

# *Norwegian Energy Symposium*

Dr Alan Finkel AO

Special Adviser to the Australian Government on Low Emissions Technologies

Chair, Australia's Low Emissions Technology Investment Advisory Council

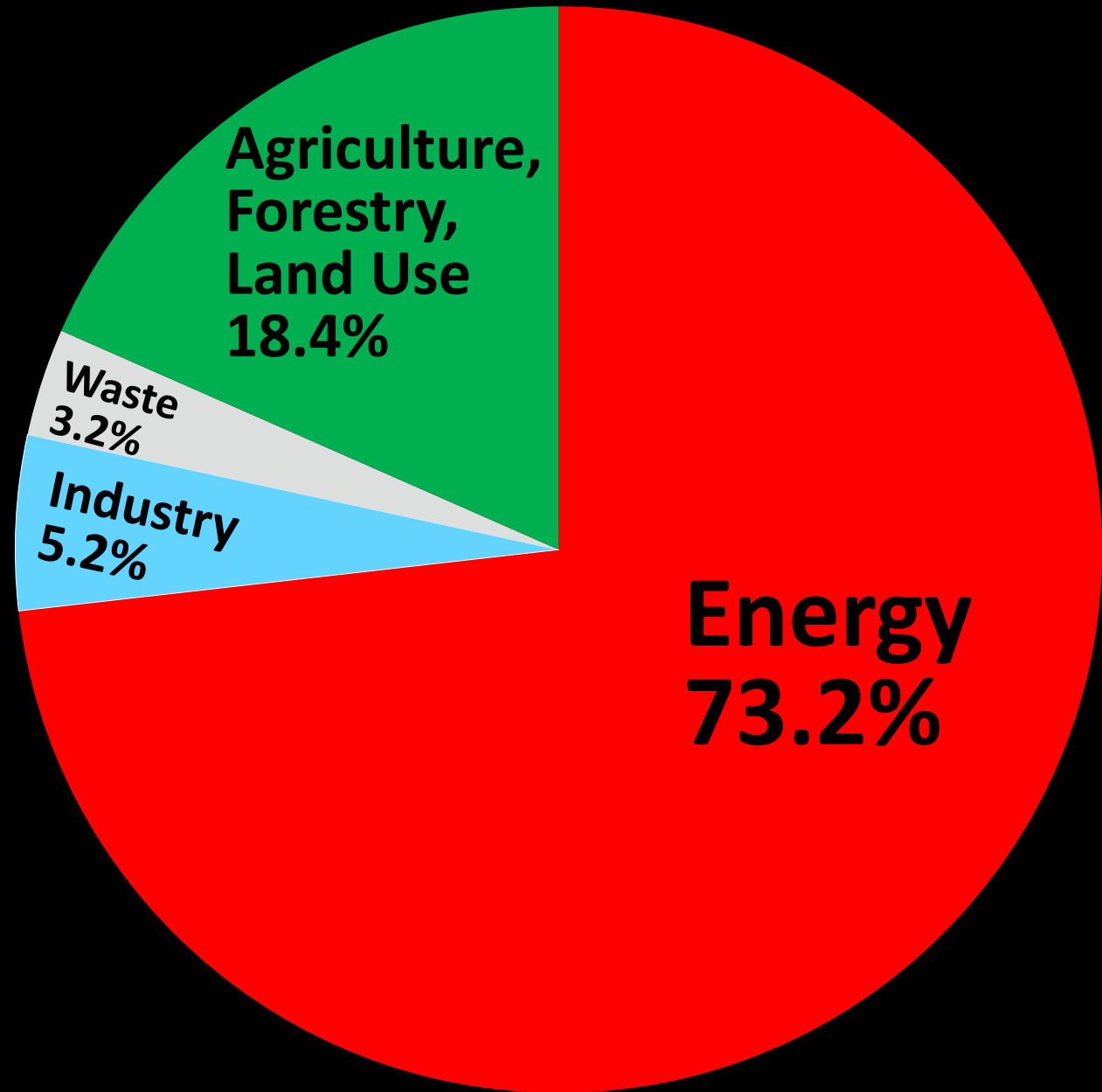
9 November 2021

The problem is clear



The reason is clear

Simplest solution  
would be to stop  
using energy!



*“To change something, build a new model that makes the existing model obsolete.”*

*—Buckminster Fuller*

# QUARTERLY ESSAY



## GETTING TO ZERO AUSTRALIA'S ENERGY TRANSITION AN INTEGRAL MODEL

civilisation needs energy. Instead, we must harness science and technology to develop alternatives that make fossil fuels obsolete. We must replace our nineteenth-century energy sources with 21st-century alternatives: low-emissions technologies that will undo the problems wrought by the high-emissions incumbents. Technology to solve technology's problems.

QE 81 2021 1

### Correspondence

**'THE HIGH ROAD'** Hugh Riminton, Colin James, Frank Bongiorno, Ben McKay, Tim Hazledine, John Quiggin, Don Russell, Andrew Leigh, Shireen Morris, Alan Atkinson, Bain Attwood & Miranda Johnson, Laura Tingle



*We need a new model*

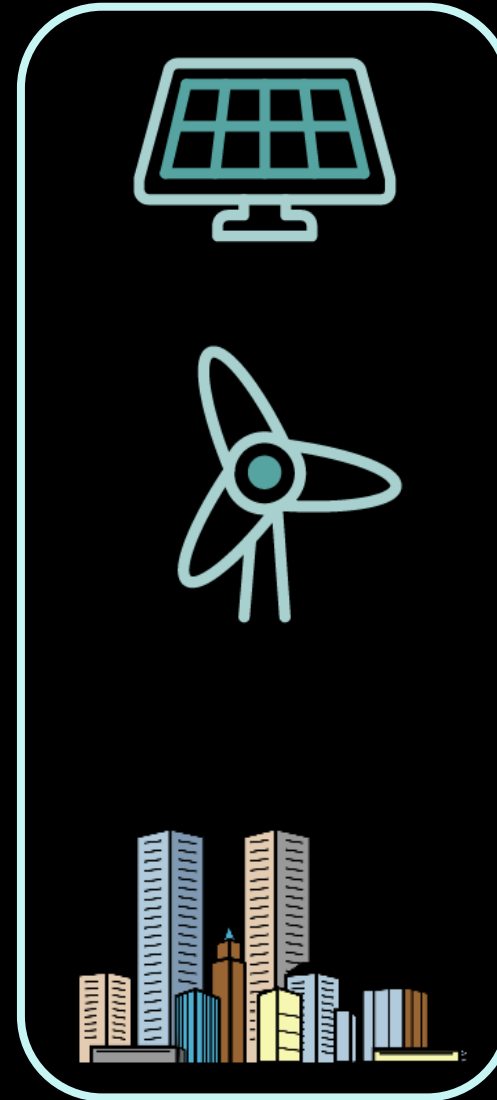
*An alternative to the existing reality*

# *The new model is clean electricity*

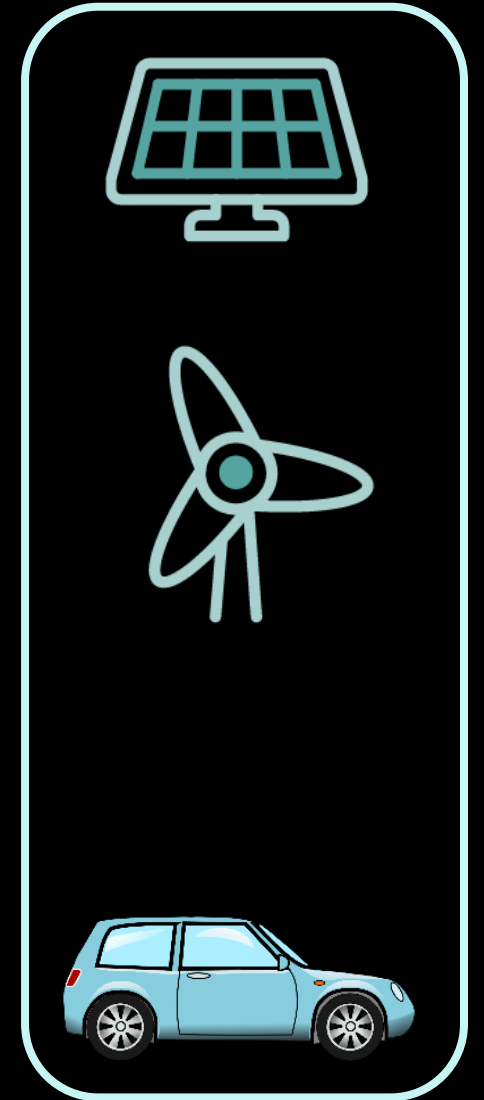
**Step 1**



**Step 2**

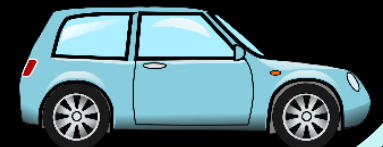


**Step 3**



# *The new model is clean electricity*

## *300%*



## *The new model in Australia*

- In 2015, **18 TWh** of solar and wind
- In 2020, **46 TWh** of solar and wind
- From 7% to 18% of total generation
- South Australia achieved a world-first milestone of 100% instantaneous solar (Jan 2021)
- National Australian grid aiming to support 100% instantaneous solar and wind electricity by 2025

## *The new model in Norway*

- In 2015, **2.5 TWh** of solar and wind
- In 2020, **10 TWh** of solar and wind
- **152 TWh** of hydro



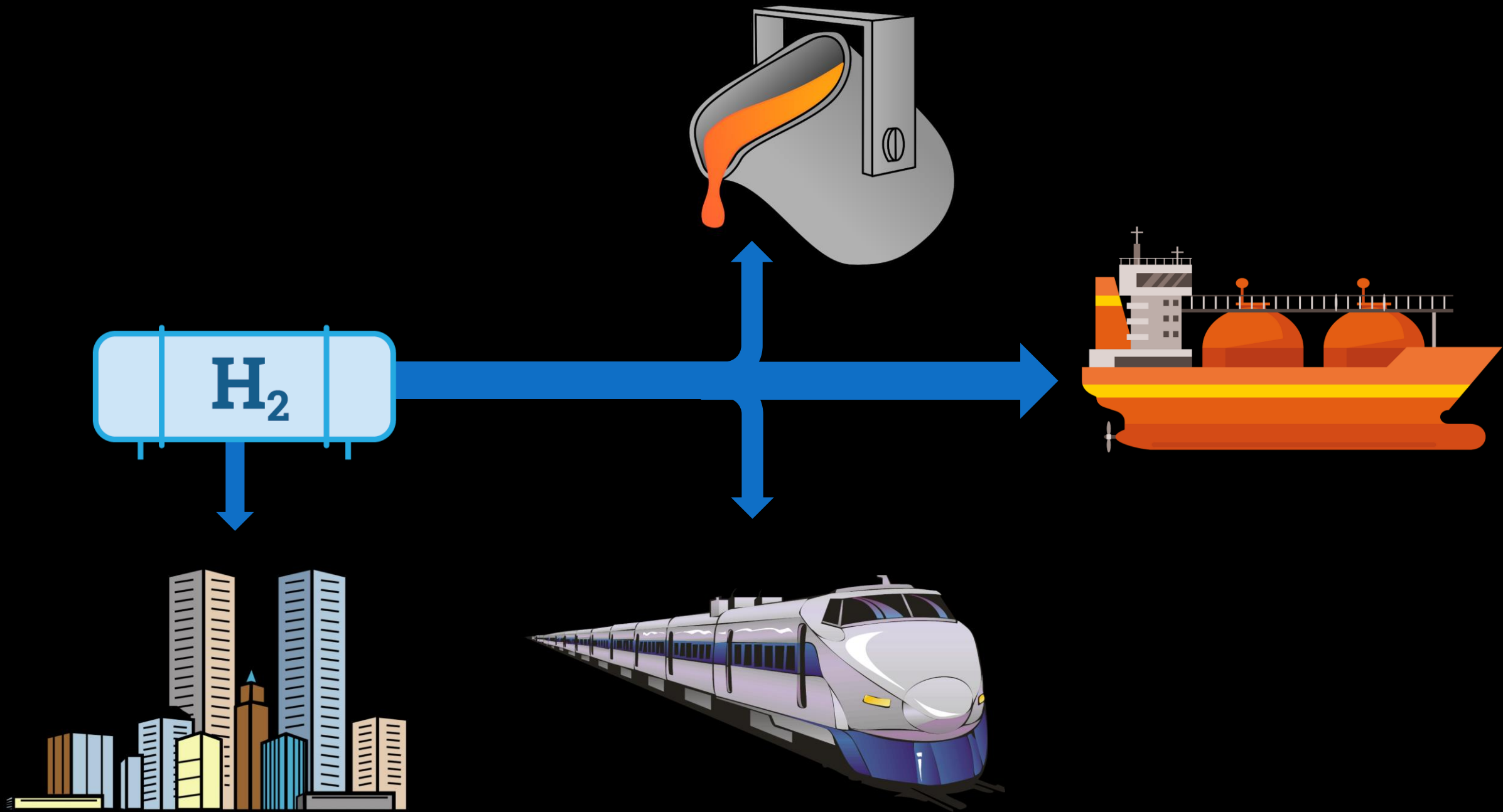
*The new model is called...*

# **The Electric Planet**

*But electrons are not always convenient*

*Sometimes we need a high-density fuel,  
or molecules for chemical industries*





The scale of the hydrogen opportunity  
is almost beyond imagining

but let's try...

# Imagine a world....

...where Australia produces hydrogen equivalent to our 2020 LNG exports

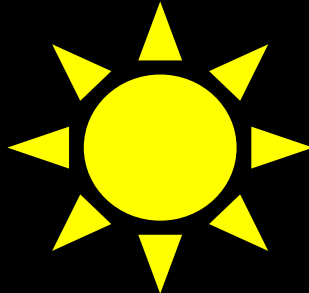


78 Mt

=



33 Mt



2,250 TWh

600,000 MW electrolysis required  
400 MW commissioned in 2021 *globally*

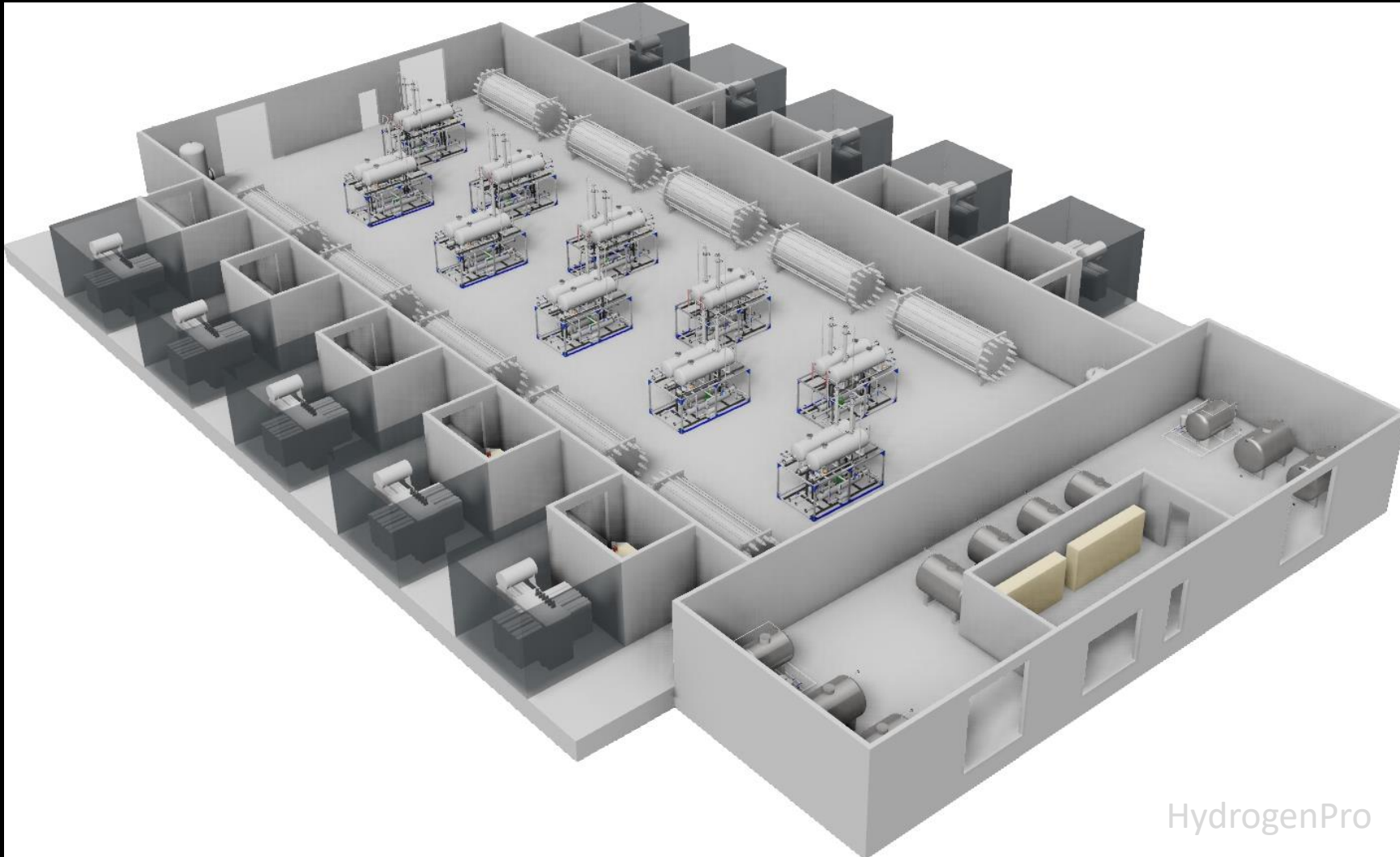


800% of 2020 generation  
Approx 600 GW solar and wind



# Local manufacturing?

A small fraction of 600,000 MW is an enormous opportunity



HydrogenPro

# *Norway has pioneered electrolyser technology*

The two largest electrolyser plants ever built



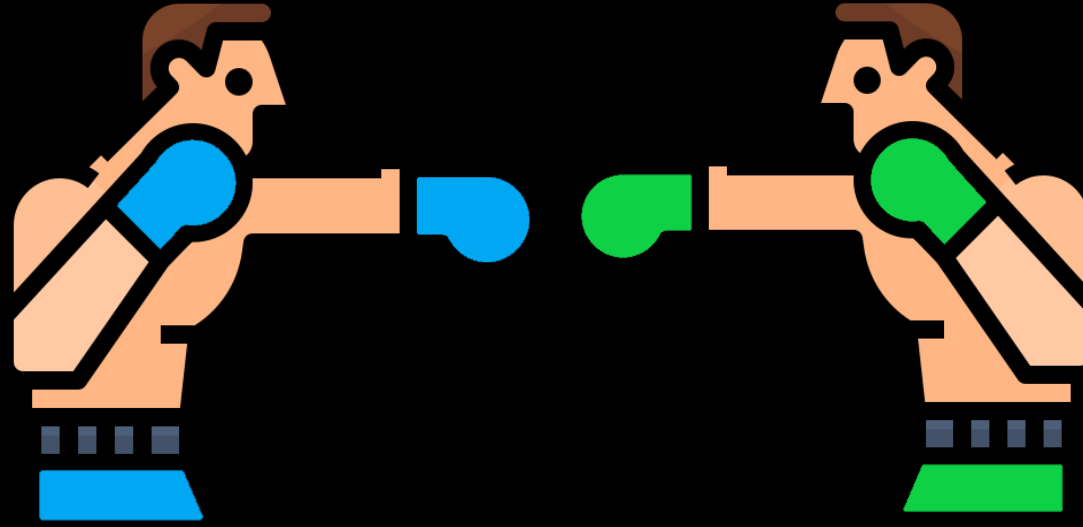
Rjukan, Norway; 1927 – 1970's



Glomfjord, Norway; 1953 – 1991

Both approximately 135 MW

Hydrogen is hydrogen is hydrogen



What counts is atmospheric emissions!

