4 October 2023

Erla Sigríður Gestsdóttir

The Icelandic Energy Transition Challenge

Powering the future of Iceland

Government of Iceland
Ministry of the Environment, Energy and Climate

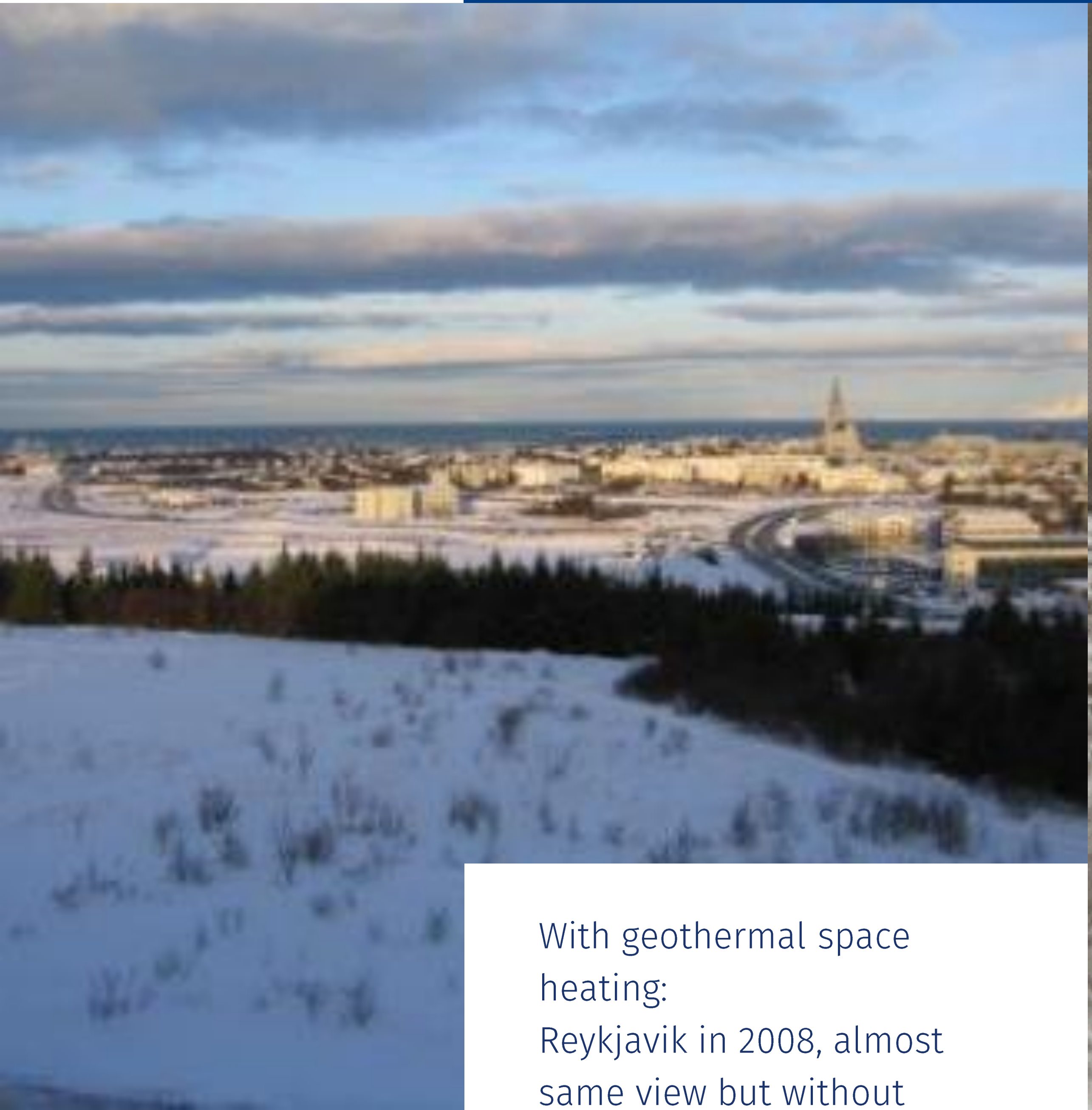
The energy landscape

Energy mix

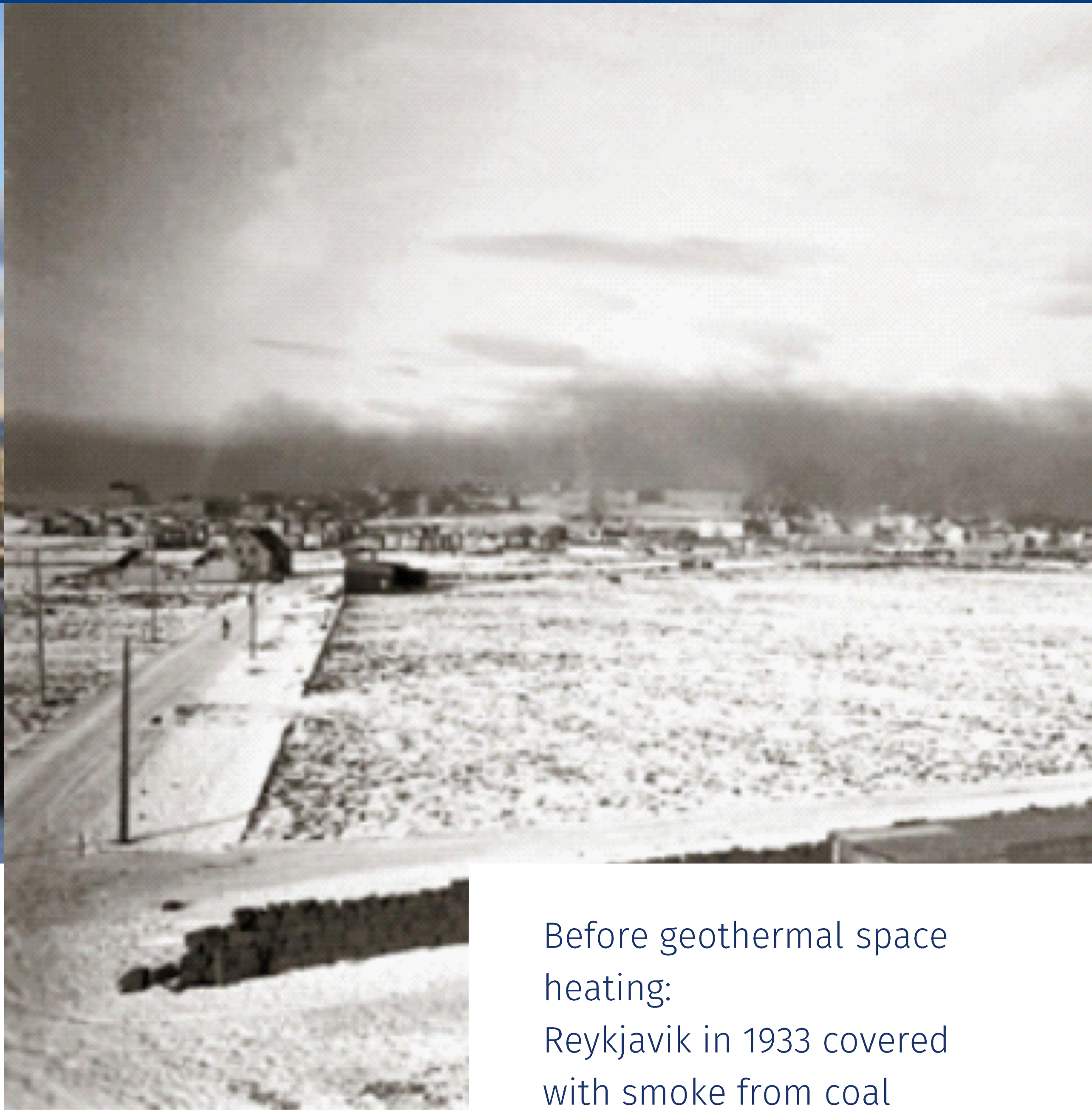
99,9% ELECTRICITY PRODUCED FROM RENEWABLES

90% OF HOUSES HEATED WITH GEOTHERMAL

85% OF PRIMARY ENERGY COMES FROM RENEWABLES

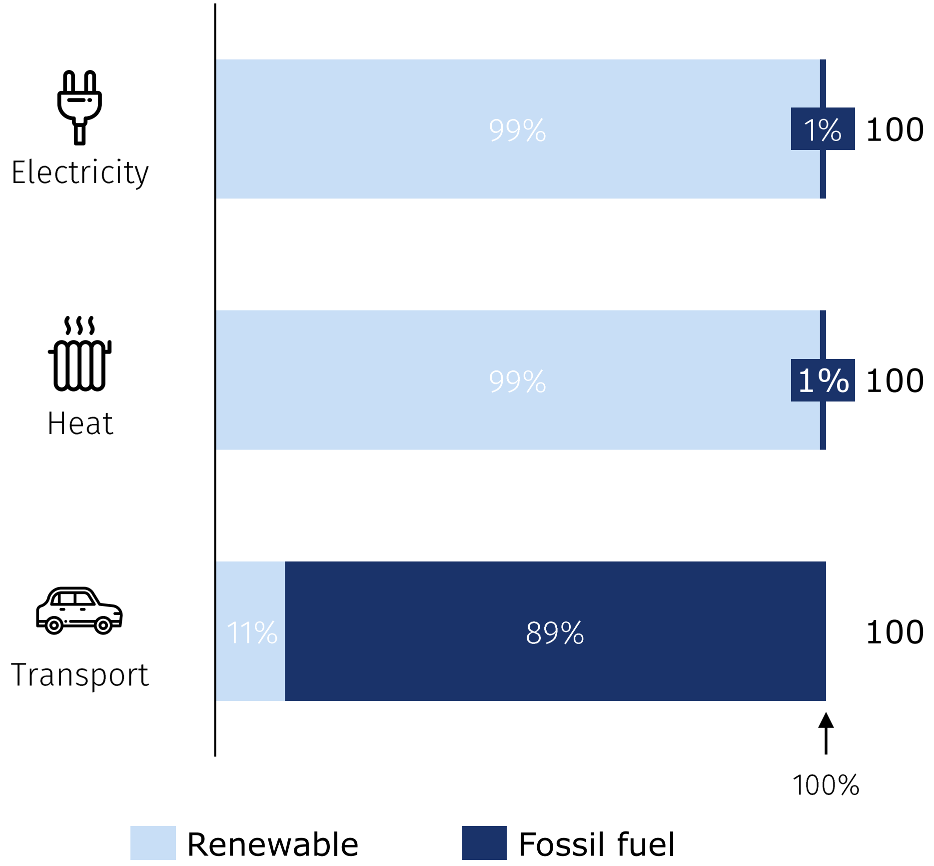


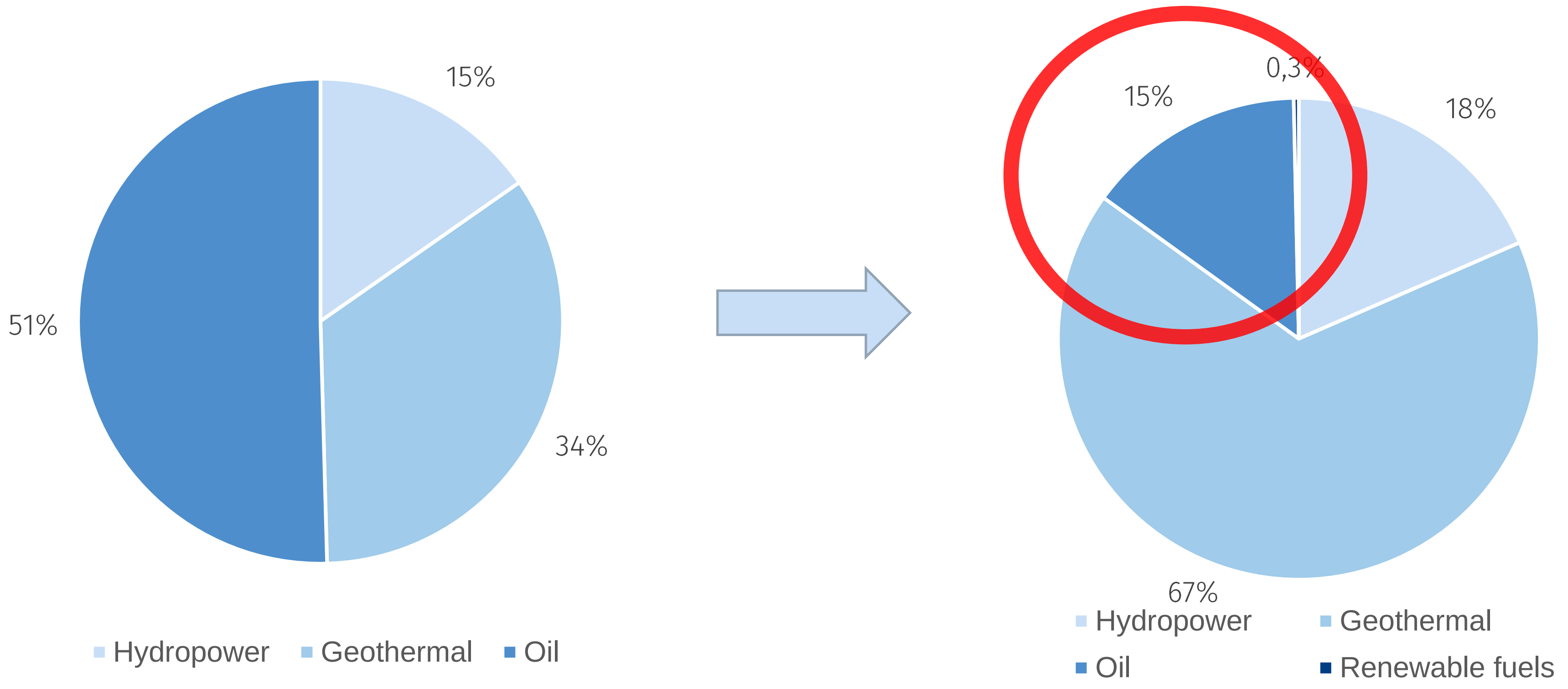
With geothermal space heating:
Reykjavik in 2008, almost same view but without



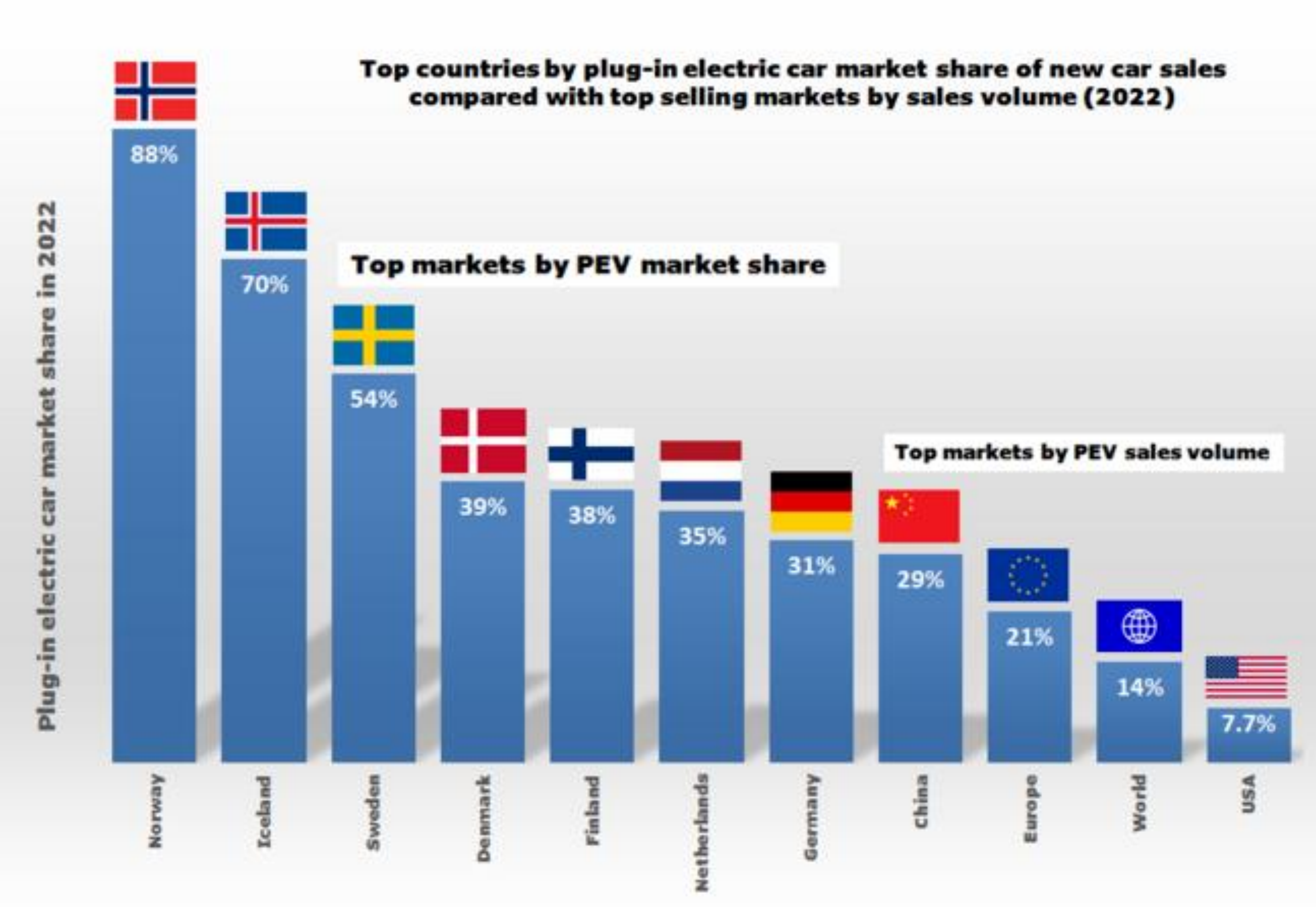
Before geothermal space heating:
Reykjavik in 1933 covered with smoke from coal

Three energy transitions

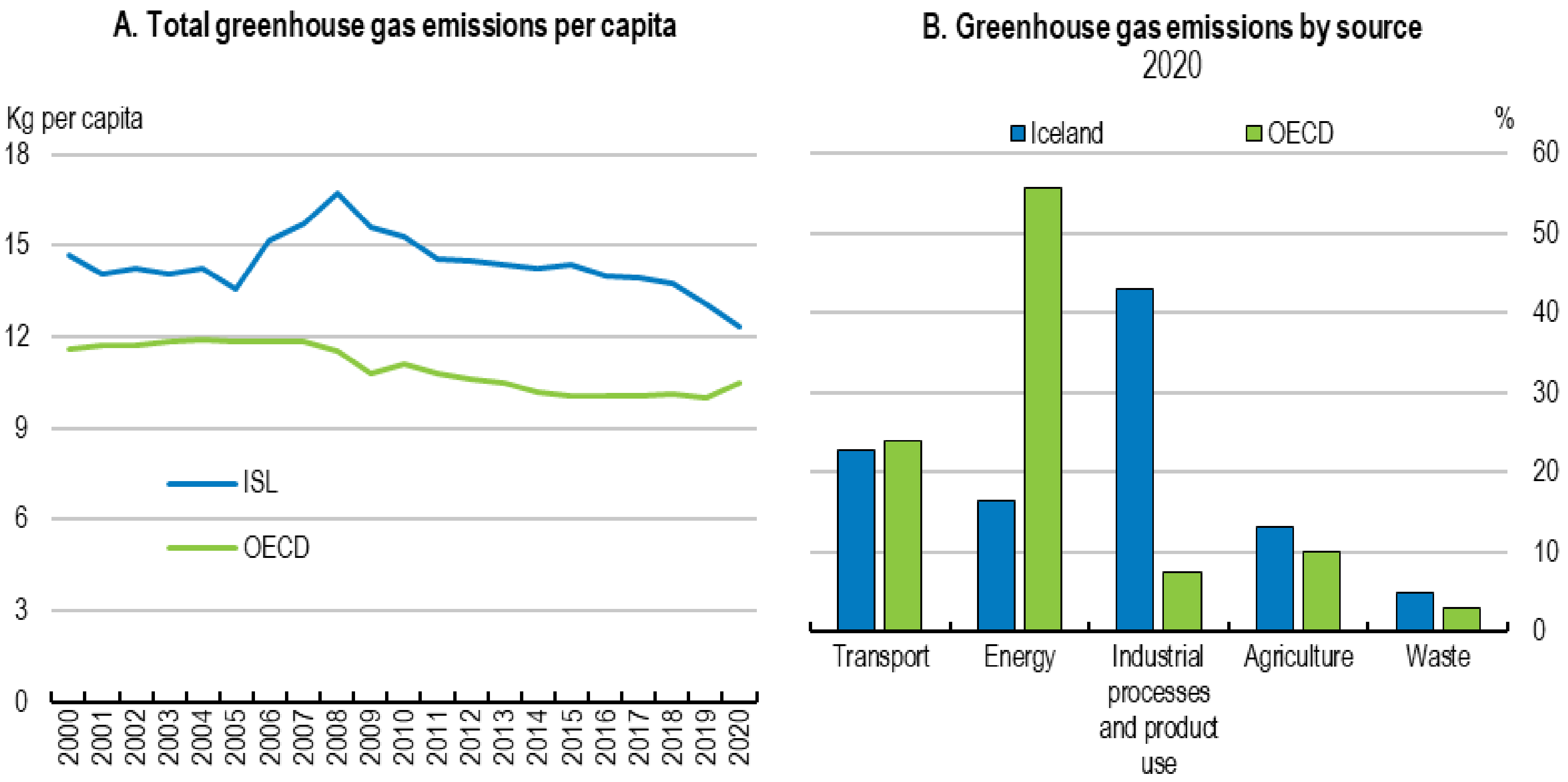



15%
51%
34%
Hydropower
Geothermal
Oil
0,3%
15%
18%
67%
Hydropower
Geothermal
Oil
Renewable fuels

