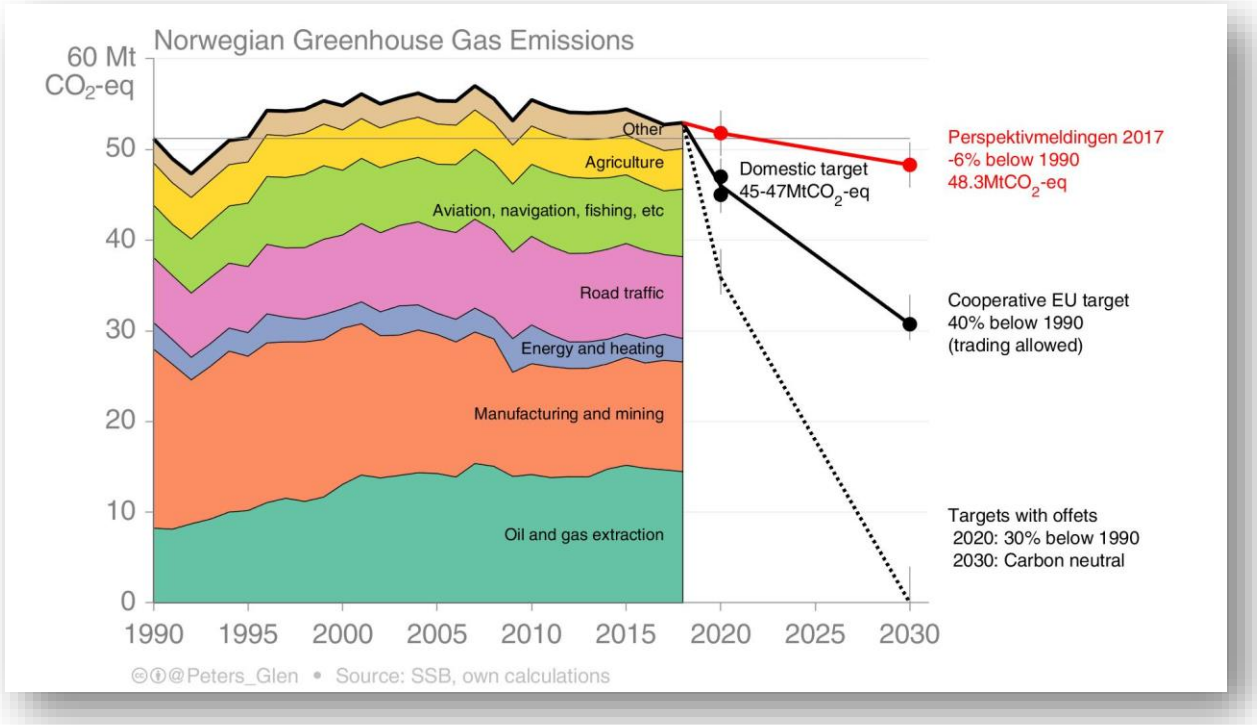
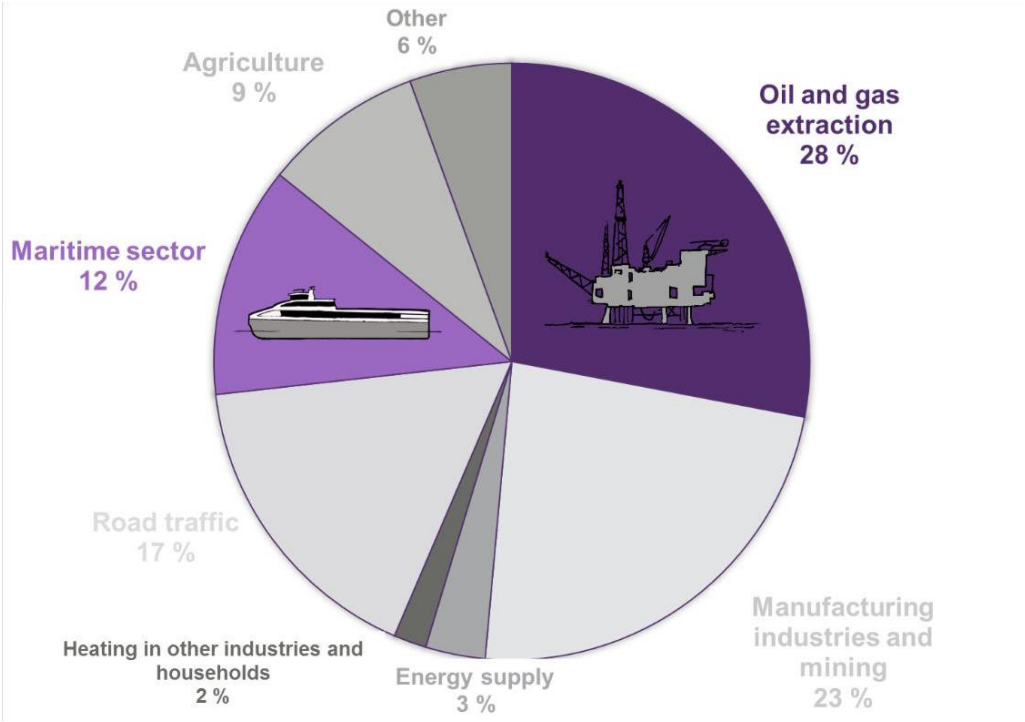
North Sea – an area for blue and/or green hydrogen

Centre for Sustainable Subsurface Resources

CSSR Centre director:
Sarah Gasda, NORCE/UiB
sgas@norceresearch.no

Norway's climate ambitions





Source: Norwegian Environment Agency

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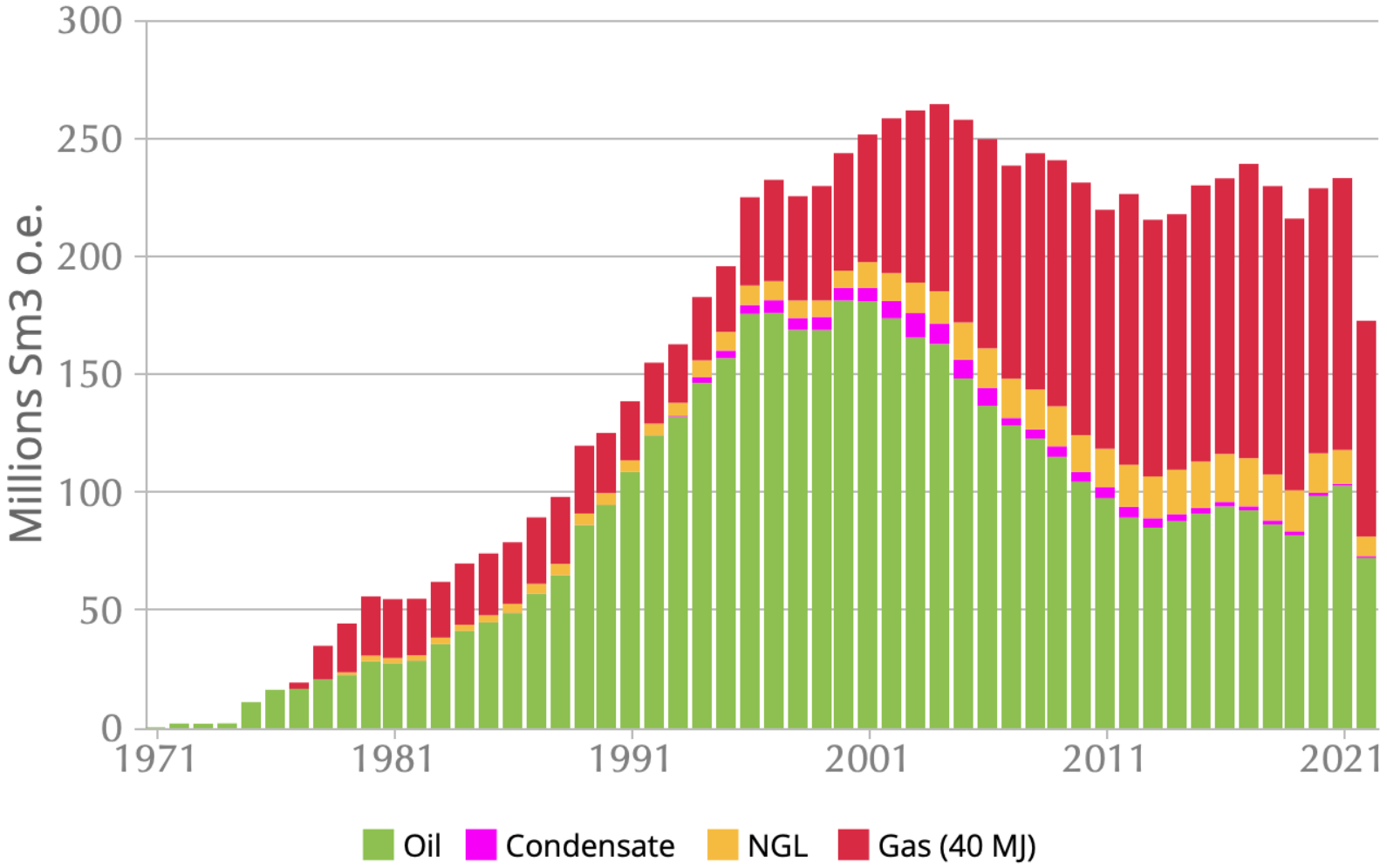
NPD Fact pages: NCS historic production