Instead of colours, we need  
a numerical certification scheme

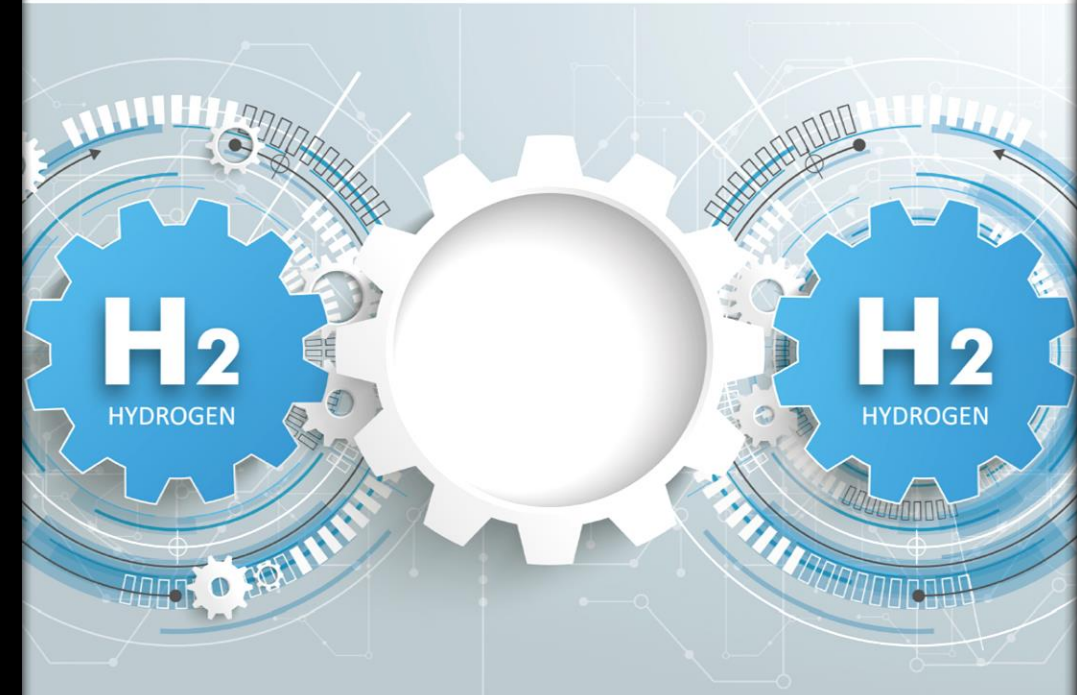
An international scheme  
is in development by the IPHE

**X tonnes of CO<sub>2</sub> emitted  
per tonne of hydrogen produced**

# Methodology for Determining the Greenhouse Gas Emissions Associated With the Production of Hydrogen

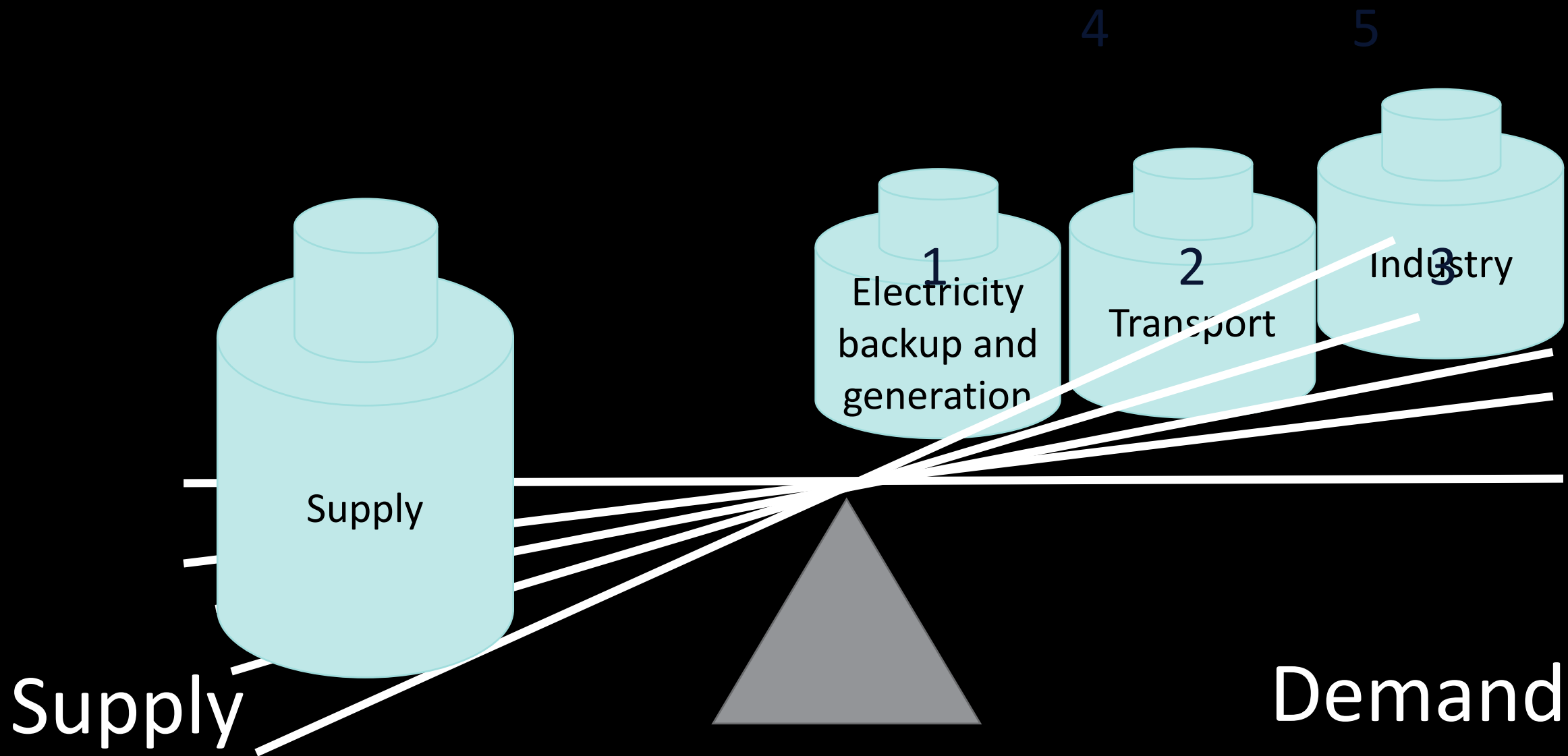


A Working Paper Prepared by the  
IPHE Hydrogen Production Analysis Task Force



VERSION 1 - OCTOBER 2021

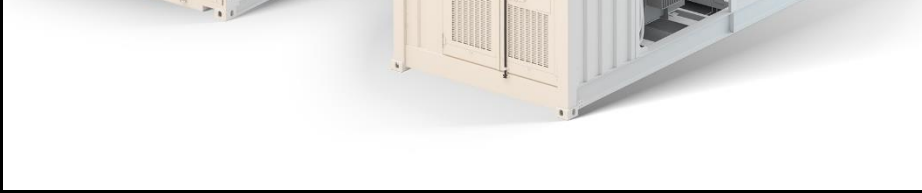
**The global challenge is to balance supply and demand**







# 2 Transport



Controller



Compressor & storage



Dispenser



# Transport



Artist's impression of *Wilhelmsen Topeka*





# Transport







# Industry



Yara Pilbara Ammonia Plant

Momentum is building in Australia

The target is clear





Australian Government

# The Plan to Deliver Net Zero

*The Australian Way*

2005



2050

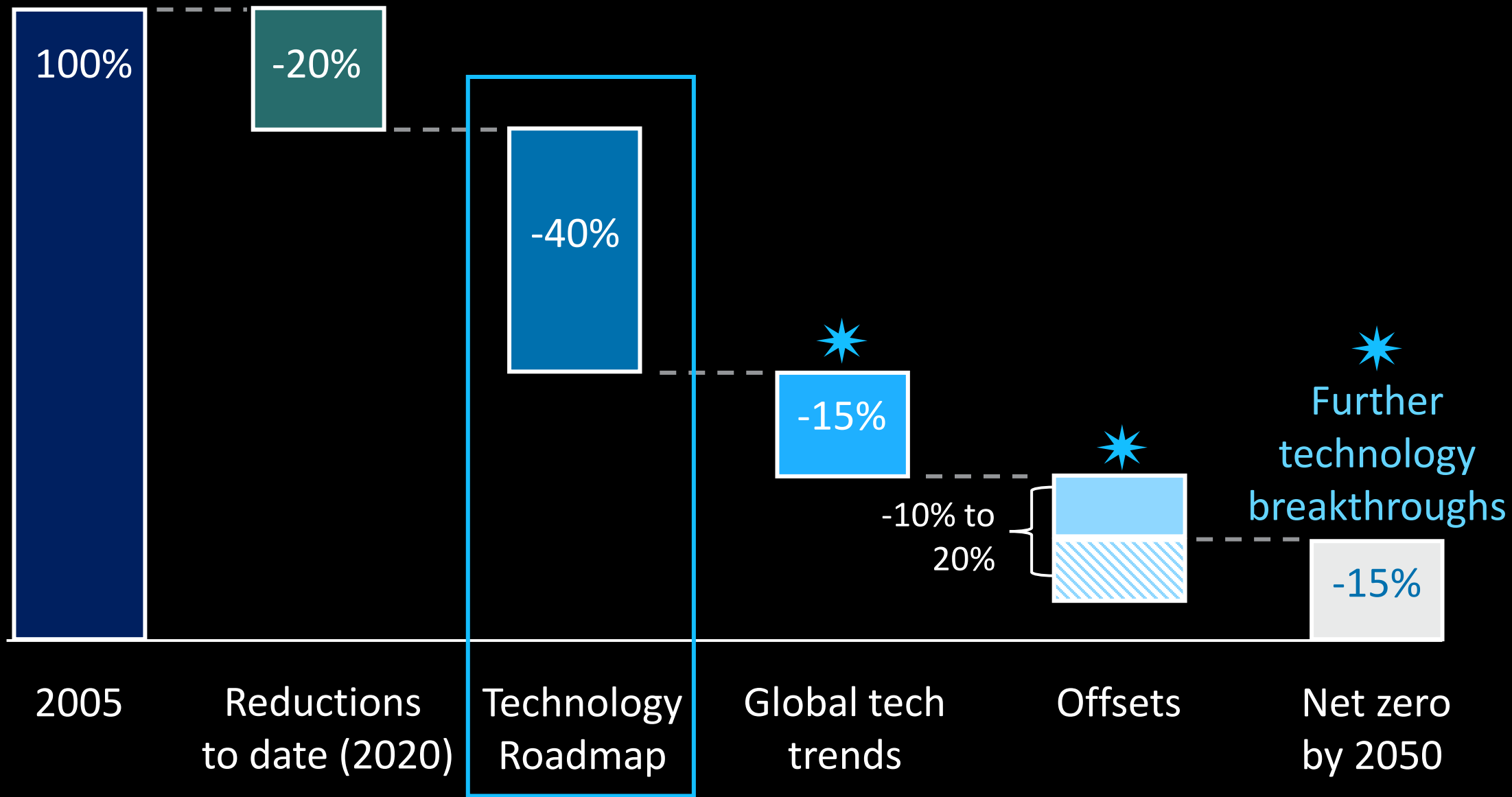
# Supported by the Technology Roadmap



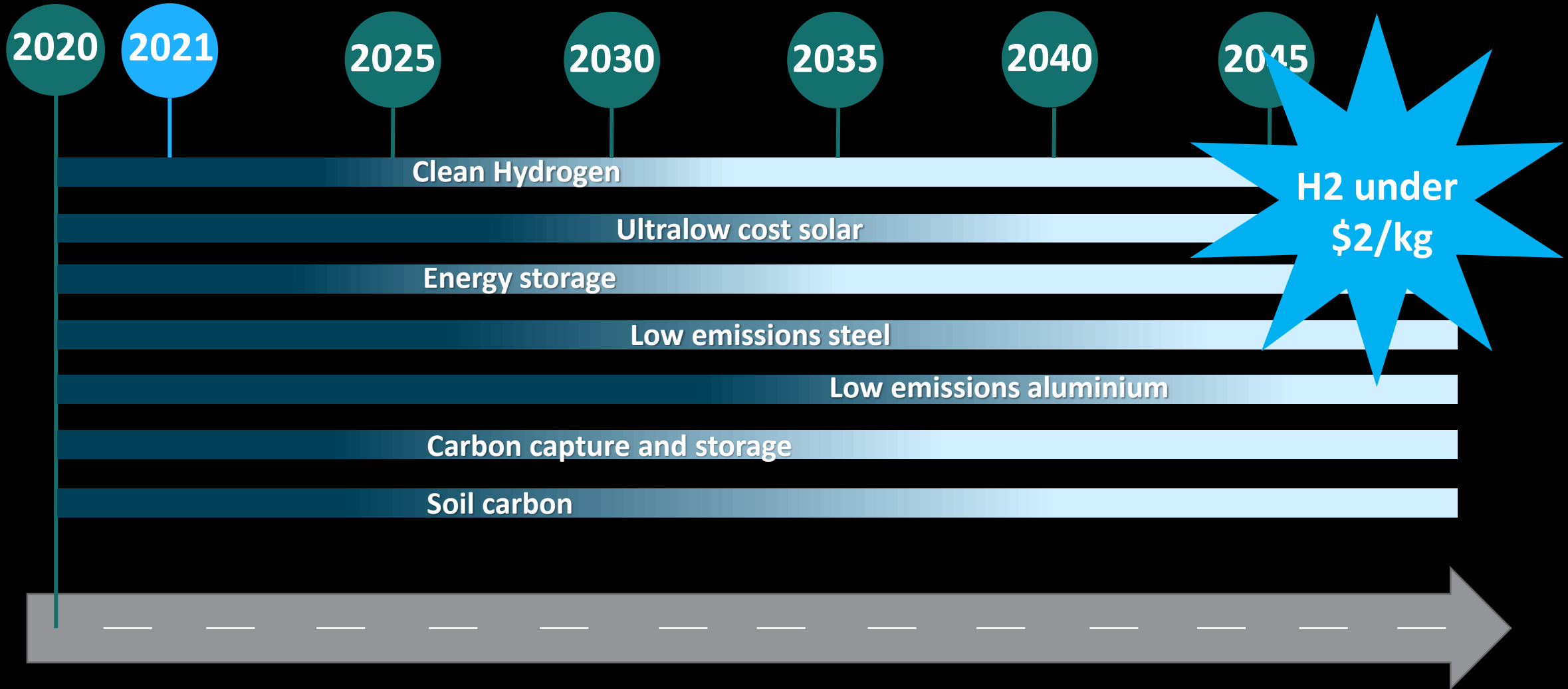
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# Emissions reduction in The Plan to Deliver Net Zero



# Stretch goal pathways





2020

## Inaugural Road Map

- Prioritisation filters
- Five priority technologies
- Investment framework

2021

## First update

- Ultra low cost solar
- Enabling infrastructure
- Deployment pathways

2022

2023

2024

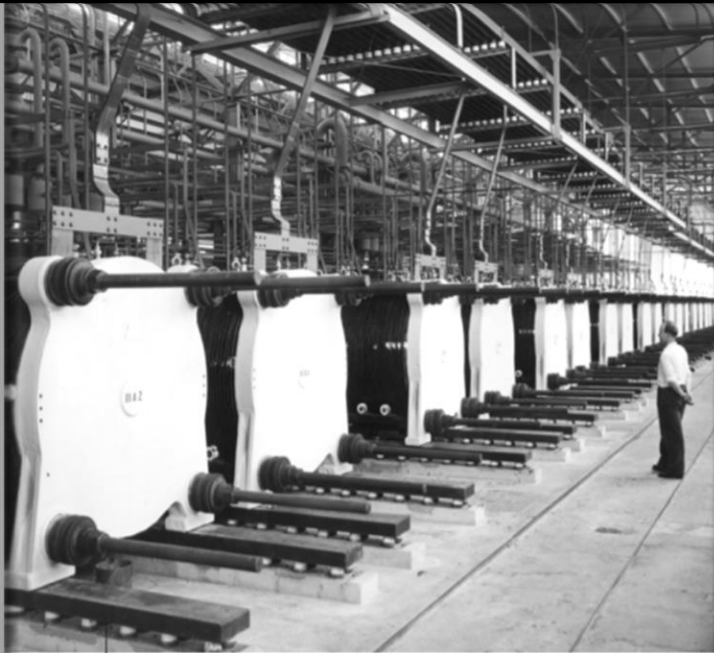
2049

# Net zero

2050



# Opportunities for Australia and Norway



Norwegian Ministry of Petroleum and Energy  
Norwegian Ministry of Climate and Environment

Strategy

The Norwegian Government's  
hydrogen strategy  
towards a low emission society

2020



AUSTRALIA'S  
NATIONAL  
**HYDROGEN**  
STRATEGY



QLD

NSW

VIC

SA

WA

TAS

NT

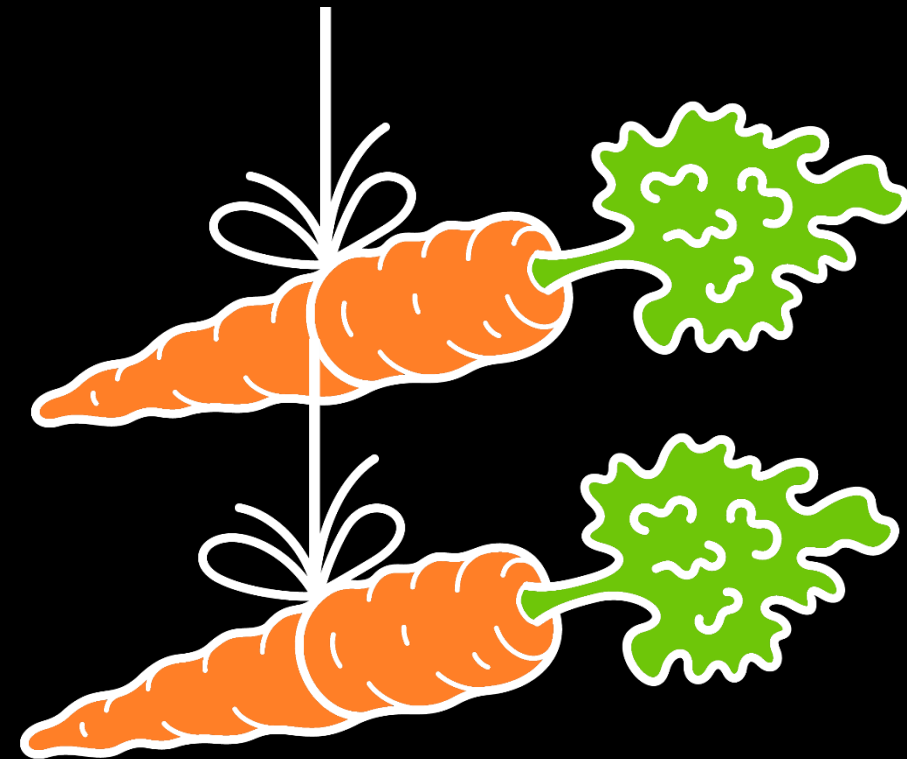
250 GW of projects announced

How can Australia incentivise hydrogen usage?

**\$464 million for hydrogen hubs**

**Zero emissions gas scheme**

**Ultra low cost solar (A\$15/MWh)**



# Yara and Engie partner to develop Pilbara Hydrogen Hub

3 Dec, 2020



\$43 million ARENA grant

Multi-phased approach

# Australia's first public hydrogen fuelling station opens in Canberra, ACT

May/June 2021



Nel Hydrogen electrolyser



# Two vintage decades

1960s



2020s



*Thank you!*

## Contact us

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on Low Emissions Technology

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Twitter: [@AusGov\\_OSALET](https://twitter.com/AusGov_OSALET)





# NCCS

NORWEGIAN CCS RESEARCH CENTRE

Norwegian Energy Symposium: H<sub>2</sub> & CCS Solutions and Technology  
Keynote Norway

2021-09-23

Dr. Mona J. Mølsvik

Director Norwegian CCS Research Centre, Research director SINTEF Energy Research







SINTEF

**An independent, not-for-profit research institute**



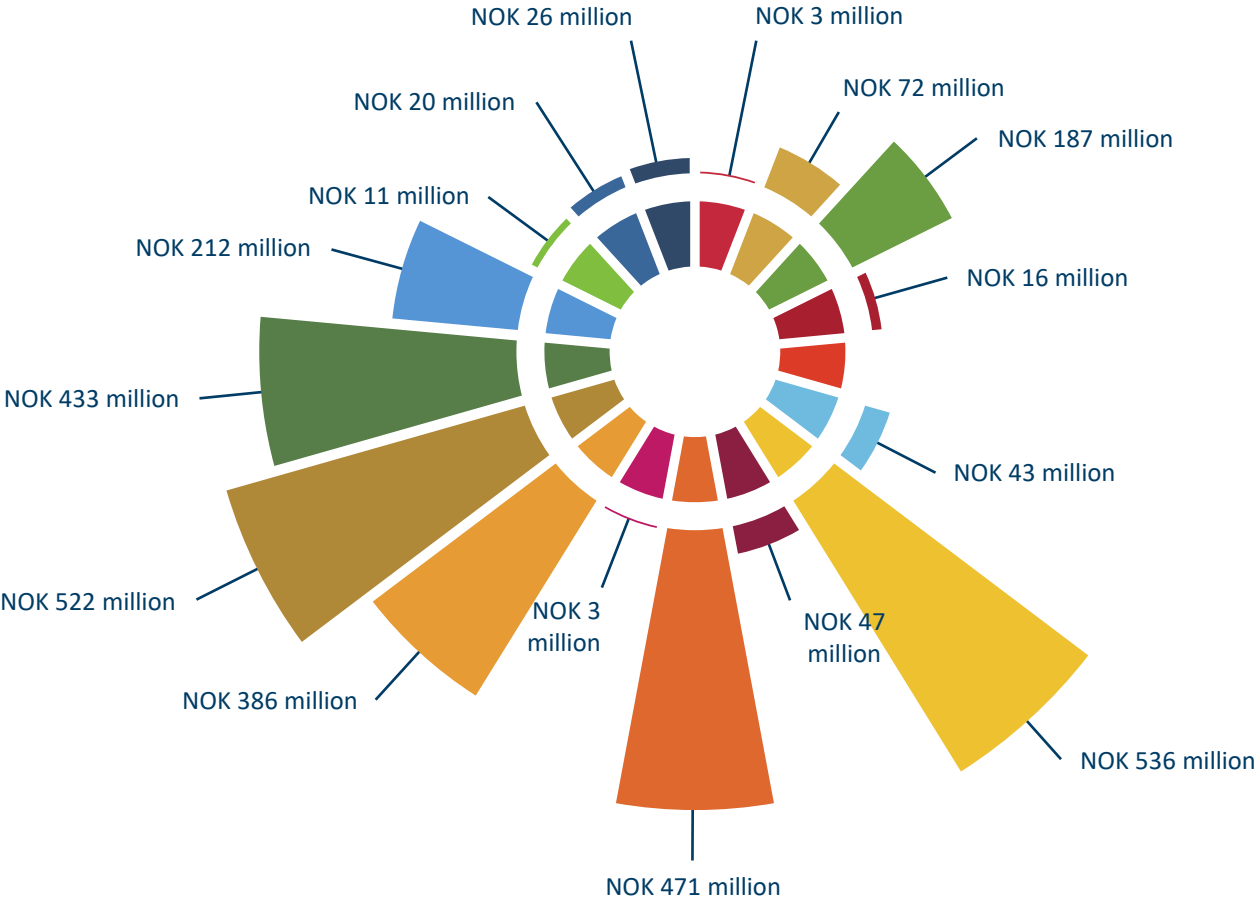
# Vision: Technology for a better society

Expertise from Ocean space to Outer Space





# Our projects contribute to meeting the UN's Sustainable Development Goals



-  1. Zero poverty
-  2. No hunger
-  3. Good health and well-being
-  4. Quality education
-  5. Gender equality
-  6. Clean water and sanitation
-  7. Affordable and clean energy
-  8. Decent work and economic growth
-  9. Industry, innovation and infrastructure
-  10. Reduced inequalities
-  11. Sustainable cities and communities
-  12. Responsible consumption and production
-  13. Climate action
-  14. Life below the water
-  15. Life on land
-  16. Peace, justice and strong institutions
-  17. Partnerships for the goals

SINTEF's net turnover in 2019 sorted according to the Sustainable Development Goals