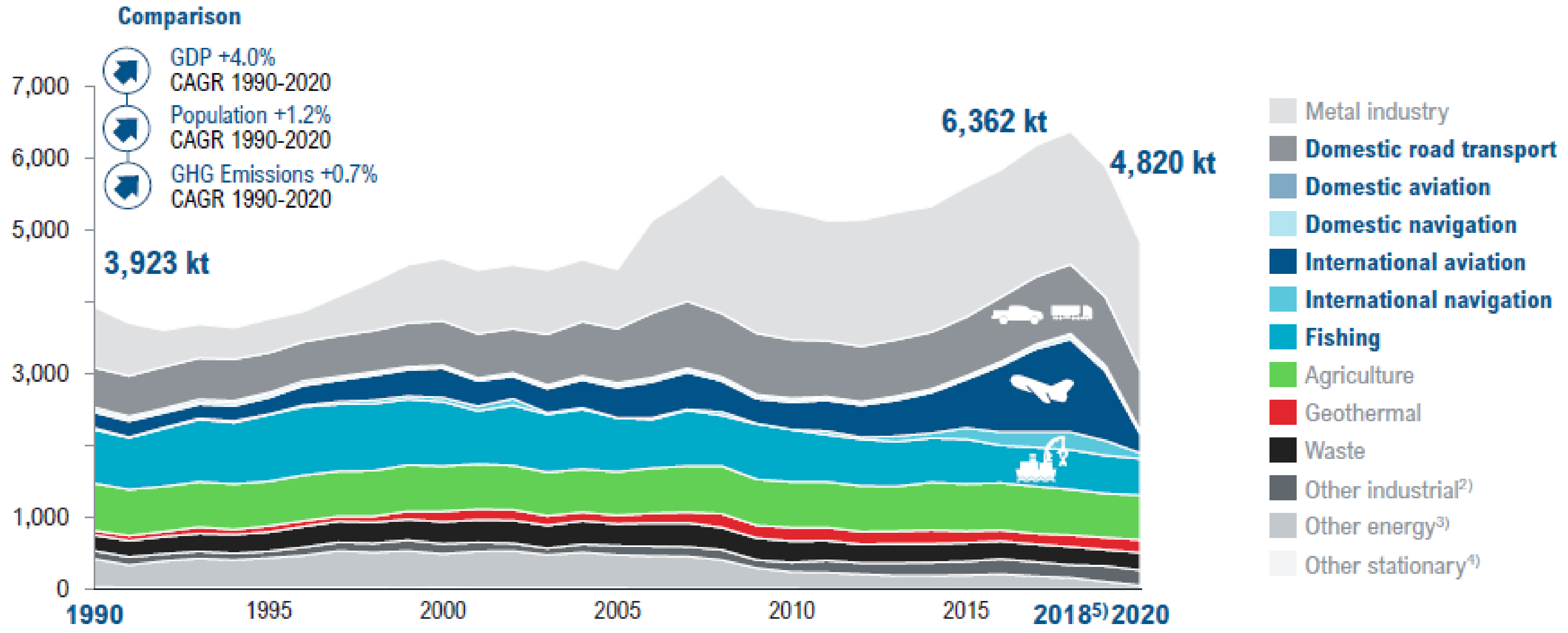
1970 **2020**


Top countries by plug-in electric car market share of new car sales compared with top selling markets by sales volume (2022)
Plug-in electric car market share in 2022
Top markets by PEV market share
Top markets by PEV sales volume
88%
70%
54%
39%
38%
35%
31%
29%
21%
14%
7.7%
Norway
Iceland
Sweden
Denmark
Finland
Netherlands
Germany
China
Europe
World
USA

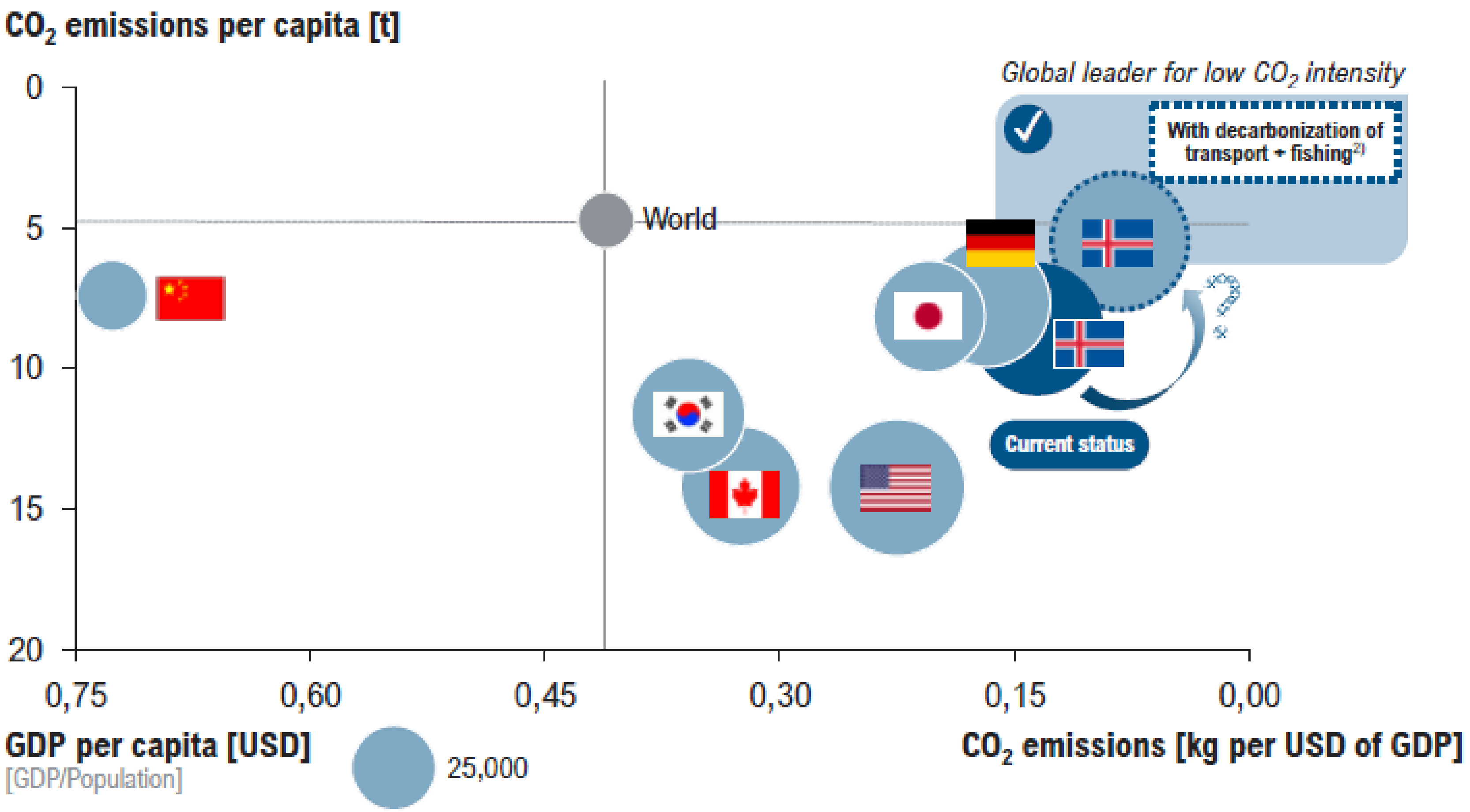
Iceland’s **Emissions Profile** – Comparison



GHG emissions in Iceland by sector (ex. LULUCF)



Emission intensity - comparison



Energy and Climate Goals

2030
The Paris Agreement

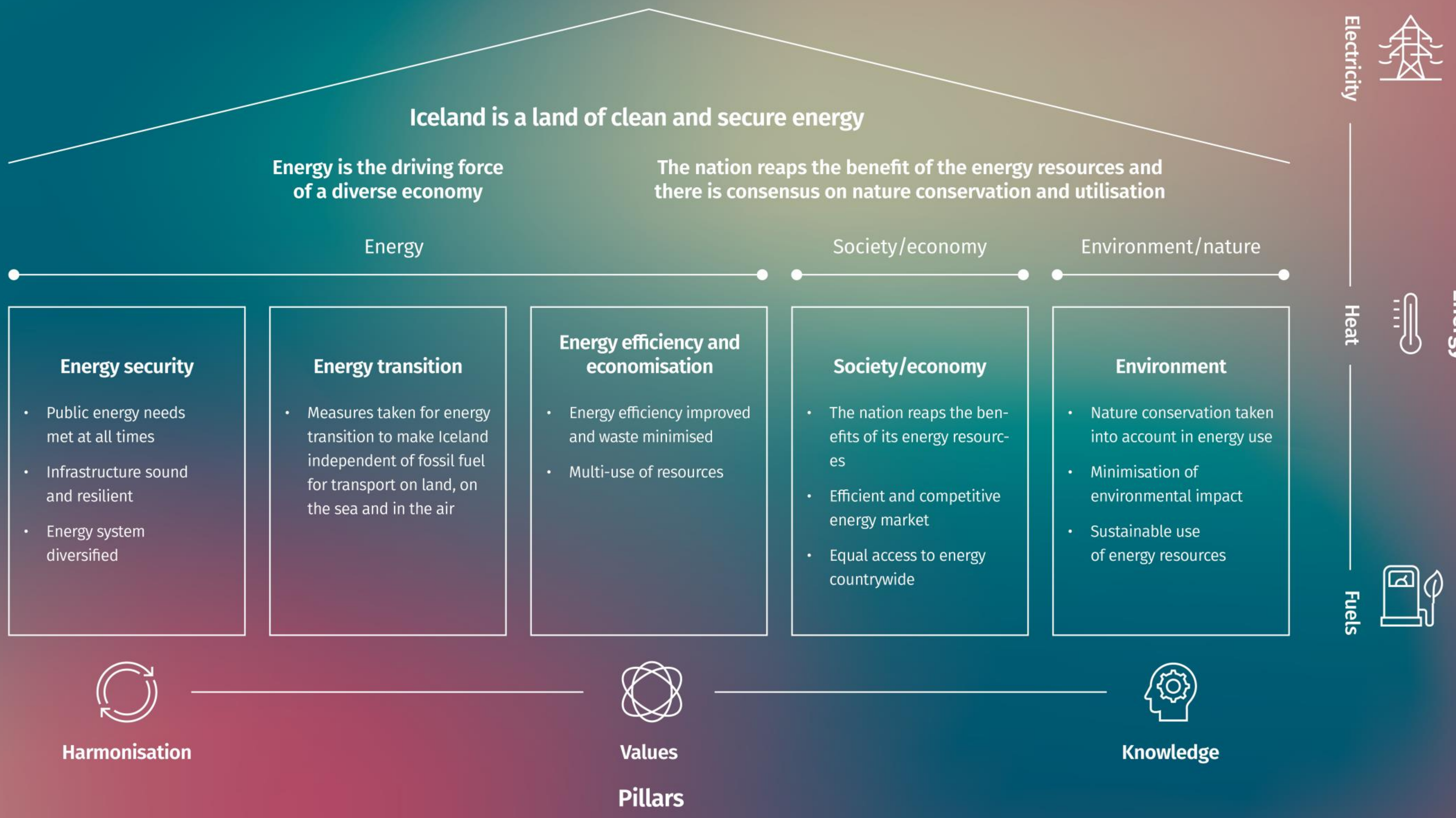
2040
Iceland's Carbon Neutrality

2040
Iceland Independent of Fossil Fuels

- Iceland takes part (with Norway) in the EU climate goal for 55% overall emission reduction (ETS, Effort sharing, LULUCF).
- Independent target of 55% cut in non-ETS emissions by 2030
- 10% renewable energy share for marine applications 2030

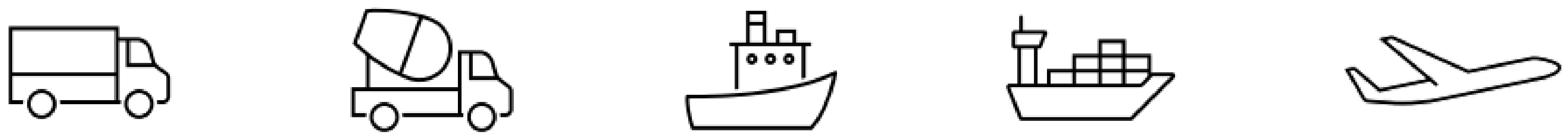
Future Vision

Sustainable Energy Future



The final energy frontier

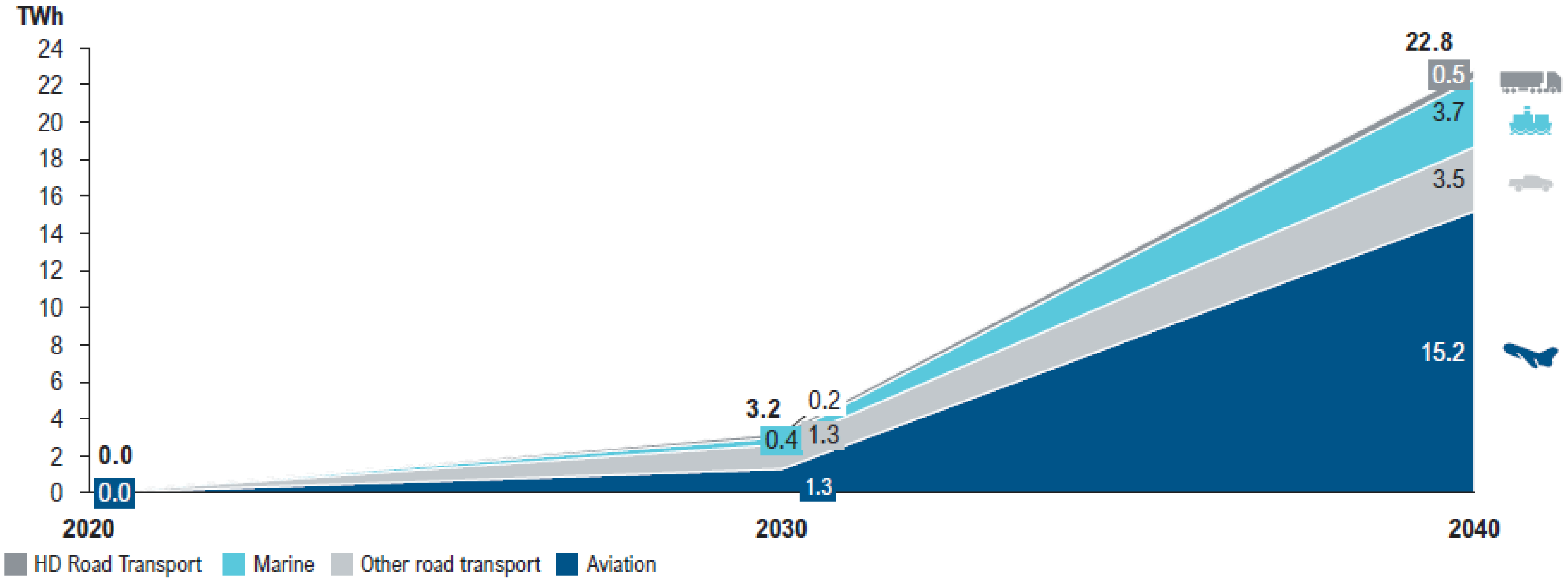
Energy transition in all transportation sectors by 2040



Challenges

- New power development with long lead times
- Energy security and competing demand (public, transition, industry)
- Infrastructure upgrades
- Public acceptance
- C02 sources limited or expensive

Required energy for a full energy transition, 2020–2040



1) 91% is assumed as capacity factor for electrolyzer and 52 kWh/kg required energy for the road and aviation sector and 59 kWh/kg for the marine sector; 2) Others include the electrification of passenger cars, light- and medium-duty vehicles as well as the share of heavy-duty vehicles which can not be fuelled with alternative hydrogen-based fuels

Source: Roland Berger

Initiatives for energy transition

Energy Fund

- Doubled every year – past 3 years
- From charging stations to more diverse fields
  - Marine
  - Aviation
  - E-fuel producers

Climate Action Plan

- Additional measures
- Sector engagement

Energy production

- Masterplan 3rd phase adopted by the Parliament
- Enlargement of current production facilities
- New energy sources (wind, waste heat, heat pumps, solar)

Thank you

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https://www.stjornarradid.is/library/01--Frettatengt---myndir-og-skrar/ANR/Orkustefna/201127%20Atvinnuvegaraduneytid%20Orkustefna%20A4%20EN%20V4.pdf

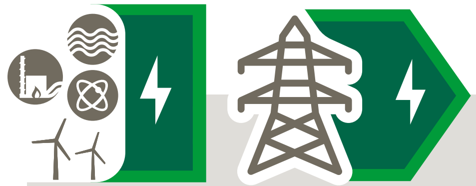
https://www.government.is/lisalib/getfile.aspx?itemid=71e9cb85-4579-11ed-9bb1-005056bc4727

The Swedish Energy Politics

Maja Lundbäck
Advisor Energy
Ministry of Climate and Enterprise

Regeringskansliet

Sweden’s energy supply



Energy systems – electricity system

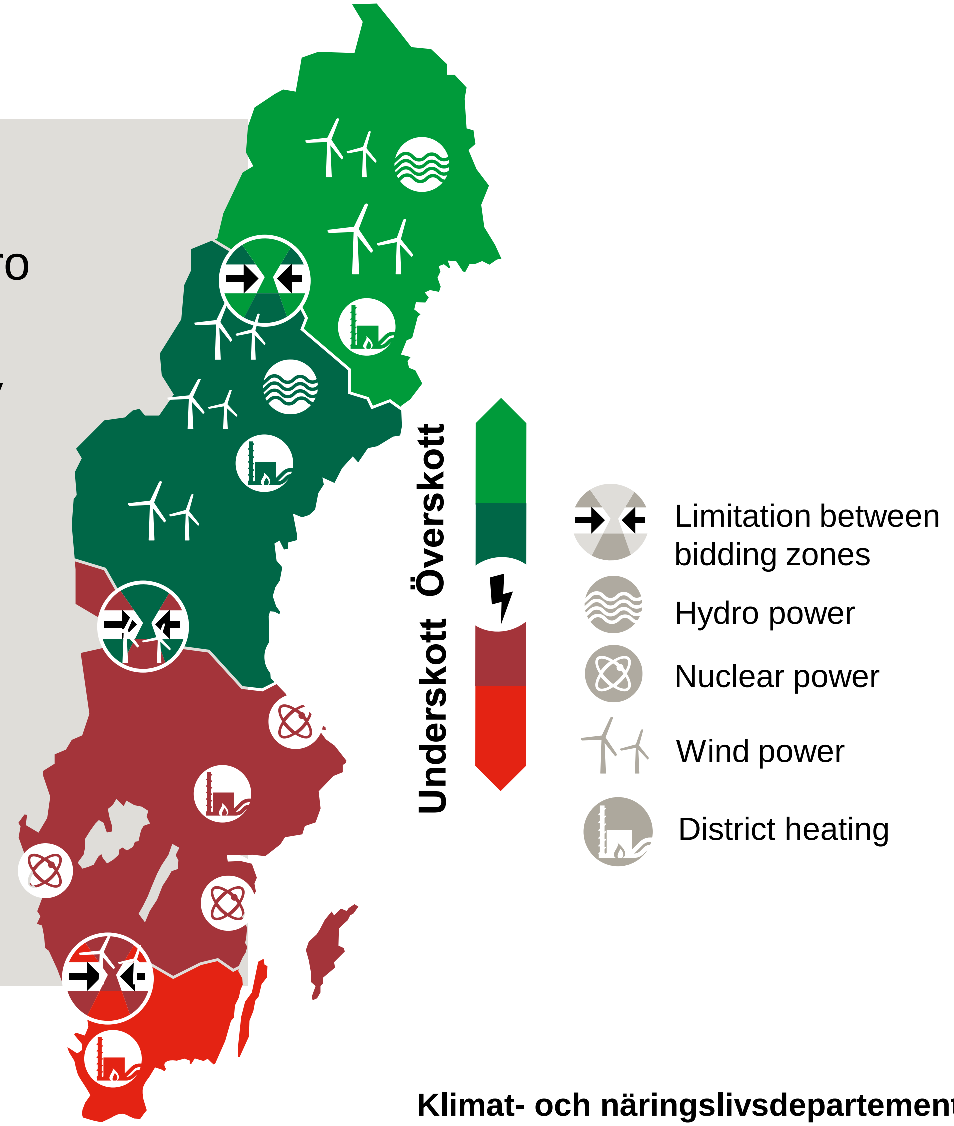
- Nuclear: 6900 MW
- Hydro: 16 300 MW
- Wind: 14 300 MW
- District heating: 6800 MW
- Sun: 2300 MW