- Norway exports natural gas to the EU primarily for home heating and cooking
- **Norway is expected to export nearly 90 billion cubic metres (bcm) of gas to the European Union**, nearly 25% of its expected gas needs this year, according to forecasts from energy consultancy Rystad. Exports to Britain could reach 36 bcm, nearly 50% of the country's total gas demand. – *Reuters, Sep 8 2022*
- ***Norway's gas exports amount to ~200 Mt/y of CO_2 emissions by end users***

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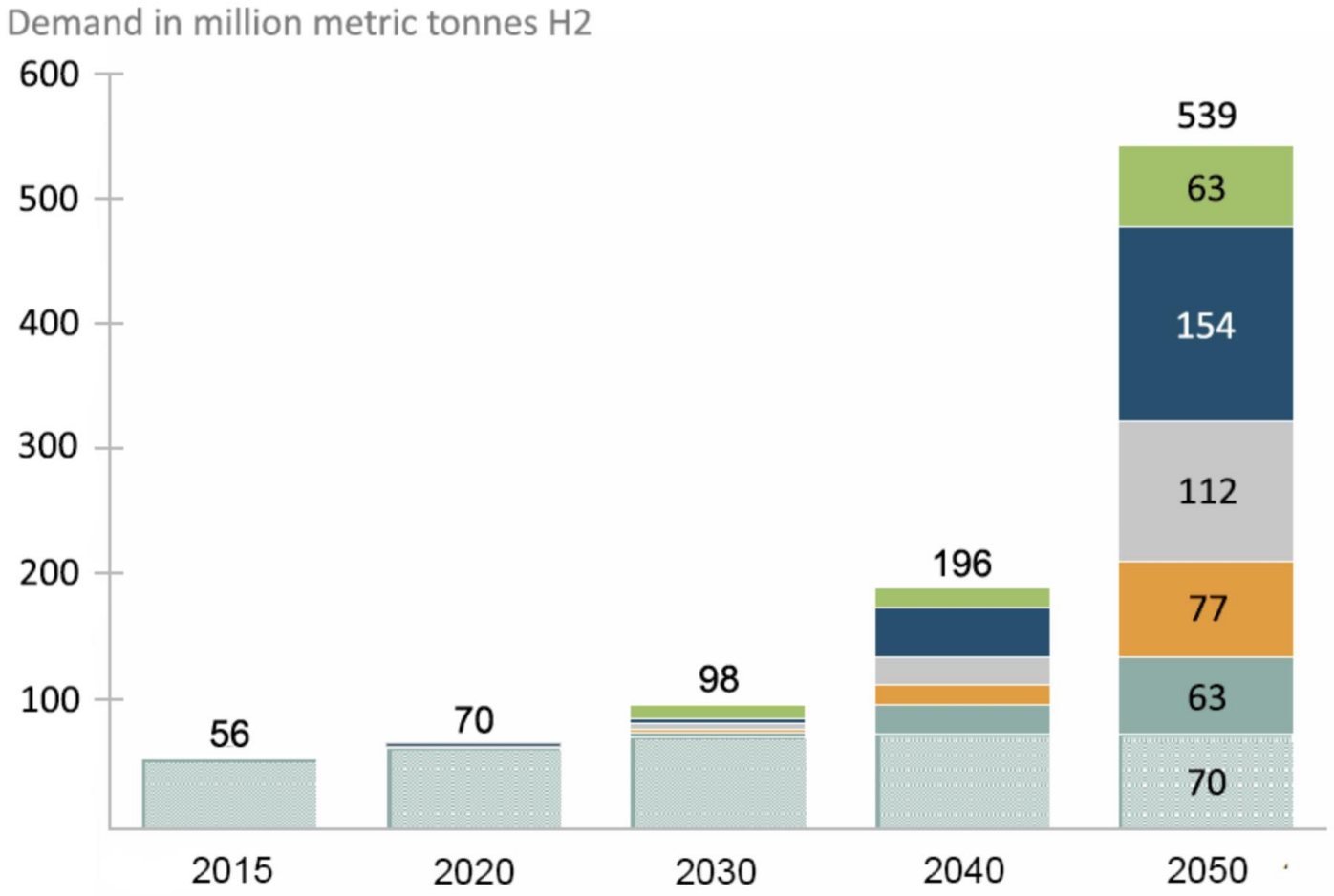
Hydrogen and the Green Transition

- Norway wants to enable Hydrogen as central to the green transition
  - Decarbonize industry and transport (heavy vehicles, maritime industry)
  - Decarbonize natural gas exports to Europe
- Hydrogen is linked to climate change but also contributes to energy security, economic development, energy diversity/accessibility

Norway’s Hydrogen ambitions/ goals

«…The Government will contribute in building a comprehensive valuechain for hydrogen where production, distribution and utilisation is developed in parallell…»
(unofficial translation)

Hydrogen demand could increase 10-fold by 2050



1 Power generation, buffering

4 Transportation

5 Industrial energy

6 Building heat and power

7 New feedstock (CCU, DRI)

Existing feedstock uses

Adapted from *Scaling Up*, Hydrogen Council, 2017. Orginal units in EJ converted to tonnes H2; 1 EJ = 7,000,000 tonnes H2.

Examples of demand specific to Norway

Domestic use

Domestic use

Export

*Hydrogen could provide up to 25% of EU energy demand, or ~2,250 TWh
https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