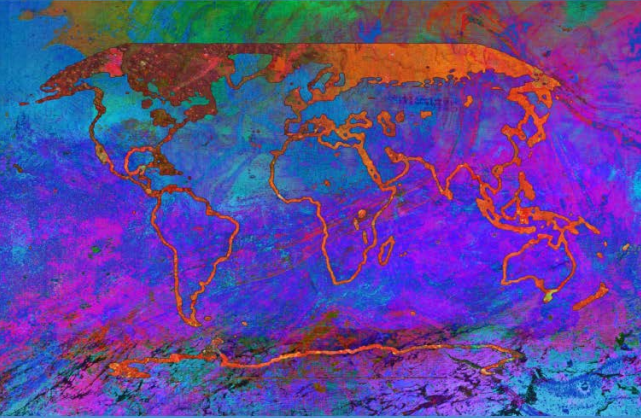


SINTEF

# Action required

ipcc  
INTERGOVERNMENTAL PANEL ON climate change

Climate Change 2021  
The Physical Science Basis  
Summary for Policymakers



Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

WGI

WMO UNEP



The Global Assessment Report on Biodiversity and Ecosystem Services



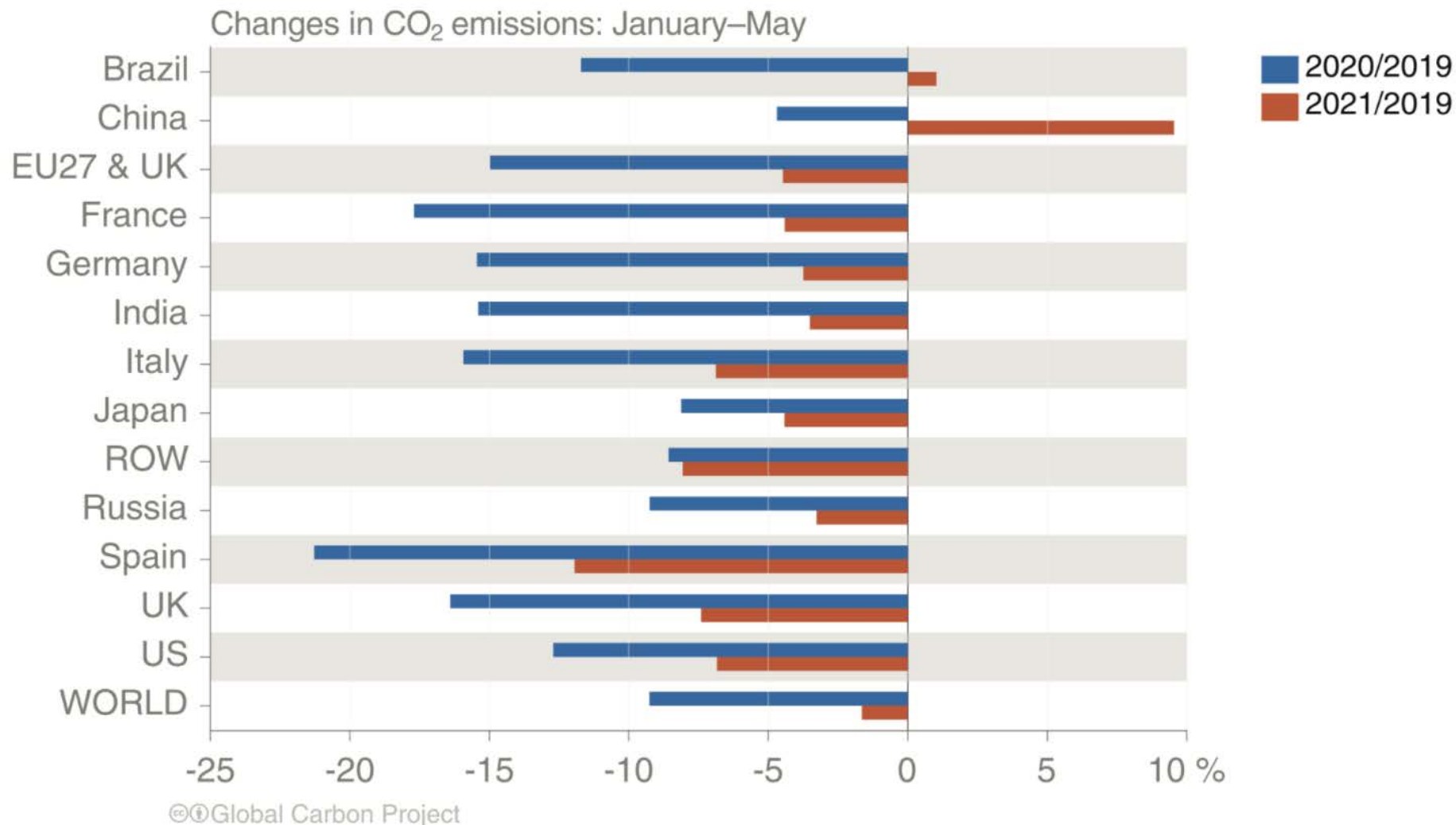




SINTEF

**COVID19  
crisis-  
back to  
2019 levels  
again on  
emissions**

**Build back  
better?**



*Changes in fossil fuel CO<sub>2</sub> emissions for the world and a selected group of countries for January-May in 2020 and 2021 compared with the same period in 2019 (Carbon Monitor).*



**UN CLIMATE  
CHANGE  
CONFERENCE  
UK 2021**

IN PARTNERSHIP WITH ITALY

The 26<sup>th</sup> UN Climate Change Conference of the Parties aims to accelerate action towards the goals of the Paris Agreement and the UN Framework Convention on Climate Change. The four research centres at the origin of this document, NorthWind, NCCS, LowEmission and NTRANS, have as one of their goals to contribute to fact-based policymaking. This document was prepared ahead of COP26 and constitutes the foundation for our advice to policy makers about the green transition in the North Sea.

# The North Sea

as a springboard for  
the green transition

**NCCS**

NORWEGIAN CCS RESEARCH CENTRE

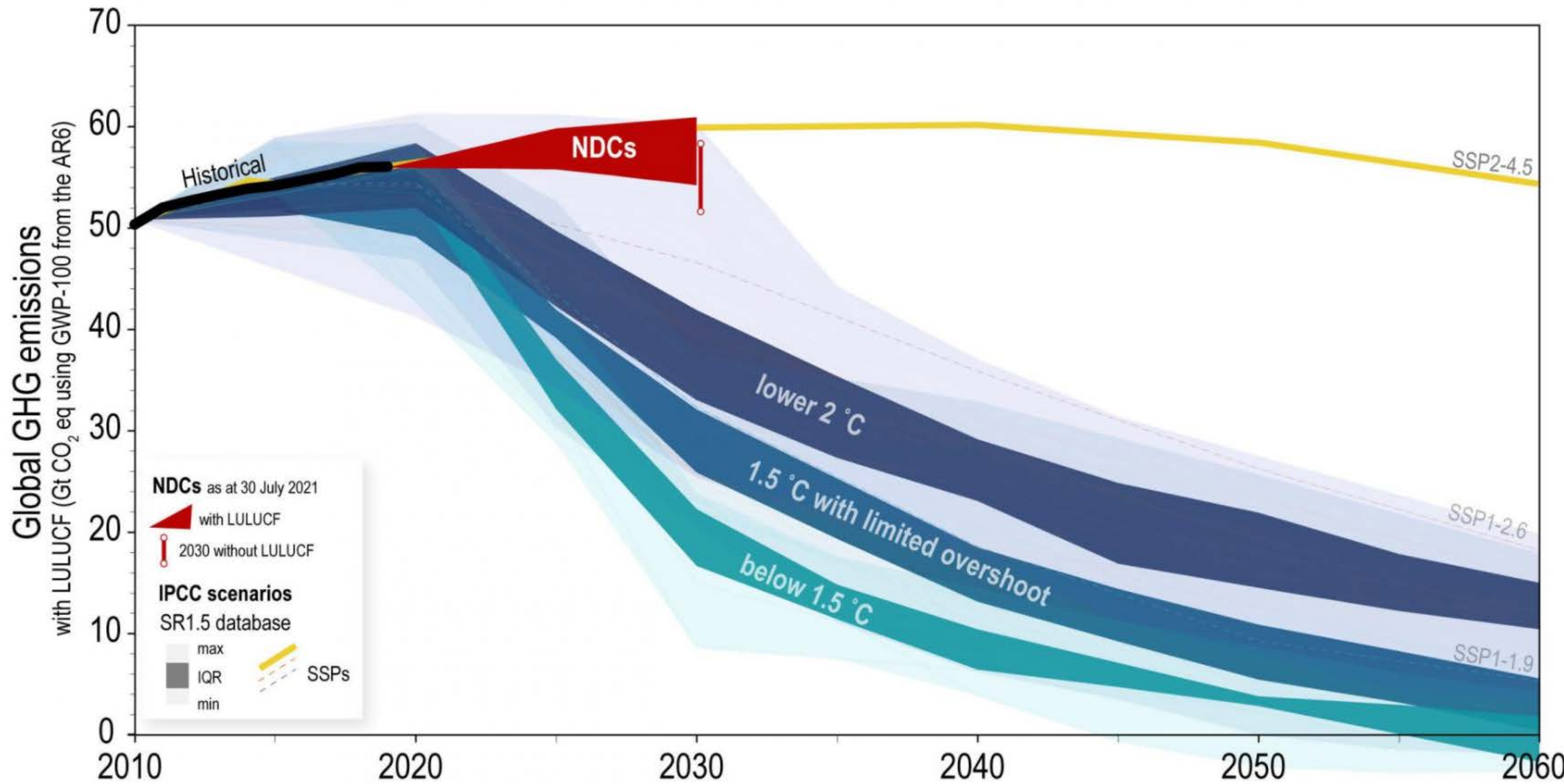
The Norwegian CCS Research Centre (NCCS) is a Centre for Environment-Friendly Energy Research in the fields of CO<sub>2</sub> capture, transport, storage and CCS chain including non-technical issues. The centre's main task is to fast-track implementation of CCS through industry- and research-driven innovation. NCCS also aims to ensure that Norway remains an international leading CCS actor and contributes to enabling large-scale CO<sub>2</sub> storage in the North Sea.

**With contributors:**

- Mona Mølnevik, director FME NCCS, Research director, SINTEF
- Roland Span, Prof. Dr.-Ing., Ruhr Universität Bochum
- Jim White, Dr, Senior CCS Researcher, British Geological Survey
- Roberta Veronezi Figueiredo, Research Scientist, TNO
- Alvar Braathen, Professor, University of Oslo
- Catherine Banet, Associate Professor, University of Oslo
- Grethe Tangen, Senior Research Scientist, SINTEF
- Rémi Abgrall, Professor, Universität Zürich







The indicative Nationally Determined Contribution (NDC)

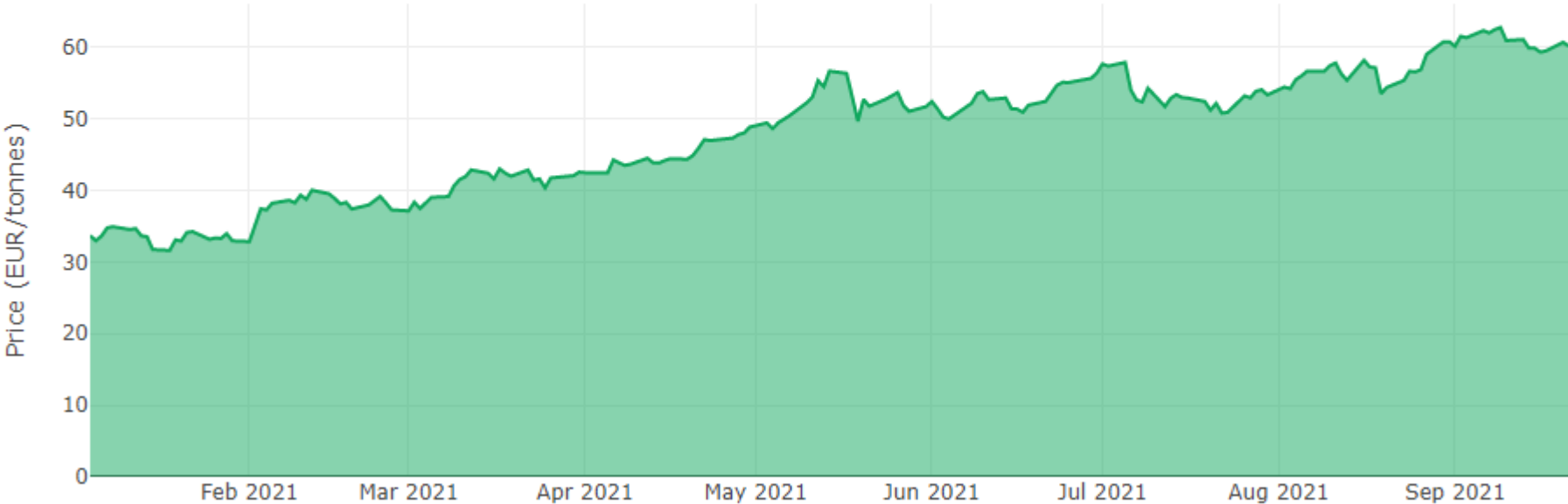


# EU ETS

Built with  anvil

Build web apps for free with Anvil

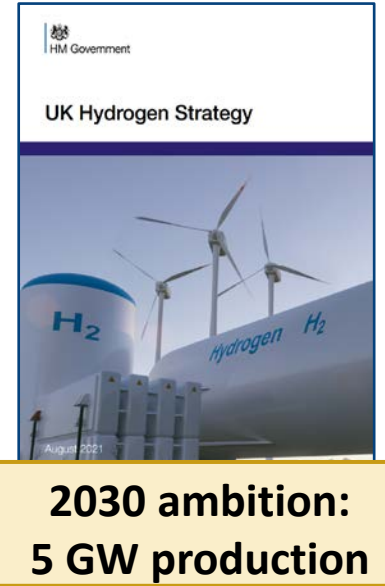
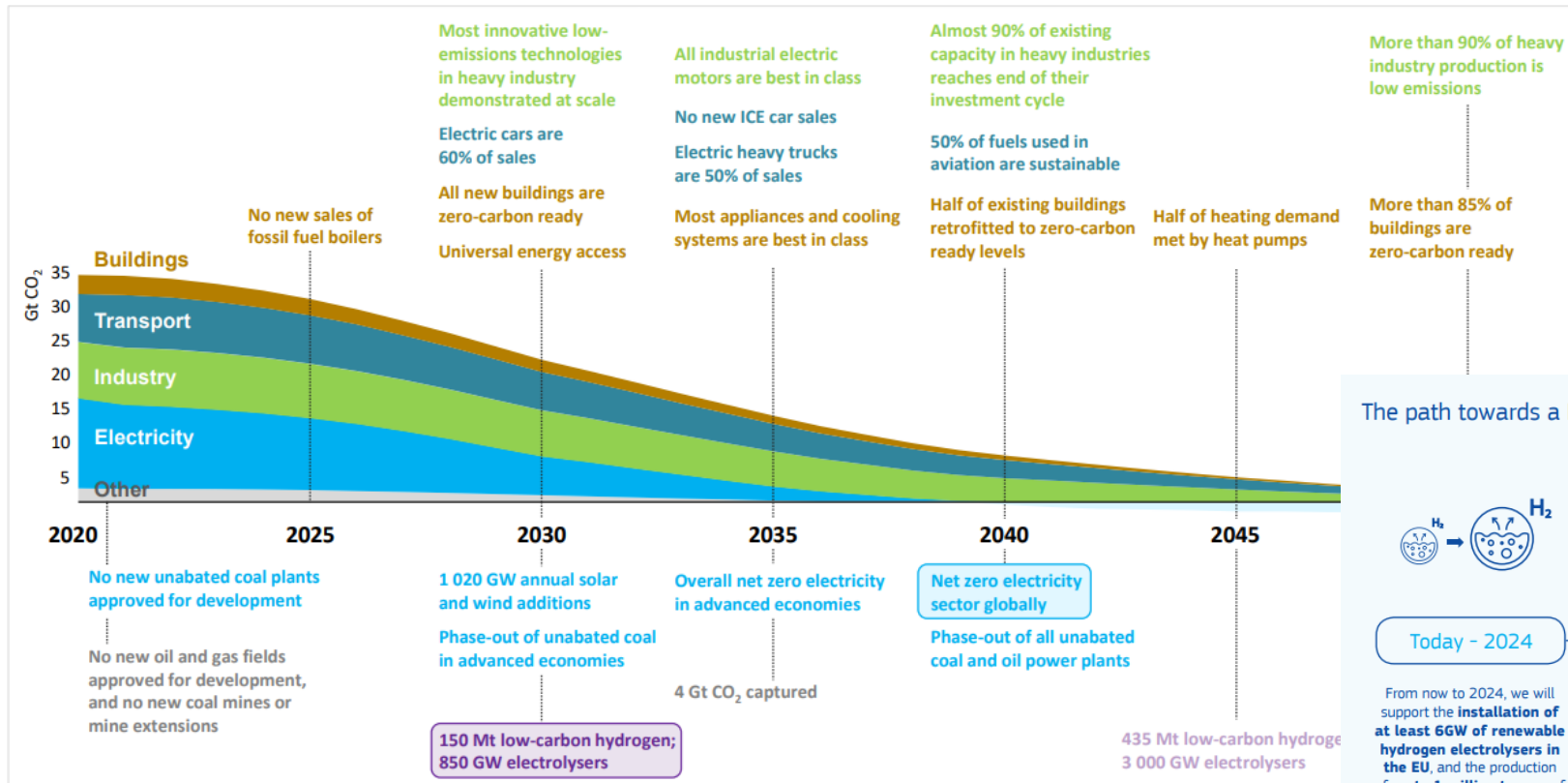
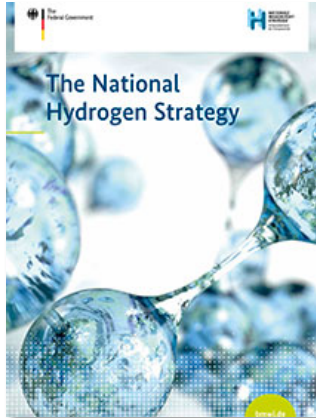
EUA (EU ETS) Futures Prices





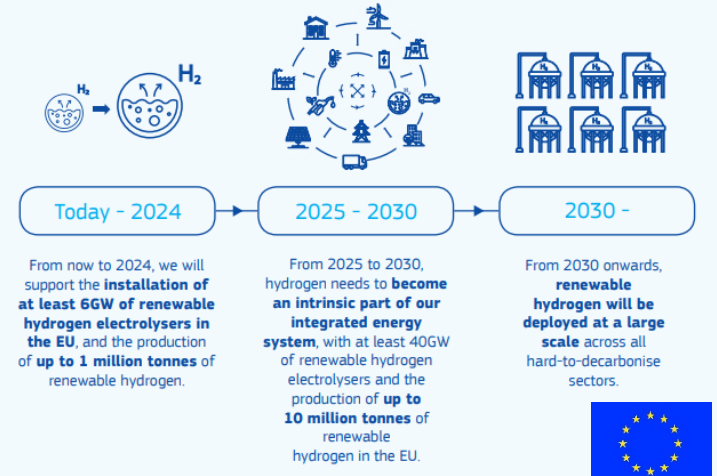
SINTEF

# Hydrogen in future global energy system



**2030 ambition: 5 GW production**

The path towards a European hydrogen eco-system step by step :



IEA 2021. All rights reserved.





SINTEF

# Hydrogen next?



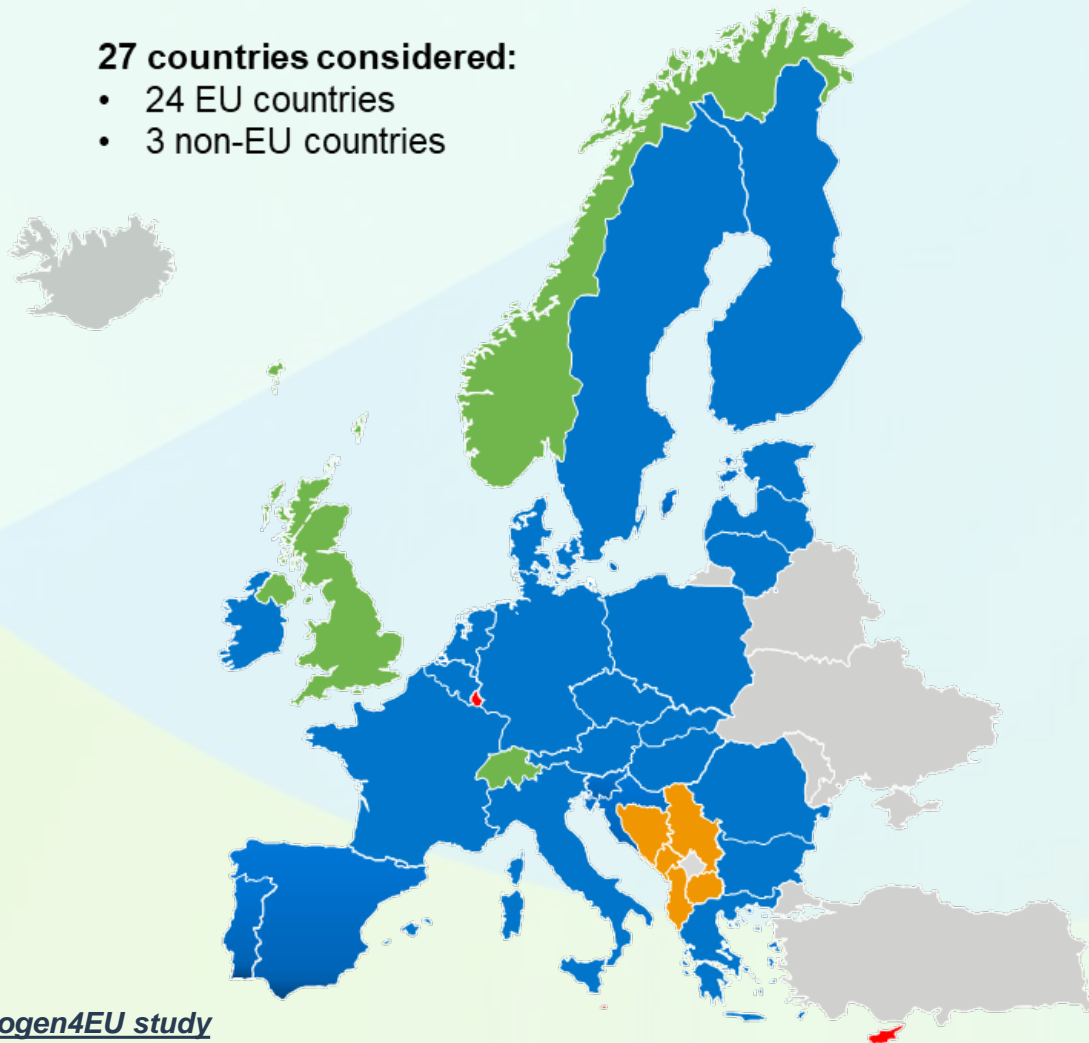
*Photo: Harald Pettersen/Equinor*

# Perspectives from Hydrogen4EU - Industry driven study focusing on Europe



## 27 countries considered:

- 24 EU countries
- 3 non-EU countries



- EU Member states included in the model
- Non-EU Member states included in the model
- EU Member states not included in the model
- Balkan region countries not included in the model
- Non-EU Member states not included in the model

## Research consortium



## Steering Committee



## Facts & Figures

8

**+100 Mt**

Driven by policy, demand for hydrogen could exceed 100 million tons (Mt) of H<sub>2</sub> by 2050.

⚡

**+50%**

More than half of total gross final energy consumption will be supplied by non-electrified technologies in 2050, such as low-carbon hydrogen and biomass.

💡

**15%**

Nearly 15% of the hydrogen needed in the transition to net-zero emissions could be imported from outside Europe.