Yearly energy consumption almost 140 TWh

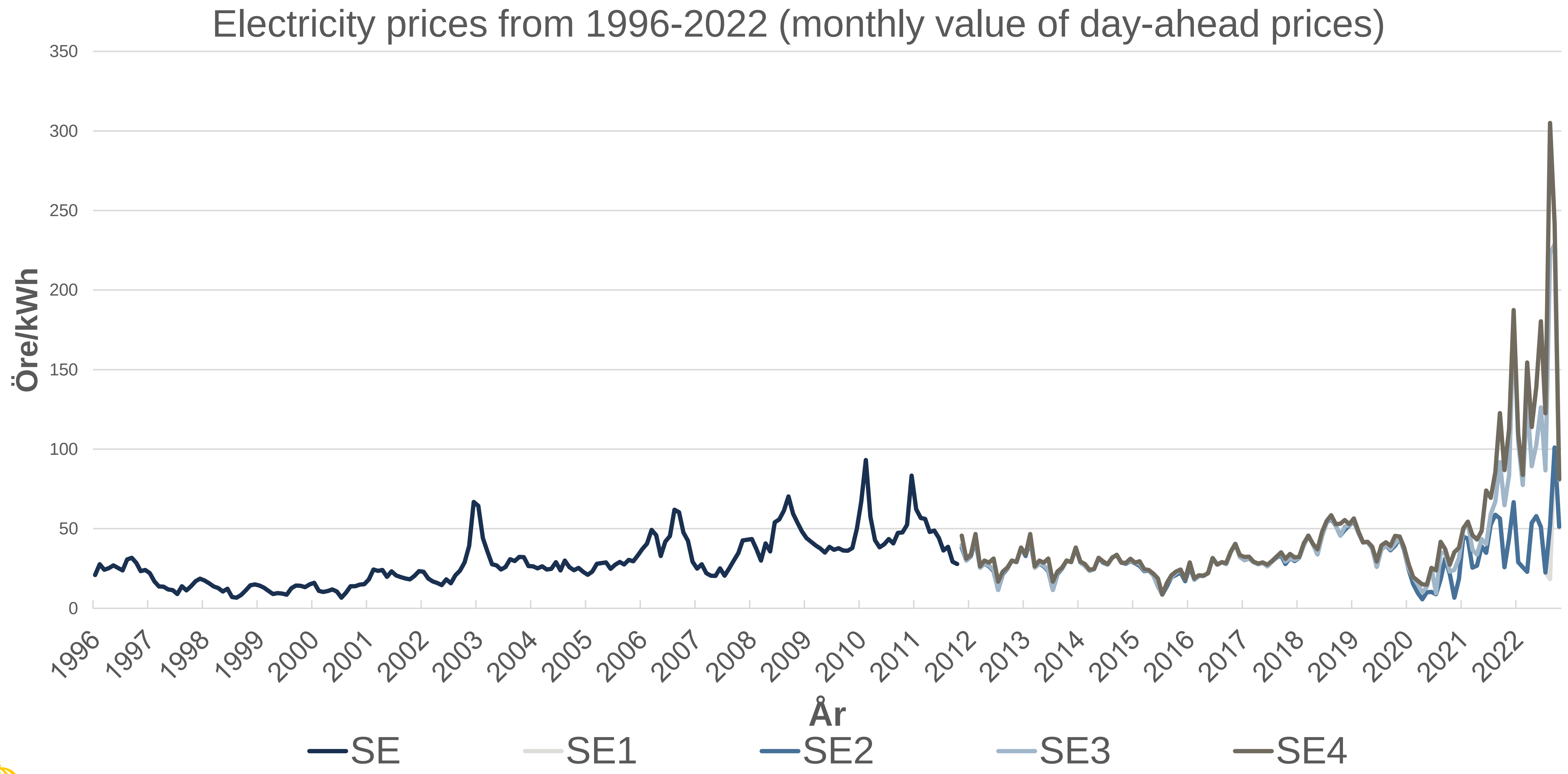
Climate target – net zero 2045

- Increase electricity demand
- Hydrogen
- Electrification and affordable prices
- Sectors coupling

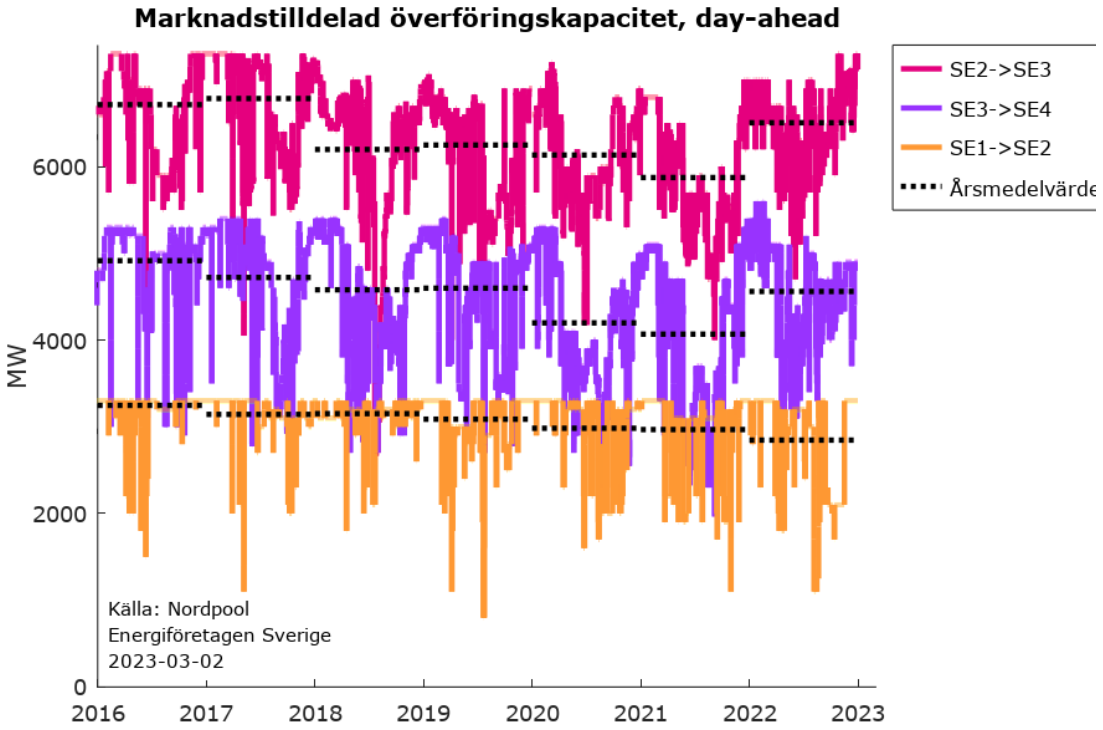
Higher dependency on the electricity system



Development of the electricity prices over time

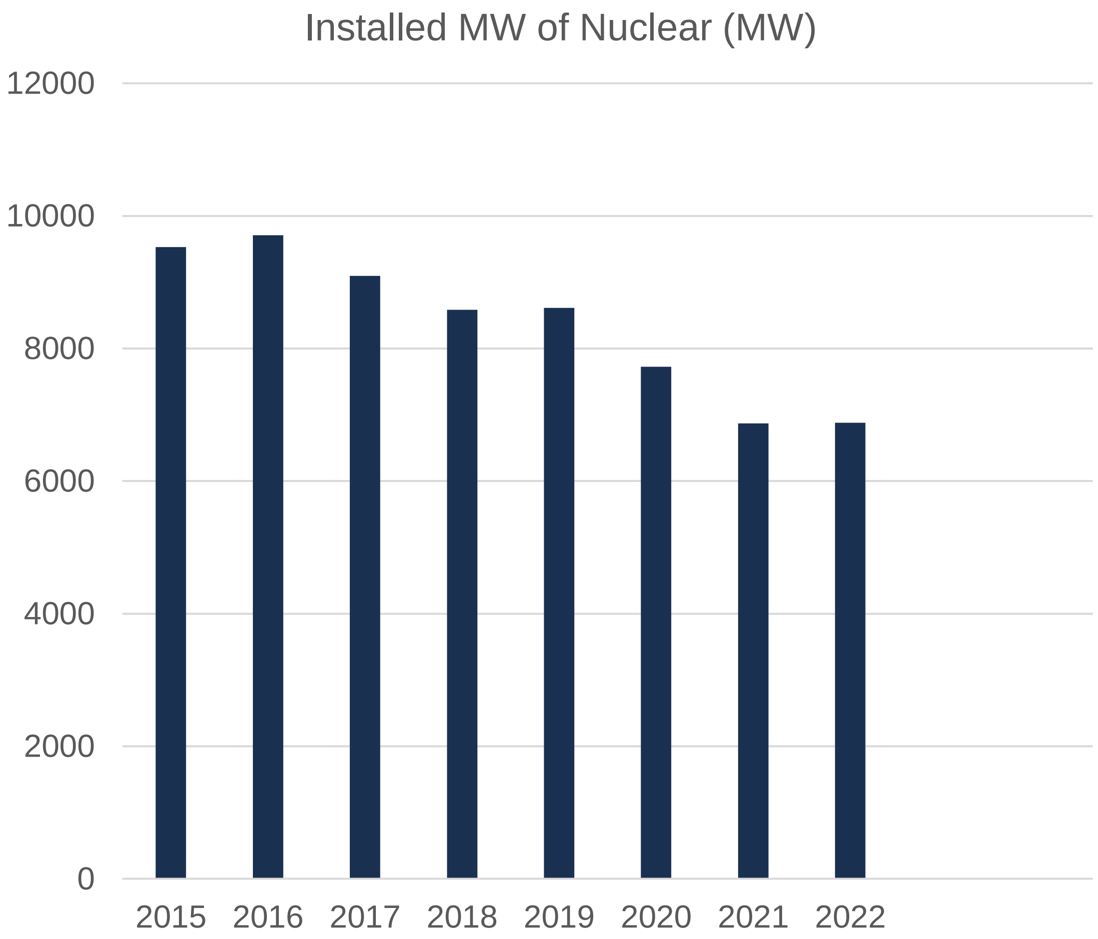


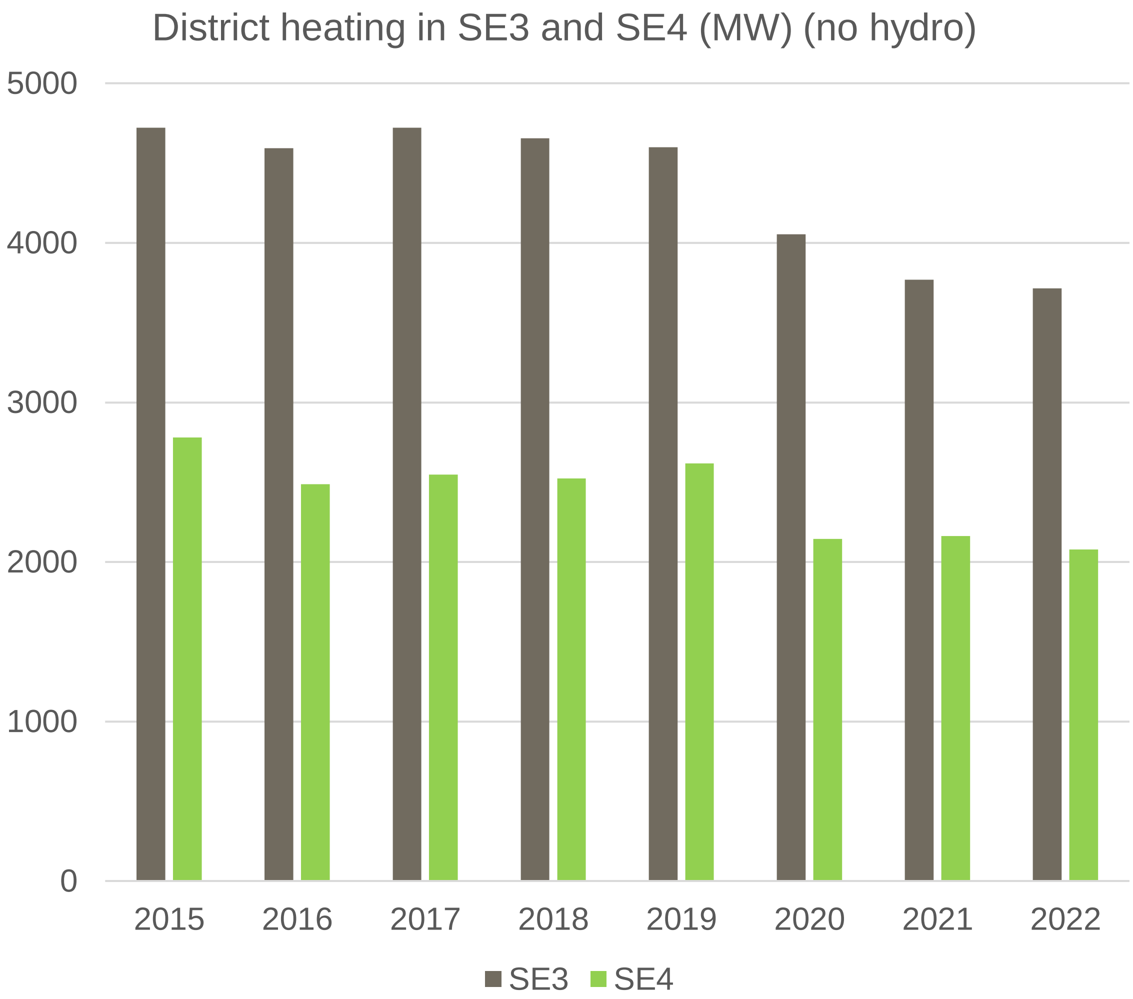
Transmission system capacity



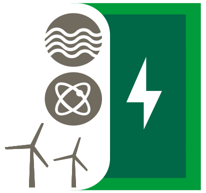
Tilldelad överföringskapacitet från SE3 till SE4. Den 27 juli 2021 togs Sydvästlänken äntligen i bruk. Den utbyggda överföringskapaciteten från SE3 till SE4 steg med det betydligt, men den överföringskapacitet som tilldelades av Svenska kraftnät sjönk.

Declining production capacity in south of Sweden





Sweden's power supply

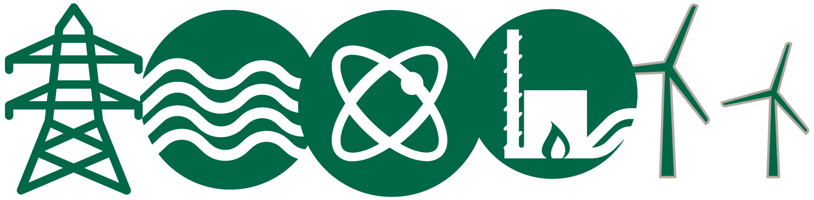


Capacity

- MW vs MWh
- Hard to connect new industries – challenging for the green transition

System operation

- Congestions and operational security limitations
- Volatile electricity prices



Power system construction

- 10 000 MW more power production today then 2013 – but what about the performance?

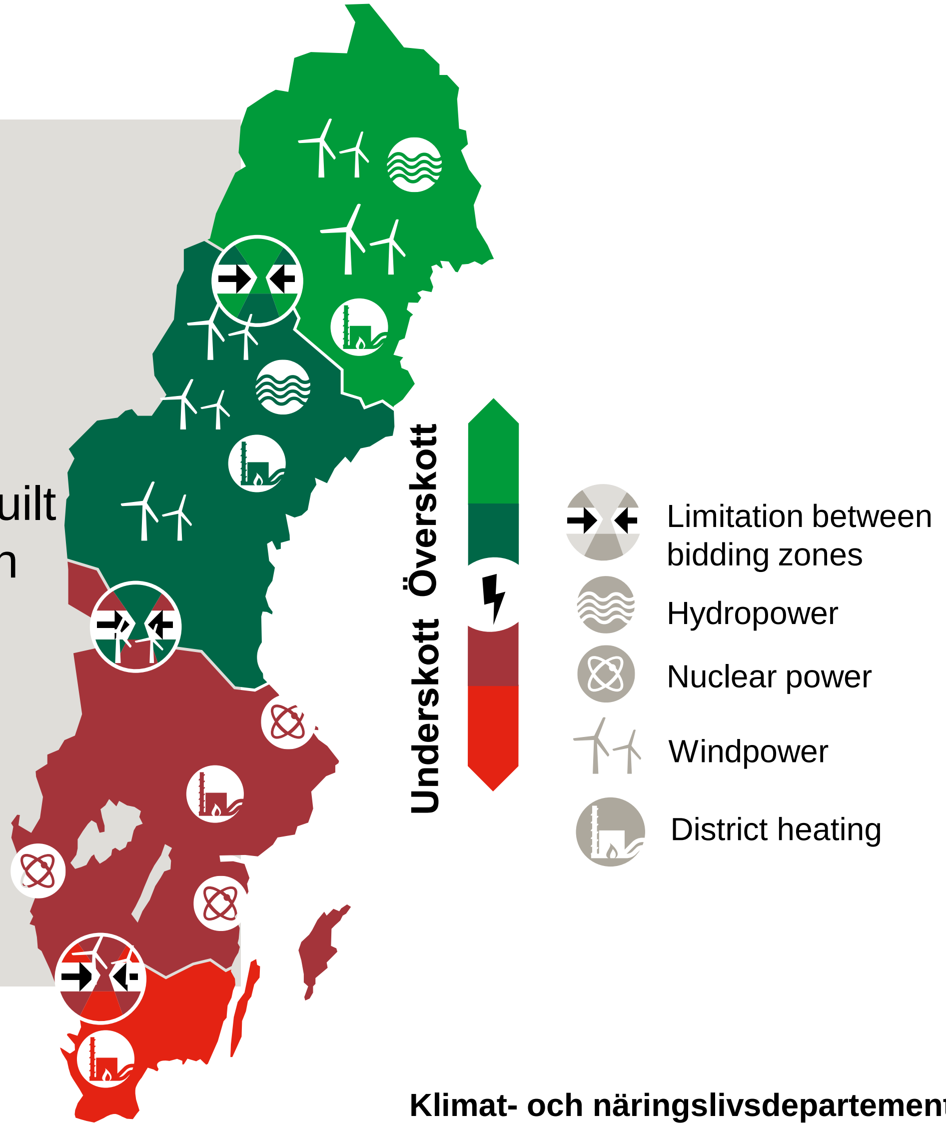
Sweden's future power supply

More then 300 TWh 2045

- More fossil free electricity production and grid capacity to meet the demand to affordable prices

