen economy spans across sectors – investment opportunities abound

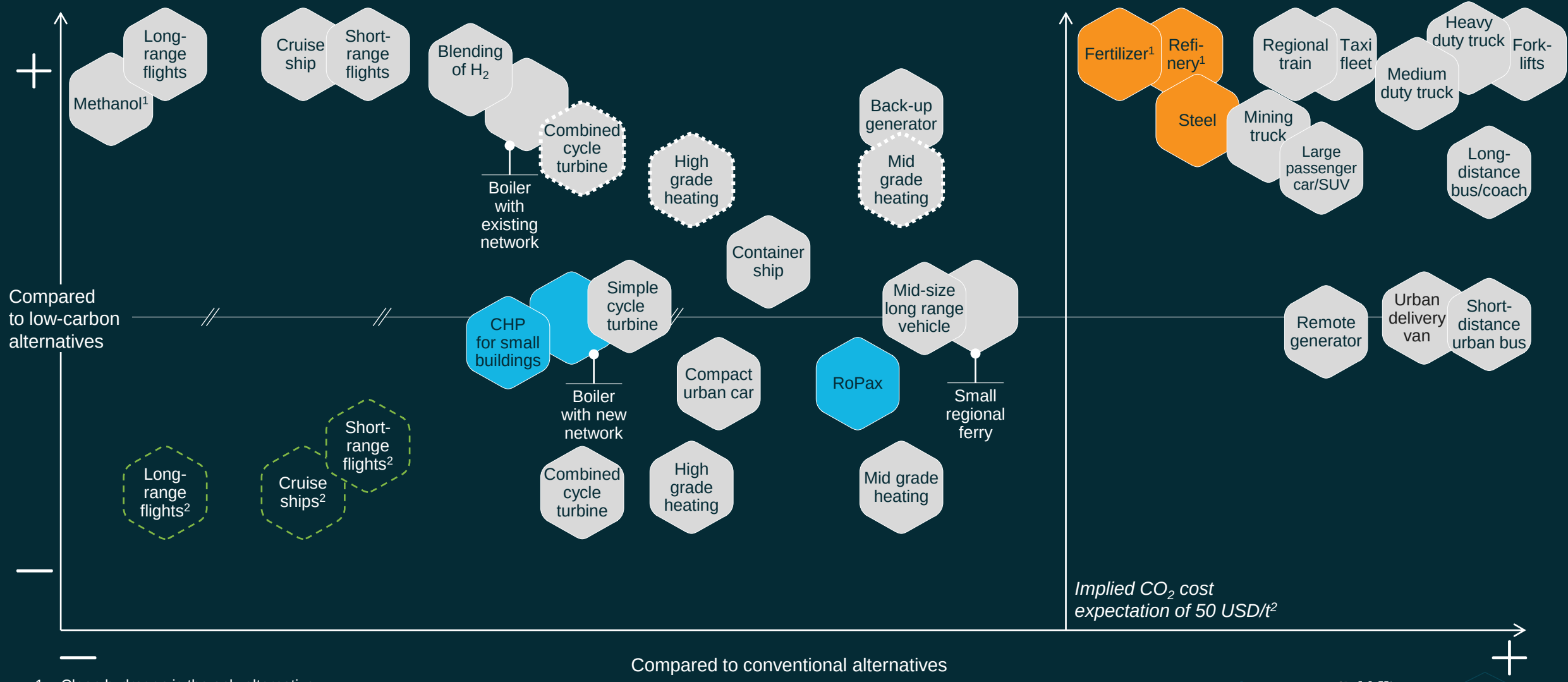


Updated competitiveness of hydrogen applications by 2030

Analysis of 35 hydrogen applications across sectors



With falling costs of hydrogen and various technologies, over 20 hydrogen applications are considered the most competitive low-carbon solution by 2030



1. Clean hydrogen is the only alternative
2. Carbon breakeven cost represents average cost over lifetime of asset

HYDROGEN STRATEGIES (1/2)