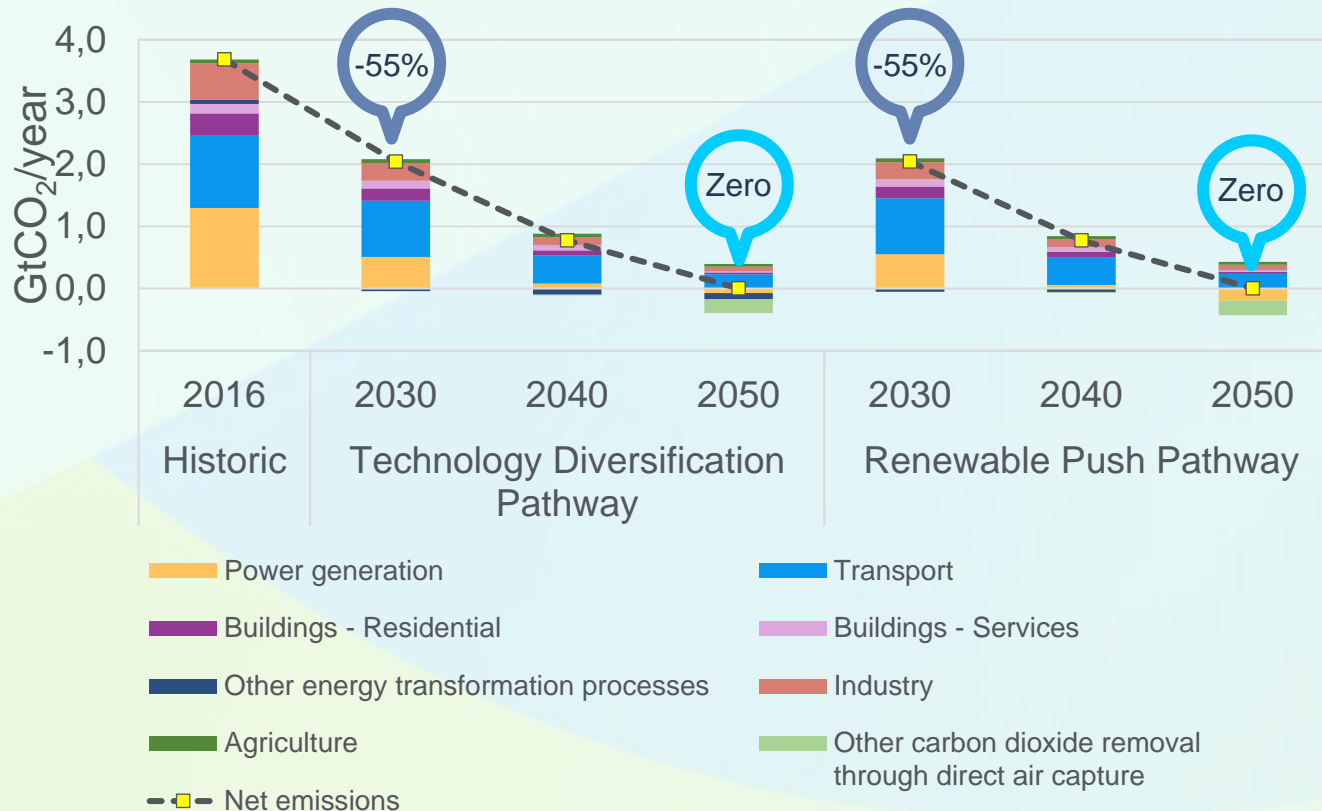
<https://www.hydrogen4eu.com/>



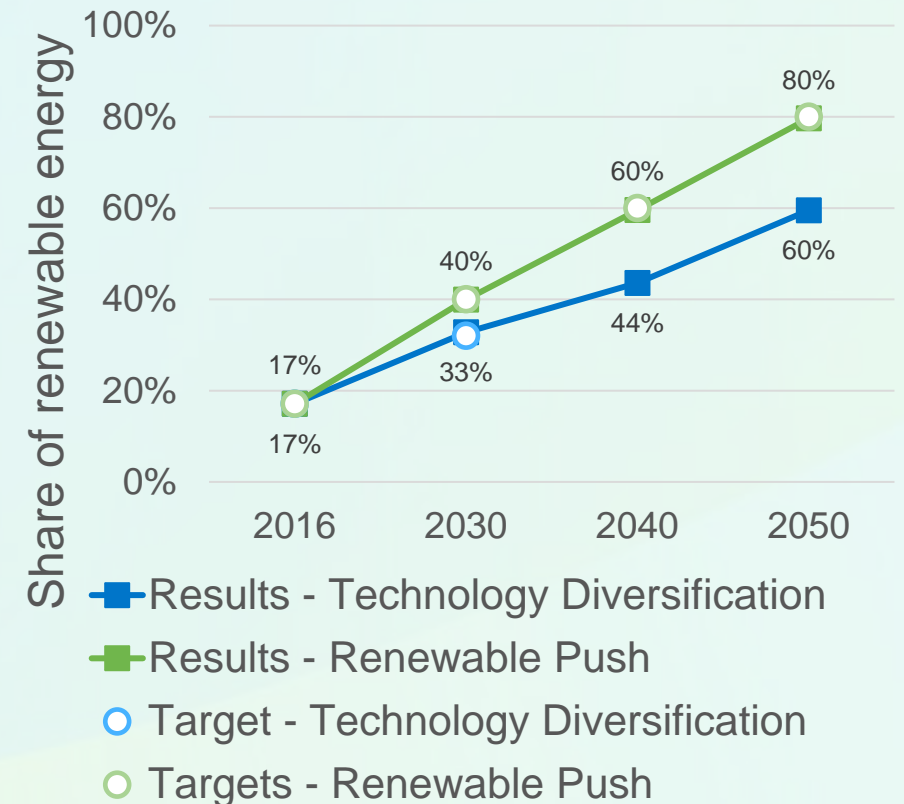
# Reaching net-zero CO<sub>2</sub> emissions in Europe



## CO<sub>2</sub> emissions - breakdown by sector



## Share of renewable energy in final gross energy consumption

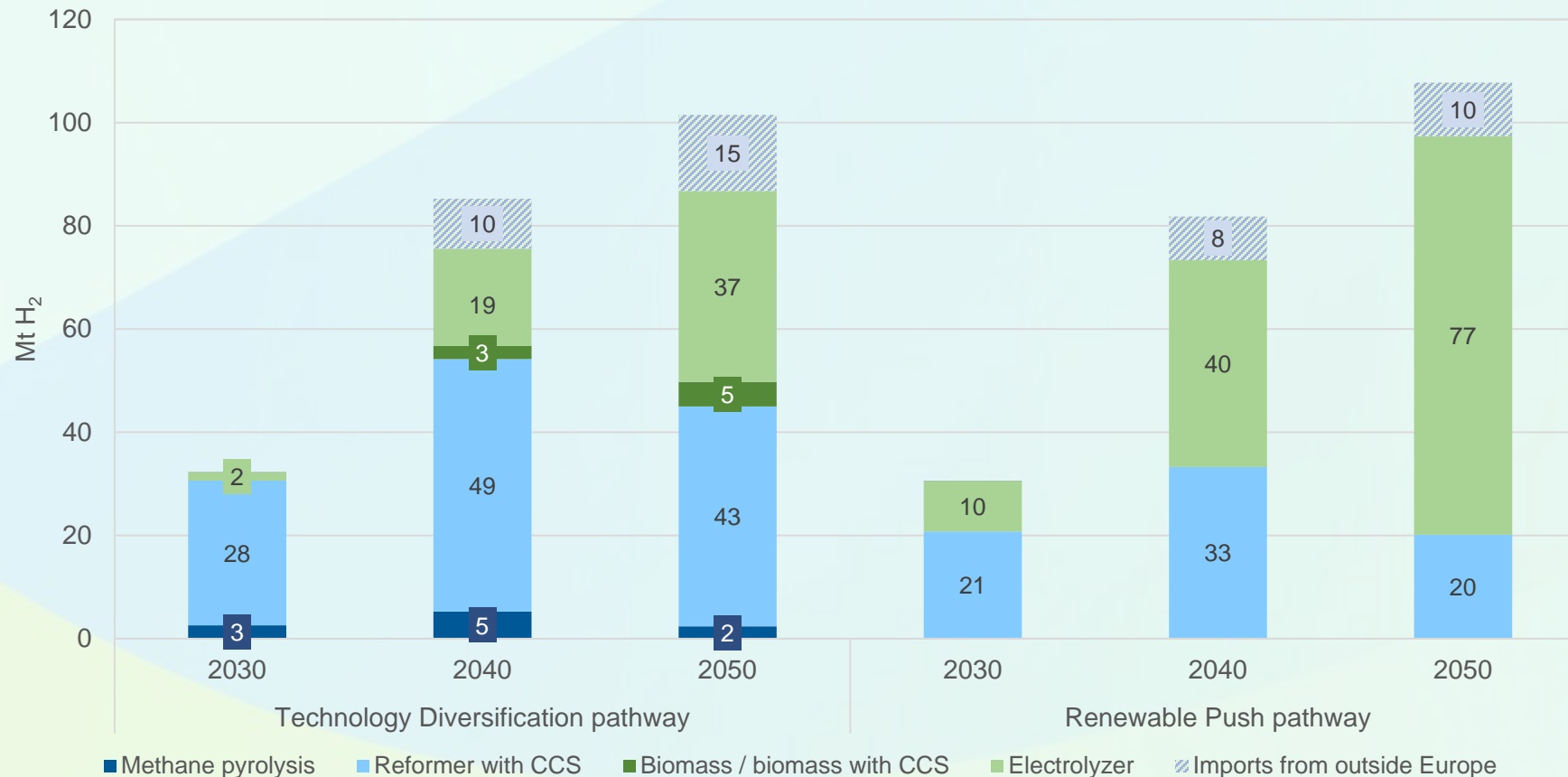




# Complementary hydrogen production from renewable sources and natural gas



Hydrogen4EU  
CHARTING PATHWAYS TO ENABLE NET ZERO



# A new era for CCS



You are here: [Home](#) • [What's new](#) •

The Government launches 'Longship' for carbon capture and storage in Norway

## The Government launches 'Longship' for carbon capture and storage in Norway

Press release | Date: 21/09/2020

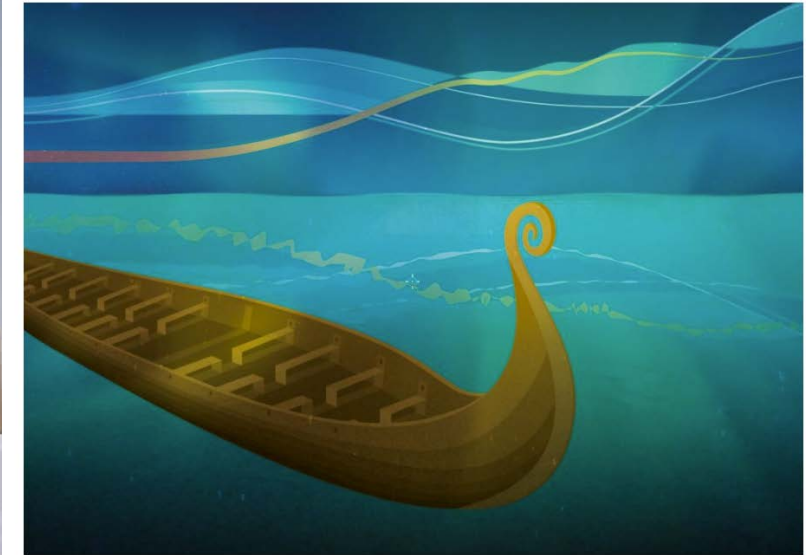
| No: 132/20

In a Government White Paper to the Norwegian parliament submitted today, the Government proposes to launch a carbon capture and storage (CCS) project in Norway. The project has been named 'Longship', in Norwegian 'Langskip'.



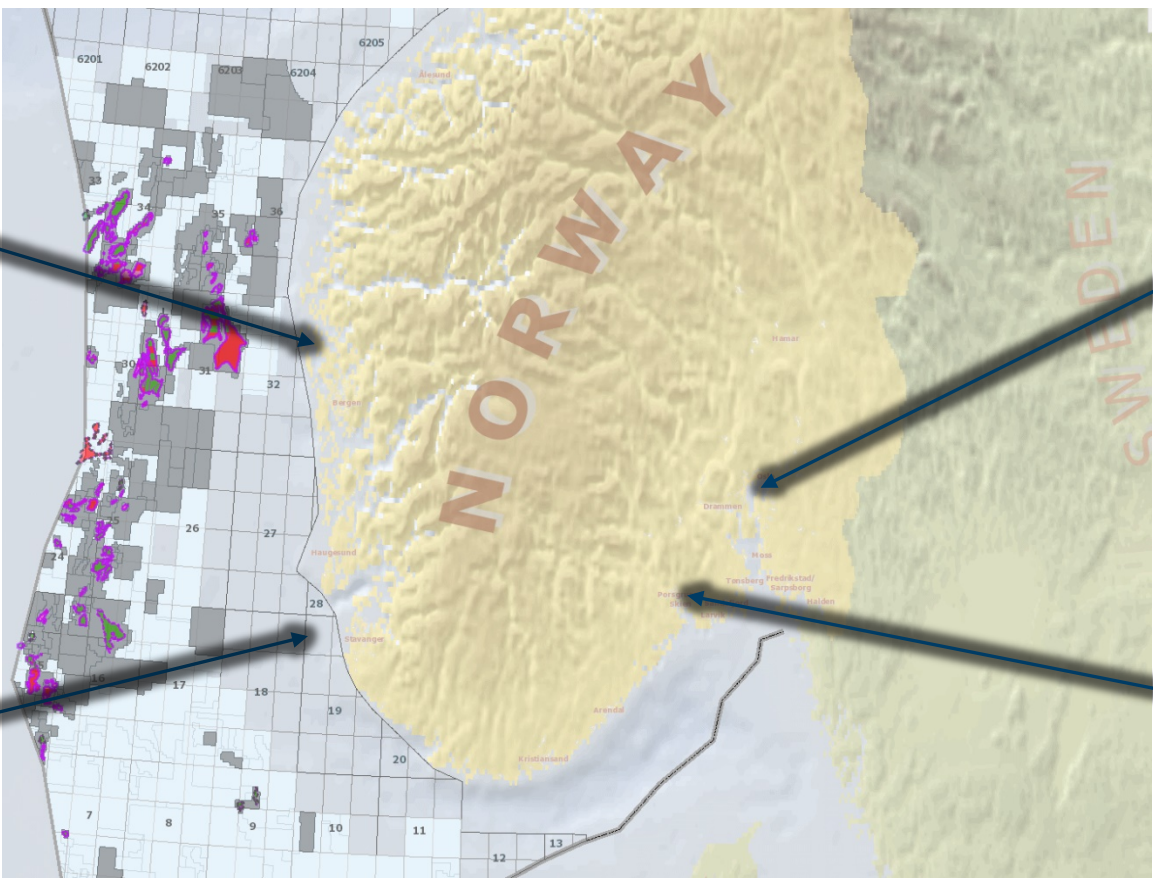
## Ready to realize full chain carbon capture and storage

21.09.2020



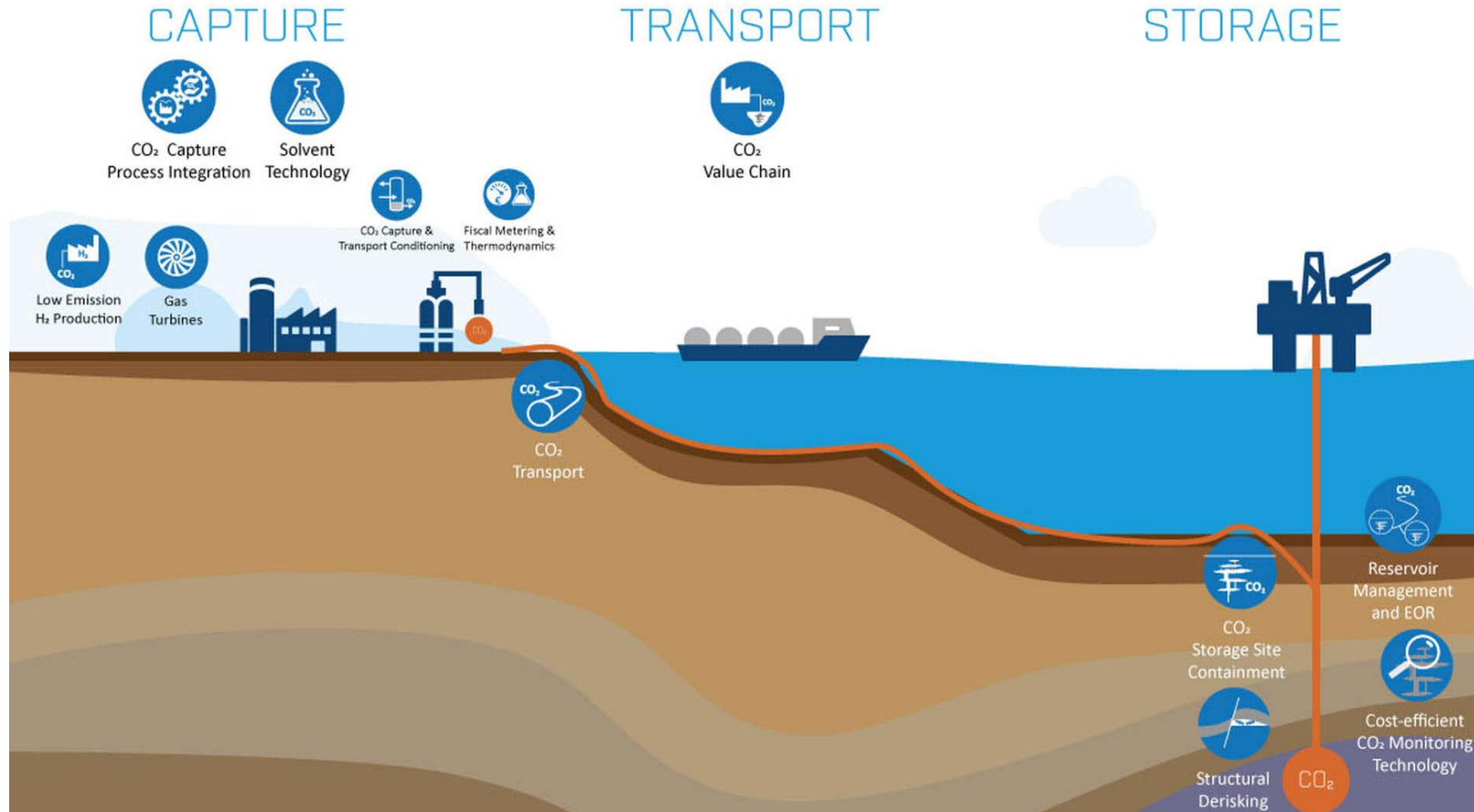
The Norwegian fullscale CCS project has been named 'Longship', in Norwegian 'Langskip'.

# THE NORWEGIAN CCS DEMONSTRATION PROJECT





# Longship – coupling with research





# NCCS

NORWEGIAN CCS RESEARCH CENTRE





## Centres for Environment-friendly Energy Research (FME)

### *Objective:*

*To establish research centres which conduct concentrated, focused and long-term research of high international calibre in order to solve specific challenges in the field.*

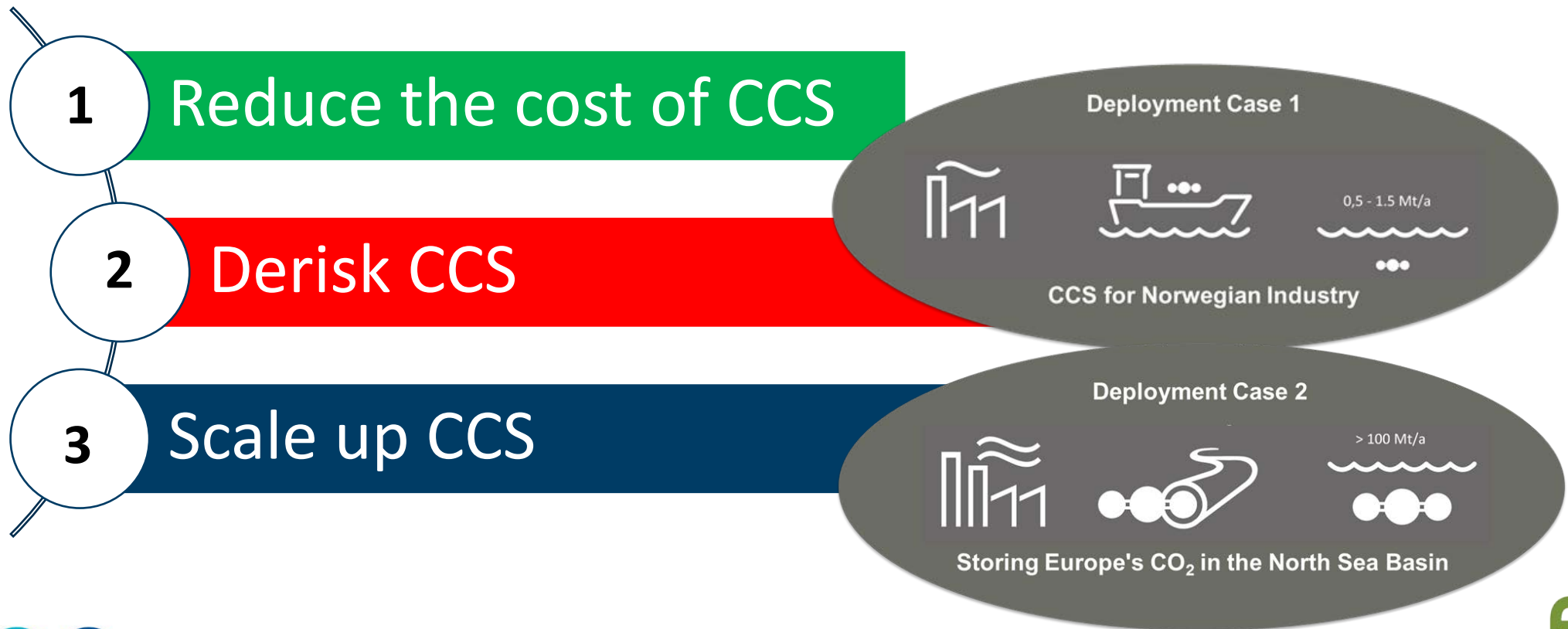


 **NTNU**  
Norwegian University of  
Science and Technology

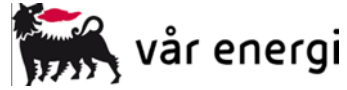
 **SINTEF**



# Overcoming barriers to CCS deployment – through R&D



users

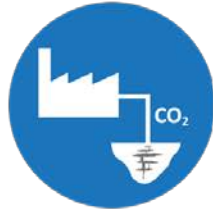


wintershall dea

research institutes



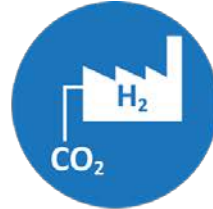
university



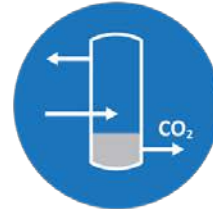
CO<sub>2</sub> value chain and legal aspects