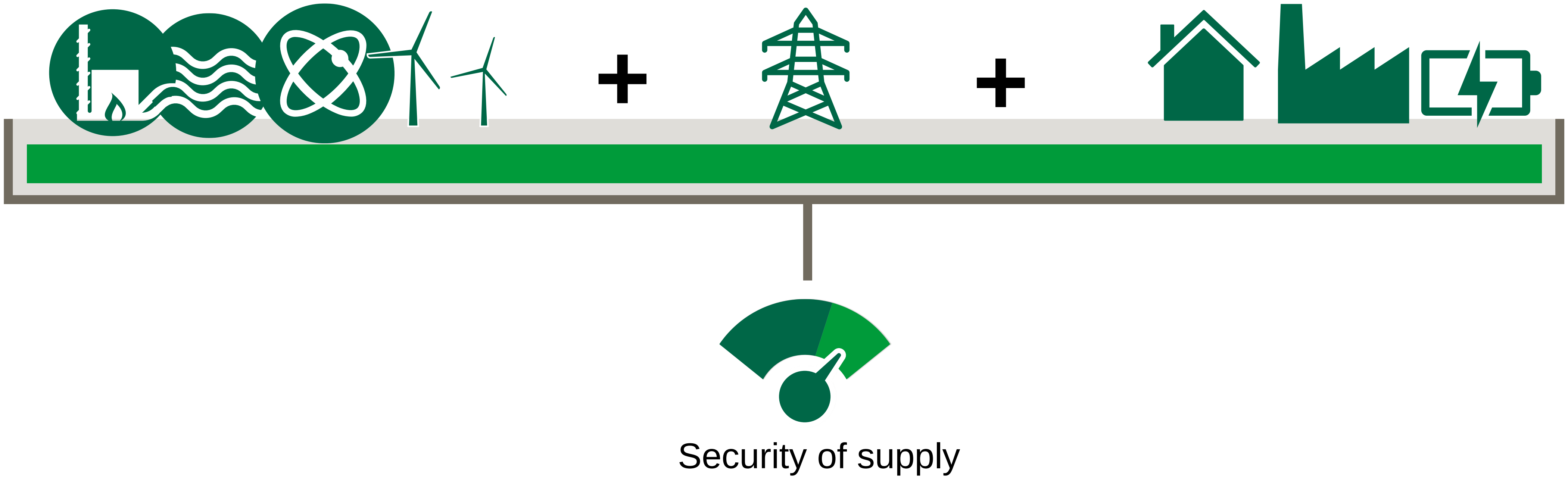
Security of supply

- Electricity production and grid need to be built at the right places with the right qualities and functions



Security of supply

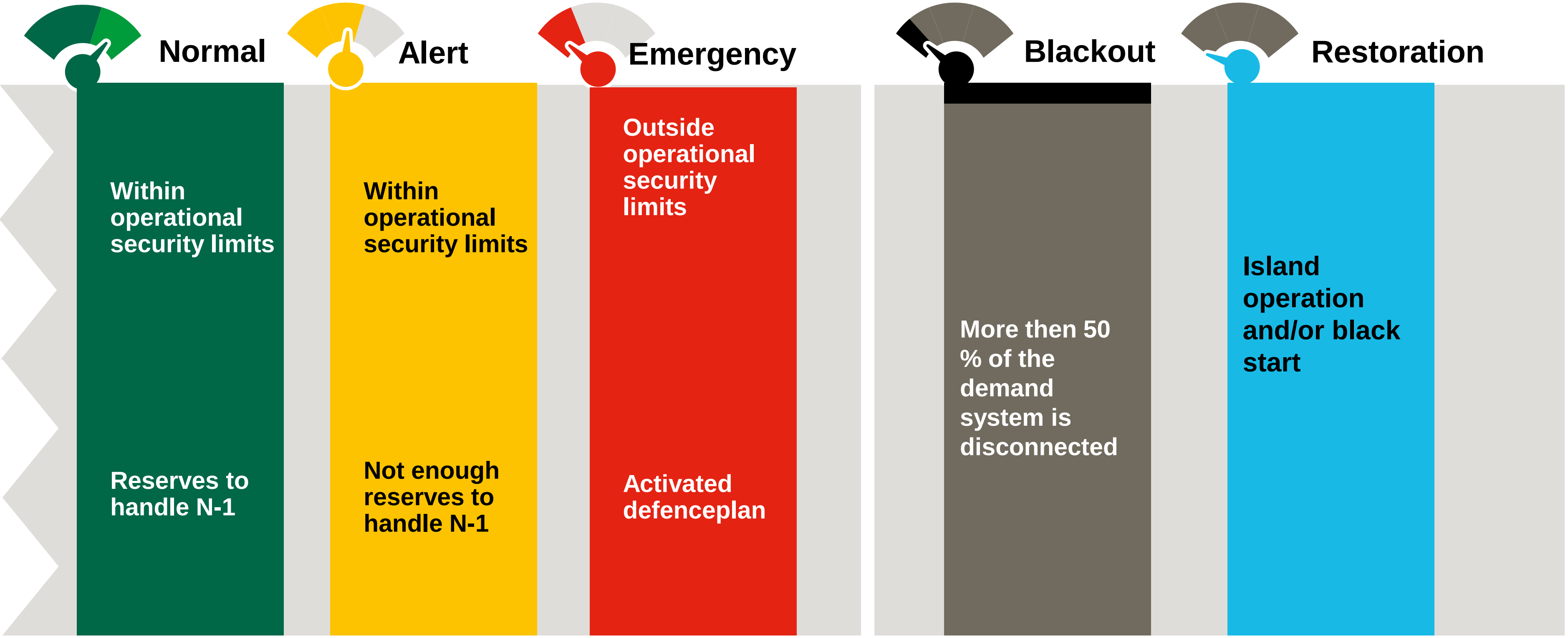
– the performance of the power system



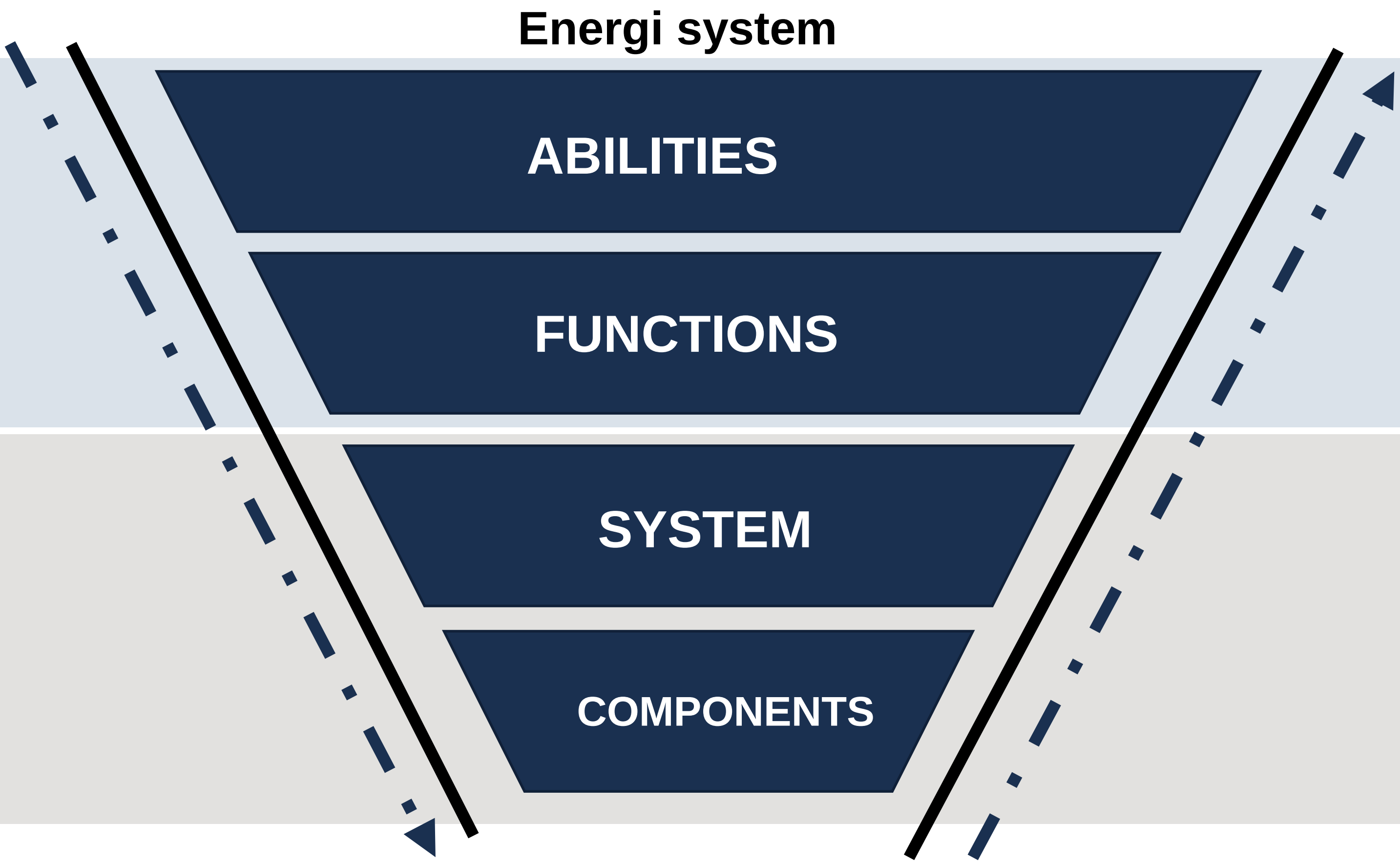
The performance of the system is already defined

Laws of physics to deliver electricity during different states

1. Balancing and frequency
2. Voltage
3. Power- and energy flows
4. Stability and resilience



The new approach for the energy politics



The political policy shall focus on the performance of the system – to deliver energy to affordable prices

Previous focus has been on what type of power production that shall be in the system

Stable, fossil free energy supply to affordable prices
– when we need it, where we need it

Goals and Targets

- Planning target to aim for a fossil free electricity system of 300 TWh to 2045
- Target for security of supply, a performance target, to make sure we expand our electricity system with the right qualities
- 100 % fossil free energy production and technology neutrality
- Energy planning and preparedness

Example of tools and incentives

- National hydrogen strategy and coordination
- New inquiry for electricity market design in Sweden
- Licensing and permitting processes
- Inquiry for structures and task of energy agencies
- Energy research and innovation

The Swedish Energy Politics

Maja Lundbäck
Advisor Energy
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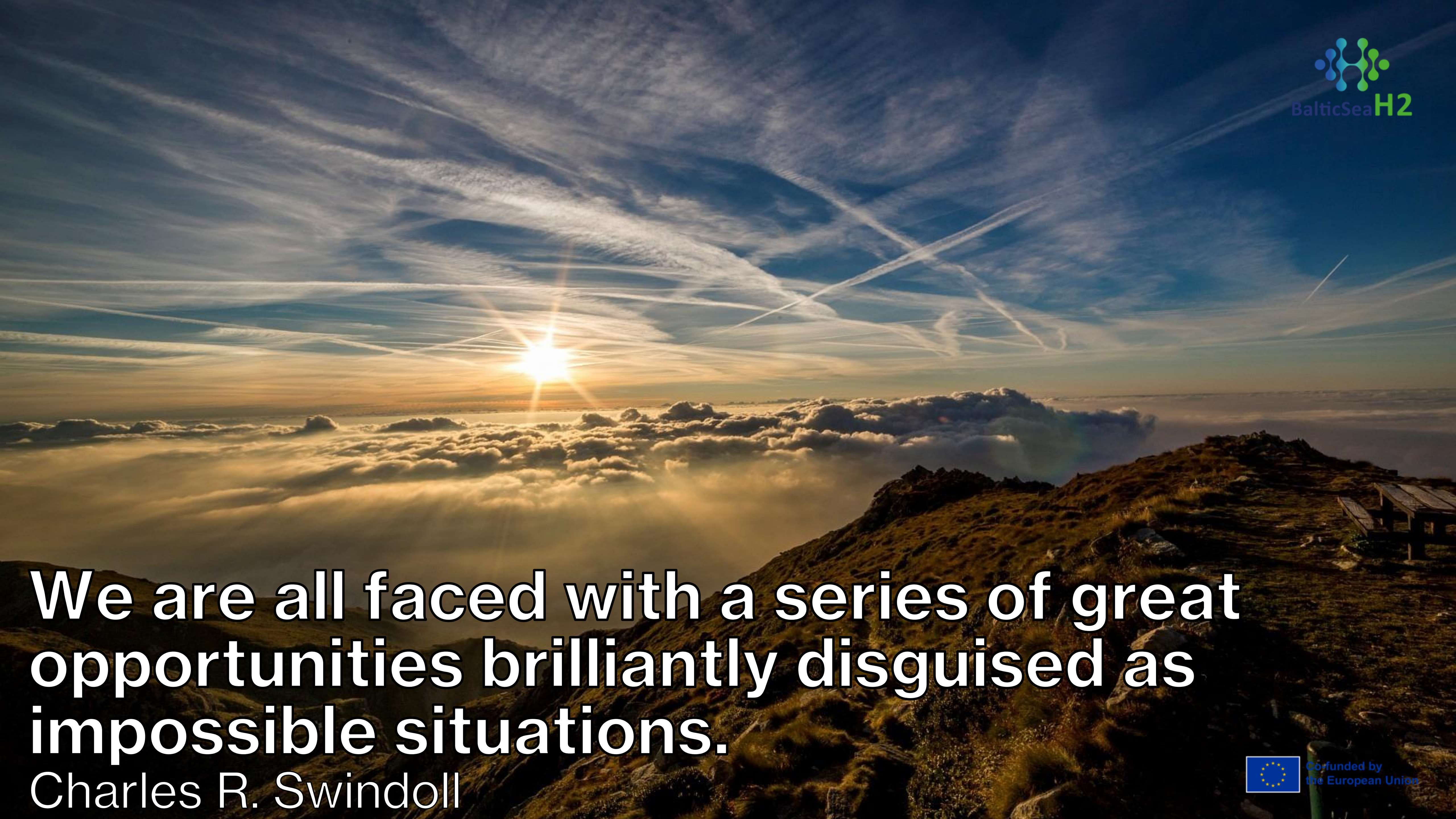
Regeringskansliet

BalticSeaH2

Demonstrating hydrogen economy with the largest cross-border Hydrogen Valley in Europe

Co-funded by the European Union


BalticSeaH2
We are all faced with a series of great opportunities brilliantly disguised as impossible situations.
Charles R. Swindoll
Co-funded by the European Union

BalticSeaH2 objective

BalticSeaH2 pioneers an innovative initiative, establishing a significant **hydrogen valley** spanning across the Baltic Sea region. Focused on main valley in southern Finland and Estonia, the project aims to revolutionize the energy landscape, fostering self-sufficiency and minimizing carbon emissions in various industries. Results from the main valley will be replicated in other regions of the project.

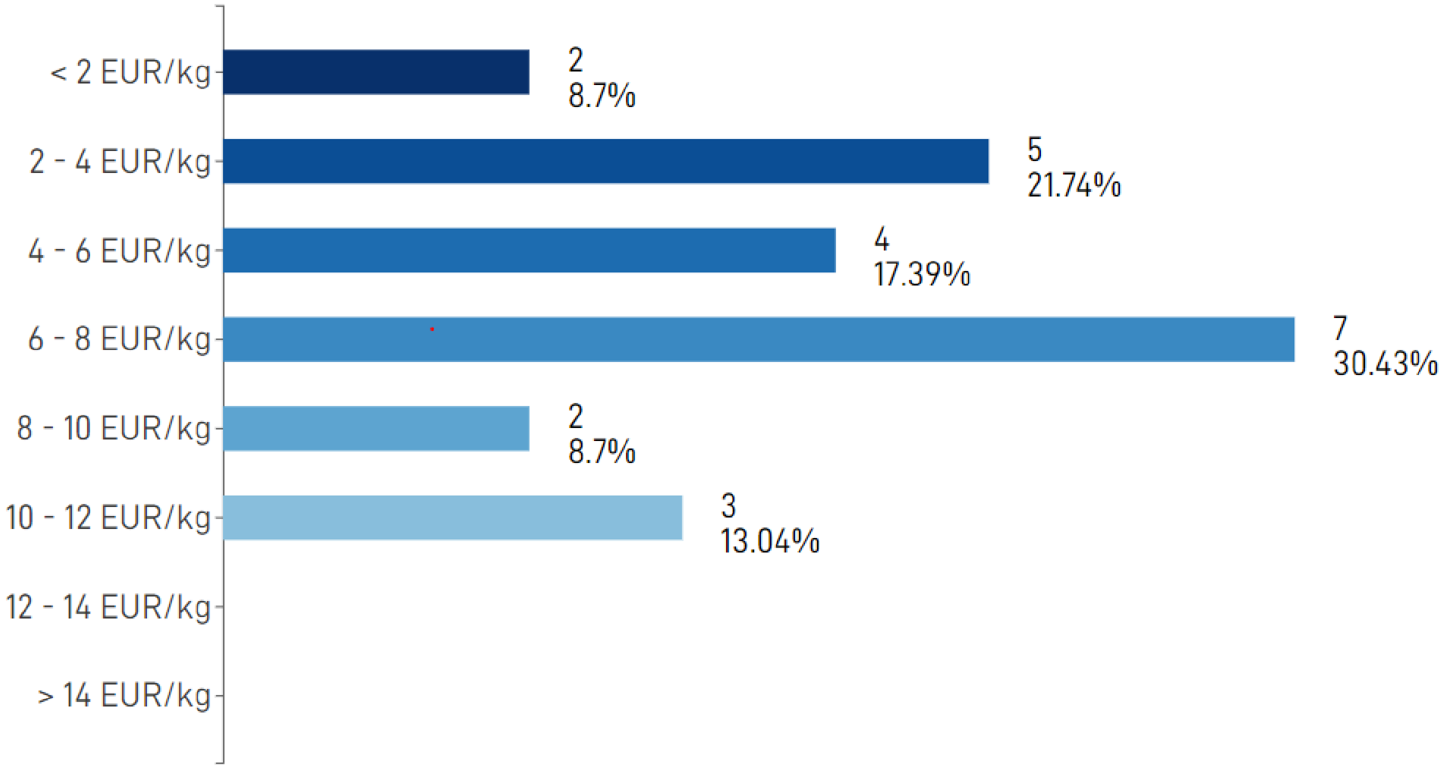
With a consortium of 40 partners from nine Baltic Sea area countries and several different industries, BalticSeaH2 strives to build **an integrated, interregional hydrogen economy on an unprecedented scale in Europe.**

Co-funded by the European Union

Drivers

Average hydrogen production cost of large-scale projects (investment volume above EUR 500 million) is between **4–6 EUR/kg**, smaller investment is between **6–8 EUR/kg**

two projects even report costs below **2 EUR/kg** (America, Asia).



https://h2v.eu/analysis/statistics/financing/hydrogen-cost-and-sales-prices

Developing the business cases for identified off-takers and establishing the right size of the valley also for scale-up maintaining the continuity of both demand and supply and at the same time pointing towards further decarbonization.

Co-funded by the European Union

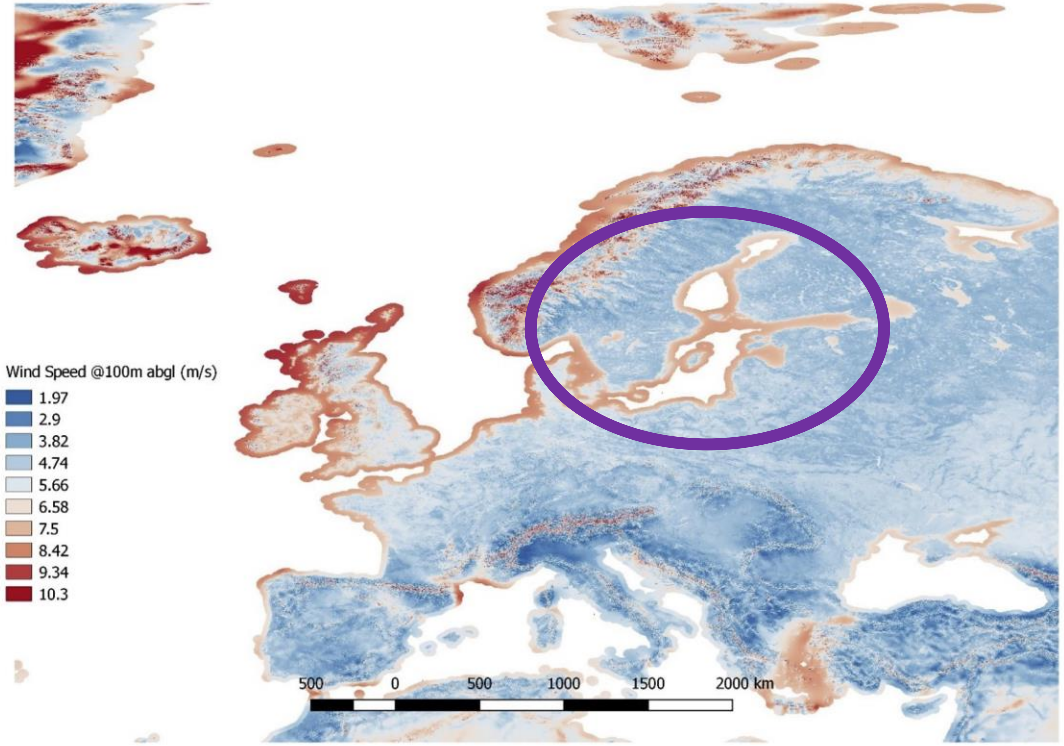
Drivers

BalticSeaH2

Hydrogen Valleys located in regions with abundant supply of renewable energy sources naturally have a lower cost of green hydrogen.