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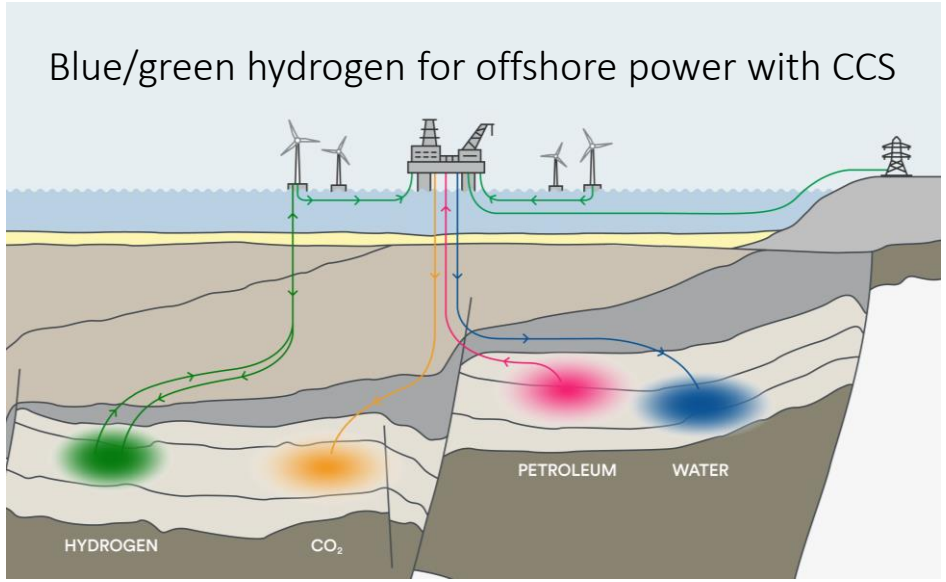
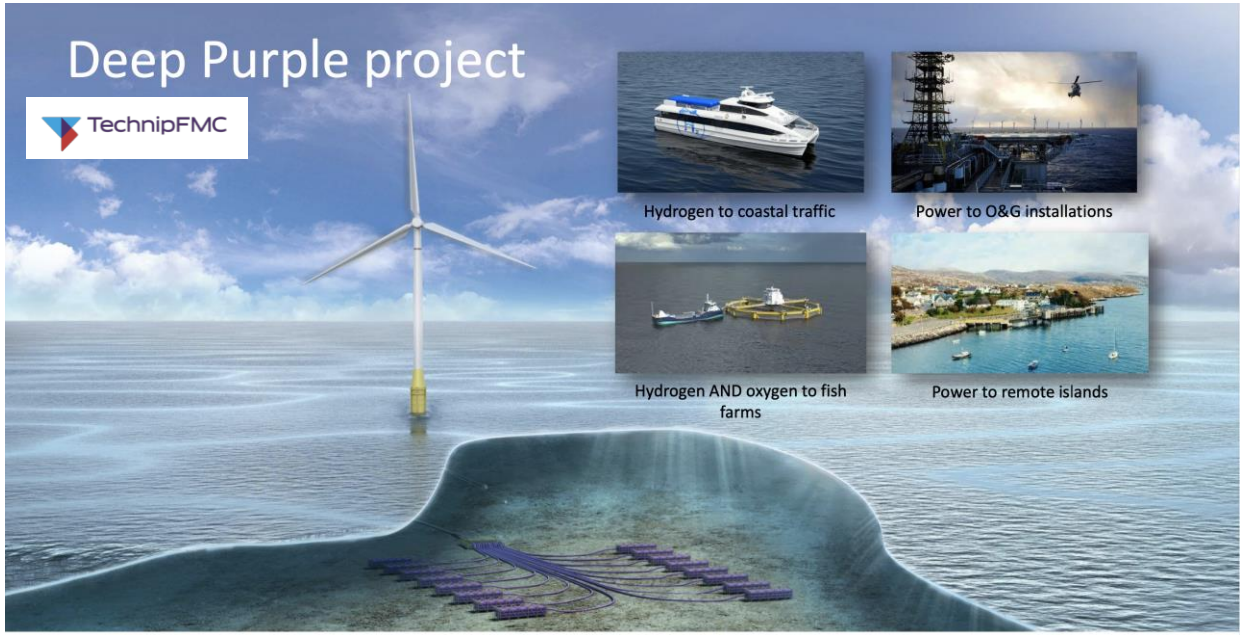
Domestic H_2 use vs export

- Stranded gas assets can be converted to blue ammonia + CCS and exported by ship
- Offshore H_2 production to power offshore facilities
- Offshore/onshore H_2 production for domestic use in the process or transport sector
- Direct export of blue H_2 to Europe is unclear..

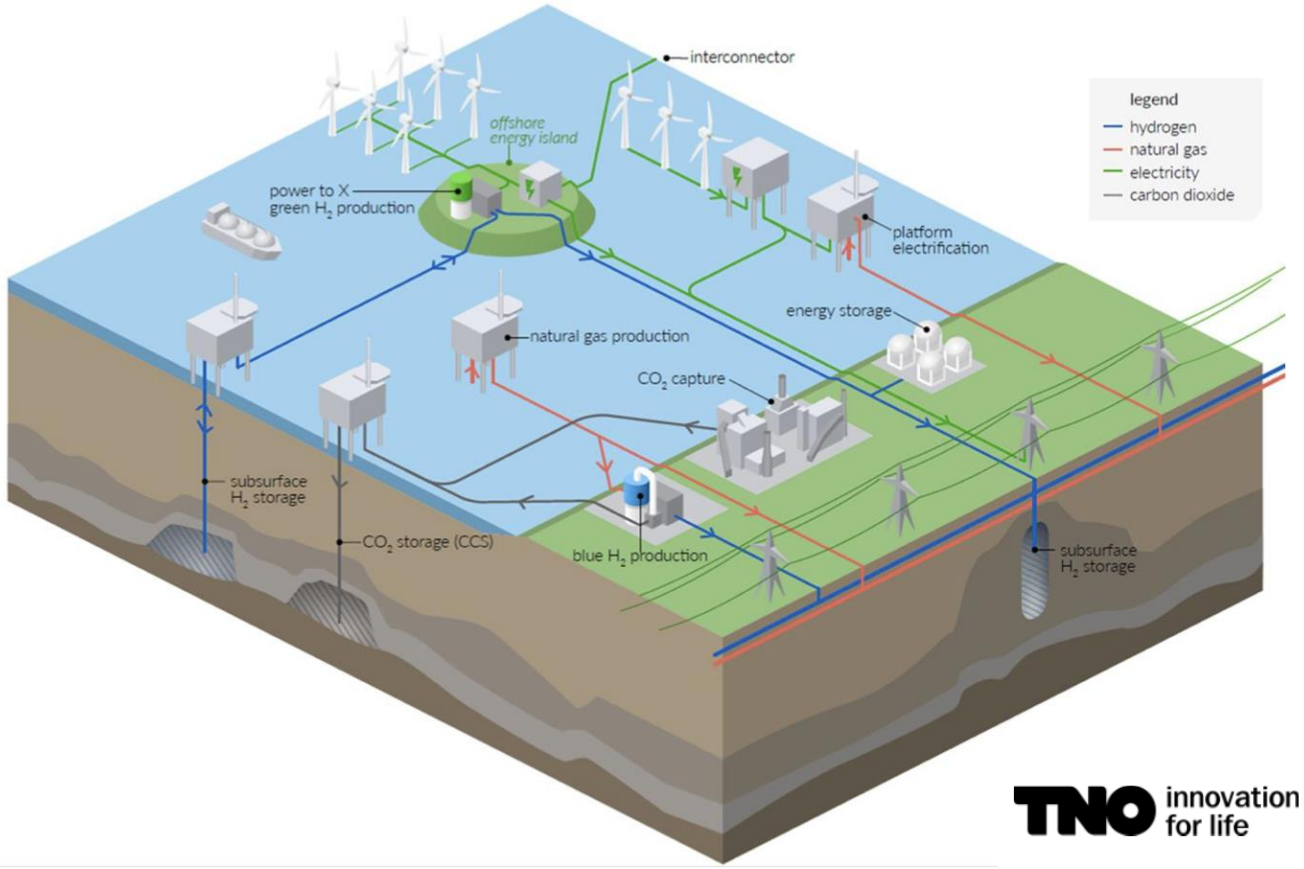




Offshore energy hubs of the future

- Energy hub integrates of wind, hydrogen, CCS, natural gas in a single offshore environment
- Growing popularity in countries with significant energy needs and existing offshore infrastructure, e.g. Netherlands
- Function is dependent on who is being served (cities, industry) and the balance between import and export, ie. techno-economics
- Is this a model for Norway?

North Sea Energy R&D program (north-sea-energy.eu)