NO SUPPORT

R&D PROGRAMME SUPPORT

INDUSTRY ROADMAP

NATIONAL ROADMAP

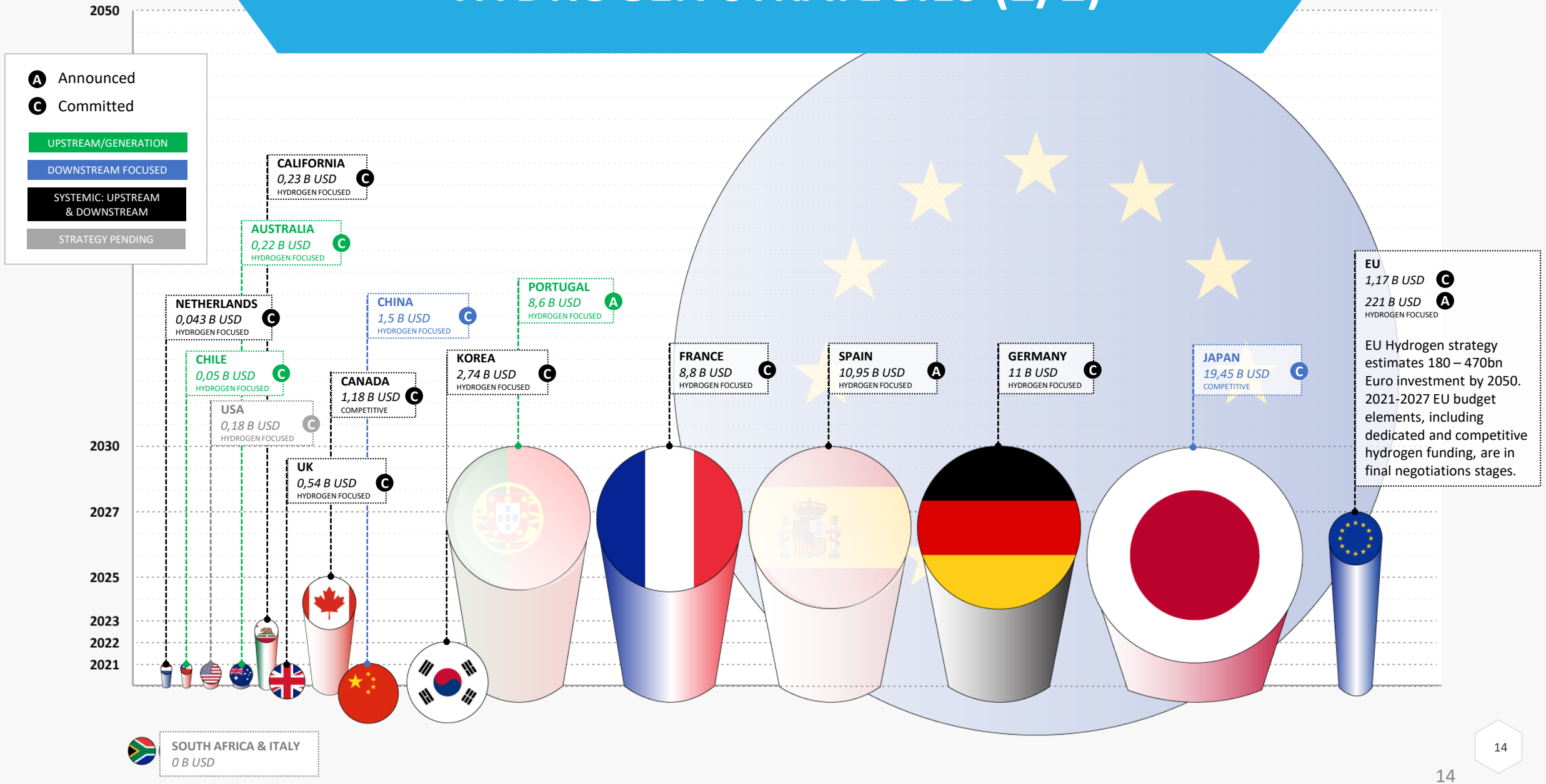
STRATEGY, TARGETS & FUNDING

STRATEGY, TARGETS, LEGISLATIVE PLAN & SUBSTANTIAL FUNDING

IMPLEMENTATION - POLICY/REGULATION

WHOLISTIC ENERGY SYSTEM INTEGRATION

HYDROGEN STRATEGIES (2/2)