Baltic today´s offshore wind capacity 2.8 GW
The **Marienborg Declaration** set target of at least seven times the current capacity (19.6 GW) by 2030
Potential for offshore wind power in the Baltic Sea basin reaching up to 93 GW

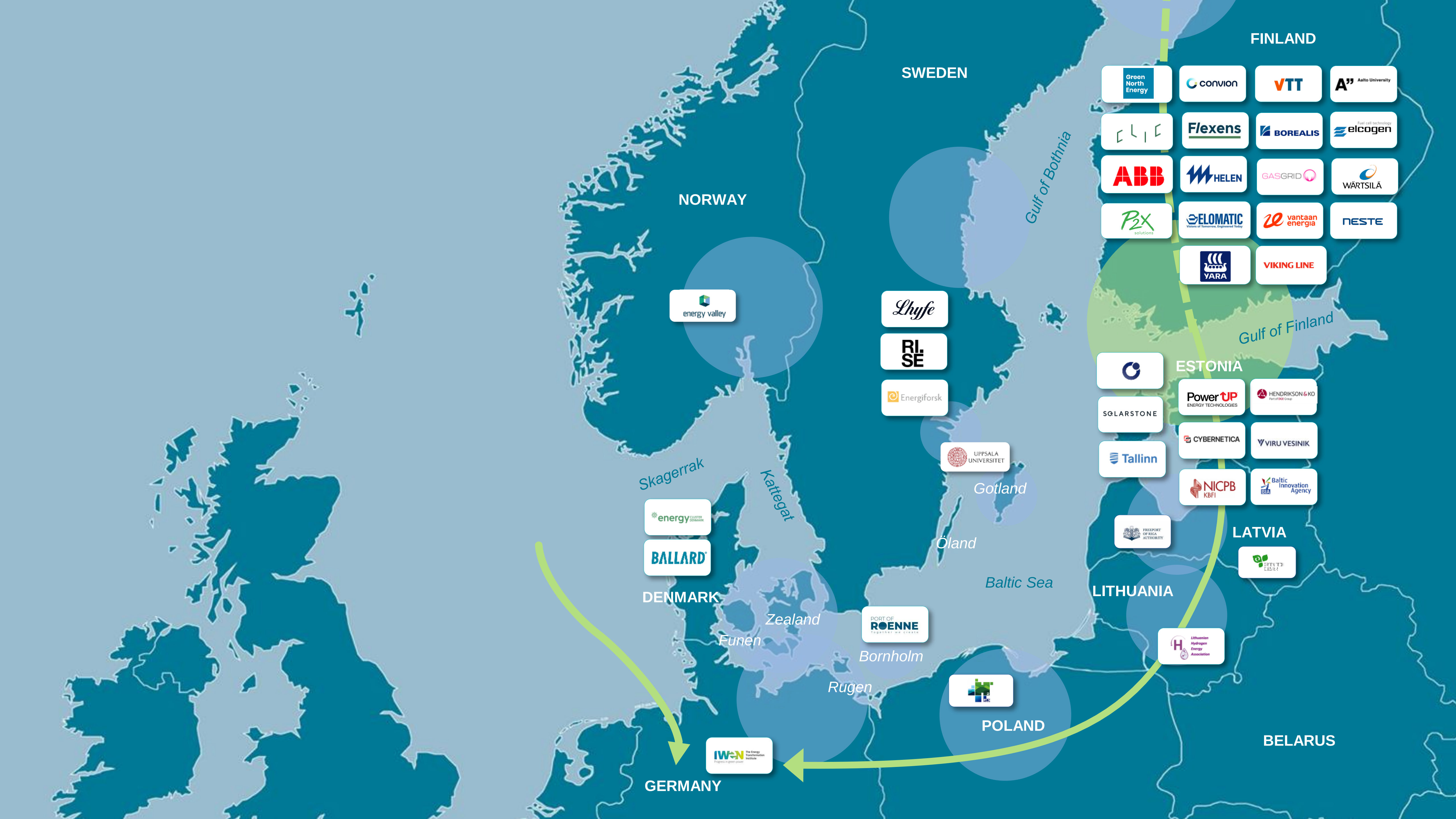
Cross-border hybrid projects will also ensure more energy security by improving electricity flows.



Source: WindEurope Baltic Sea Countries sign declaration for more cooperation in offshore wind,, https://windeurope.org/newsroom/press-releases/baltic-sea-countries-sign-declaration-for-more-cooperation-in-offshore-wind/

Source: Peter Enevoldsen, Finn-Hendrik Permien, Ines Bakhtaoui, Anna-Katharina von Krauland, Mark Z. Jacobson, George Xydis, Benjamin K. Sovacool, Scott V. Valentine, Daniel Luecht, Gregory Oxley, How much wind power potential does europe have? Examining european wind power potential with an enhanced socio-technical atlas, Energy Policy, Volume 132, 2019, Pages 1092-1100, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.06.064.

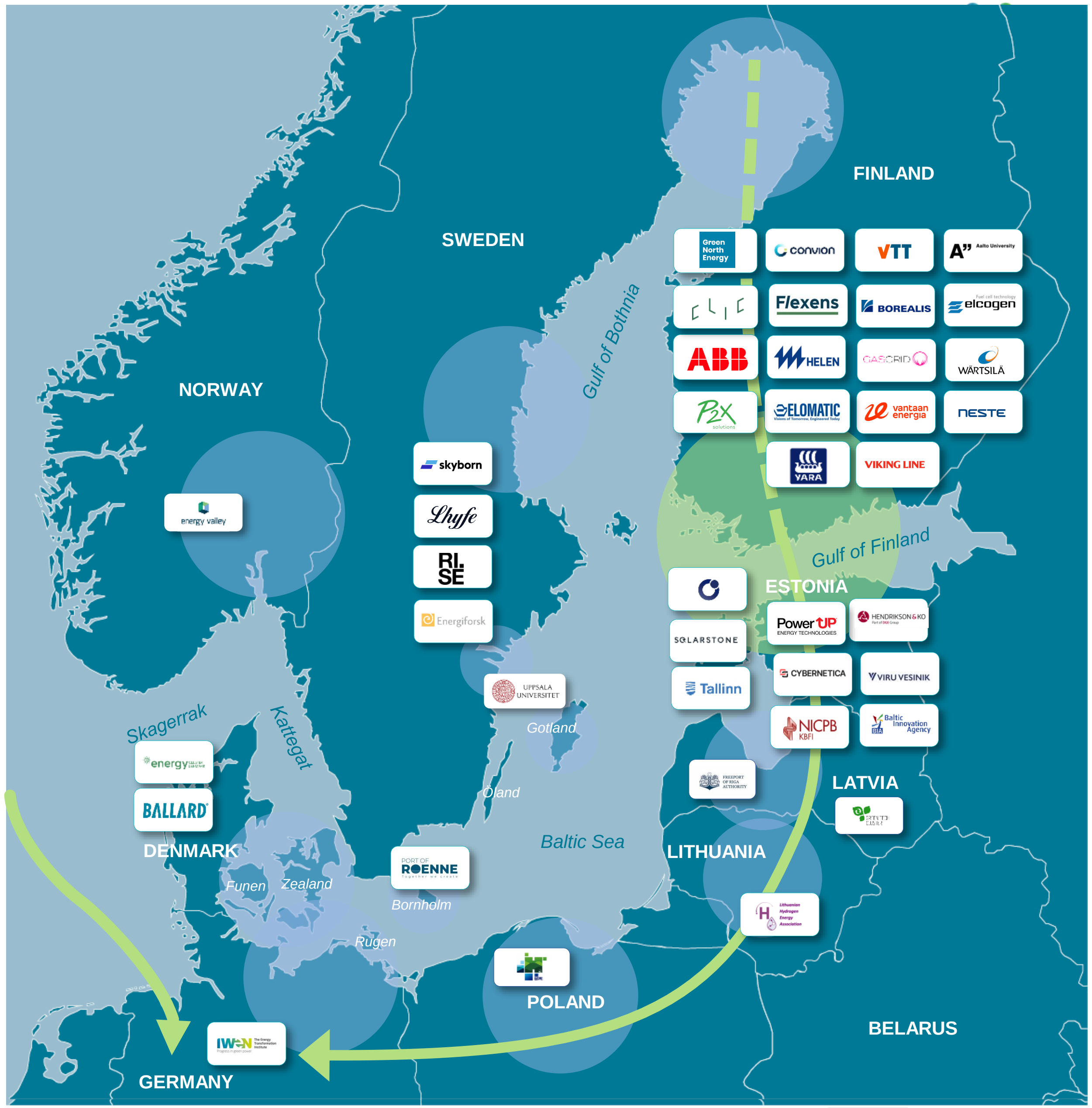
Co-funded by the European Union



FINLAND
SWEDEN
NORWAY
Gulf of Bothnia
Gulf of Finland
ESTONIA
LATVIA
LITHUANIA
BELARUS
POLAND
GERMANY
DENMARK
Skagerrak
Kattegat
Gotland
Öland
Baltic Sea
Zealand
Funen
Bornholm
Rugen

About BalticSeaH2

- 40 partners in 9 countries
- Coordinated by CLIC Innovation and Gasgrid Finland
- Main valley between Finland and Estonia: replication valleys in Norway, Sweden, Denmark, Latvia, Lithuania, Poland and Northern Germany
- Total budget 33 M€, EU funding for 25 M€



Co-funded by
the European Union

BalticSeaH2 Main Valley

Special features:

- Cross-border main Valley Estonia - Southern
- Finland with pipeline connection
- Included end-use sectors in the main Valley:
    - Traffic (direct use and e-fuels)
    - Chemical industry
    - Energy industry (P2X with X=different products)
    - Maritime: usage and hydrogen transport

- 7 connected Valleys via pipeline and maritime connections support build-up of a full Baltic Hydrogen Economy

Co-funded by the European Union

Hydrogen value chain and infrastructure

BalticSeaH2

Renewable energy production

- Solarstone
- Helen
- Viru Vesinik
- Flexens
- IWEN
- Skyborn Renewables Sweden AB
- Energy Valley Norway
- Energy Cluster Denmark
- Energiforsk
- Estonian Hydrogen Cluster
- Green and Smart Technology Cluster (GreenTechLatvia)

Hydrogen production

- Helen
- P2X Solutions
- Green NorthH2 Energy
- Vantaan Energia Energy
- PowerUp
- LHYFE

Hydrogen infrastructure and transmission

- Gasgrid
- Flexens
- LHYFE
- Borealis
- Helen
- VTT
- Topeka
- Lithuanian Hydrogen Energy Association
- Polish Hydrogen Cluster

Fuel cell demos

- Ballard
- ABB
- Helen
- Elcogen
- Convion
- Vantaan Energia
- Solar Stone
- Power UP
- VTT

Hydrogen utilization

- Borealis
- Green NorthH2 Energy
- ABB
- City of Tallin
- Helen
- Vantaan Energia
- P2X Solutions
- Flexens
- Solar Stone
- Power UP
- Viking Line
- YARA
- Neste
- Free Port of Riga
- Port of Ronne
- RISE
- Uppsala University
- Wartsilä

Highly dynamic market model digitalization, modelling and digital twins

- ABB
- Cybernetica
- Gasgrid
- Helen
- P2X Solutions
- Green NorthH2
- Power UP
- VTT
- Aalto
- Schlumberger
- CLIC Innovation

- Electricity markets
- Heat market
- Hydrogen Market
- P2X markets
- Transport sector

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BalticSeaH2

1

Pioneering digitalized multimarket optimization and operation model which can be scaled to other Hydrogen valleys in EU

2

Maximizing the value of the extensive sector coupling opportunities to integrate hydrogen across industries as well as energy (both electricity and heat) and transport sectors (maritime, heavy duty)

3

South Finland- Estonia main valley: a cross country valley with possibilities to reutilize existing electricity and gas connections. Utilizing the abundant clean fresh water resources

4

Supporting the rapid growth of cost-competitive renewable and emission free electricity available in the main Valley

5

Setting up financing mechanisms for investments to develop cross-border hydrogen economy between South Finland and Estonia

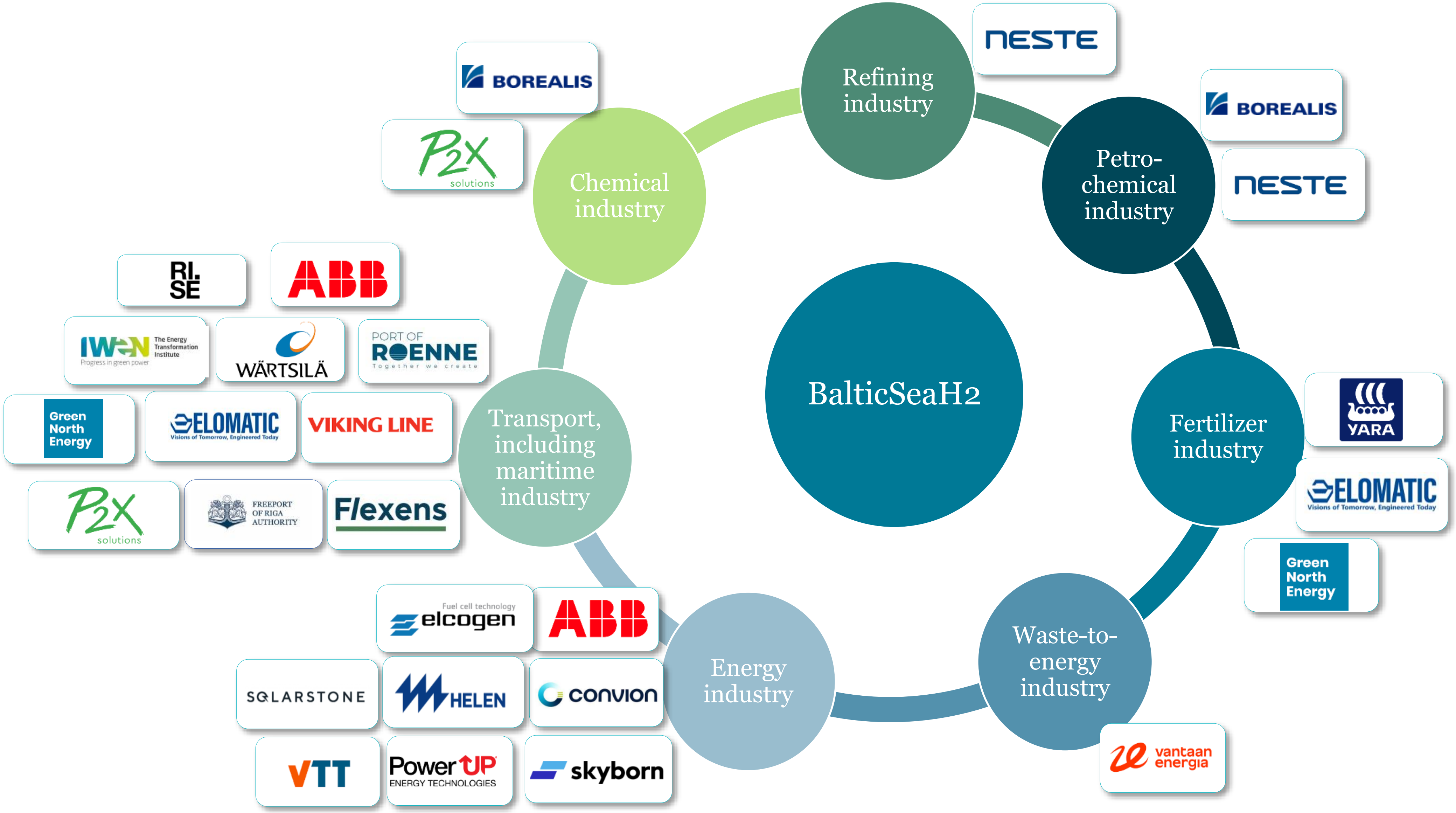
6

Connecting with collaboration and replication valleys in Norway, Sweden, Denmark, Latvia, Lithuania, Poland & Northern Germany and creating a share regulation and safety framework

Vision

Co-funded by the European Union

Use cases and industries involved in BalticSeaH2



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Cross-border Hydrogen Valley around the Baltic Sea (BalticSeaH2)

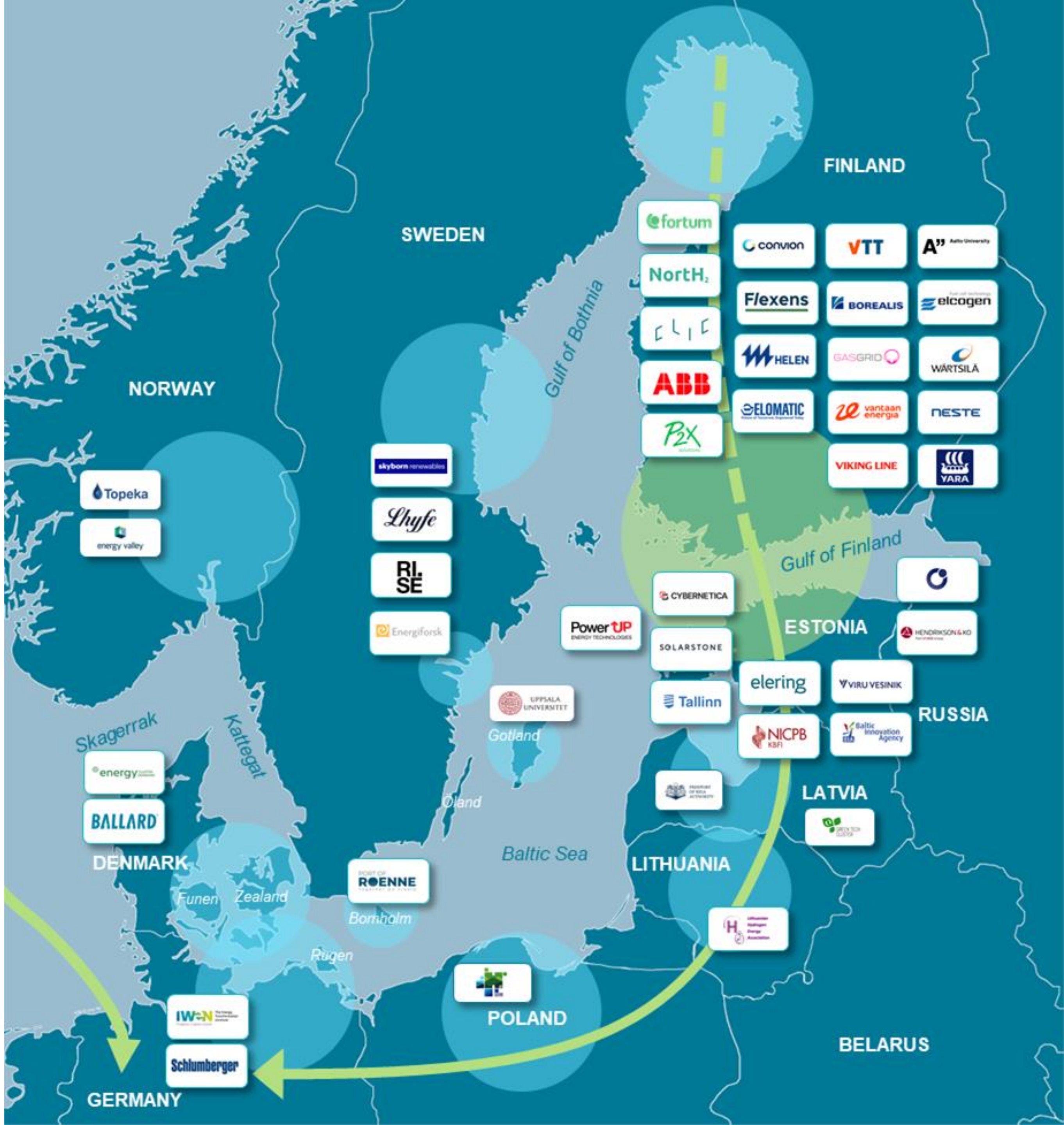
- BalticSeaH2 project creates a large-scale, cross-border hydrogen valley around the Baltic Sea
  - The **main Valley** is between southern Finland and Estonia

- Included end-use sectors for hydrogen in the **main Valley** (green):
  - **Traffic (direct use and e-fuels)**
  - **Chemical industry**
  - **Energy industry (P2X with X=different products)**
  - **Maritime: usage and hydrogen transport**

- 7 connected Valleys via pipeline and maritime connections (blue) support build-up of a full Baltic Hydrogen Economy

- The consortium includes 40 partners from nine Baltic Sea region countries: Finland, Estonia, Latvia, Lithuania, Poland, Germany, Denmark, Norway, and Sweden. Total project volume is 33 M€.