TNO innovation for life

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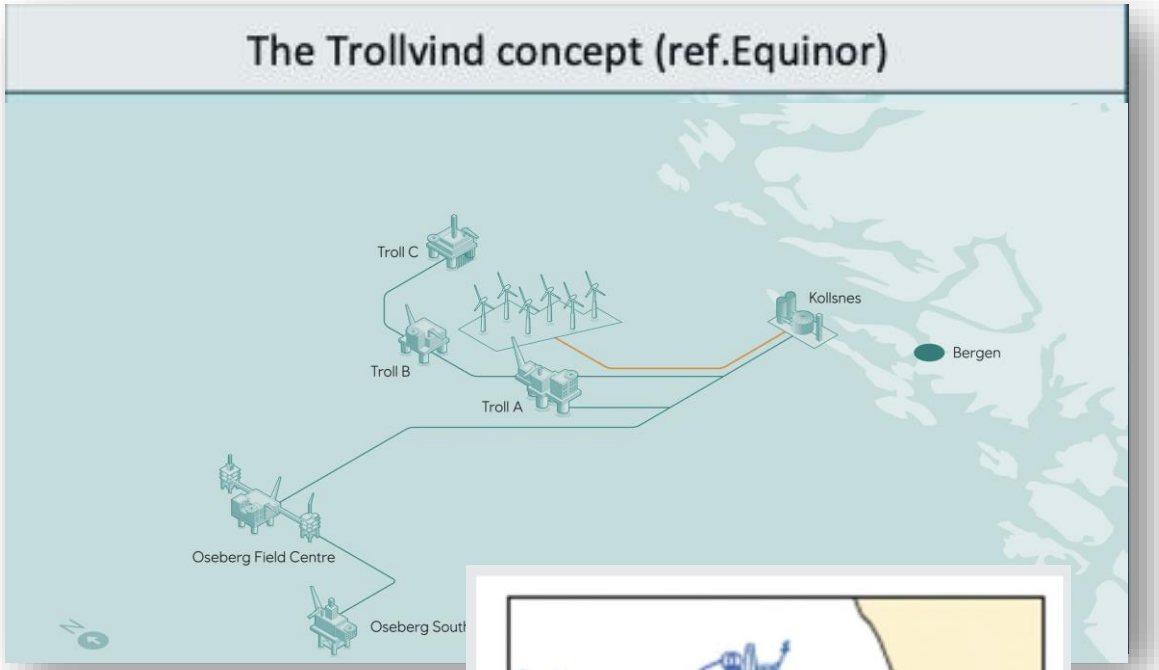
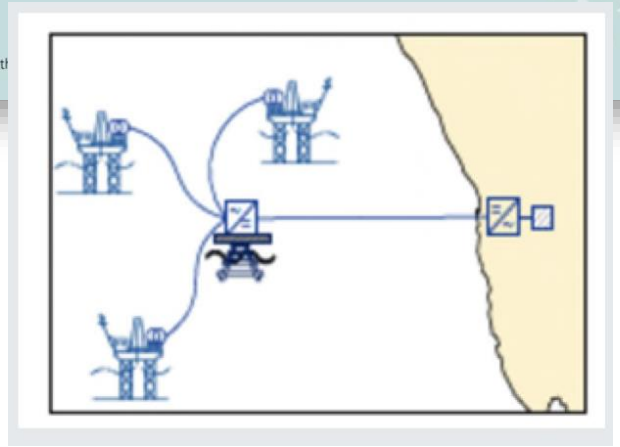
Offshore clean power concepts in Norway





DNV qualifies Aker Carbon Capture's Just Catch Offshore™: ready to cut emissions from oil and gas production

AKER CARBON CAPTURE

TUE, OCT 25, 2022 09:00 CET

Report this content

BLÅ STRØM

Hjem Ho

Blå strøm - Konsept

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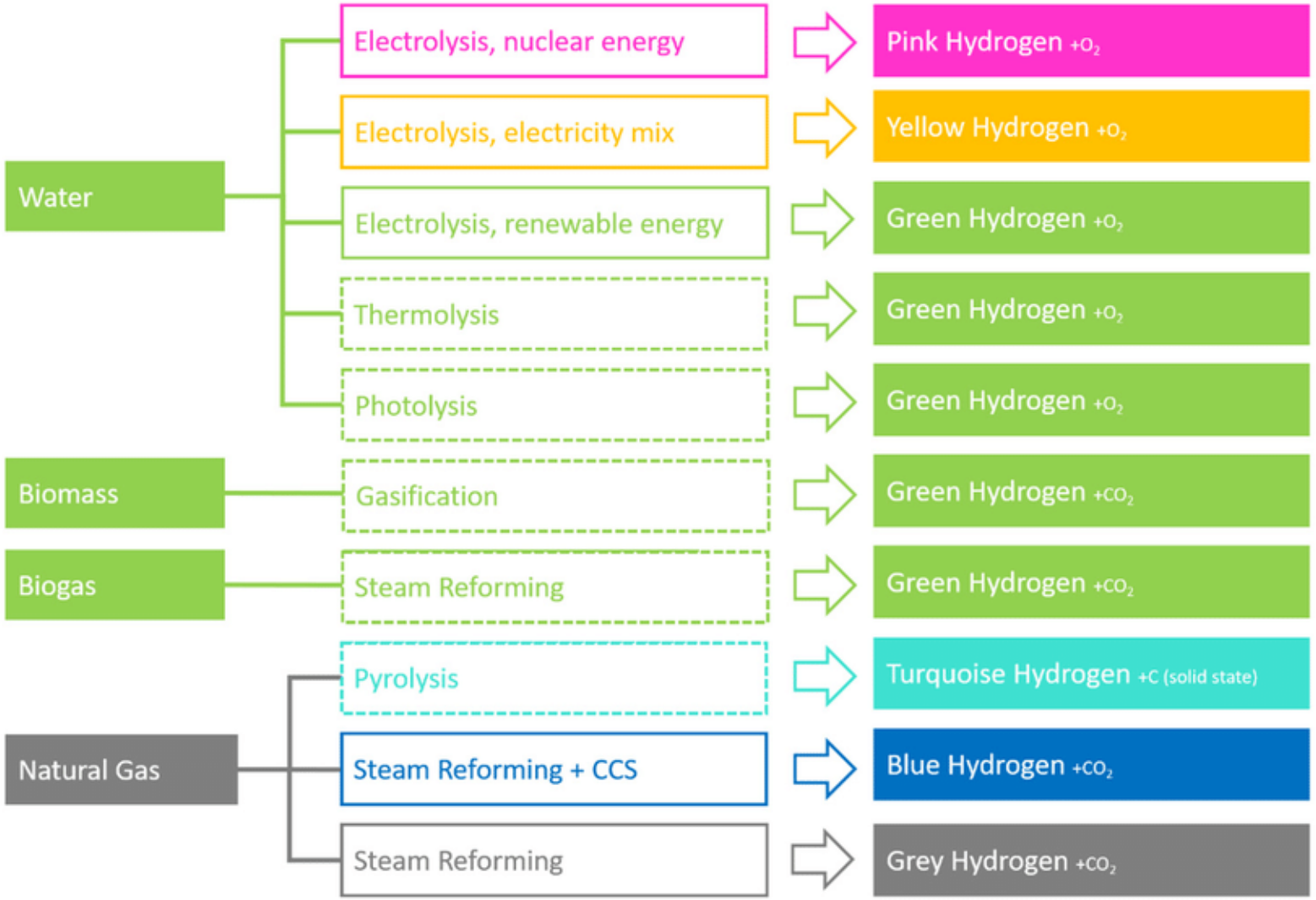
Rainbow of H_2 production pathways



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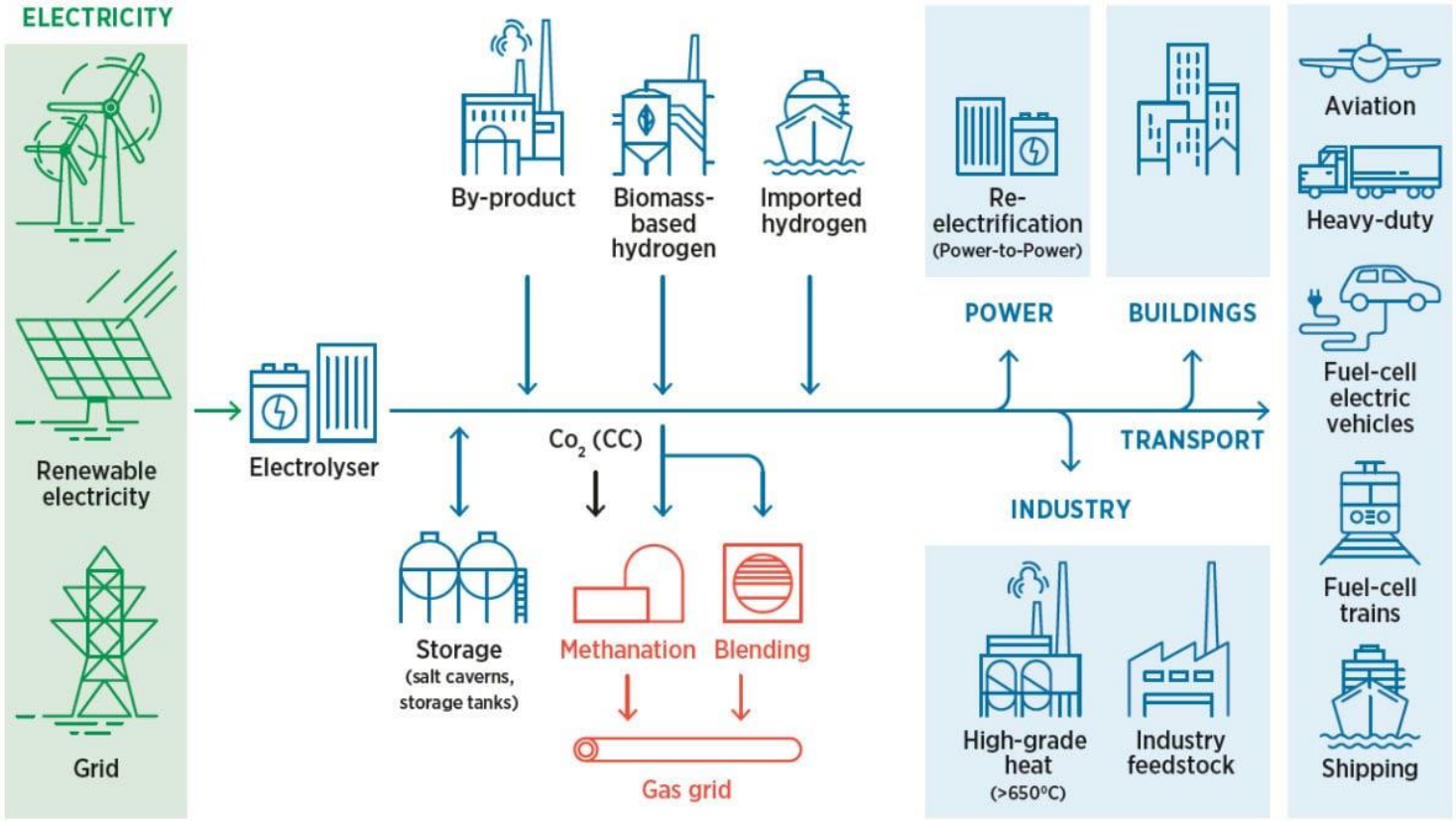
Power-to-gas can decouple renewable energy generation from energy demand