Solvent technology – environmental issues



Low emission H<sub>2</sub> production



Conditioning through liquefaction



Gas turbines



CO<sub>2</sub> capture process integration



CO<sub>2</sub> transport



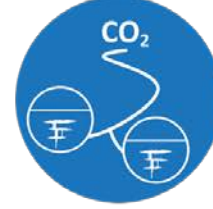
Fiscal metering and thermodynamics



Structural derisking



CO<sub>2</sub> storage site containment



Reservoir management and EOR



Cost-efficient CO<sub>2</sub> monitoring technology

vendors



associated partners



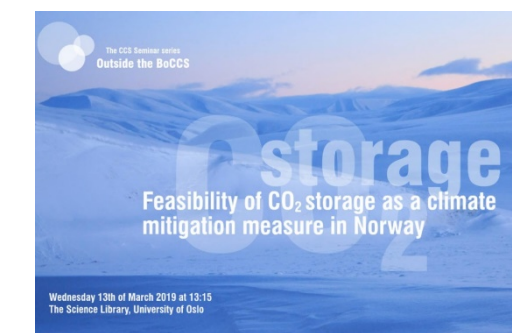
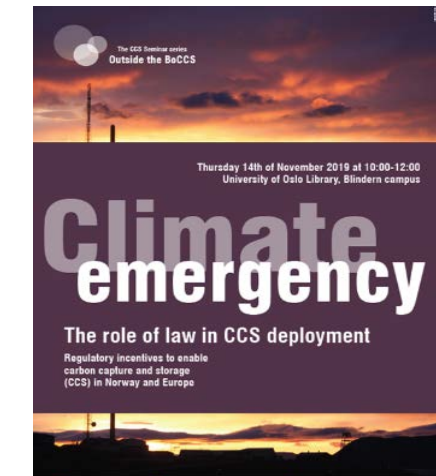
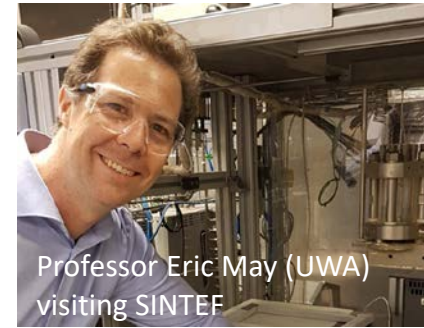
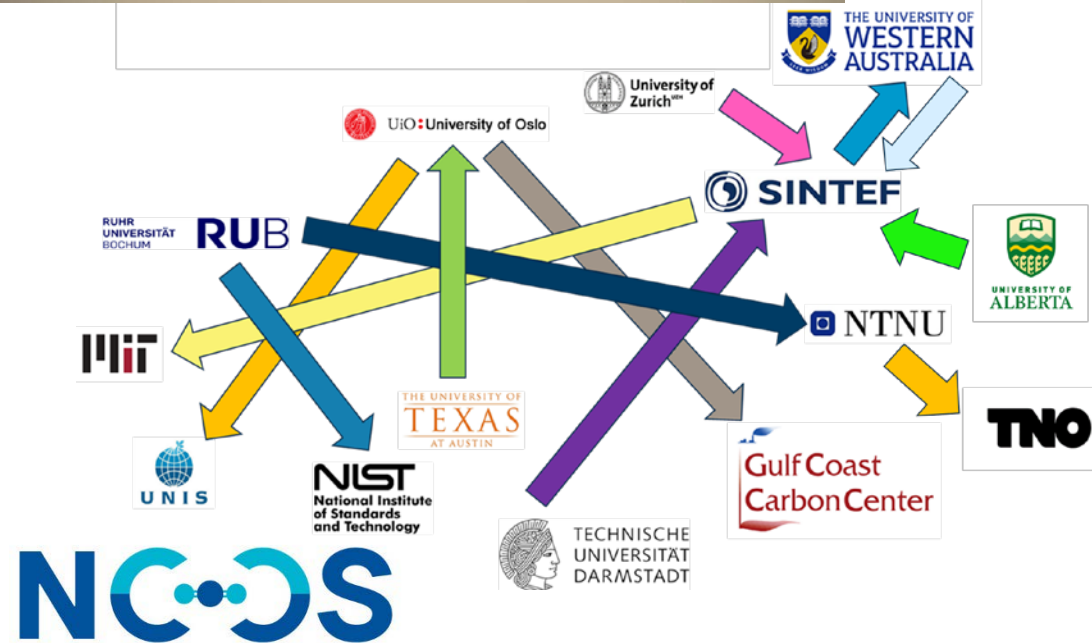
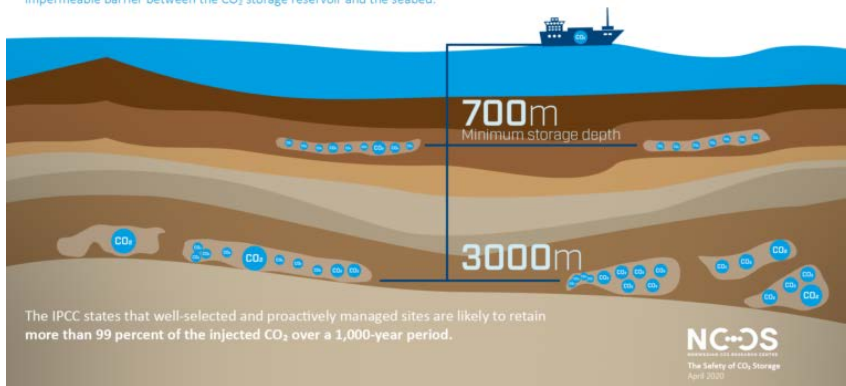


# Accelerate understanding of CCS

## For a variety of stakeholders

### CO<sub>2</sub> is unlikely to leak

The minimum depth for a CO<sub>2</sub> storage site is 700 metres below the seabed. For well-selected storage sites, there will be several different rock layers that provide an impermeable barrier between the CO<sub>2</sub> storage reservoir and the seabed.



# Summary

- EU ETS up from just over 30 EUR/ton CO<sub>2</sub> at the beginning of 2021 to over 60 EUR/ton CO<sub>2</sub> in September
- Upscaling of renewable energy and CCS - two sides of the same coin, not either or
- CCS is a tool for securing the process industry's jobs
- The Hydrogen 4EU study shows that Europe will need 100 million ton of hydrogen per year by 2050 and a CO<sub>2</sub> storage capacity of more than 1000 million ton of CO<sub>2</sub>/year
- CCS is not the oil industry's tool to continue as before. The natural gas must be decarbonized and the emissions to production must be eliminated
- Longships with Northern Lights are about to be established, need to double this capacity many times for Norway and Europe to succeed in achieving the goals of the Paris Agreement. It is possible - and not so expensive compared to alternatives
- It is important to continue investing with strong public funding of hydrogen and CCS research, and there are plenty of reasons to collaborate across borders and continents.



The logo features the letters 'NORWEGIAN CCS RESEARCH CENTRE' in a stylized, blue, sans-serif font. The 'O' is replaced by a graphic of the Earth, showing continents and oceans. The 'C' and 'S' are also stylized, with the 'C' having a circular cutout that aligns with the Earth. The background is a dark blue space filled with numerous white stars of varying sizes and colors, creating a starry night sky effect.

**NORWEGIAN CCS RESEARCH CENTRE**

**NORWEGIAN CCS RESEARCH CENTRE**  
Industry-driven innovation for fast-track CCS deployment





RYSTAD ENERGY

# GREEN HYDROGEN WARS

TRENDS IN THE RACE FOR GLOBAL EXPORTS

**ANJA GUDBRANDSEN, BUSINESS DEVELOPMENT & APAC RENEWABLES**

[anja.gudbrandsen@rystadenergy.com](mailto:anja.gudbrandsen@rystadenergy.com)

**NOVEMBER 2021**



# Agenda

- The state of utility renewables today
- The race to develop green hydrogen
- Who are the movers and shakers?
- Will the rate of green hydrogen project announcements show any signs of slowing?

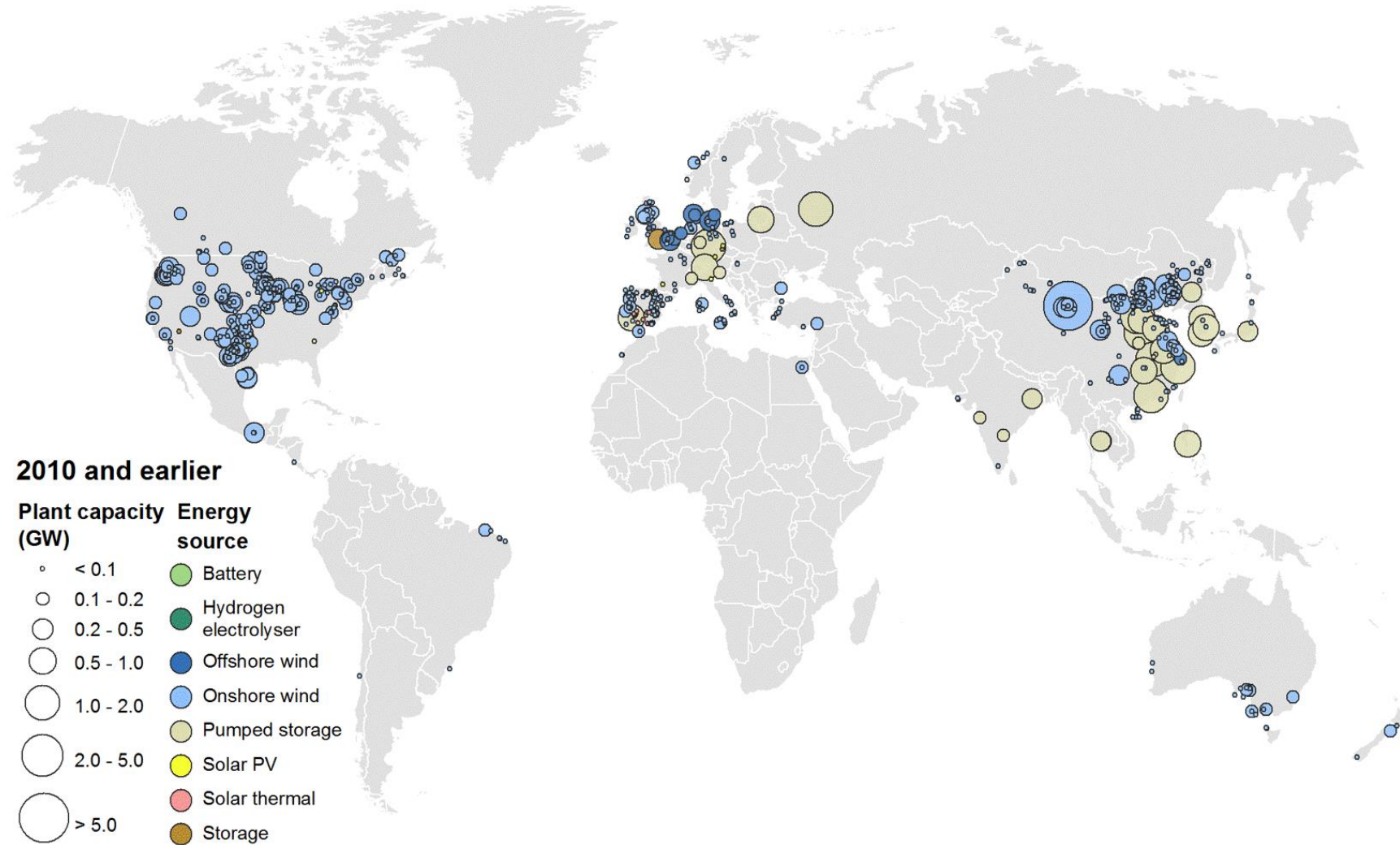
# Rystad Energy

We are a **global independent** energy research and business intelligence company, providing **data, analytics and advisory** services to clients exposed to the energy industry.



# Electrolyser size will increase over 20 times over the next two years

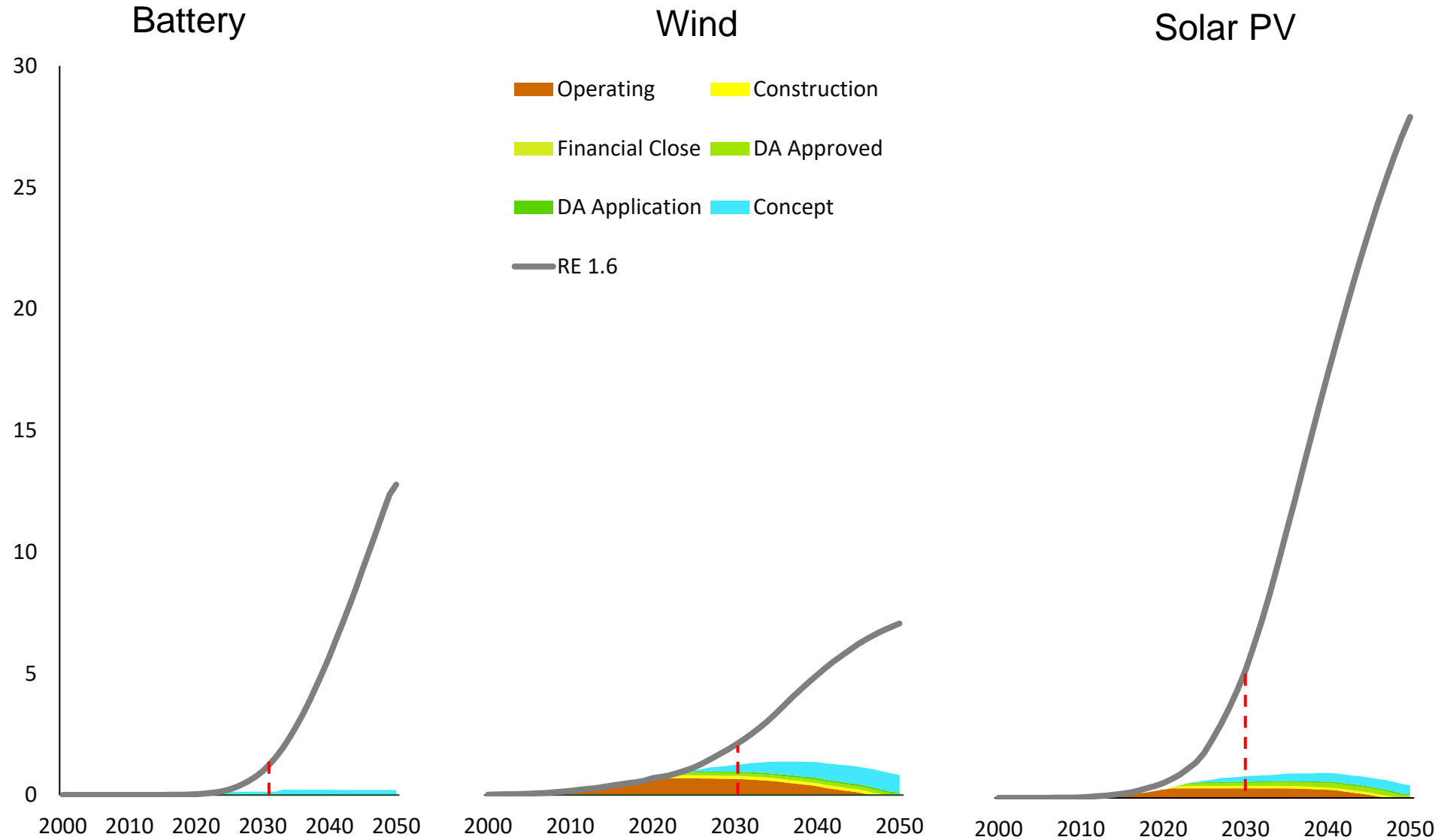
100,000 utility solar, wind and storage assets across 181 countries (GWAC)



Source: Rystad Energy RenewableCube

# By 2030, 7 times the current solar pipeline is required to deliver the 1.6 degree Celsius scenario

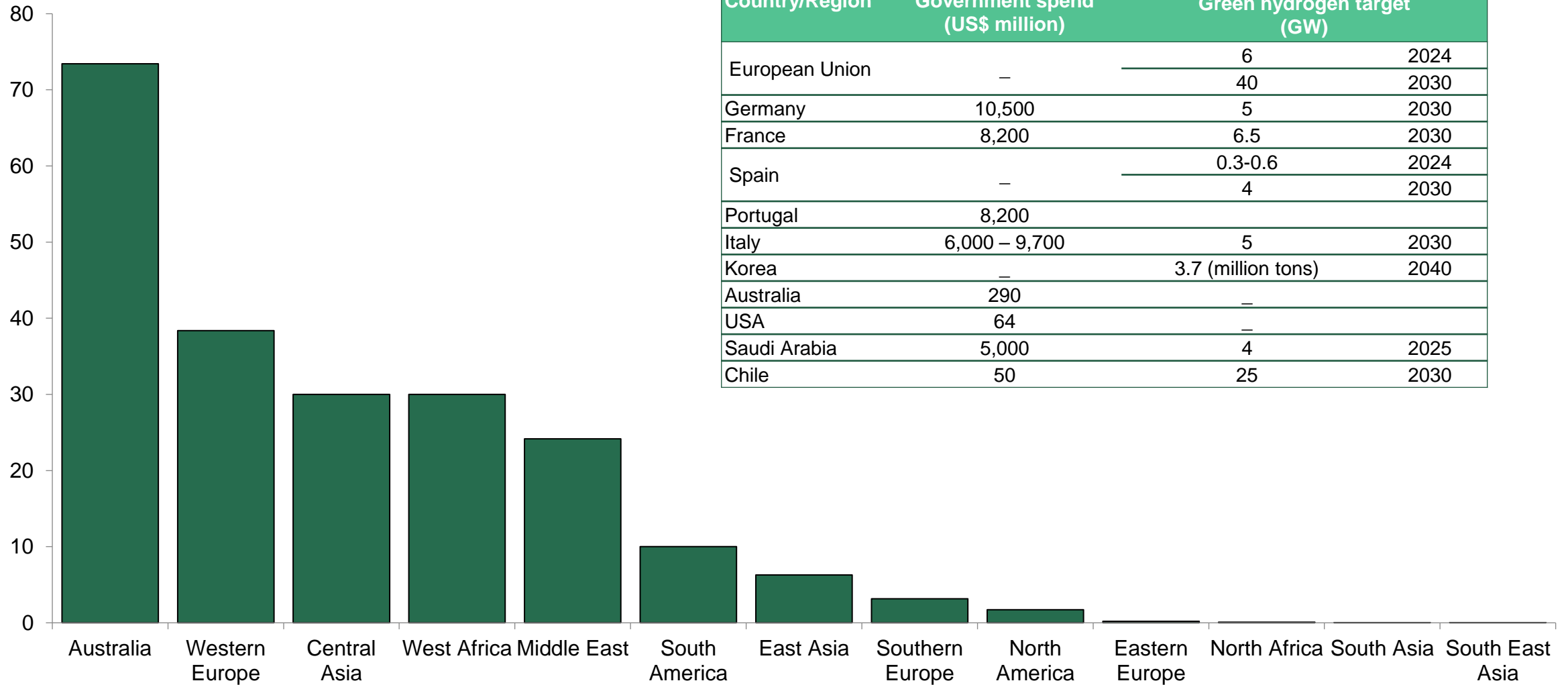
Terawatt (TW)



# Green hydrogen – 258 GW pipeline

Countries are racing to incentivize projects for domestic use and export markets

Electrolyzer Capacity (GW)

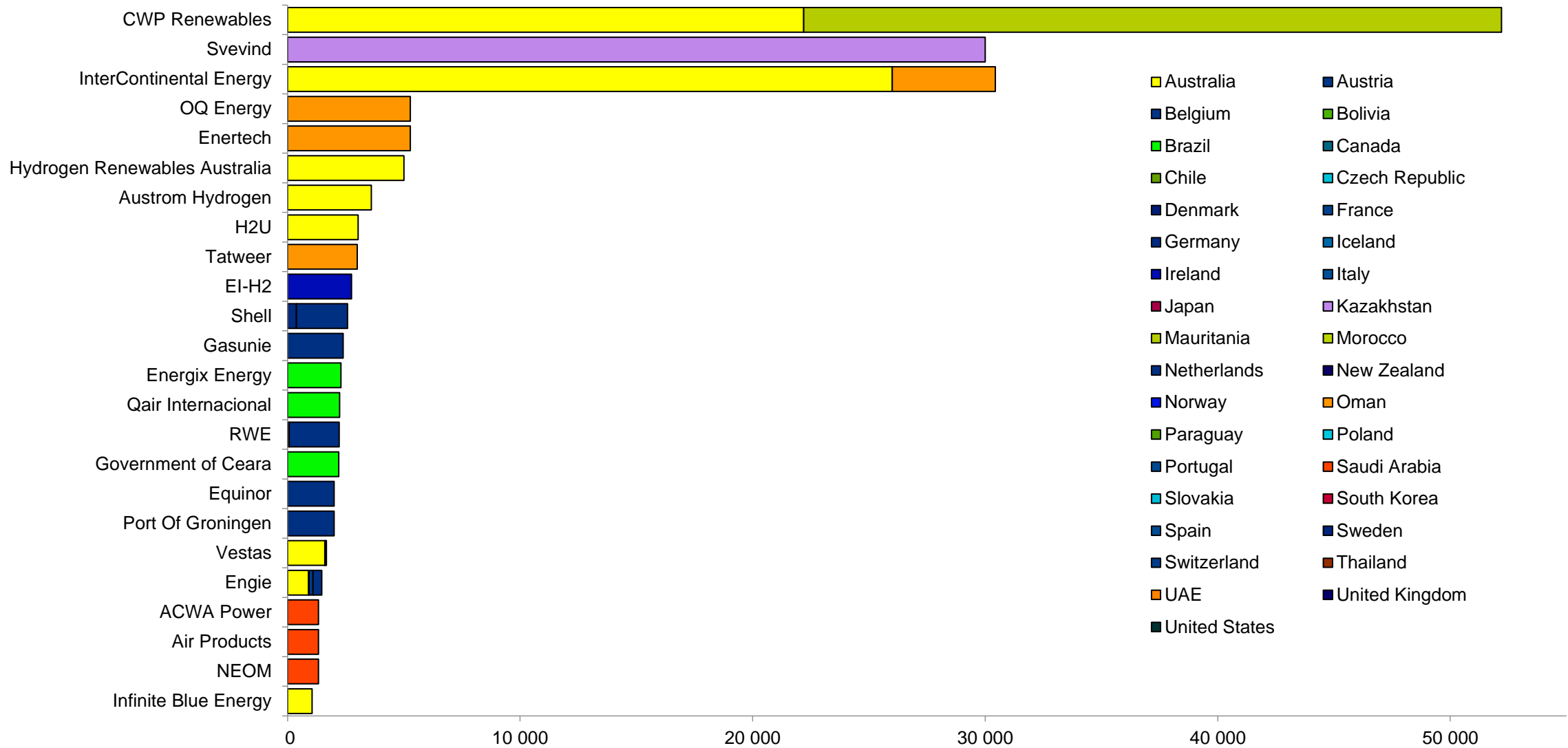


Government support and country targets

Country/Region	Government spend (US\$ million)	Green hydrogen target (GW)	Target Year
European Union	–	6	2024
		40	2030
Germany	10,500	5	2030
France	8,200	6.5	2030
Spain	–	0.3-0.6	2024
		4	2030
Portugal	8,200		
Italy	6,000 – 9,700	5	2030
Korea	–	3.7 (million tons)	2040
Australia	290	–	
USA	64	–	
Saudi Arabia	5,000	4	2025
Chile	50	25	2030