- The project started in 6/2023 and lasts five years



Follow the project!

BalticSeaH2

- X: @BalticSeaH2
- LinkedIn: BalticSeaH2

- Website: https://balticseah2valley.eu
- Contact person: Dr. Francesco Reda , VTT , francesco.reda@vtt.fi

  Research Manager Industrial energy and Hydrogen

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KTH ROYAL INSTITUTE OF TECHNOLOGY

Challenges and Opportunities when hydrogen meets the electrical power system

Sonja Monica Berlijn
Prof.dr.techn.ir.MBA

prof.Sonja.Berlijn
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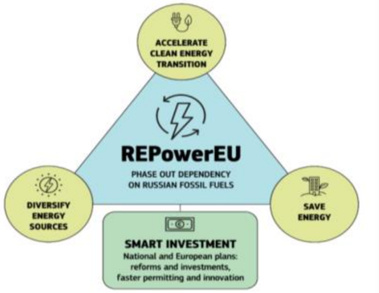
@sonja_berlijn
prof. Sonja Berlijn

Net Zero Emissions by 2050

Emissions have to come down and many are committed to reach this target

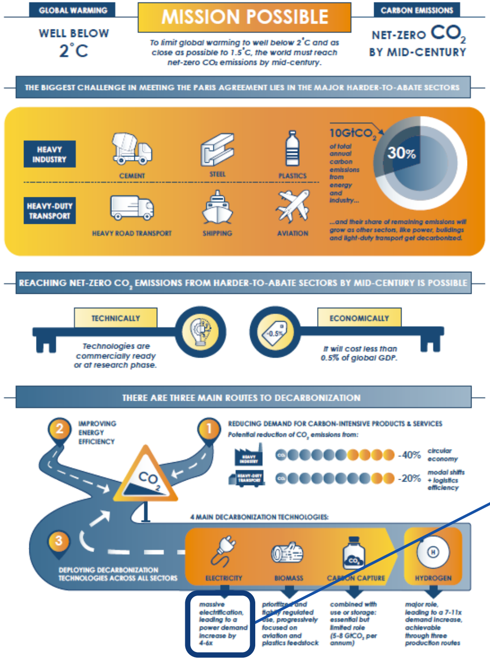
European Green Deal: **The first climate-neutral continent by 2050** through boosting the economy, improving people's health and quality of life, caring for nature and leaving no one behind

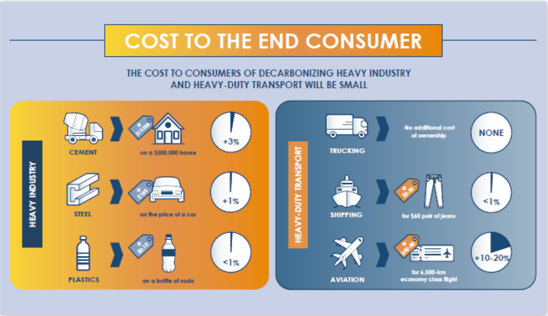
REPowerEU is about rapidly **reducing our dependence on Russian fossil fuels** by fast forwarding the clean transition and joining forces to achieve a more **resilient energy system** and a true Energy Union.



Fit55, NetzeroIndustry act, etc

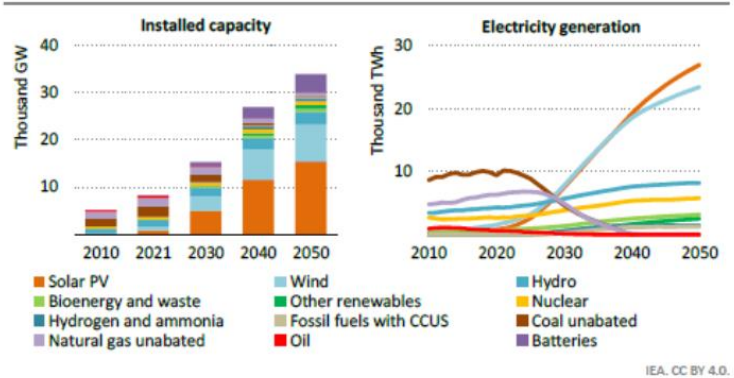
Can we do this? Yes we can!
Technologies are ready.
It will cost less than 0,5% of GDP





Massive electrification, leading to an electrical power demand increase in Europe by a factor 4 to 6 and internationally by a factor of 7

Increased demand requires increased power production and increased transmission

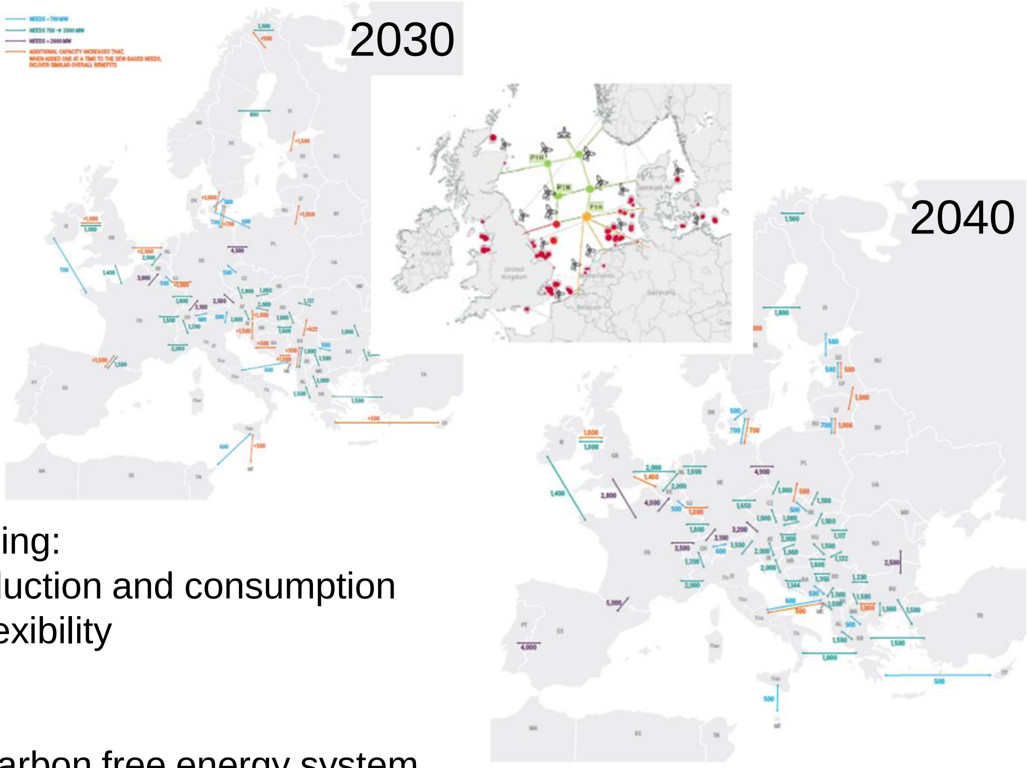


Total electricity generation nearly triples to 2050, with a rapid shift away from unabated coal and natural gas to low-emissions sources, led by solar PV and wind

Source: Energy Outlook 2022

Source: Energy Transitions Commission 2018 and IEA Energy outlook 2022

European Electricity Grid planning



Adresses challenges and solutions for adding:

- Significant more and other type of production and consumption
- Large and/or many storage facilities, flexibility
- New technologies

It will take time to build a grid ready for a carbon free energy system, but it is a prerequisite!

Source: ENTSO-E TYNDP 2020

Some history – a simple power system

- In 1891 Hammerfest became the first town In Norway with public street lighting.
- In 1912 Froland–Bergen was the first overhead line in Norway
- Power System was simple: Generation, Transmission, Load

Photo: Hammerfest Energi

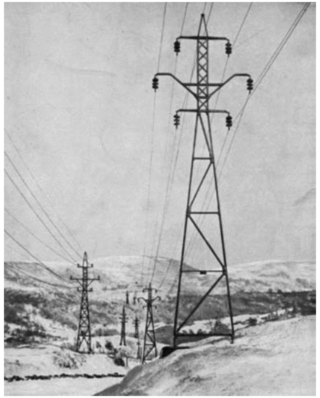
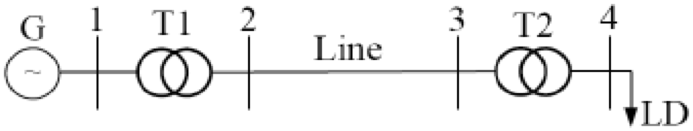


Photo: NVE



That simple power system developed into a more complex power system

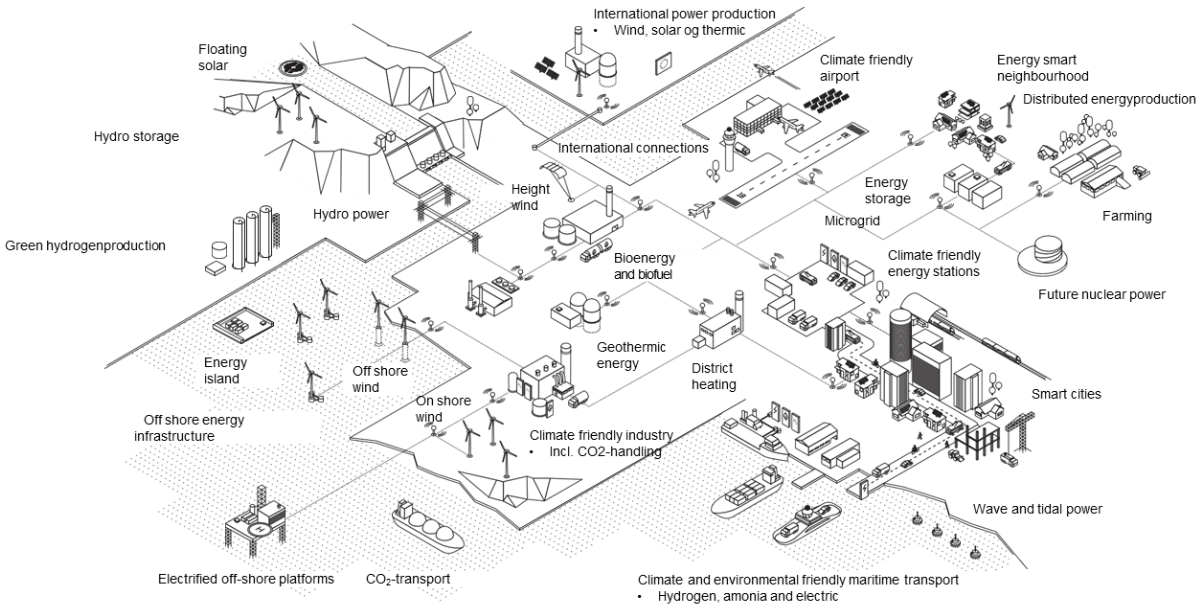
- It comprises
  - Multiple generators of different types: Nuclear, hydro, wind, solar, geothermal, coal, gas…
  - Load centers distributed all around
  - Transmission lines to transport energy
  - Interconnection between countries for import and export
  - Different markets, different rules and regulations
  - Different tax systems
  - Communication and control systems

In the mean time the physics remain the same:

One main rule for a whole grid:
Total power production = total consumption + losses

One main rule for a portion of a grid (e.g. one country, like Norway):
Total power production + imports = total consumption + losses + exports

Our future integrated energy system will be even more complex



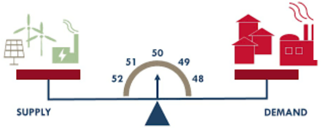
Source: Energi21

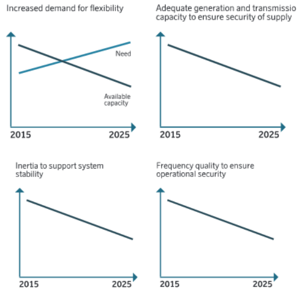
- Our electrical power system is already complex and hard to comprehend and will only be more complex and more difficult to comprehend
- We need to build new infrastructure while at the same time using the infrastructure we have even better
- We need to implement smart solutions such as smart grids, smart protection and control. We need new market solutions as well as better insight for which sensors and digital and better communication is needed.
- Digitalization, automation, optimization, AI, IoT, Cybersecurity, open source, are the new buzz words

So what are the challenges and opportunities when hydrogen meets the electrcity grid?


Vecteezy

- Simplified: It is about keeping the lights on and this has become more and more difficult.
  - The supply and demand need to be in balance every single moment
  - More actions are needed with less time to act
- The (market) system will change maybe 2 times
  - from a system where the production follows the consuptiom to a system where the consumers will need to follow the consumption and then maybe change again back
- Renewable electricity will be produced at a time it is not needed and a place where it is not needed
- Hydrogen meeting the electricity grid is both a challenge and an opportunity
  - The plants/valleys need to be connected, new load centres
  - They can play a big role for the flexibility needed, local, regional, national, international, short term to long term
  - They can play a role for alternative transportation and maybe prevent wrong long term infrastructure investments






Fiverr

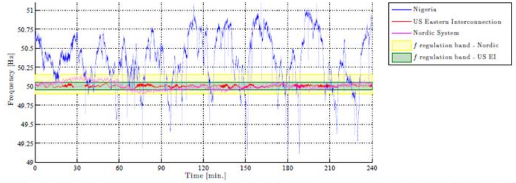
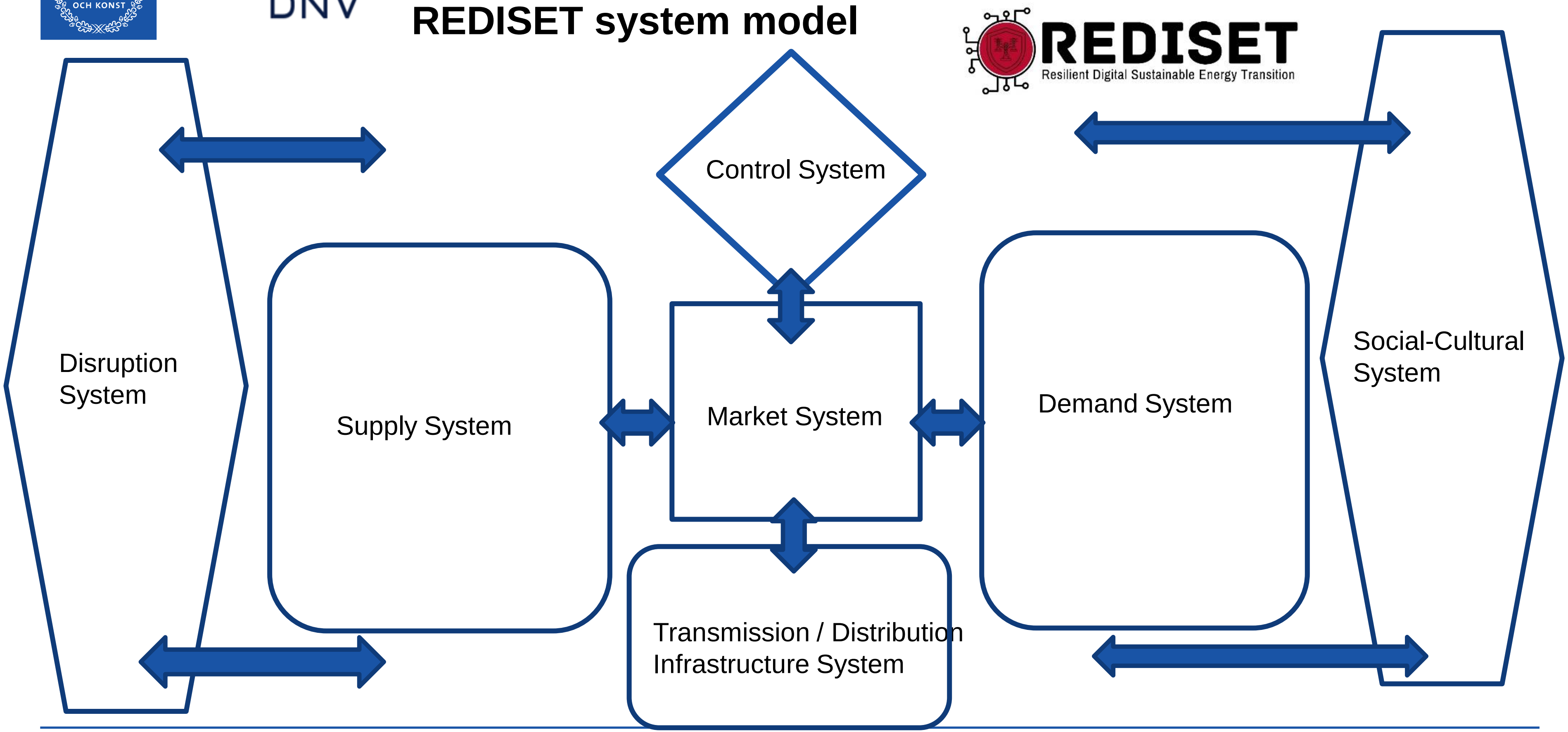


Figure 13. Comparison of the system frequency in different power systems over a 4-hour period. The steady state frequency at the US EI has been shifted by 10 Hz to coincide with the system frequencies of the Nigerian and Nordic networks.

What is there to learn from the electricity grid?

REDISET system model



Take aways

- The electricity grid has been developed over now more than 100 years
- It started as something relatively easy to understand for all and has become now so complex that no-one understand all elements
- Hydrogen meeting the electricity grid is both a challenge and an opportunity
- When building the hydrogen ‘grid’ a lot is to learn from the electricity sector
- When designing and building it now, design the future system and system model first
- Don’t think just local, regional and national. Think international directly.
- Don’t underestimate the complexity of the final hydrogen ‘grid/system’

Questions?