Power-to-gas requires short- to long-term storage solutions at docks, filling stations, industrial areas, cities.

Hydrogen has typically been produced close to end users due to:

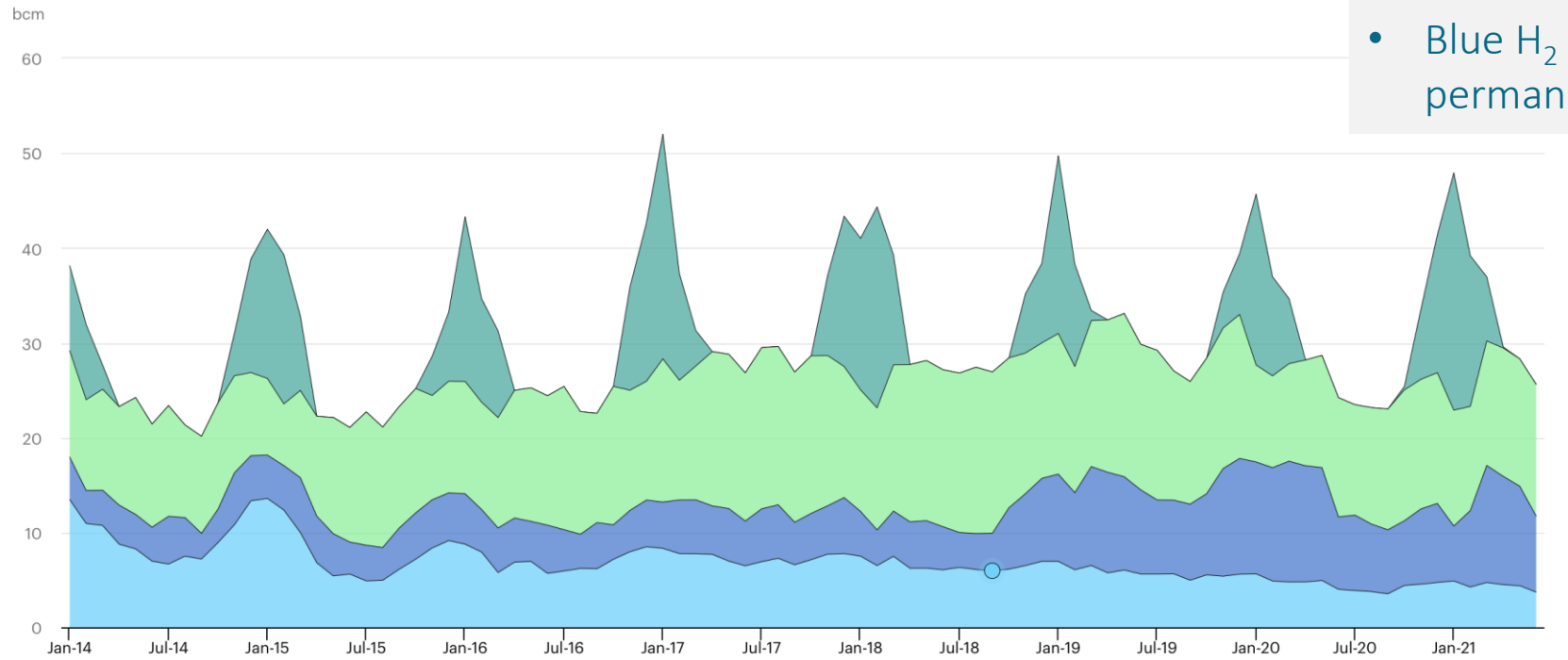
- Safety
- Material issues / embrittlement
- Low energy density

Graphic source: International Renewable Energy Agency (IRENA)

Monthly gas supply balance in the European Union, 2014-2021

Last updated 26 Oct 2022

Download chart ↓



IEA. License: CC BY 4.0.

Domestic production · LNG imports · Piped imports · Storage withdrawal

- Gas storage is not a new concept!
- Seasonal gas storage is 1572 TWh, which accounts for 25-30% of total gas consumption in Europe (GIE gas storage database (April 2021)
- H_2 can be a substitute for natural gas
- Blue H_2 will need to also account for permanent storage of CO_2

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Underground Hydrogen Storage (UHS)

- Nearly all of Norway's gas exports are used for home heating and cooking
- Seasonal storage is an essential component of the natural gas consumption in N. Europe
- EU gas storage volume amounted to 990.16 TWh in October 2022, accounting for approximately 89.02 percent of its capacity (www.statista.com)
- Energy density of H_2 is 25% of CH_4 need new gas storage facilities
- A future H_2 distribution network and subsequent need for UHS is less likely if home heating is electrified.

maps from ESTMAP (after GIE gas storage database and DOE energy storage database)

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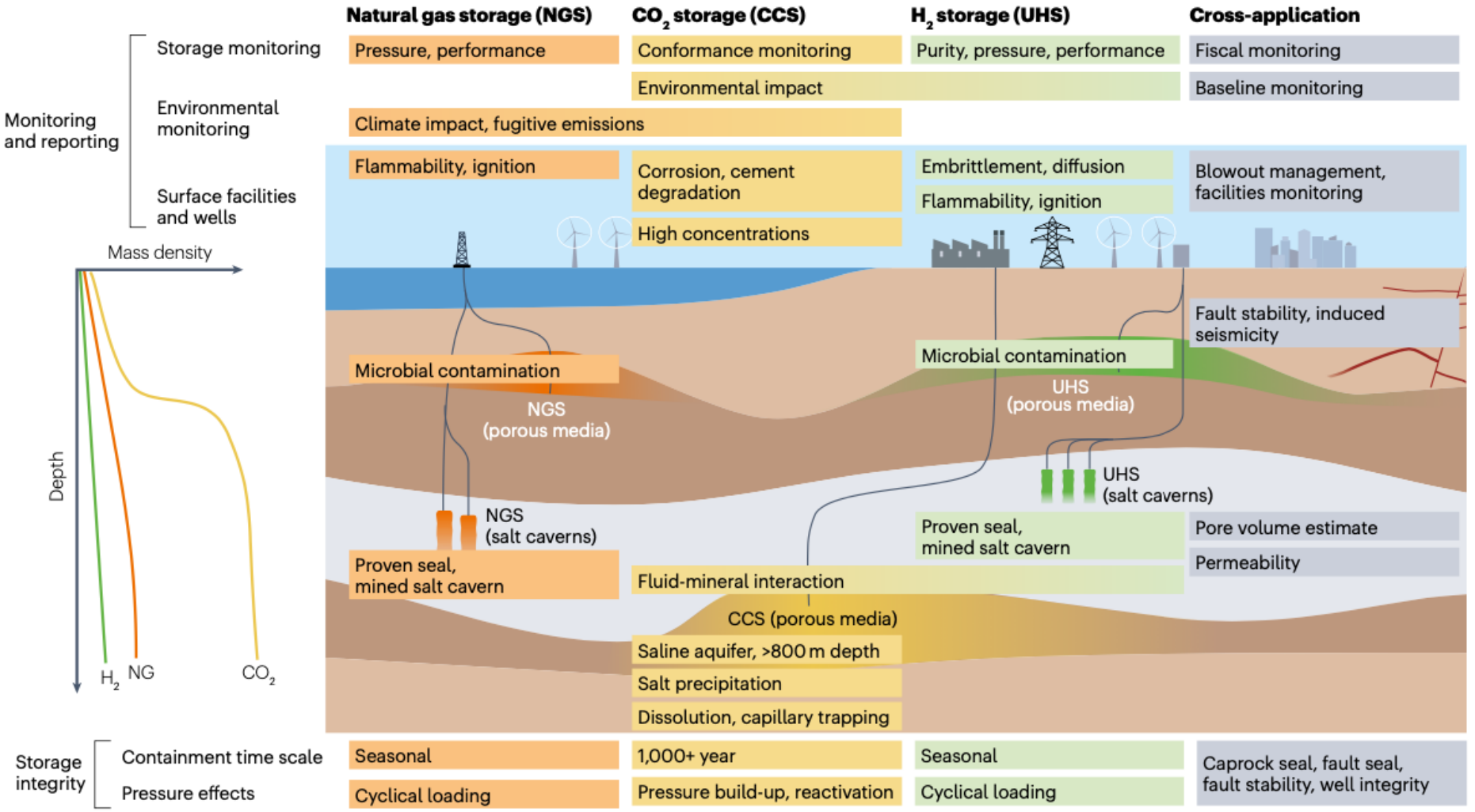
Underground storage applications