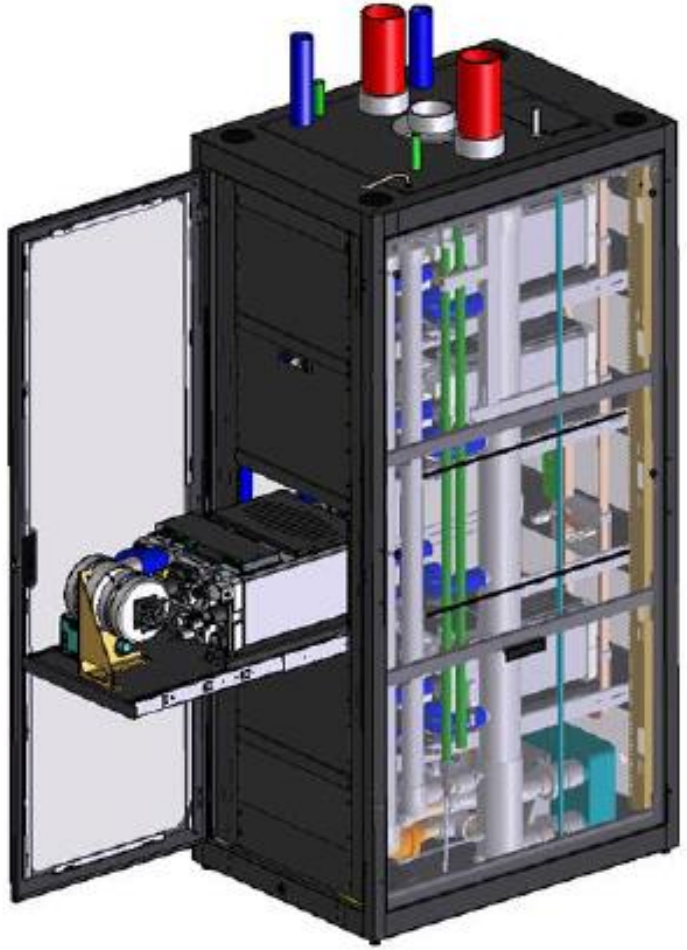
14

H2 AS A MARINE FUEL

Mirroring the Battery Solution Approach

Source: Corvus Energy

HyPM™-R120 Fuel Cell Power Rack



120 kW

240 kW

Hydrogen Marine Applications

1

Zero/V
Feasibility of FC

- Zero Emissions Research Oceanographic Vessel (ZERO/V) powered by hydrogen fuel cells

2

MarFC
Demonstrating in Maritime

- Powering commercial units in demanding marine environment

3

SINTEF and ABB
Test & Model Main Propulsion

- Model operation and control of marine power system for MW-scale propulsion plant

4

Water-Go-Round
Commercial adoption

- First high-speed hydrogen powered fuel cell marine vessel in the U.S.

Zero/V

- Review design, identify potential barriers for technology adoption
- DNV-GL Conditional Approval
- Funded by the MARAD

MarFC

- Lower the technology risk
- Estimated Costs – CapEx, OpEx
- Permitting and acceptance
- Engage potential adopters/end users

SINTEF and ABB

- Determine technicalities of scaling-up
- Control of fuel cell plant in combination with energy storage
- Optimize efficiency, reliability and the lifetime of fuel cell stacks

Water-Go-Round

- Commercial operation (2020), 84 passenger (reconfigurable), 22 knot top speed
- 2x 300 kW electric motors, 360 kW PEM fuel cell
- 100 kWh Li-ion battery, H2: 242 kg @ 250 bar

Ships
powered by Ballard

- Megawatt scale systems for cruise ships with ABB
- HySeas III, the world's first sea-going renewables-powered ferry
- Hjelmeland ferry in Norway
- FLAGSHIPS project to power:
  - Norled ferry in Norway
  - River barge in France (ABB)
- ELEKTRA fuel cell river barges in Germany
- C-H2 Ship to transport compressed green hydrogen

Ballard's Marine Center of Excellence

Established in 2019. Dedicated to the engineering, manufacturing and service of heavy duty fuel cell modules for the marine industry.