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Prof.dr.techn.ir.MBA
Professor Sustainable Integrated Energy Systems - KTH
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prof. Sonja Berlijn

KTH Royal Institute of Technology in Stockholm, Sweden

WHEN TRUST MATTERS

The Nordic fuel transition roadmap and green shipping corridor pilots

Eirill Bachmann Mehammer, Senior Consultant, DNV
Task Leader – Piloting and Collaboration Platform

Nordic Council of Ministers

The Nordic commitment

- **Declaration on Zero Emission Shipping by 2050** (COP26, November 2021)
- **Clydebank Declaration for green shipping corridors** (COP26, November 2021)
- **Ministerial Declaration on zero emission shipping routes between the Nordic countries** (May 2022)
- **Joint Statement by the Nordic Prime Ministers on a Sustainable Ocean Economy and the Green Transition** (August 2022)

+ The 2023 IMO Strategy on Reduction of GHG Emissions from Ships

DNV

The Nordic roadmap project (2022-2025)

Nordic Council of Ministers

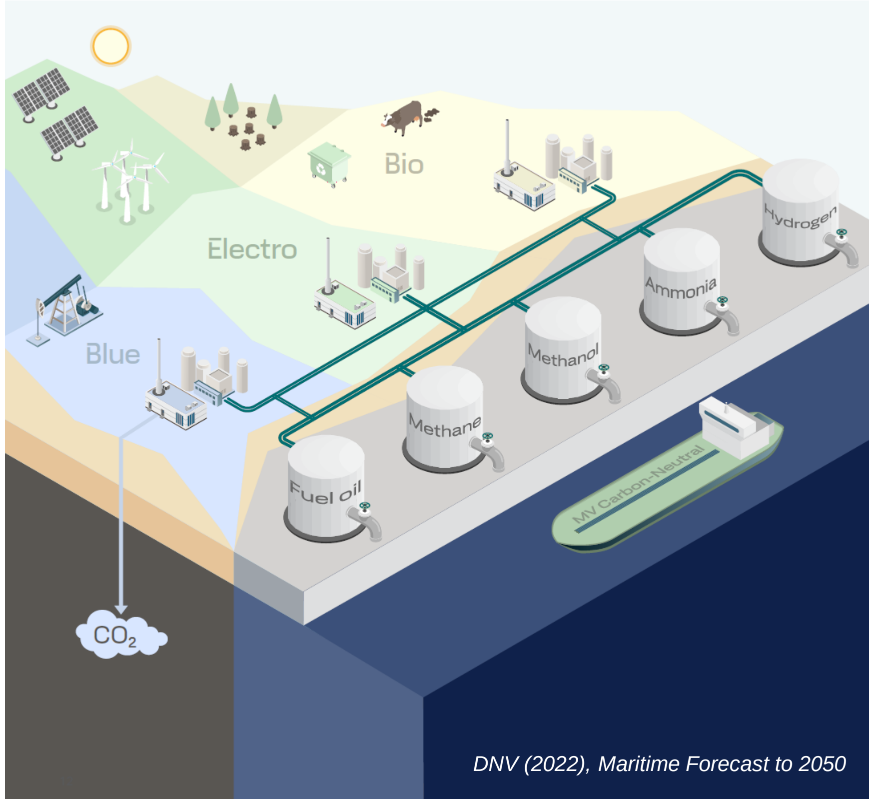
Nordic collaboration coordinated by DNV and funded by the Nordic Council of Ministers

Overall aim:

Reduce ***key barriers*** *to implementation and establish a common roadmap for the whole Nordic region and logistics ecosystem towards zero-emission shipping.*

Objectives:

- Gain **technical knowledge** and regulatory development
- Establish a **Nordic collaboration platform** and **green shipping corridor pilot studies**
- Develop a **Nordic fuel transition roadmap**



DNV (2022), Maritime Forecast to 2050

Contact persons:

Eirill Bachmann Mehammer

Task Leader Collaboration Platform & Pilots

Øyvind Endresen

Project Manager

Please log on to: https://futurefuelsnordic.com/

More than 50 partners

Nordic Council of Ministers

Contributing partners:

CHALMERS UNIVERSITY OF TECHNOLOGY
ivl Swedish Environmental Research Institute
MAN Energy Solutions
DNV
LITEHAUZ
MENON ECONOMICS

Supporting partners:

AMOGY
amon MARITIME
amon OFFSHORE
AZANE Fuel Solutions
CHNL CENTRE FOR HIGH NORTH LOGISTICS
Color Line
DANISH TECHNOLOGICAL INSTITUTE
DFDS
Suomen Varustamot / Rederierna i Finland / Finnish Shipowners' Association
Finnish Transport Infrastructure Agency
Flexens
FURSTENBERG MARITIME ADVISORY
Gasum
INAB INFRASTRUKTUR I UMEÅ AB
Kvarken Ports
KYSTVERKET NORWEGIAN COASTAL ADMINISTRATION
MERIAURA
NIB
NORSEPOWER
Norwegian Hydrogen
NTNU
PEVATECH
PORT OF OSLO
PORT OF TURKU FINLAND
Port of Ystad
Norges Rederiforbund / Norwegian Shipowners' Association
SAMORKA Icelandic Energy and Utilities
Sjøfartsdirektoratet Norwegian Maritime Authority
SMYRIL LINE
Stena
sternula
Swedbank
Transportministeriet
Umeå Hamn
Umeå kommunföretag
UNO-MARITIME-LTD
UZMAR
VASEK
VIKING LINE
VIRIDIS BULK CARRIERS
WÄRTSILÄ
wasaline
YARA

For more information, visit the project website: https://futurefuelsnordic.com/

https://futurefuelsnordic.com/partners-and-contributors/

Ten technical deliverables to date

Nordic Council of Ministers

Reports available at: https://futurefuelsnordic.com/project-deliverables/

DNV

Key highlights from our deliverables

Nordic Council of Ministers

81 potential green corridors identified

140 fuel production assets

LCA for 28 green fuel and propulsion combinations

Technical and regulatory analysis for ammonia, hydrogen and methanol

6 green corridors short-listed

3 key bottlenecks for fuel uptake

https://futurefuelsnordic.com/project-deliverables/

DNV

Focus for the rest of the Nordic Roadmap project

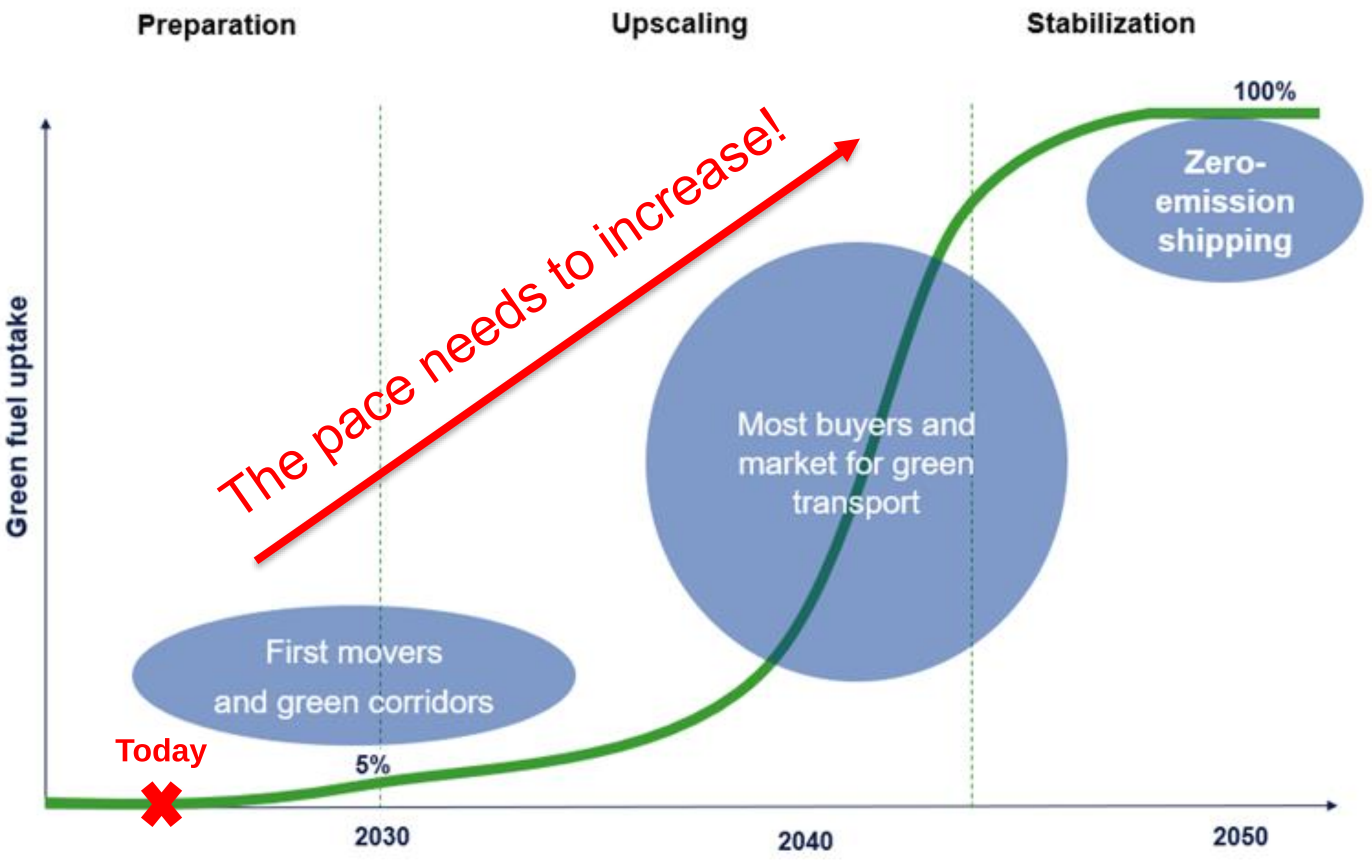
https://futurefuelsnordic.com/projects/

Nordic fuel transition roadmap

Aims to **accelerate** the uptake of green fuels

- Assumes that the fuel transition follows an **S-curve**
- Details **stakeholder actions** to overcome barriers
- Identifies **green shipping corridors as** key enablers for acceleration

Critical for success to get **input** from all players in the maritime value chain

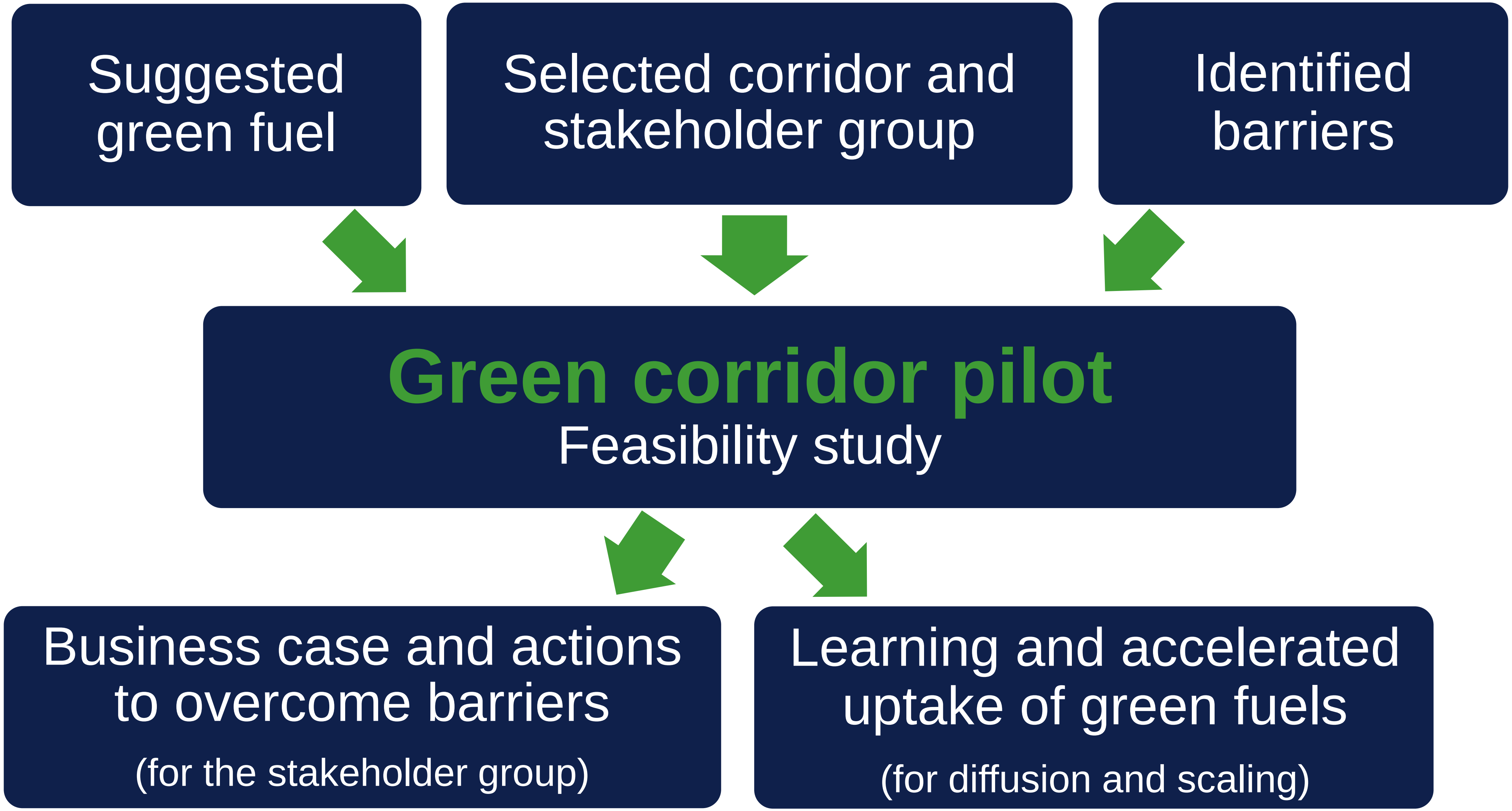


The S-curve can describe the market development of many new technologies, including up-take of LNG and battery powered ships

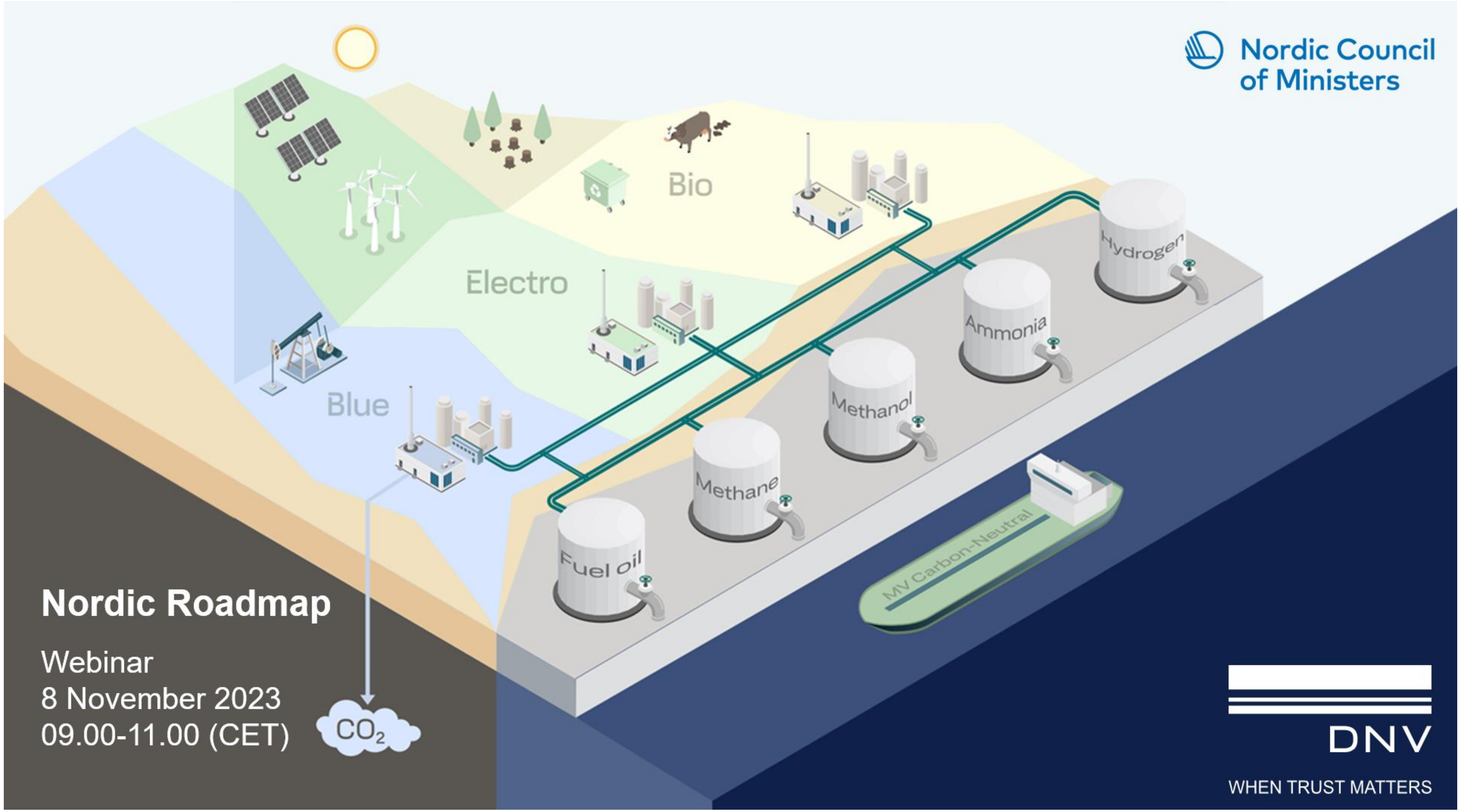
Green shipping corridor pilot studies

- Ongoing work to establish **3 pilot studies** (techno-economic feasibility studies)
  - Public-private **collaboration** with **high visibility**
  - Network of **contributing partners**
  - **Pilot owner** – decides the scope of the pilot study
  - **Pilot facilitator** financed through Nordic roadmap

- **Expected outcome of each pilot study:**
  - Established partnership
  - Assessed specific corridor and relevant fuels
  - Identifying critical bottlenecks
  - Preparing the ground for a real-life corridor


Suggested green fuel
Selected corridor and stakeholder group
Identified barriers
Green corridor pilot
Feasibility study
Business case and actions to overcome barriers
(for the stakeholder group)
Learning and accelerated uptake of green fuels
(for diffusion and scaling)

Our next event: Webinar 8 November



https://futurefuelsnordic.com/nordic-roadmap-webinar-on-future-fuels/

For more information contact:

Task Leader – Piloting and Collaboration Platform
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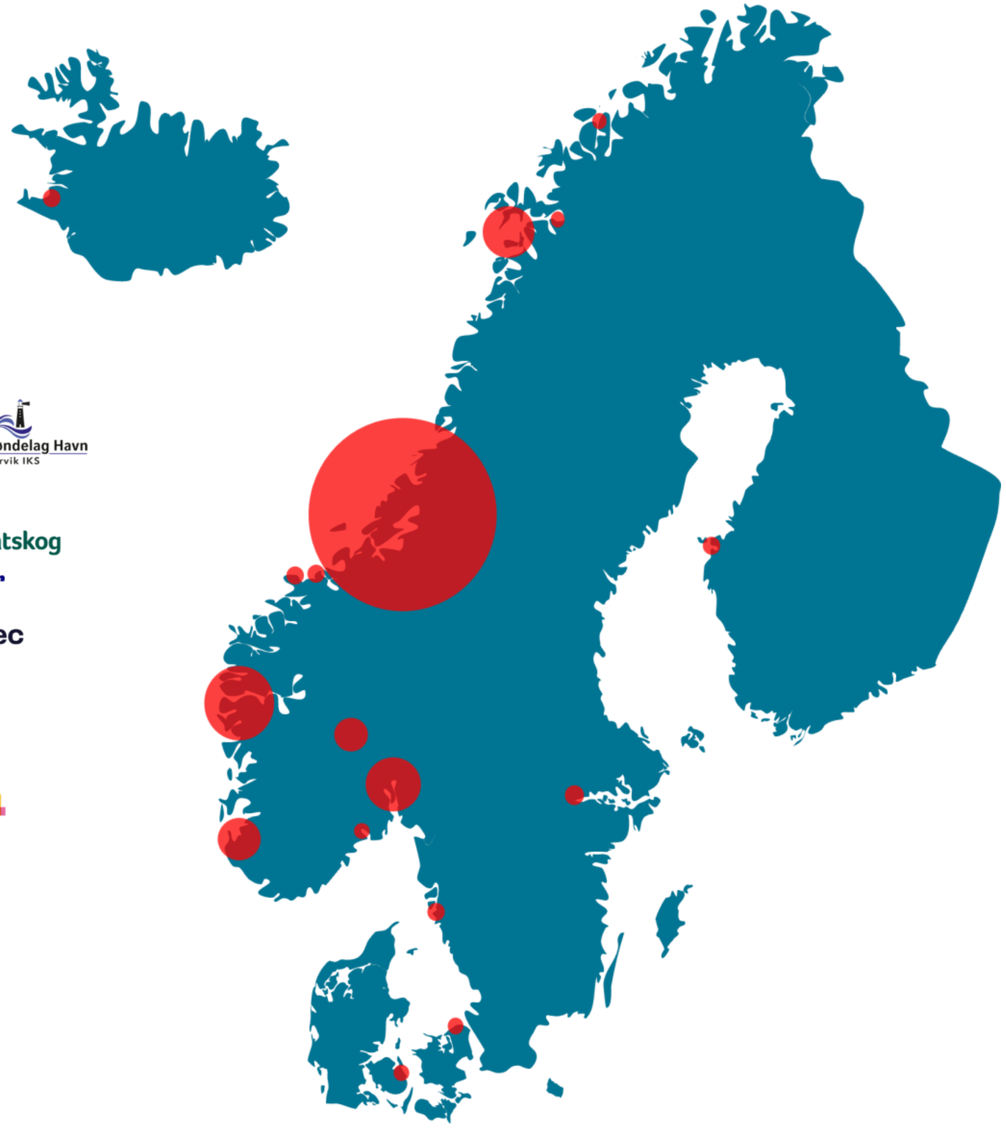
Eirill.Bachmann.Mehammer@dnv.com
+47 40551236