Krevor et al. **Subsurface carbon dioxide and hydrogen storage in a sustainable energy future ,** Nature Review: Earth & Environment (NREE) in press.

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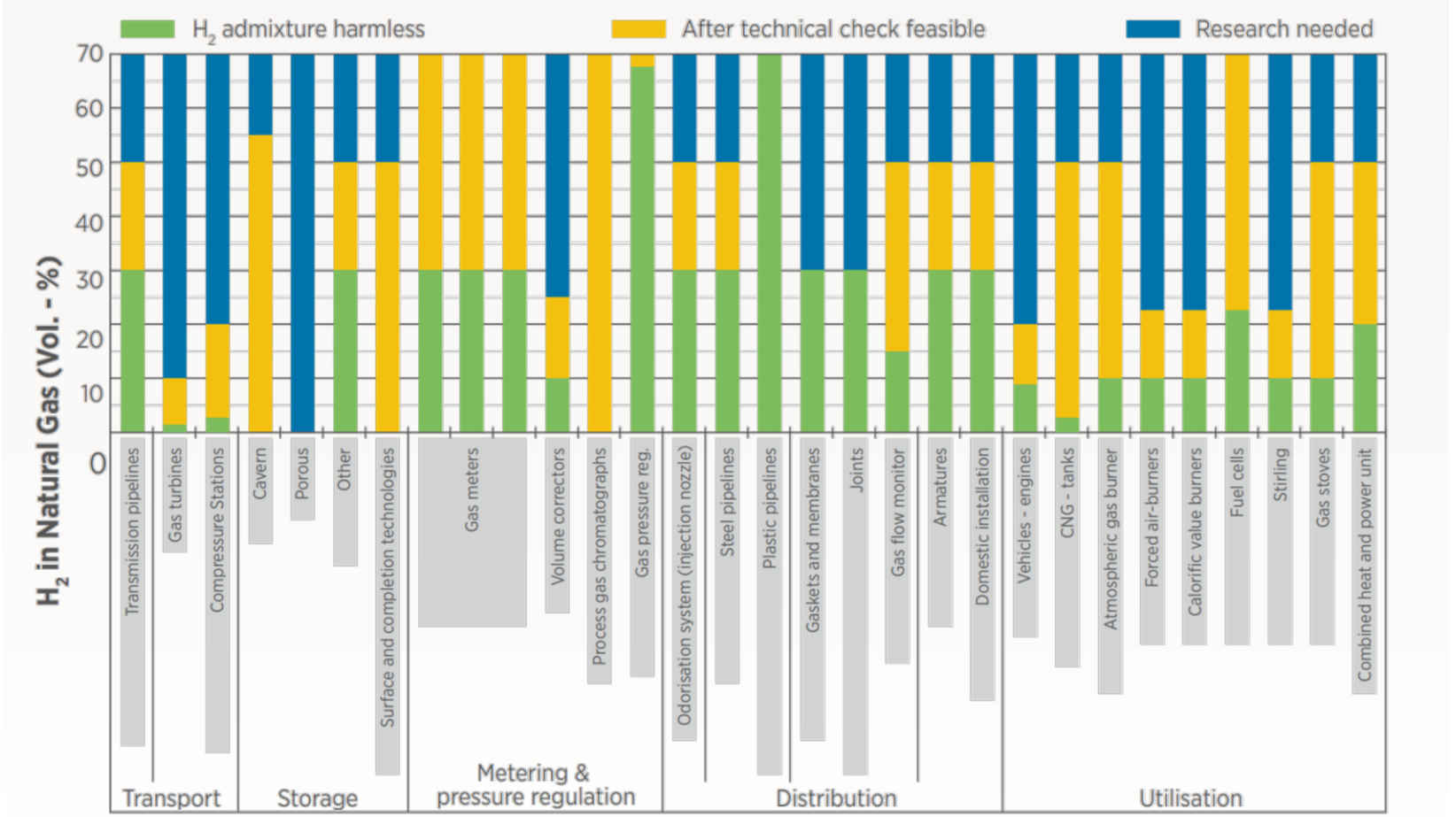
Need for R&D for entire H_2 value chain.



Source: Adapted from DVGW (2012).

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Norwegian Centre for Hydrogen Value Chain Research

Research for safe and sustainable development of value chains for hydrogen and hydrogen-based fuels in industry and society.

Main objective of HyValue: *Build on Norwegian comparative advantages by developing knowledge, methodology and innovative solutions for hydrogen energy carriers to create and support a competitive hydrogen energy sector*

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NHH

SNF
CENTRE FOR APPLIED RESEARCH AT NHH

UNIVERSITY OF BERGEN

Universitetet i Stavanger

toi

Western Norway University of Applied Sciences

Forskningssenter for miljøvennlig energi

The Research Council of Norway

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FME Forskningssenter for miljøvennlig energi · Norges forskningsråd · Forskningsrådet

HyValue structure

Project management

WP1 Novel production methods

WP2 Storage and distribution

WP3 End user application

WP4 Safety science and risk

WP5 Societal impact and embeddedness

WP6 Integrating hydrogen in value chains

Industry partners

Industry projects

Associated projects

1.Municipal planning for future hydrogen-based businesses and infrastructure: Green transition Øygarden

1.Transition of industry parks to a sustainable and circular hydrogen-based future: Mongstad Industrial Park

1.Production and transport.

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Research for optimal reservoir operations and value generation in the green transition