Source: Rystad Energy RenewableCube & research and analysis

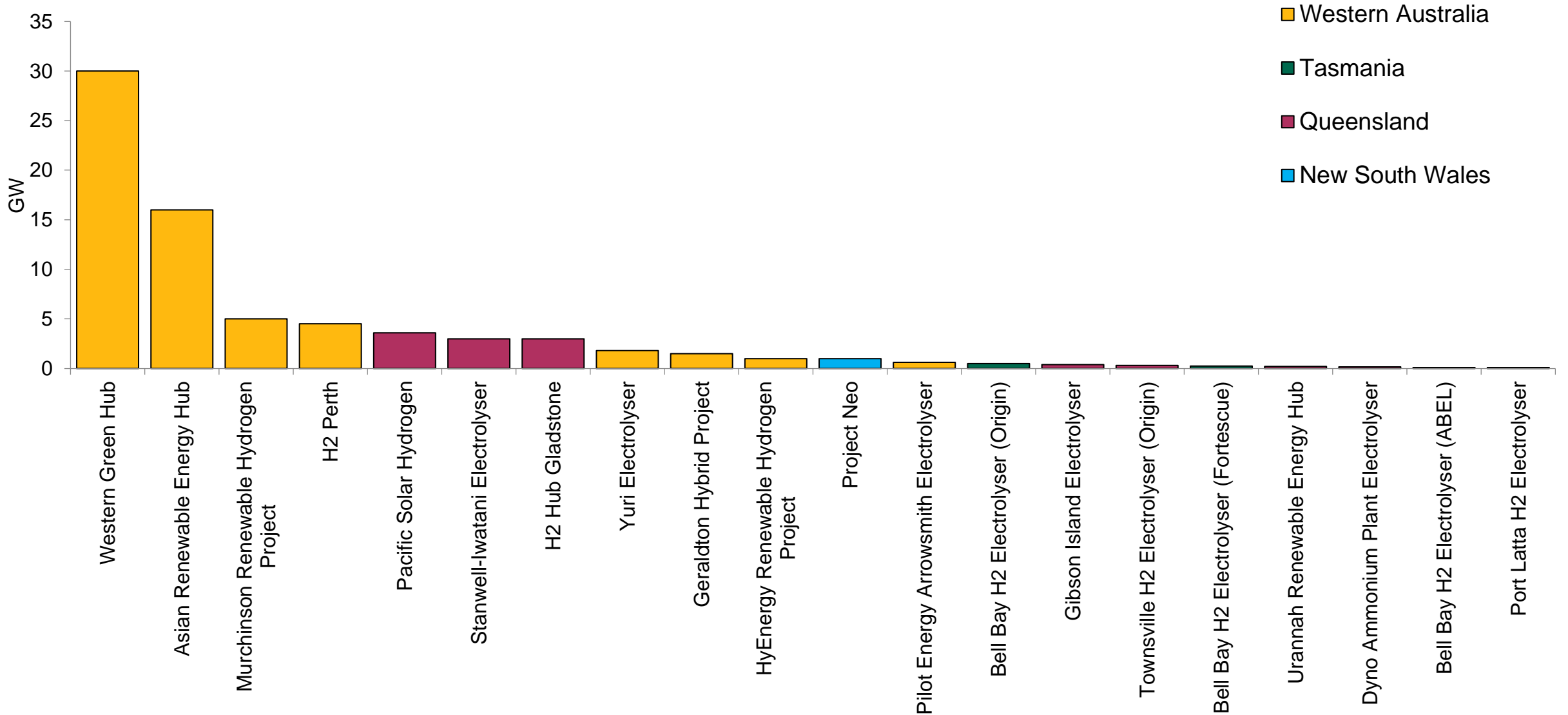
# Top 25 companies - green hydrogen electrolyser capacity (GW)



Source: Rystad Energy RenewableCube



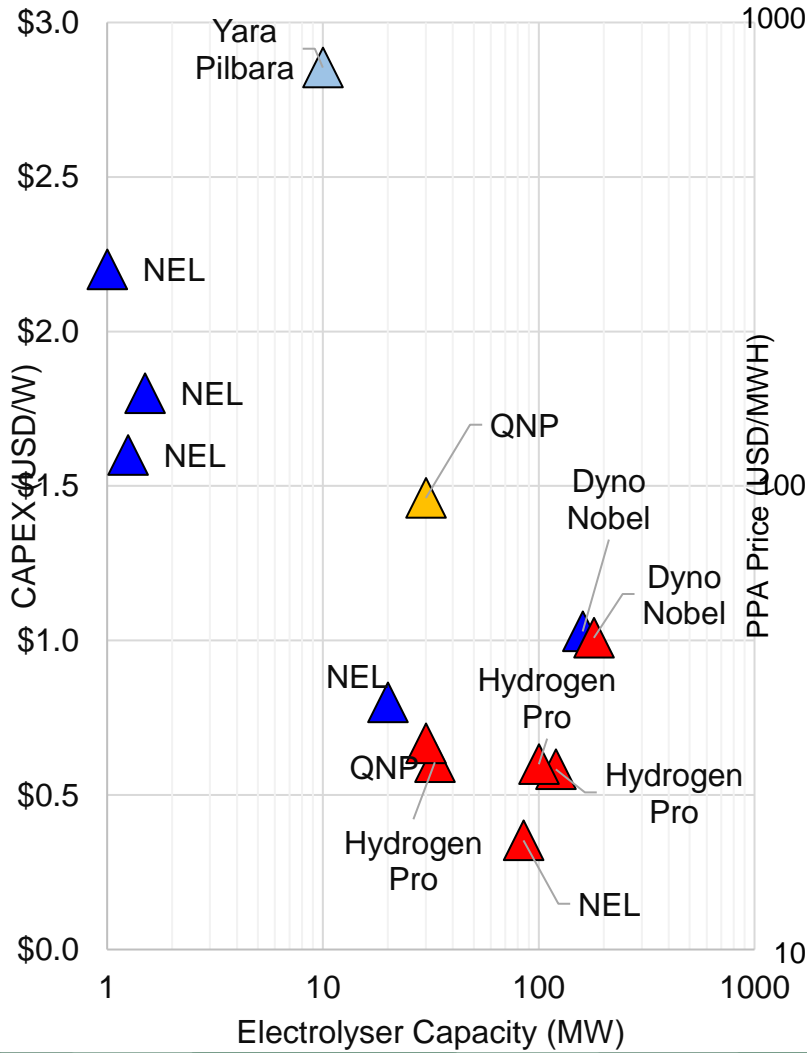
# Top 20 hydrogen projects in Australia by electrolyser capacity – Western Australia the export hub



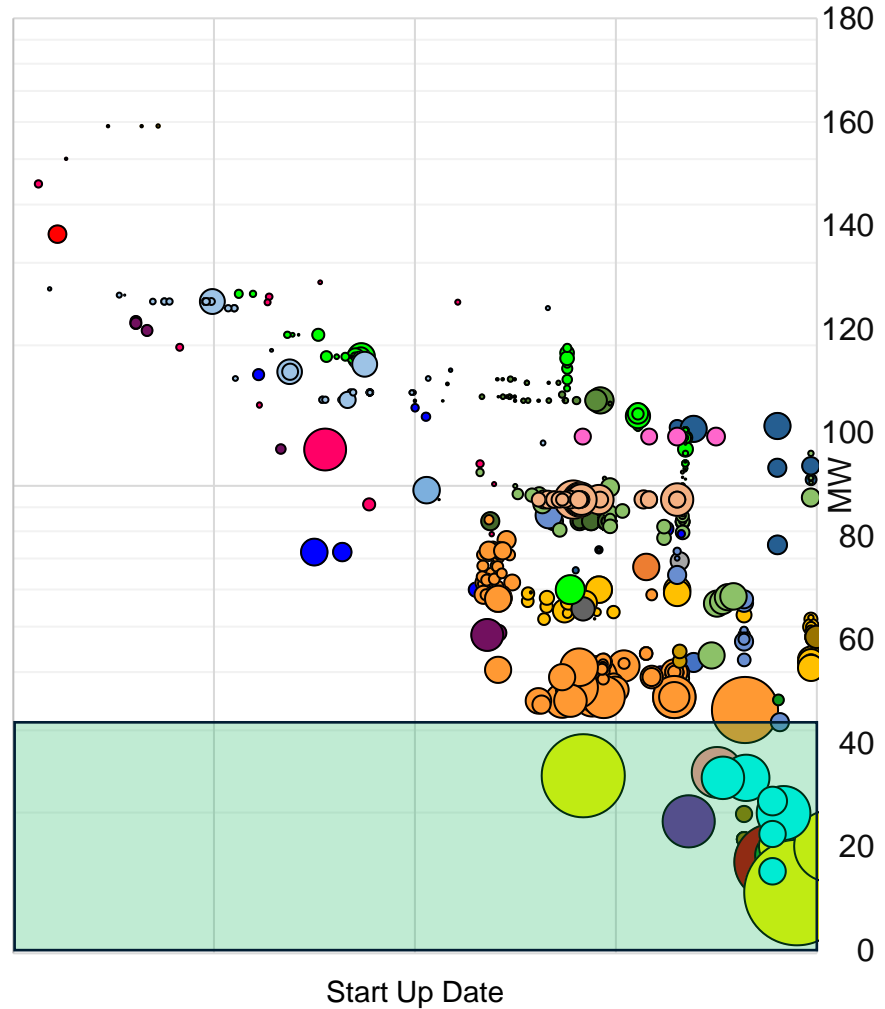
Source: Rystad Energy RenewableCube

# 75% of CAPEX needs to be subsidized to reach 2 AUD/kgH2 - The three pillars of cheap green hydrogen

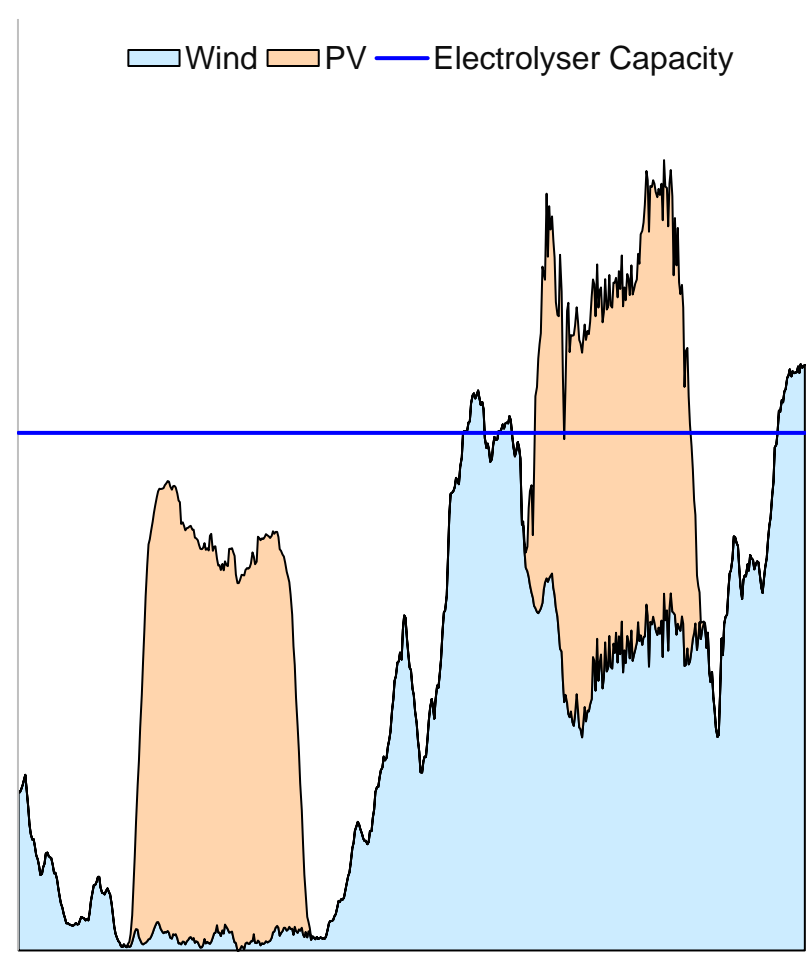
## LOW-COST ELECTROLYSERS



## LOW-COST POWER

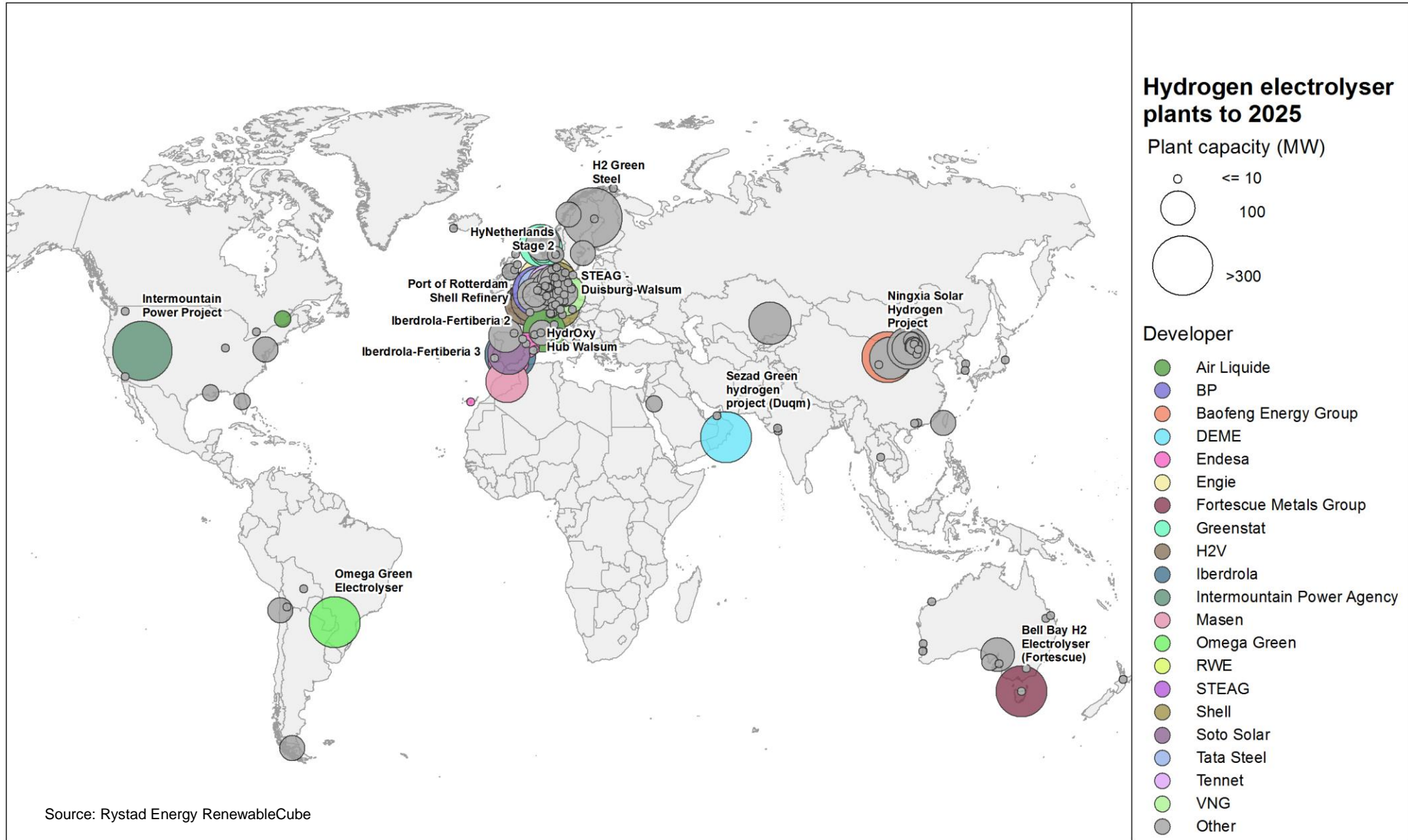


## HIGH UTILISATION



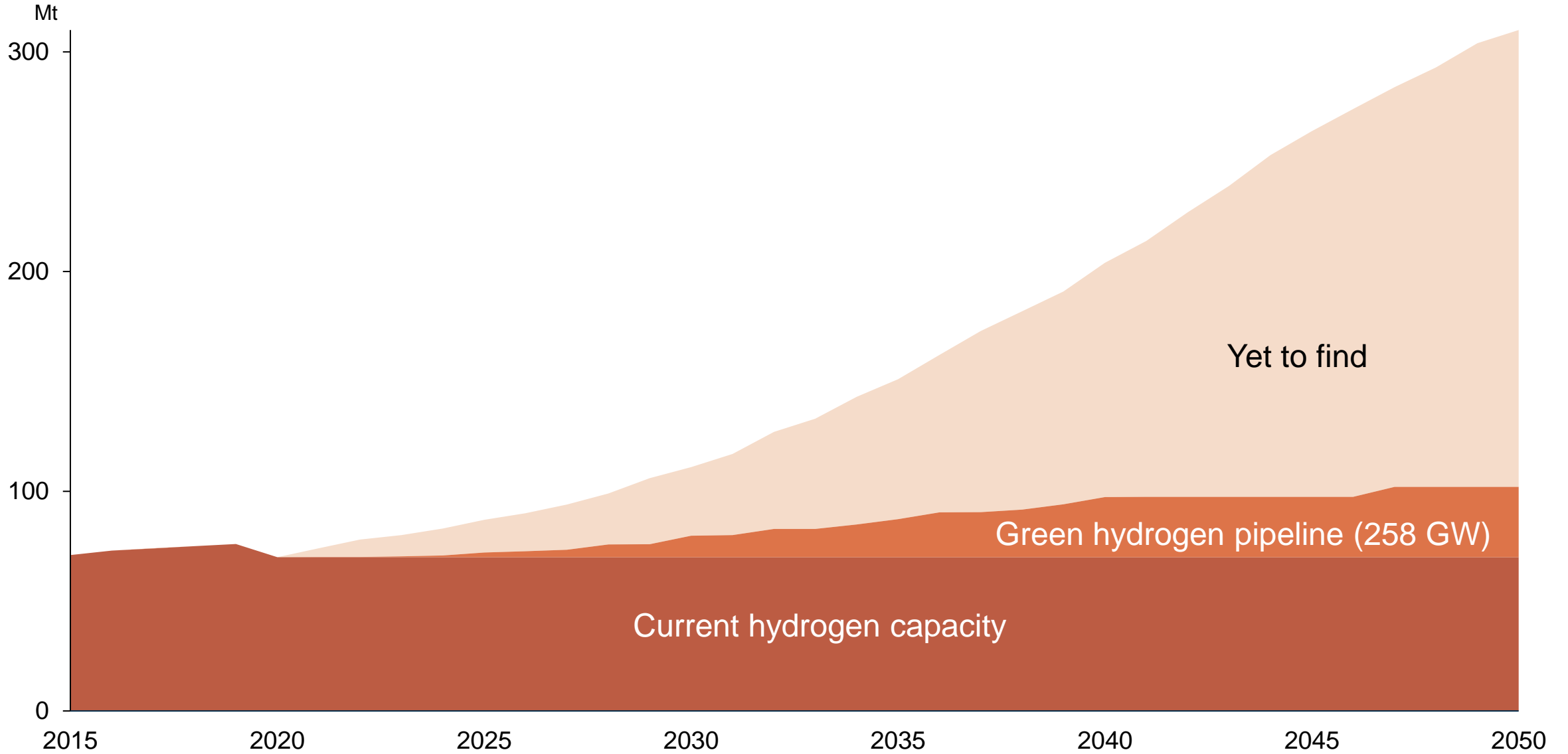
Source: Rystad Energy RenewableCube

# Green hydrogen start up year 2021-2025 and company



# Green hydrogen could double the demand for utility renewables

Hydrogen demand outlook vs existing capacity and the green hydrogen pipeline (Mt)





## Conclusion - green hydrogen wars

- Countries are racing to supply green hydrogen and supporting the development through funding
- Australia accounts for the lion's share of hydrogen projects
- CWP Renewables has the largest hydrogen pipeline
- The opportunity – hydrogen demand is expected to grow five-fold towards 2050 and this could double the demand for utility renewables



RYSTAD ENERGY

**Rystad Energy is an independent energy consulting services and business intelligence data firm offering global databases, strategy advisory and research products for energy companies and suppliers, investors, investment banks, organizations, and governments. Rystad Energy's headquarters are located in Oslo, Norway.**

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AKER  
CLEAN  
HYDROGEN

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# An efficient hydrogen value chain integrator

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**Norwep, 9 November 2021**

Anders Storstenvik  
Asset Development Manager

# PLANET-POSITIVE: AKER HORIZONS ECOSYSTEM



26.10.2021



# Three pillars driving demand for clean hydrogen for industrial use

1

**Demand for emission-free products**



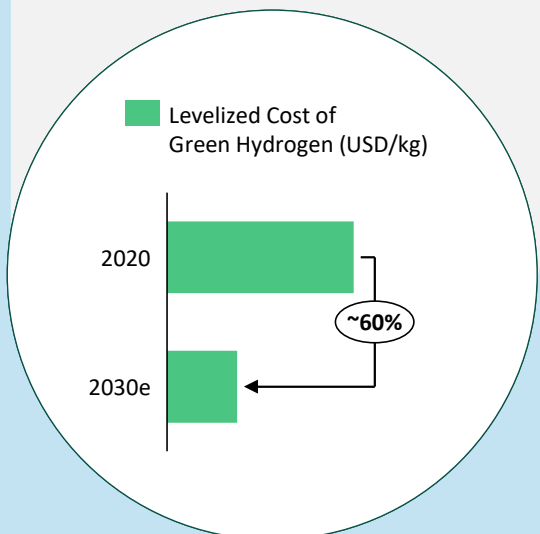
2

**CO<sub>2</sub> taxes and regulatory incentives**

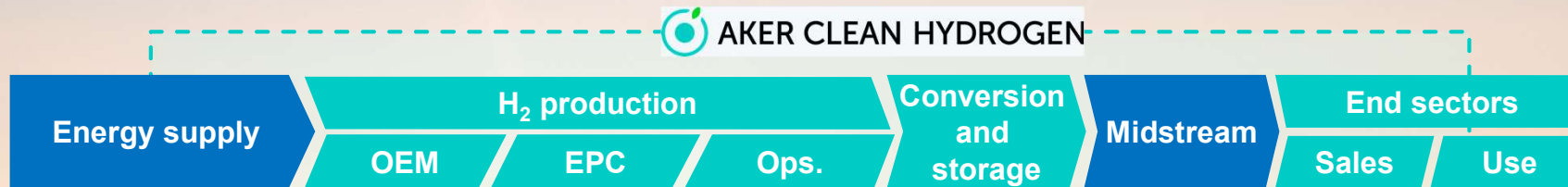


3

**Cost reductions of clean hydrogen production**



# Affordable hydrogen...



## INTEGRATED HYDROGEN PRODUCER Develop, build, own and operate hydrogen facilities

- **End-to-end optimized design and operations** - from energy mgmt. to plant operations, storage and output (e.g. right-sizing)
- **Partnering** with **strong players** along the value chain
- **Cost-leading** modular architecture based on product catalogue and serial production
- Value optimized project with **short timeline from FID to first production**
- Fully digitalized **integrated concept screening** and simulation with early cost estimate
- **Digitalized and cost-leading** operating model
- **Safe** design, development and operatorship through Aker know-how built up over 180 years of industrial excellence



- ✓ Affordable
- ✓ Safe
- ✓ Easy



Photo by Henrik Ørsted – Oslo Museum/Oslobilder.no  
(April Fools' day in 1950: "Free wine at the wine store")

## ...to the end-users

What is required for end-users to queue up for **affordable** green hydrogen?