BALLARD

FCwave™

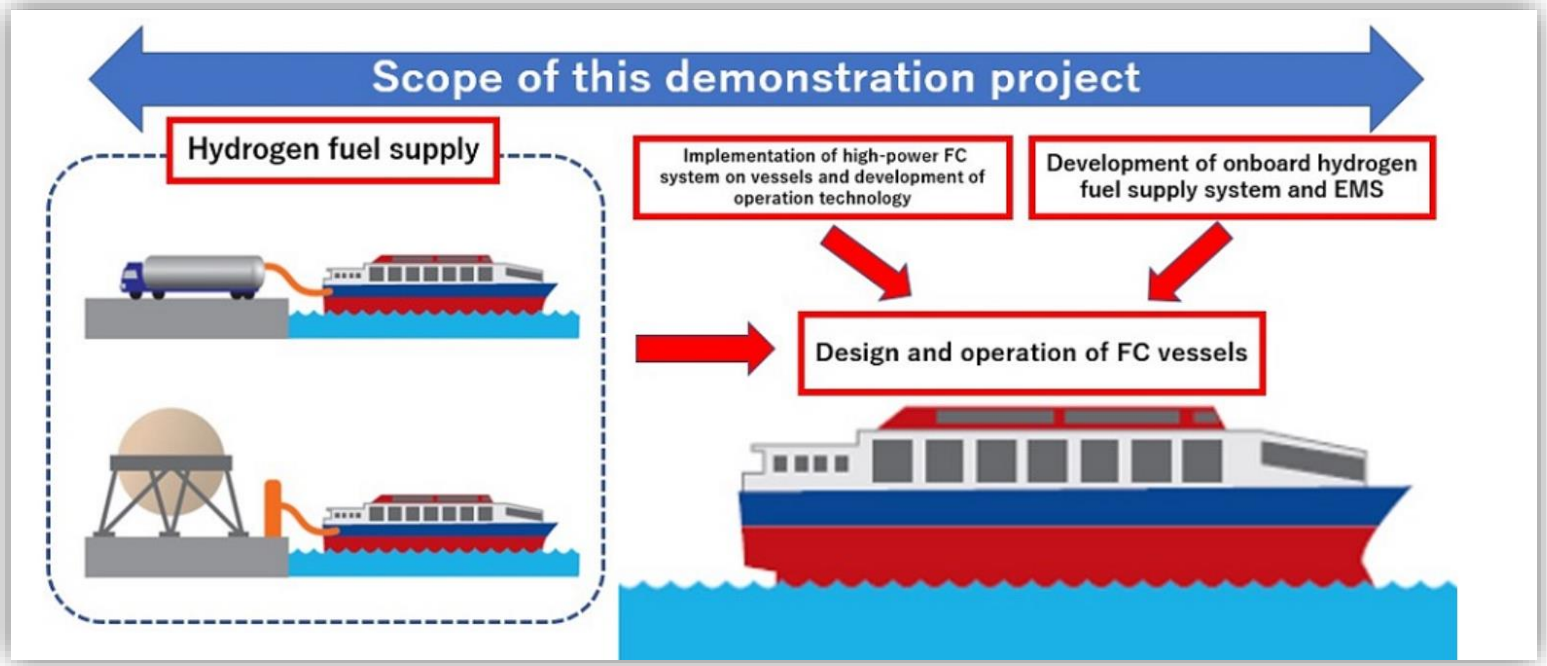
Zero-emission fuel cell power for marine vessels

Power from 200kW to megawatts to suit a broad range of marine vessels

ONGOING PROJECT

AN EXAMPLE INVOLVING HYDROGEN COUNCIL MEMBERS:

- NYK Line (in partnership with Kawasaki Heavy Industries, ENEOS Corporation and other Japanese players) is working on demonstration project for the commercialisation of high-power fuel cell vessels.
- The project, which has begun in September 2020, is Japan's **first effort to develop a commercially available FC vessel and carry out a demonstration operation involving the supply of hydrogen fuel.**
- By using FCs as a power source, it will be possible to eliminate greenhouse gas (GHG) emissions during navigation.



More information via NYK Line

COST COMPETITIVENESS

ASSESSING DIFFERENT FUEL CHOICES

- To shift toward low- or zero carbon shipping, two innovations must happen in parallel:

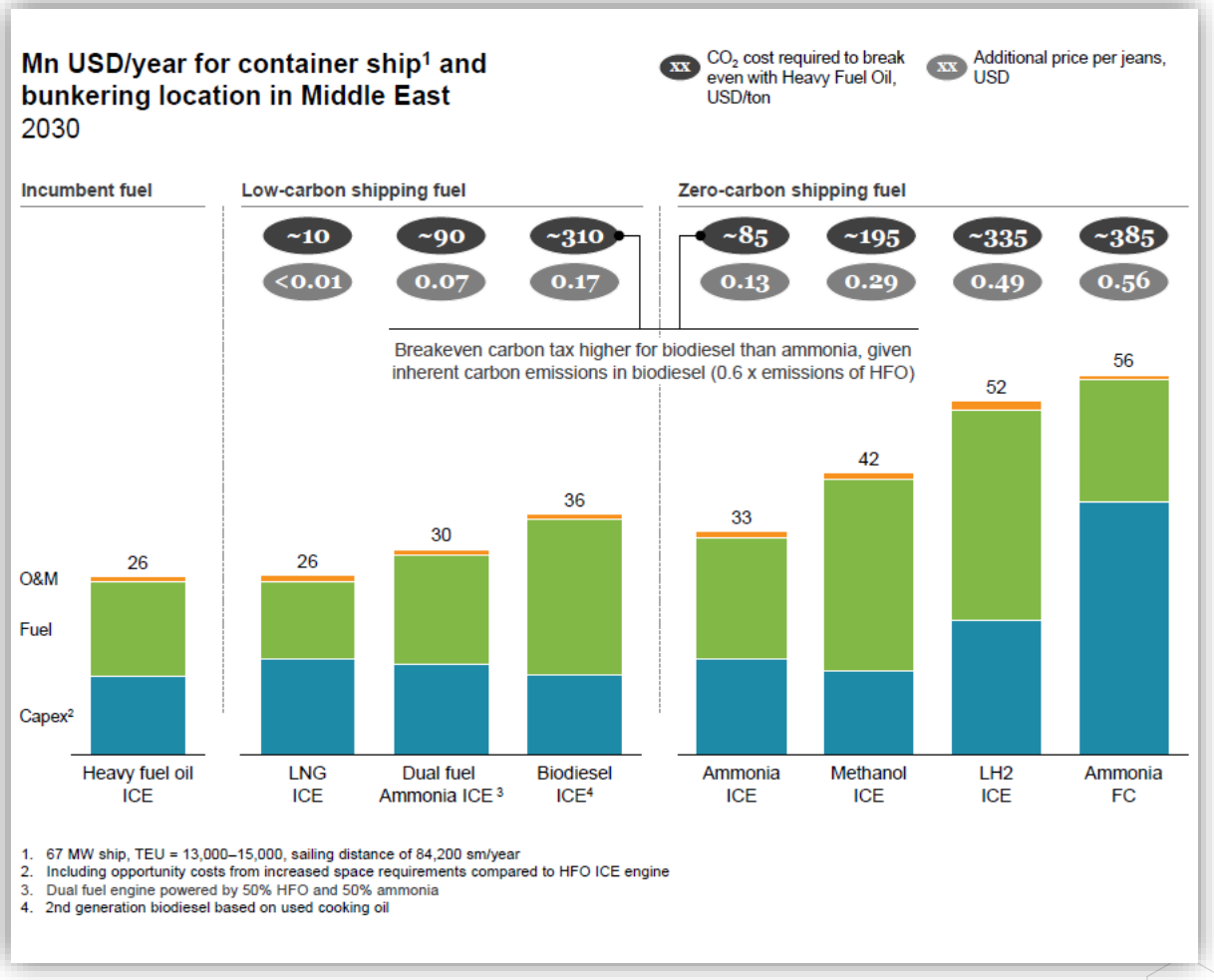
1. the **production of decarbonised fuels**
2. the **development of new propulsion systems** that enable the efficient use of these low-carbon fuels

- Industry players are discussing various fuel alternatives to conventional liquid fossil fuels that differ in terms of feedstock availability and technology maturity.

- Depending on regulation-induced constraints, routes, and driving modes, the applicability of the alternative fuels for different ship types will also vary

- Hydrogen-based fuels remain a viable option.

Competitiveness of alternative fuels in container shipping in 2030



SOURCE: McKinsey Hydrogen Insight Report 2021, Hydrogen Council

PROSPECTS & BARRIERS

- Reduction of CO2 emissions during marine transportation
- Available, renewable energy is available
- Hydrogen electrolysis processes are mature and available
- Hydrogen Liquefaction processes are available with sufficient unit capacity output for shipping demands
- Onshore bunker fuel storage systems are mature and available
- Liquid Hydrogen has been used as a fuel for over 50 years
- Onboard power generation via Fuel Cells are available, mature, and rising in power output (presently +3MW)

- Lack of:
  - proper infrastructures to supply hydrogen to ships
  - safety regulations for hydrogen bunkering
- Cost (see next slide)
- Revision of the International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels
- A more vast scale of projects to validate and risk mitigate LH2 propulsion system design is required to
  - allow definition of safety standard, technical standards and regulation
  - incite makers to invest and develop equipment and systems for Hydrogen
- Investment in LH2 (port and floating bunker facilities + production and regional availability)

Hydrogen Council

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