Energy-efficient petroleum production

Strategies to synchronize water injection with intermittent energy

Energy storage in the subsurface

Scalable solutions for subsurface storage of hydrogen, air, and thermal

CCS: Carbon storage

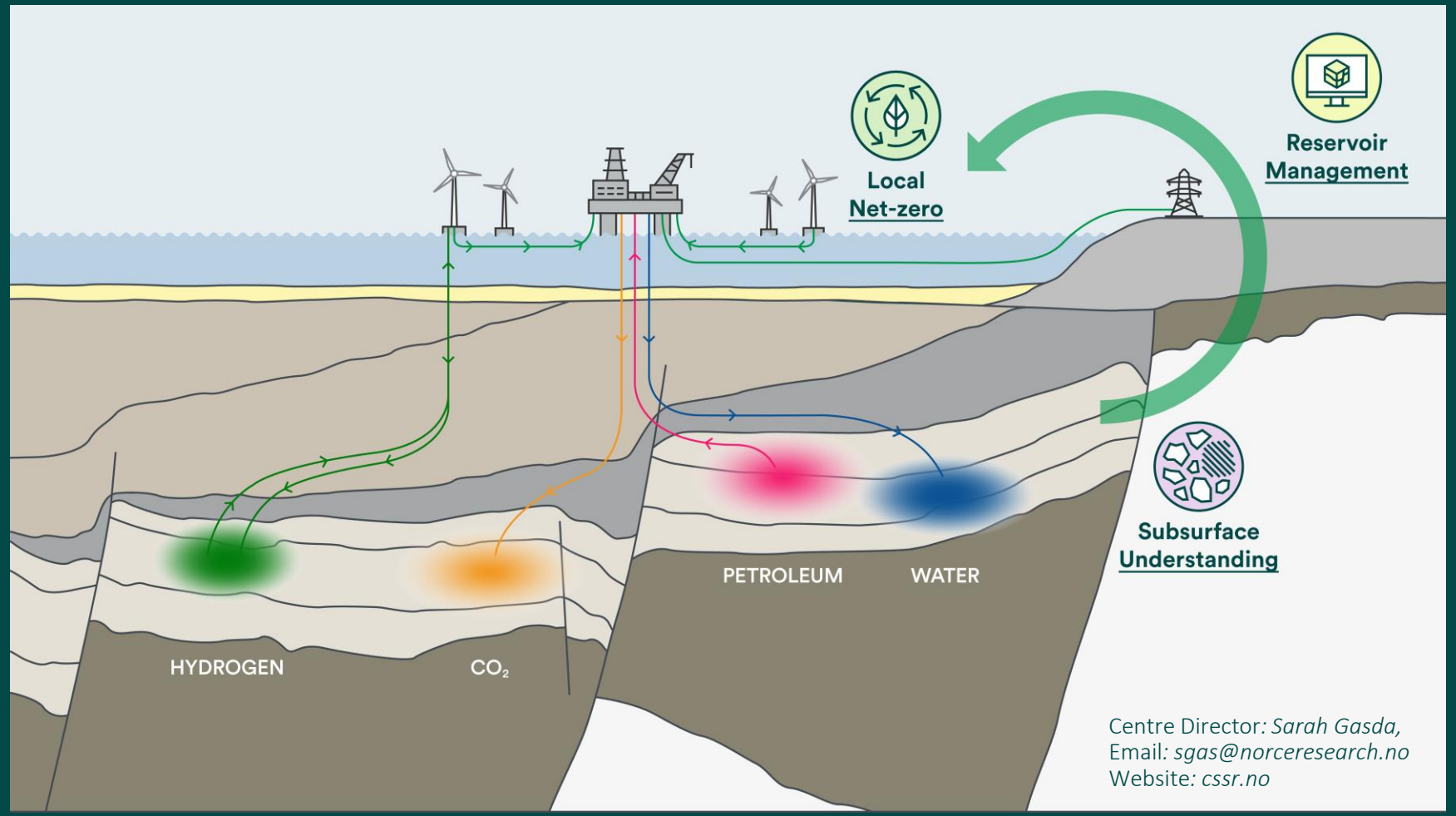
Streamlined methods to integrate CO_2 storage with electrification

Digital workflows for subsurface management

Update workflows to increase predictive capacity and harness the value of subsurface data

Interdisciplinary research and education

Reservoir physics, geosciences and applied mathematics



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Forskningsrådet

CSSR is a Petrocentre financed by NFR (nr: 331841)
NORCE lead, UiB partner, 170 MNOK budget, start-up 2022.
Supported by major operators and technology providers

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UNIVERSITY OF BERGEN
equinor
wintershall dea
Sumitomo Corporation
EARTH SCIENCE ANALYTICS
Universität Stuttgart
TNO innovation for life
Schlumberger
GCE Ocean Technology
Oregon State University
Imperial College London
TU Delft
Delft University of Technology

Summary

- Norway's strategy for the hydrogen economy is ambitious
- Emerging offshore energy hub concepts can facilitate domestic H_2 production for offshore industry
- Should we be optimistic for a future EU market for hydrogen? Uncertain who will be the first movers.
- How will public investment and industry collaboration play out?
- Decarbonization of gas exports is attractive, but is it better to produce blue H_2 close to source or users?
- Role of subsurface for large-scale H_2 energy storage is far from certain even if technical challenges are solvable.
- Many technical challenges to overcome along entire value chain.

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Tusen takk!

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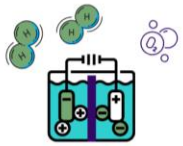
Centre for Sustainable Subsurface Resources

CSSR is a collaboration between NORCE and the University of Bergen and receives funding from the Research Council of Norway (nr: 331841) and industry stakeholders.

Novel production methods



PEM electrolysis

Turquise hydrogen

Methane Cracking

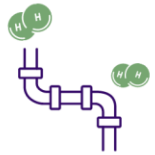
WP1

Novel production methods

Green hydrogen via photocatalysis

Feasibility study

Storage and distribution



Efficient transport and distribution system

Regulation and standardization of H2 infrastructure

Robust metering for supply chains

WP2

Flexible storage systems

Large-scale subsurface storage solutions

End user applications

Maritime application of hydrogen and hydrogen-carriers

Next minutes wave prediction

Reduce carbon footprint

WP3

The use of hydrogen in CCU at industrial sites

Cost-efficient hydrogen driven maritime operations

Safety science and risk

Strength of knowledge

Explore safety control structures and regulatory frameworks

Risk communication and comprehension

WP4

Prevention and safe design

Mitigation and consequence modelling

Scenarios and phenomena

Societal impact and embeddedness

Assessment of how hydrogen is coupled to and embedded in sociotechnical systems

Exploration of public literacy and legitimacy with regards to hydrogen and related technologies

WP5

Societal dilemmas

Input from other WPs regards regulation, legislation, value chains etc.

Living labs

Integrating hydrogen in value chains

Key European market conditions, politics and policies

Business models in the hydrogen value chains

Financing hydrogen investment

WP6

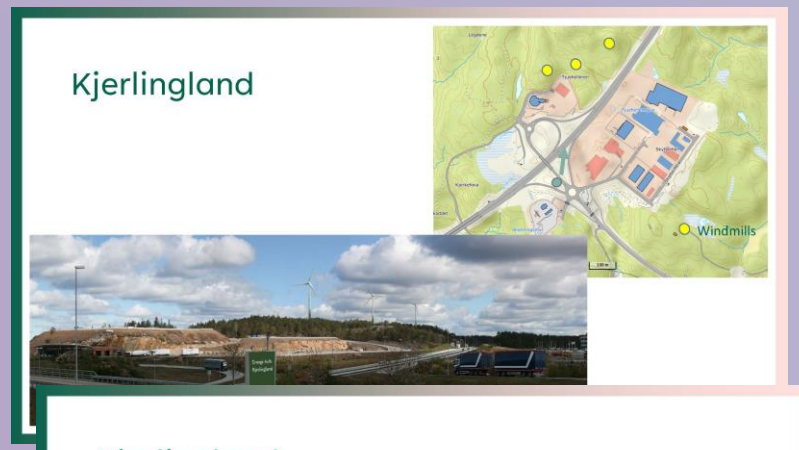
Sustainability and energy assessments in the maritime sector

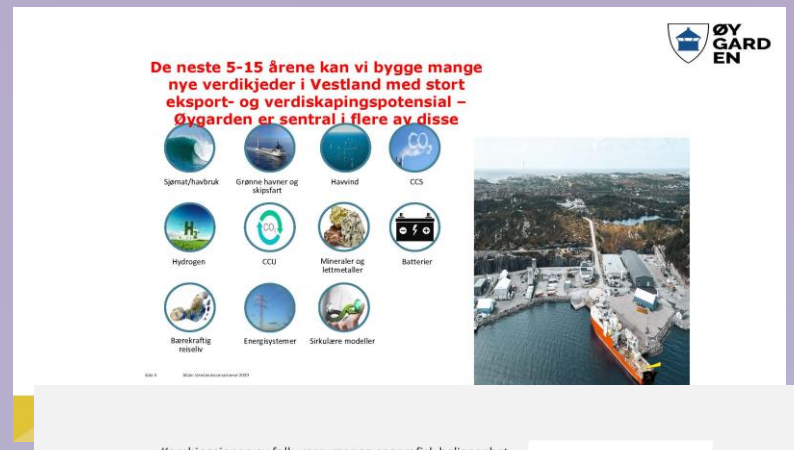
Regulating sea spaces for hydrogen and other maritime users.