Applying HSSE culture, toolbox and solutions from our oil & gas and industrial heritage to make it

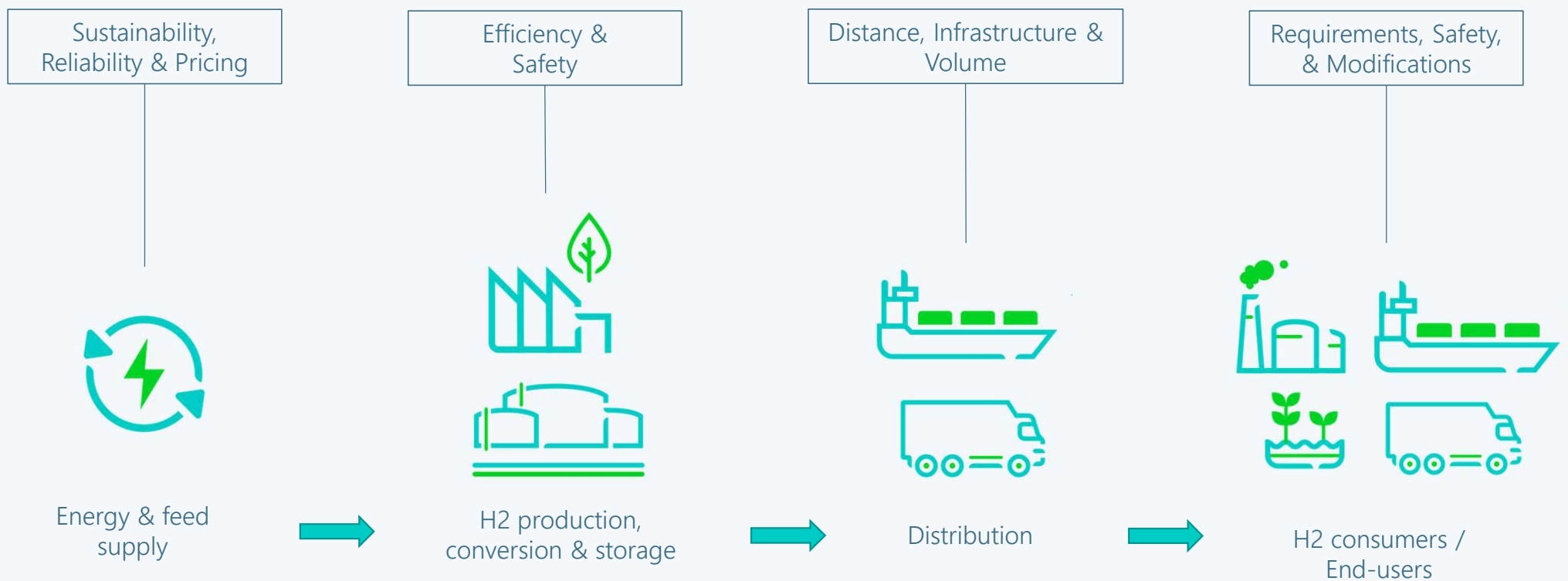
**safe**

Understanding end-users' technical and commercial hurdles and collaborate to make the transition

**easy**

# Affordable, safe and easy hydrogen - to the end-user

## *Understanding the-full-value chain*





# Green Ammonia Berlevåg | Understanding the-full-value chain



Green Ammonia Berlevåg

Key standardized building blocks

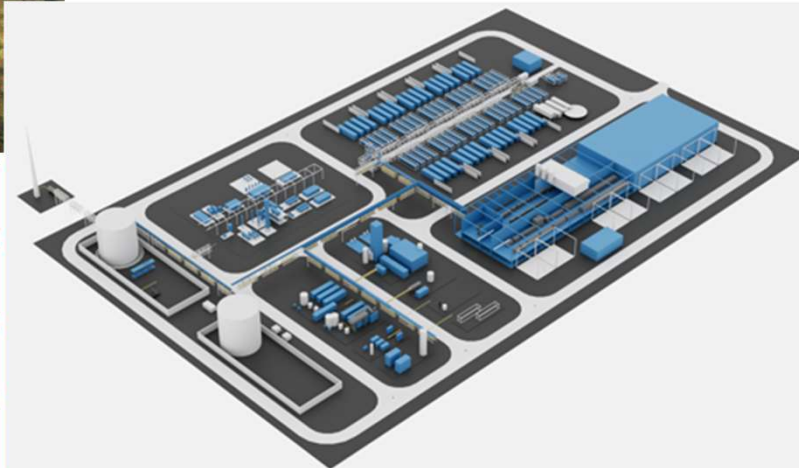
Multi contracting agreement with selected OEMs

- Electrolyser stack
- TRU container
- Production module
- Control system
- Substation
- Ammonia plant

FEED ready solution

Plant

Results



- Simplified
- Standardized
- Configurable
- Reduced CAPEX
- Reduced delivery time
- Improved safety



AKER CLEAN  
HYDROGEN



# Norwegian Energy Symposium

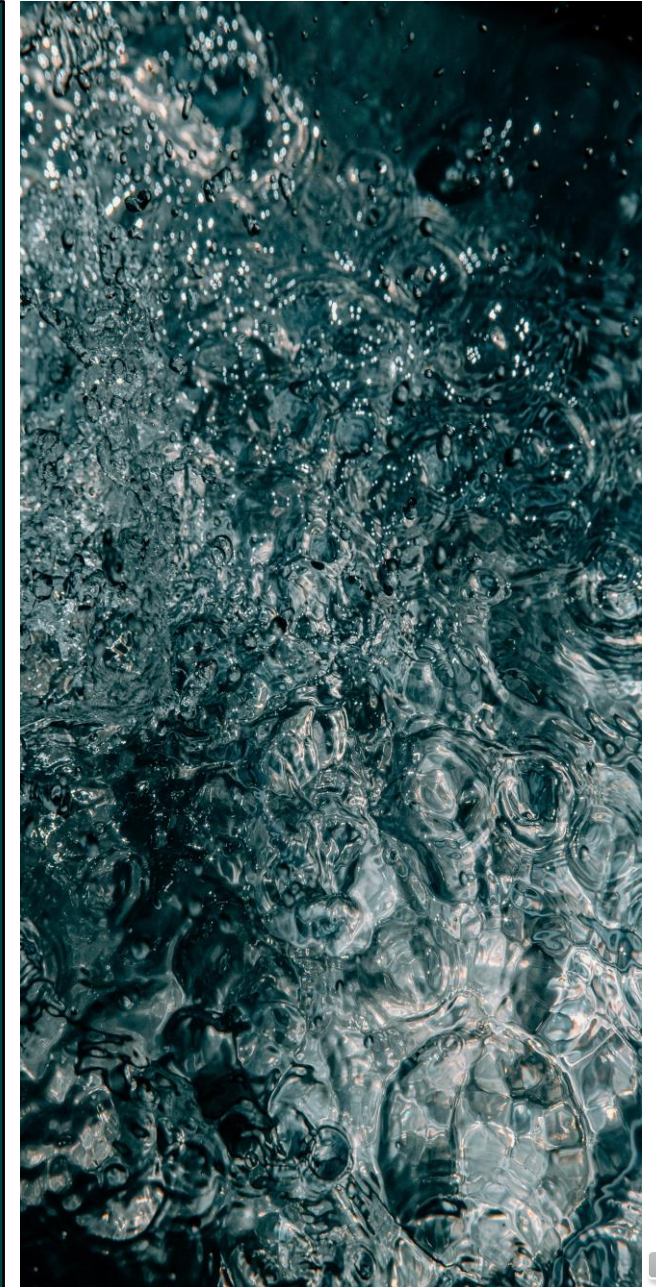
November 2021

Hydrogen pro 



# Content

- I. About HydrogenPro
- II. HydrogenPro key markets
- III. HydrogenPro partnerships
- IV. HydrogenPro technology





# About HydrogenPro

## Introduction

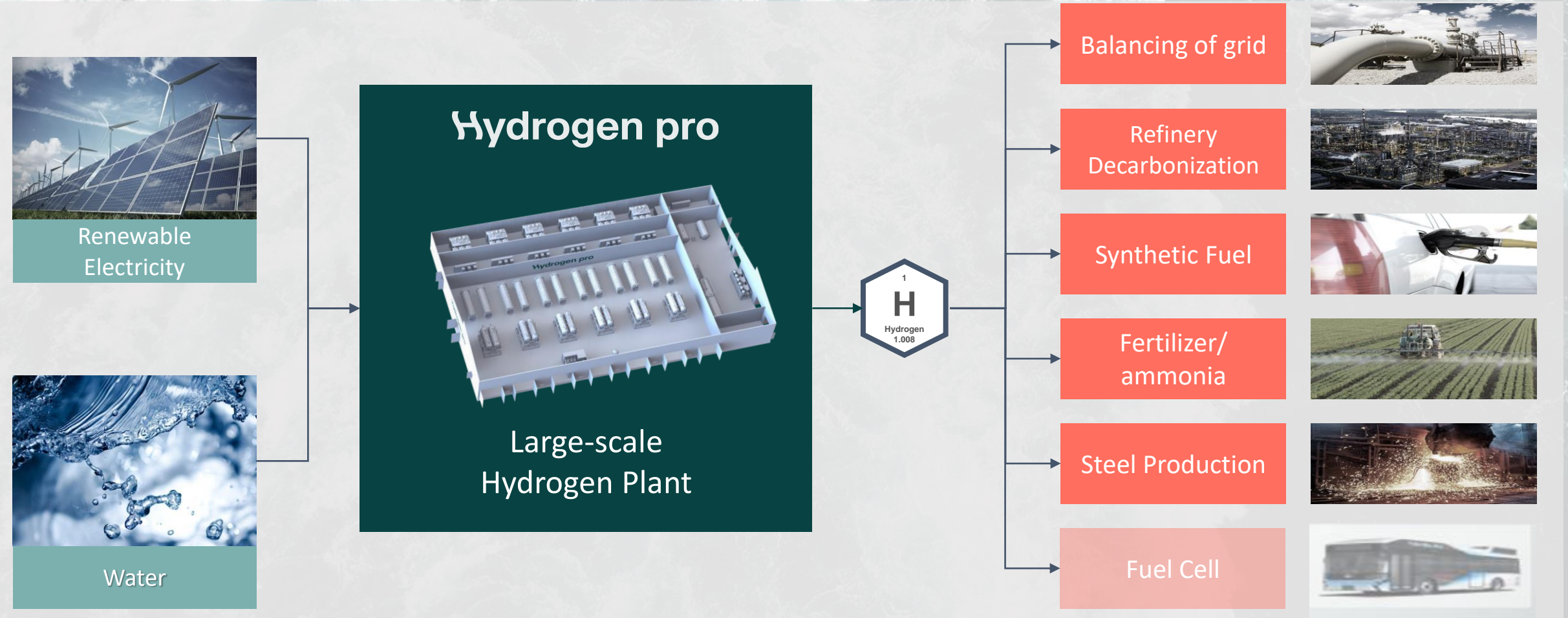
- Founded 2013 by core team with several years of experience from electrolyser industry from Norsk Hydro
- Headquartered in Porsgrunn, Norway
- Focused on high pressure alkaline technology
  - Core technology developed through a combination of Norwegian and Chinese electrolyser competence and experience
- IPO and stock listing at Oslo Stock Exchange in October 2020
- Ownership of next generation electrode technology





# HydrogenPro key markets

## Large scale hydrogen plants





# HydrogenPro partnerships

## Partnership strategy

- HydrogenPro is actively participating in partnerships to fast-track global upscaling of the company



- Open attitude to partnerships, specially focused on partnerships for local competence and opportunities





# HydrogenPro technology

System benefits high pressure alkaline

## Low CAPEX

- High pressure in electrolyser unit
- Low footprint

## Low OPEX

- Low power consumption
- Low cooling need
- Limited maintenance and low degradation
- Utilization of O<sub>2</sub>

## Fit for future

- Scaling benefits with no noble metals
- No use of Polyfluorinated alkyl substances (PFAS)

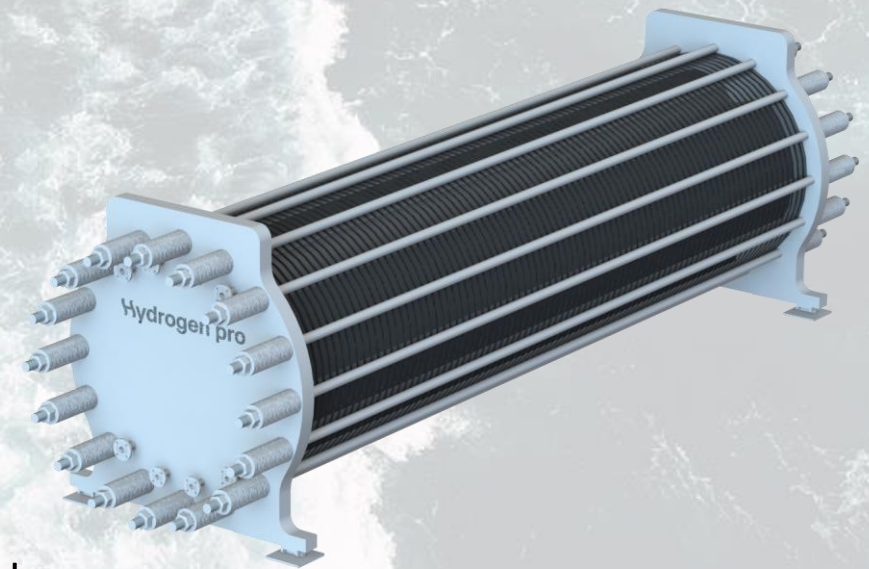




# HydrogenPro technology

## World largest single cell stack

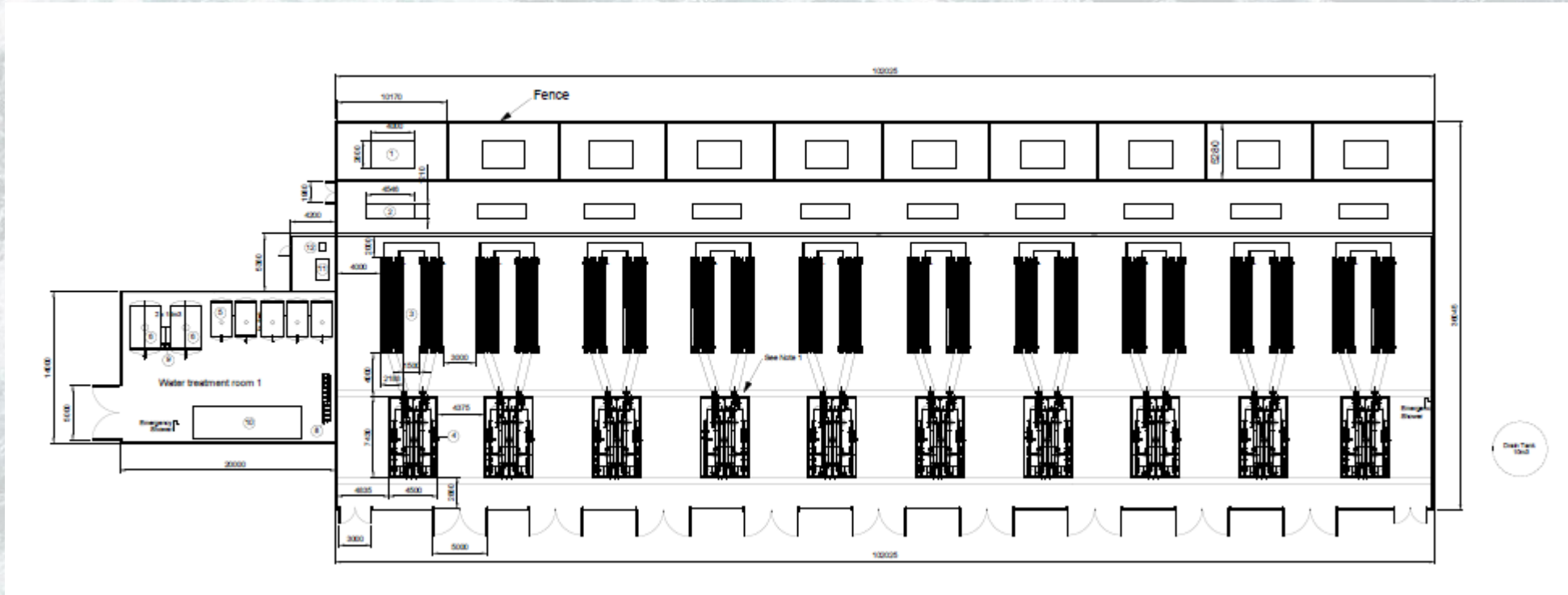
- **HydrogenPro has developed the world largest single cell stack**
  - 30% larger than the largest stack delivered
  - Producing 1100 Nm<sup>3</sup>/h (~99 kg) H<sub>2</sub> at 15 bar
  - Length 8 m, diameter 2,5 m, weight approx. 50 tons
- **Benefits with the new cell stack:**
  - Optimization of standard electrical equipment
  - Reduction of BoP equipment
  - Lower CAPEX
- Mitsubishi Power has already ordered a pilot of the stack to be tested at Herøya, Norway





# HydrogenPro technology

Layout example for large scale electrolyser plant



# HydrogenPro technology

## New advanced electrode technology

### About the new advanced electrode technology

- Developed with partners in Denmark over the last 5 years
  - Acquisition of 100% of the shares in Advanced Surface Plating in December 2020
- Ownership of technology
  - Proprietary next-generation advanced electrode technology
  - Lower the voltage for hydrogen formation -> increased efficiency
  - Potential to improve operating efficiency of electrolyzers with up to **14%**
    - Current electrolyzers consume **4.4 MW** to produce **90 kg H<sub>2</sub>/hour**
    - Tests show that this is reduced to **3.8 MW**
    - Reaching an efficiency factor of **93%** of theoretical maximum capacity
- A plating facility for full scale electrode production was opened in Sept 2021 in Aarhus, Denmark

Timeline	2021			
	Q1	Q2	Q3	Q4
Conclusion on location	■			
Setting up R&D test plating		■		
Setting up R&D test facilities / QC for production		■		
R&D test plating of small-scale electrodes			■	
Testing and validating high-performance R&D electrodes				■

***First production of full-scale electrodes in 2021, ready for market in 2022***

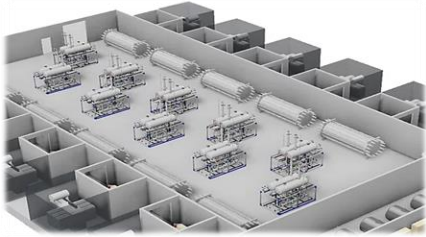




# HydrogenPro technology

Technology roadmap 2021-2025

## Today's technology



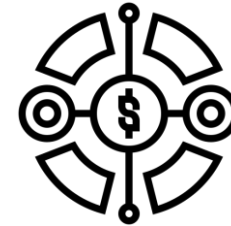
- Well proven and delivered since 1994
- Use current technology to implement the first 100 MW plant globally to be the flagship

## Optimize OPEX



- Increase efficiency by:
  - full-scale verification of advanced electrode technology
  - simplification and optimization of balance of plant
  - reduced need for cooling water
- Optimization of fluid mechanics and thermo mechanics

## Optimize CAPEX



- Scaling up, optimization and automatization will gradually drive down capex
- Reduce footprint
- Increase current density and operational flexibility
- Increase pressure on both H<sub>2</sub> and O<sub>2</sub> up to 50 bar

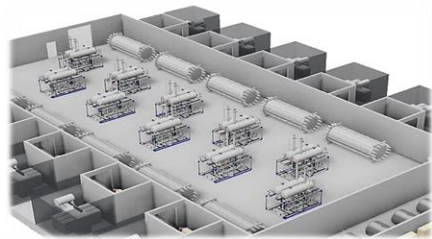
***Our ambition: #1 large-scale hydrogen production systems player***



# Good progress towards our ambition: #1 large-scale hydrogen production systems player

*HydrogenPro with a clear roadmap to become global leader in large-scale hydrogen systems*

## Secure and deliver on key contracts



- Secure and deliver on key contracts for the four largest hydrogen plants globally
- Use first mover advantage to implement the 100 MW stack as the industry standard to drive global growth in large-scale plants

## Market leadership through technology and consortium



- Asset light consortium strategy together with strategic partners
- Further develop and optimize the technology for large-scale systems
- Optimize supply chain and 3<sup>rd</sup> party supplier agreements

## Expand service offering



- Optimize supply chain for Europe, USA and China
- Build central manufacturing hub supported by local assembly and service units in JV structures
- Develop ESG-focused lifecycle service capabilities
- Introduce overhaul after 10 years
- Develop digital solutions for control system monitoring

## Production target



- Short - medium term target of >1GW annual production



# Hydrogen pro

[www.hydrogen-pro.com](http://www.hydrogen-pro.com)





**Wilhelmsen**

Espen Gjerde | VP Strategy and M&A | Wilhelmsen

Norwegian Energy Partners - October 2021



# The Wilhelmsen group

Founded in Norway in 1861  
Wilhelmsen is now a  
comprehensive global  
maritime group

Offices in 60+  
countries

Providing essential products,  
services, crew and technical  
management

15000  
employees



150+ years in  
**Australia**

Australian offices  
**22**

Offshore project agency  
Ichthys / Gorgon / Wheatstone / Amrun

Leading agency player  
**LNG & LPG**



# New Energy

Driving energy infrastructure transformation and maritime decarbonisation



Zero emission hydrogen vessels



Providing offshore logistics in The North Sea basin and beyond



Data-driven vessel operations optimization services



Full-service autonomous shipping



Purpose-built vessels to the global offshore wind market



# Hydrogen value chain

Production, distribution and...