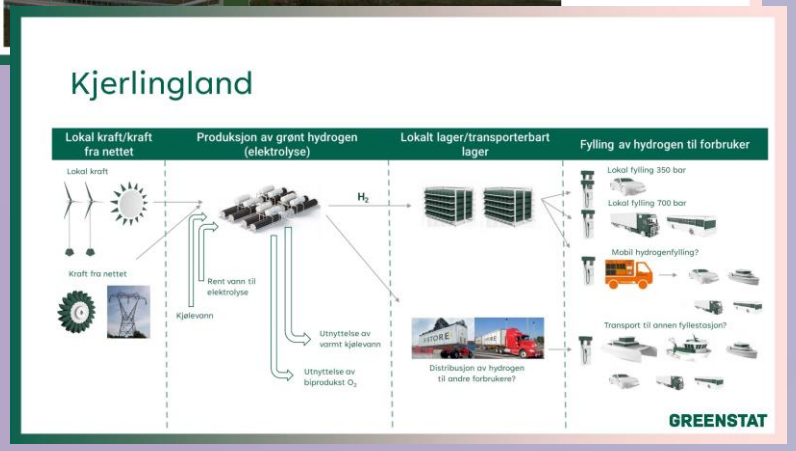
HyValue

Forskningssenter for miljøvennlig energi

User cases


Kjerlingland
Windmills

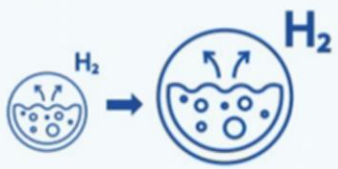

De neste 5-15 årene kan vi bygge mange nye verdikjeder i Vestland med stort eksport- og verdiskapingspotensial – Øygarden er sentral i flere av disse
ØYGARDEN
Sjømat/havbruk
Grønne havner og skipsfart
Havvind
CCS
Hydrogen
CCU
Mineraler og lettmetaller
Batterier
Bærekraftig reiseliv
Energisystemer
Sirkulære modeller

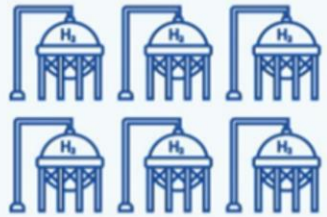

Kjerlingland
Lokal kraft/kraft fra nettet
Produksjon av grønt hydrogen (elektrolyse)
Lokalt lager/transporterbart lager
Fylling av hydrogen til forbruker
Lokal kraft
Kraft fra nettet
Rent vann til elektrolyse
Kjølevann
Utnyttelse av varmt kjølevann
Utnyttelse av biprodukt O2
Lokal fylling 350 bar
Lokal fylling 700 bar
Mobil hydrogenfylling?
Transport til annen fyllestasjon?
Distribusjon av hydrogen til andre forbrukere?
GREENSTAT


The Mongstad Gold
59 companies
2400 ship arrivals
105 200 sqm floor space
2400 Empoyees
4 900 000 sqm available land


Kombinasjonen av folk, ressurser og geografisk beliggenhet gjør at Øygarden har alle forutsetninger for å bli utstillingsvinduet for fremtidens næringsliv

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





Today - 2024	2025 - 2030	2030 -
From now to 2024, we will support the **installation of at least 6GW of renewable hydrogen electrolysers in the EU**, and the production of **up to 1 million tonnes** of renewable hydrogen.	From 2025 to 2030, hydrogen needs to **become an intrinsic part of our integrated energy system**, with at least 40GW of renewable hydrogen electrolysers and the production of **up to 10 million tonnes** of renewable hydrogen in the EU.	From 2030 onwards, **renewable hydrogen will be deployed at a large scale** across all hard-to-decarbonise sectors.

Drivers and Indicators of Hydrogen's Momentum

Drivers of renewed interest in hydrogen

Stronger push to limit carbon emissions

Falling costs of renewables and hydrogen technologies

Indicators of hydrogen's growing momentum

Strategic push in national roadmaps

Industry alliances and momentum growing

8

Years remaining in the global carbon budget to achieve 1.5° C goal

80%

Decrease in global average renewable energy prices since 2010

70%

Share of global GDP linked to hydrogen country roadmaps to date

60

Members of the hydrogen council in 2021 up from 13 in 2017

66

Years remaining in the global carbon budget to achieve 1.5° C goal

55x

Growth in electrolysis capacity by 2025 vs. 2015

10 m

2030 target deployment of FCEVs announced at the Energy Ministerial in Japan

30 +

Major investments announced globally since 2017 , in new segments e.g. heavy duty & rail

Hydrogen Council, 2020

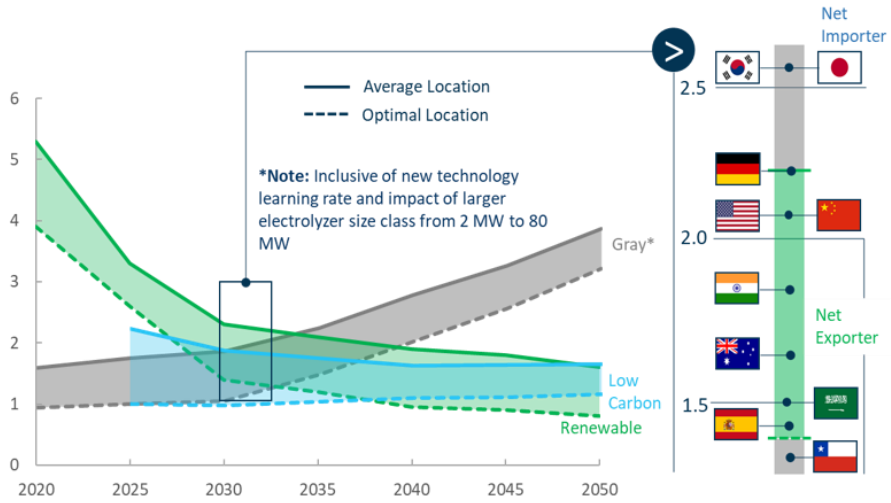
Hydrogen is strongly linked with climate change but also contributes to

- energy security
- improved air pollution
- economic development
- energy accessibility
- energy and economic diversity

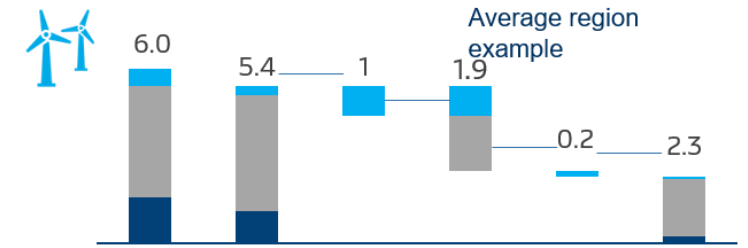
Hydrogen production costs

Production cost of hydrogen – Global comparison

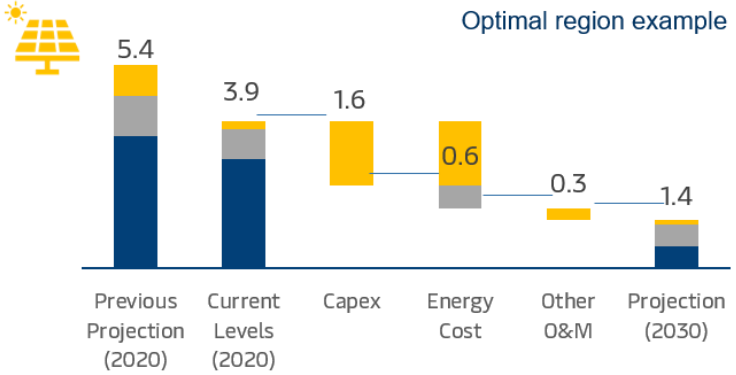
Production cost of hydrogen (H2) – Global comparison US$/kg



Wind & solar based hydrogen production cost trajectory – Global benchmarks & India (US$)



For average projects such as offshore, wind based electrolysis in Central Europe , renewable hydrogen production costs could decline from **USD 5.4/kg in 2020 to USD 2.3/kg in 2030**, with LCOE declines having the greatest cost down impact



For projects using low-cost renewables like solar PV based electrolysis in the Middle east , the cost of renewables based hydrogen production could decline to USD 1.5 /kg in 2030

Key Assumptions –

- Gas price $2.6 – 7/Mmbtu
- Cost of CO2/Ton in US$ - $30 (2020), $50 (2030), $150 (2040) & $300 (2050)
- LCOE ₹1.90 - ₹5.50/kWh (2020), ₹1.00-₹2.90/kWh (2030) & ₹0.50-₹1.90/kWh

Source: Eninrac research, Hydrogen council, Mckinsey

- Cost projections pre-Russian war on Ukraine.
- Costs are too high, strongly tied to energy prices

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