## Industry cluster for hydrogen & carbon capture

- Blue Hydrogen production
- Carbon capture inbuilt
- Under construction



## Green bunkering at facilities

- Support infrastructure
- Key coastal locations
- First vessel bunkering 2024





**FROM ROAD  
TO SEA**



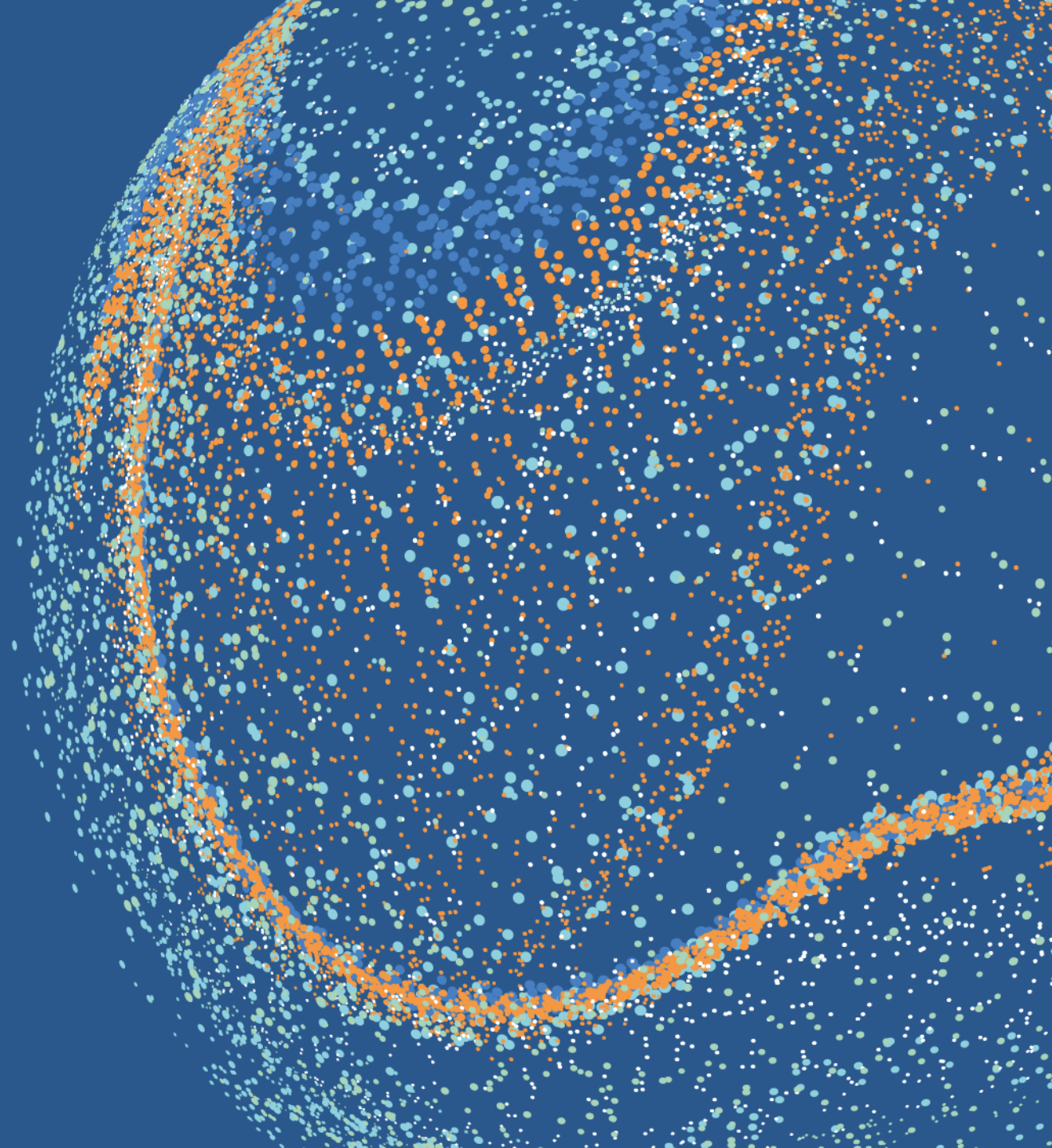
**H2-DISTRIBUTION**



**EMISSION CUTS**



**Wilhelmsen**





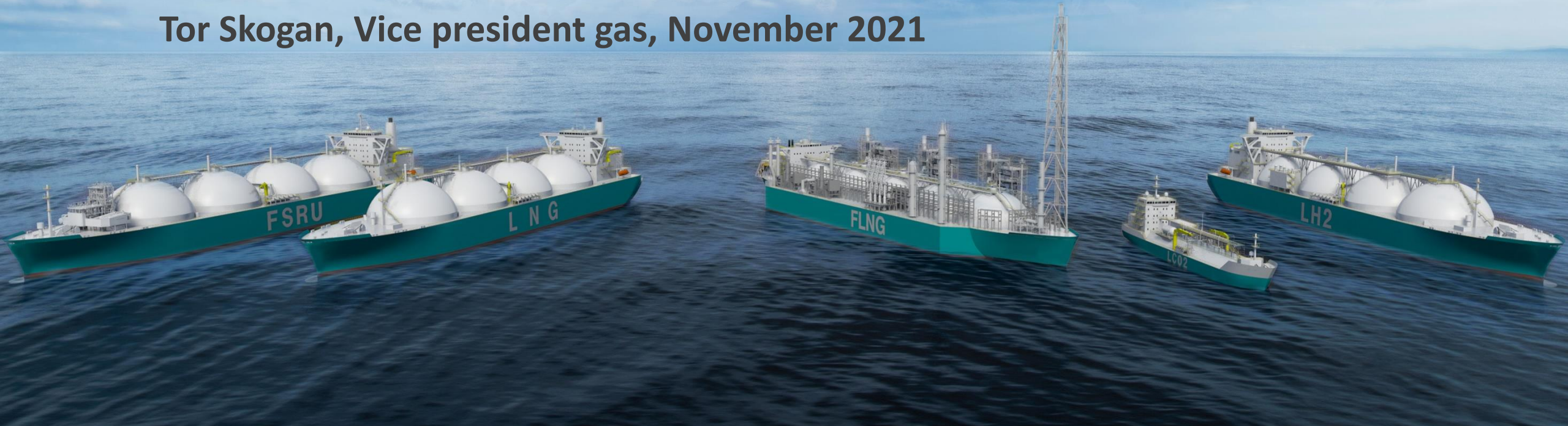
Gas Technologies



Moss technology for the transportation of green liquefied gas

**moss**maritime

Tor Skogan, Vice president gas, November 2021





# mossmaritime

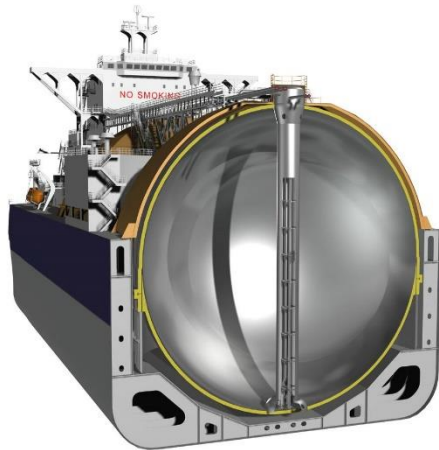
## Company facts

- Engineering company within the maritime energy sector
- Office: Lysaker, Norway - 65 employees
- Owned by Saipem; a world class energy EPC contractor, since 2001
- Business focus: Design & engineering for LNG and floating renewable solutions
- Clients: Shipyards, shipowners, energy companies, EPC contractors



# mossmaritime LNG carriers

- Moss is the originator & owner of technology for Moss LNG carriers with the famous spherical LNG tanks
- From 1973 until today 145 Moss LNG carriers have been built world-wide (many built for Australia exports)
- Moss LNG tanks = superior robustness & reliability



LNG carrier «Pacific Breeze» (2018) – Ichtyos project



# mossmaritime

## Floating LNG terminals (FSRU, FLNG, FSU)

- Moss Maritime is a pioneer for design & engineering of floating LNG terminals (FSRUs, FSUs and FLNGs)
- Moss provides a wide range of multi-discipline engineering services to shipowners, shipyards and charterers
- Concept evaluation → basic engineering/FEED → detail engineering
- Moss special competence related to conversions → Moss has engineered the conversion of 10 x LNG carriers into floating LNG terminals

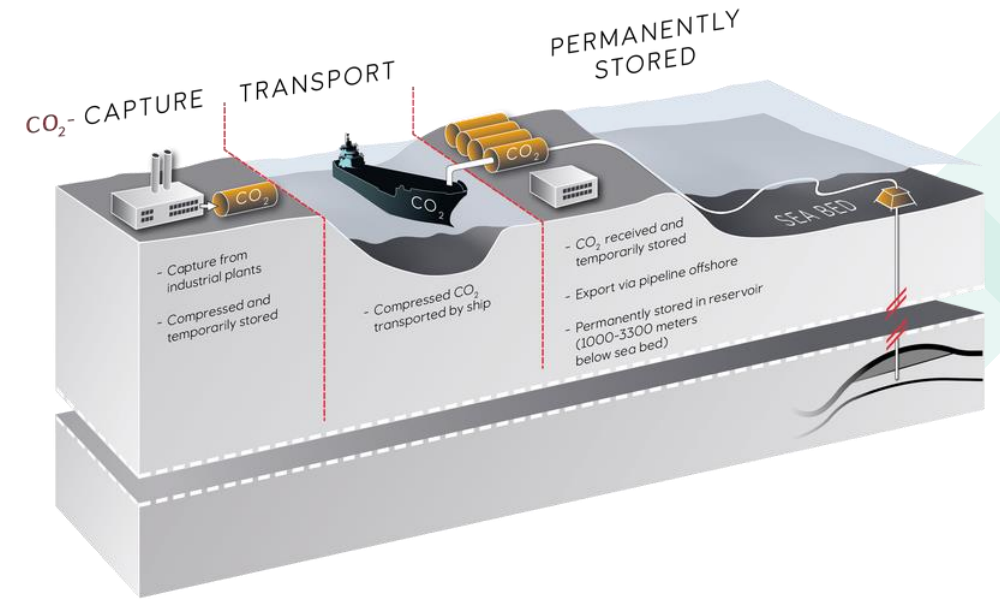




# mossmaritime

## CO2 ship transport – Northern Lights project

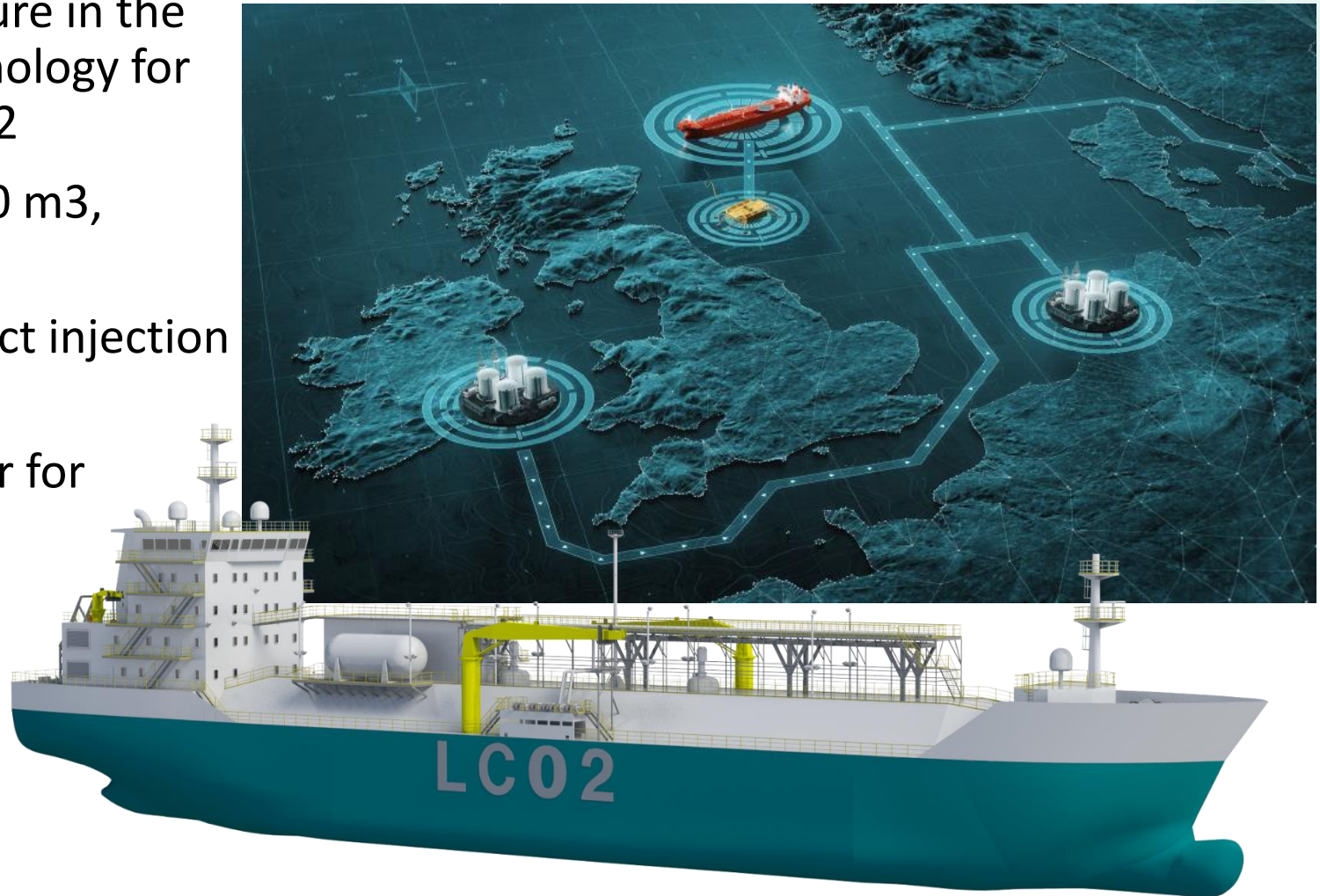
- Moss LNG experience → Moss LCO<sub>2</sub> design
- 2019: Moss engaged by Equinor, Total & Shell for design of cargo system for the Northern Light CO<sub>2</sub> ships
- Ship transport by 7500 m<sup>3</sup> ships for CO<sub>2</sub> captured & liquefied from various sources – storage in Norwegian continental shelf
- Moss work scope: Basic design of the ship CO<sub>2</sub> handling systems
  - Process definitions of cargo system including operational procedures
  - Layout & piping basic design
  - Equipment definitions & budgetary pricing



# mossmaritime

## CO2 ship transport – the Stella Maris project

- Moss engaged by Altera Infrastructure in the Stella Maris project – develop technology for ship transport for low pressure LCO<sub>2</sub>
- Ship transport capacity up to 50.000 m<sup>3</sup>, type C cargo tanks
- Offshore offloading (direct or indirect injection from ships)
- Moss is the project process designer for handling of LCO<sub>2</sub>



# mossmaritime

## Hydrogen bunkering & ship transport

- In 2018 Moss developed an LH<sub>2</sub> carrier with bunkering capability
- Collaboration with Equinor, Viking Cruises, DNV and ship operator (Wilhelmsen)
- Cylindrical vacuum insulated tanks – 2 x 4500m<sup>3</sup>
- Suitable for short/medium distance transport and providing LH<sub>2</sub> fuel to other ships





## Long distance hydrogen ship transport

- Small ships will lead to high unit transport cost → larger ships for LH2 transport will be required
- Technology does not yet exist for large ship tanks for LH2 transport → technology development is required
- Several technology challenges, in particular related to insulation (LH2 has boiling point of  $-252^{\circ}\text{C}$ ) and tank structure definition
- Low pressure transport → utilize boil-off as fuel..?
- Concept definition study ongoing with support from energy majors and governmental funding agencies



Moss LNG carrier



Artist impression of Moss large LH2 carrier

## Why choose to engage Moss for your project

- Decades of recognized experience from design of ships & floating terminals for liquefied gases/LNG
- Multidiscipline team
- Renewable focus (LH2, LCO2)

[www.mossw.com](http://www.mossw.com)

[mossmaritime@mossw.com](mailto:mossmaritime@mossw.com)

[tor.skogan@mossw.com](mailto:tor.skogan@mossw.com)



# mossmaritime





**TECO 2030 FUEL CELL**

**A pathway towards sustainable operation**





# TECO 2030 AS IN BRIEF



## CLEANTECH

TECO 2030 develops and supplies technology that reduces the climate and environmental impacts of the maritime and heavy-duty industry.

## NORWEGIAN

TECO 2030's headquarter is located at Lysaker, outside Oslo. The company has production facility in Narvik, northern Norway and offices in Miami and Singapore. The company was established in autumn 2019.

## 27 YEARS OF EXPERIENCE

TECO 2030 is a spinoff from TECO Maritime Group, which was established in 1994 and has approx. 150 land-based employees in 10 countries.



TECO Electronics



BLOM Maritime



TECO Solutions



Crosscomar



TECO Chemicals

# FUEL CELL MODULE - FCM400™

## THE MULTI-APPLICATION FC UNIT

- A purpose-made fuel cell system for heavy duty and maritime applications
  - High power density design
  - Dynamic load profile enabling optimized battery combinations
  - Long lifetime
  - Purposely designed for replacing diesel generator in compact spaces
  - **“Approval in Principle”** by DNV acquired for FCM 400™
- Expected class **“Type Approval”** in late 2022 / early 2023
- Local required approvals on case-by-case basis
- Design basis building on multi-standard approach enabling usage in several industries with one standardized design.



### COLLABORATION WITH INDUSTRY LEADERS, WITH MORE TO COME



# FCM400™

## STATE OF THE ART CAPABILITIES

### POWER DENSITY / DURABILITY

- Class leading power density/durability
- 4,1 kW / liter (compressed cell row)
- Up to 35.000 hours operating life

### DYNAMIC OPERATION

- 3 seconds ramp up (idle – 90 load)
- Enabling peak shaving by the FC
- Auxiliary battery systems optimized

### HIGH VOLTAGE LEVEL

- Optimized voltage operation for heavy duty
- Reduces amount of DCDC converters by 50 %
- Increases efficiency

### FUTURE PREPARED

- Next generation FC available 2026
- Aims to increase power density, lifetime and efficiency
- Existing FC systems can increase efficiency/power capabilities

### ENVIRONMENTAL PHILOSOFY

- Platinum content in stacks is 50 % compared to peers
- Bi-polar plates: Non-metallic material
  - Reusable stack-components through factory overhauling

**FCM400 PROVIDES A VIABLE ZERO EMISSION ALTERNATIVE TO DIESEL GENERATORS**



# CONTAINERIZED SOLUTIONS



Turn-key,  
plug-and-play ready



Standardized /  
tailored



Models

FCC 1600™ – 1.6 MW

10 ft. ISO Container

FCC 3200™ – 3.2 MW

20 ft. ISO Container

FCC 6400™ – 6.4 MW

40 ft. ISO Container



Flexible installation



Equipped with all auxiliary -,  
process- and safety systems



# FLEXIBLE FUEL APPROACH

By partners TECO2030 can provide full or partial turnkey projects



## Compressed hydrogen (CH<sub>2</sub>)

Can operate on pressure ranges up to 700 bar



## Liquid hydrogen (LH<sub>2</sub>)

Maintains high efficiency with low H<sub>2</sub> input pressure



## Liquid organic hydrogen carriers (LOHC)

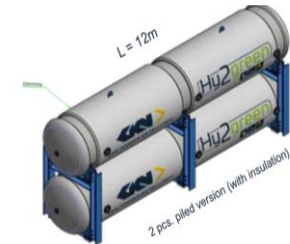
Eliminates the need for compression and makes it safer



## Methanol / Ammonia

Pre-treatment

Active research on pre-treatment



## Metal Hydride hydrogen storage

Unique fuel tank-fuel cell heat regulation system

# FUEL CELLS POWERING MARITIME AND HEAVY-DUTY INDUSTRY



River and waterway vessels



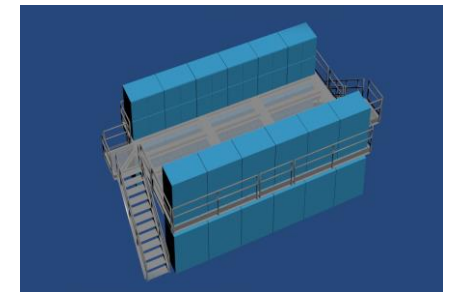
Short-sea vessels and ferries



Cruise vessels



Deep-sea shipping



Micro grid solutions



Shore power solution



Fast ferries/work boats



Heavy duty equipment



Mobile power solutions



# TECO 2030 - NORWAY'S FIRST LARGE-SCALE PRODUCTION OF HYDROGEN FUEL CELLS



## FUEL CELL GIGAFACTORY

TECO 2030 plans to set up a combined factory and innovation center to produce hydrogen-based fuel cells in Narvik in northern Norway.



## 1.2 GW OF FUEL CELLS

The factory is planned to start production in 2023, and to have an annual output of 1,200 MW of fuel cells by 2030.



## 500 NEW JOBS

TECO 2030 expects to have 100 employees at the factory before the end of 2025, and up to 500 by 2030.

# FUEL CELL TECHNOLOGY DEVELOPED IN COOPERATION WITH AVL

- AVL is the world's largest independent company in powertrain development, simulation and testing.
- AVL has experience in developing engines for the maritime sectors, passenger cars, commercial and construction vehicles, trains, mining and other heavy machinery.
- Fuel Cell specific experience:

**>300**  
fuel cell projects  
completed

**450**  
fuel cell engineers and  
fuel cell scientists

**20 years +**  
fuel cell experience

**AVL owns four times more fuel cell patents  
than all competitors combined!**



## Quick facts and figures



Source: AVL

**11,000**  
employees  
worldwide

**1,500**  
engine designs

**12%**  
of turnover invested  
in inhouse R&D

**1,500**  
granted patents in  
force

**1.7**  
billion Euro in  
turnover

**70+**  
years of experience



# FUEL CELLS CAN REPLACE DIESEL GENERATORS ON CONSTRUCTION SITES



TECO 2030 and Implenla will develop zero-emission construction site solutions with support from Norwegian state enterprise Enova.

## DEVELOPING ZERO-EMISSION CONSTRUCTION SITE SOLUTIONS TOGETHER WITH IMPLENLA

TECO 2030 is cooperating with Implenla Norway on developing and piloting zero-emission hydrogen fuel cell generators for use on construction sites. The project has received NOK 15.6 million in funding from the Norwegian state enterprise ENOVA.

## A LEADING EUROPEAN INFRASTRUCTURE DEVELOPER

Headquartered in Switzerland, Implenla plans and builds complex infrastructure projects in Switzerland, Germany, Austria, France, Sweden and Norway, and employs more than 8,500 people in Europe.

## FIRST FUEL CELL DELIVERY IN 2023

The first fuel cell delivery is planned for 2023.





# TECO 2030 IS A PARTNER IN THE PROJECT GREEN HYDROGEN @ BLUE DANUBE

## CONCEPT

Green hydrogen produced from solar and wind energy in Romania will be transported on barges along the Danube river to industrial buyers in Austria and Germany.

TECO 2030 could deliver from 2024 up to 200 MW of fuel cells to Chemgas Shipping's new hydrogen-powered tugboats, which will take the barges along the Danube. Projected delivery of 2.4 MW per tugboat.

## FACTS

- 2,000 MW off-grid wind and solar energy production
- 1,800 MW electrolysis for hydrogen production
- 40-60 push tugs and up to 120 hydrogen transport barges
- 80,000 tons of hydrogen for industry, power + mobility hubs (500 trucks/100 HRS) along the Danube
- 3.2 million tons of annual CO<sub>2</sub> reductions

Verbund



# CUSTOMIZED FUEL CELL SOLUTIONS FOR FOR LARGE ENERGY CONSUMERS







# Thank you for your attention

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post@teco2030.no

*Follow us on*