www.dnv.com

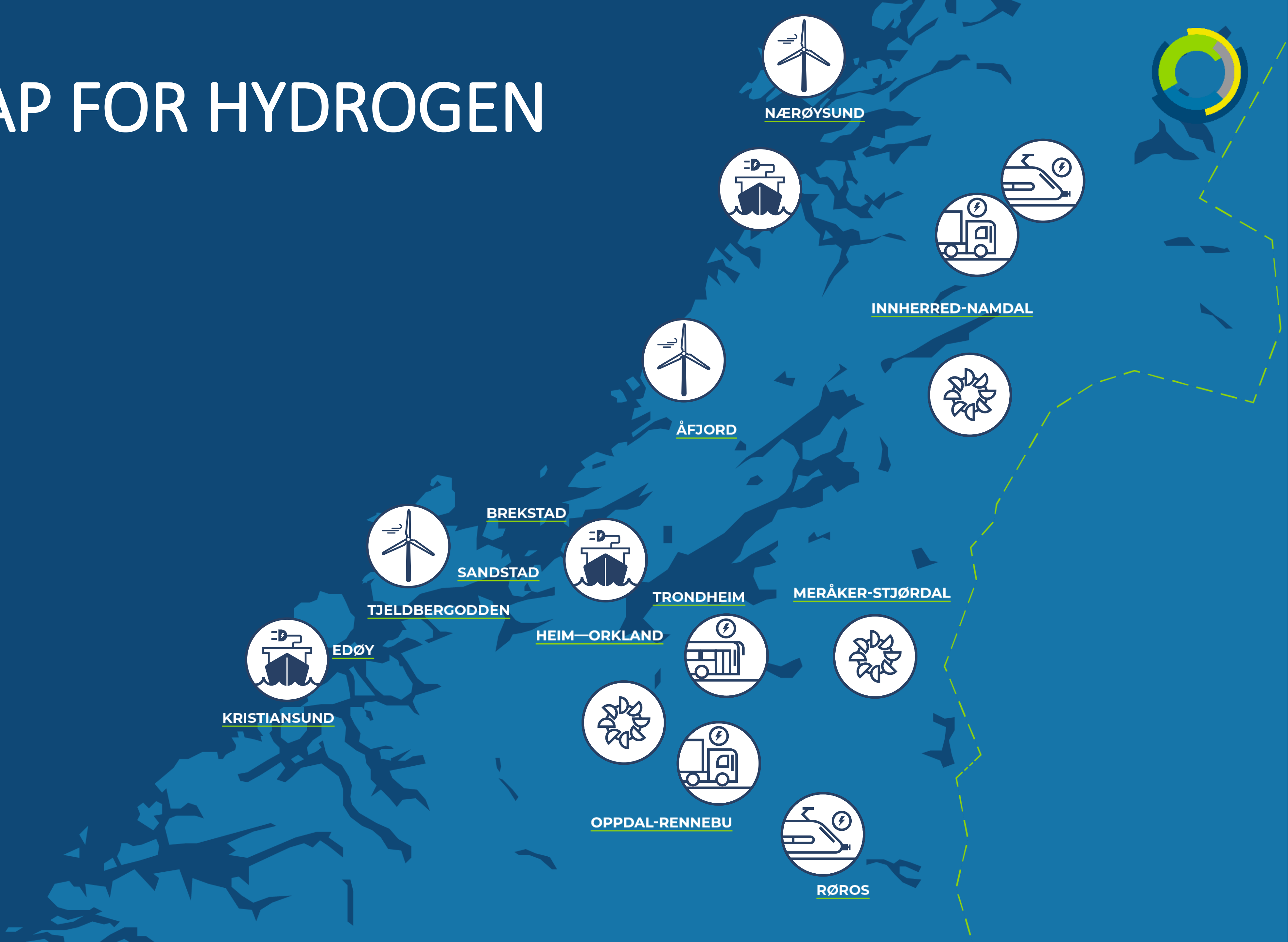

RENERGY
Norwegian Renewable Energy Cluster
Powered by FI

The Norwegian Renewable Energy Cluster RENERGY gathers over 100 businesses and organisations from the entire energy value chain

RENERGY

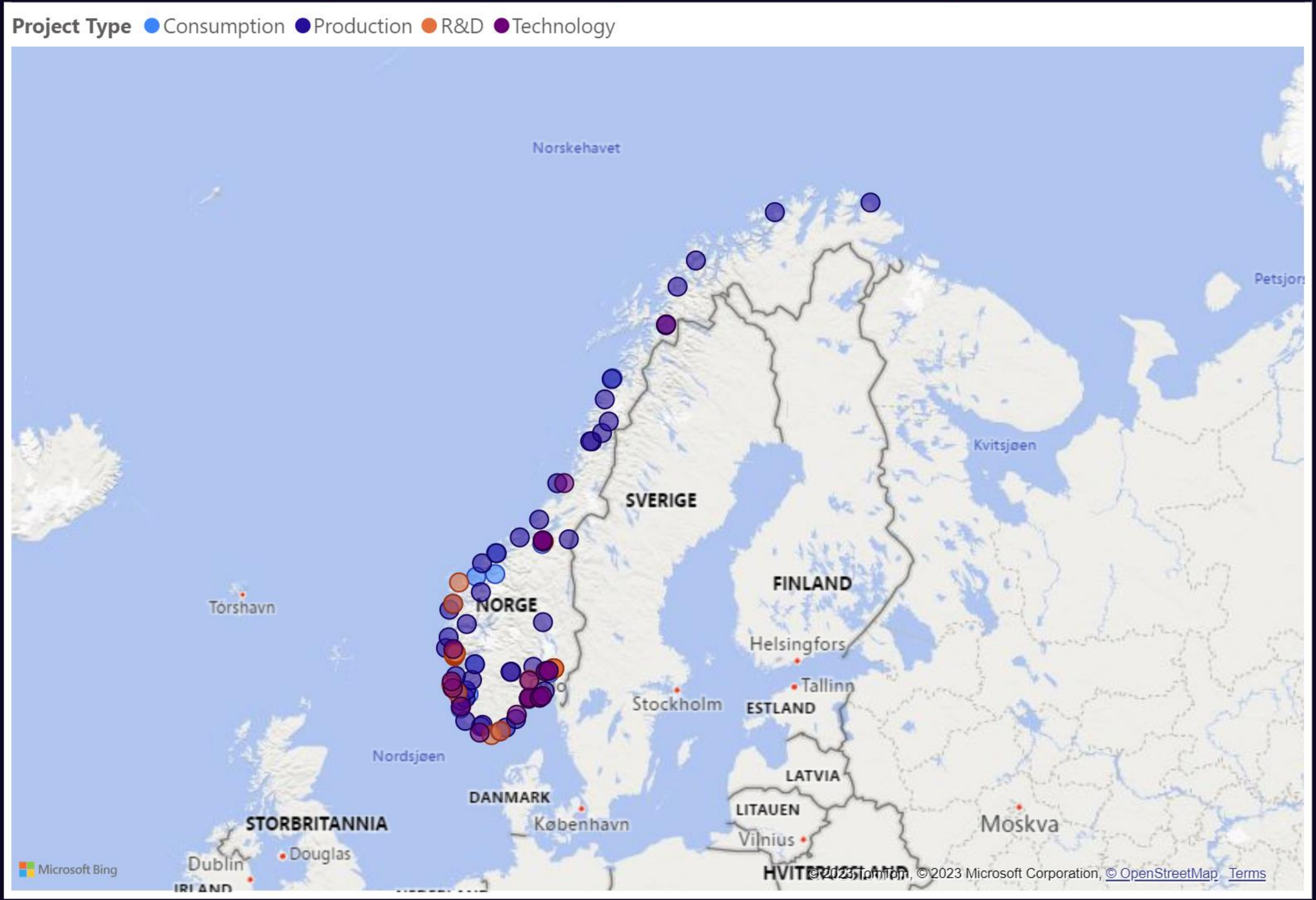


ROADMAP FOR HYDROGEN



The Norwegian Hydrogen Landscape

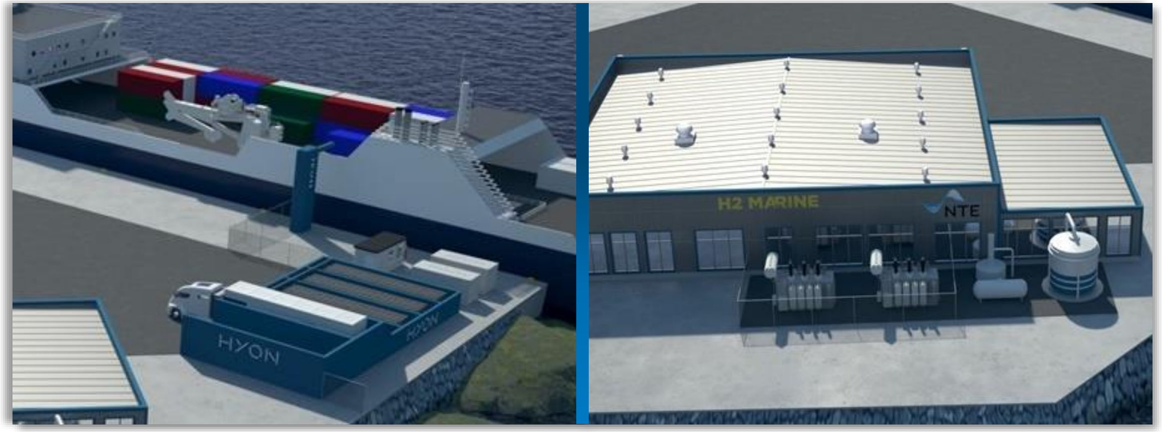
Norwegian Hydrogen Forum



Coordinates are only illustrative and do not necessarily reflect the exact location of the project

NATIONAL HYDROGEN HUBS

RENERGY



NTE
H2 MARINE
ENOVA

ANEO
ENOVA

RENERGY

4 H2 TRUCKS IN OPERATION

Key points:

- Norwegian wholesaler ASKO and Scania have put in operation four hydrogen trucks with electric driveline in Trondheim, Norway.
- Four trucks have been in operation for two years.
- The next (commercial) versions from Scandia is ordered.

Hydrogen vessel and bunkering system

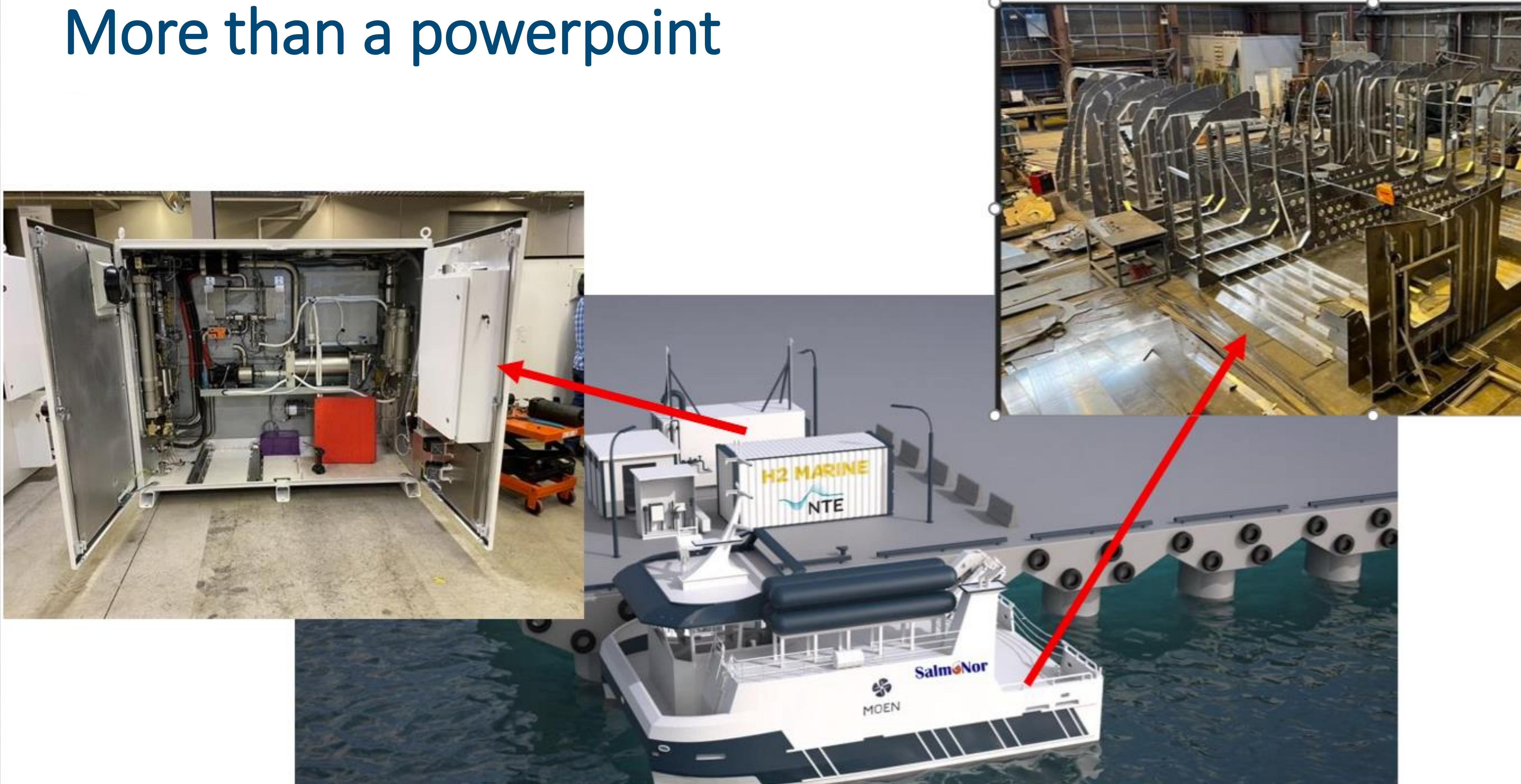
RENERGY

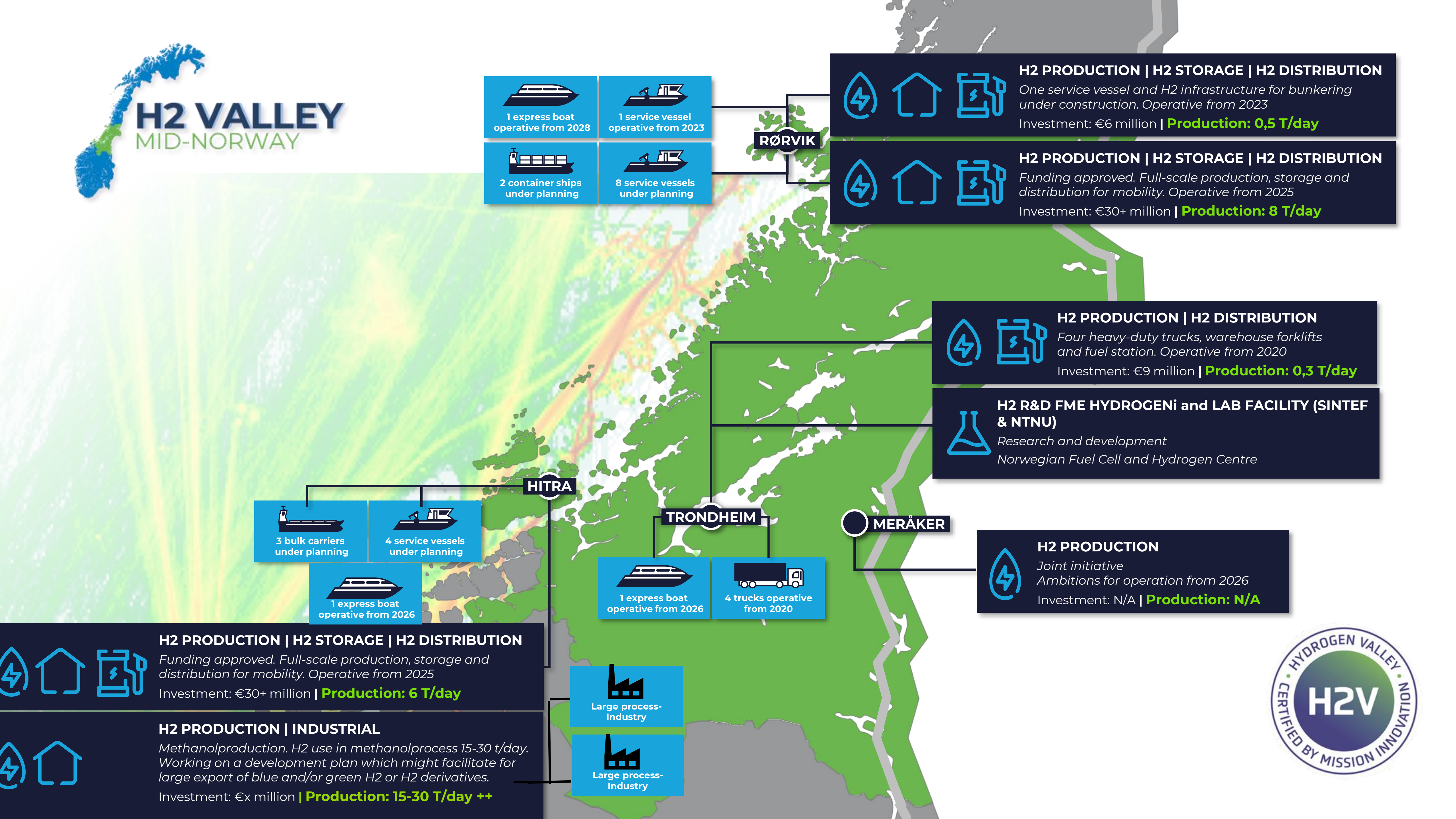
Hydrogen infrastructure doesn’t have to be expensive!

H2 Marine and NTE’s innovative solution includes

- As few components as possible
- Approx. 15–20 % lower CAPEX
- Lower OPEX; approx. 5 % lower power consumption
- Mobile combined storage and bunkering unit
- Flexible and scalable

More than a powerpoint




H2 VALLEY
MID-NORWAY
1 express boat operative from 2028
1 service vessel operative from 2023
2 container ships under planning
8 service vessels under planning
RØRVIK
H2 PRODUCTION | H2 STORAGE | H2 DISTRIBUTION
One service vessel and H2 infrastructure for bunkering under construction. Operative from 2023
Investment: €6 million | Production: 0,5 T/day
H2 PRODUCTION | H2 STORAGE | H2 DISTRIBUTION
Funding approved. Full-scale production, storage and distribution for mobility. Operative from 2025
Investment: €30+ million | Production: 8 T/day
H2 PRODUCTION | H2 DISTRIBUTION
Four heavy-duty trucks, warehouse forklifts and fuel station. Operative from 2020
Investment: €9 million | Production: 0,3 T/day
H2 R&D FME HYDROGENi and LAB FACILITY (SINTEF & NTNU)
Research and development
Norwegian Fuel Cell and Hydrogen Centre
HITRA
3 bulk carriers under planning
4 service vessels under planning
1 express boat operative from 2026
TRONDHEIM
1 express boat operative from 2026
4 trucks operative from 2020
MERÅKER
H2 PRODUCTION
Joint initiative
Ambitions for operation from 2026
Investment: N/A | Production: N/A
H2 PRODUCTION | H2 STORAGE | H2 DISTRIBUTION
Funding approved. Full-scale production, storage and distribution for mobility. Operative from 2025
Investment: €30+ million | Production: 6 T/day
Large process-Industry
H2 PRODUCTION | INDUSTRIAL
Methanolproduction. H2 use in methanolprocess 15-30 t/day. Working on a development plan which might facilitate for large export of blue and/or green H2 or H2 derivatives.
Investment: €x million | Production: 15-30 T/day ++
Large process-Industry
HYDROGEN VALLEY
H2V
CERTIFIED BY MISSION INNOVATION

SINTEF

RENERGY
Renewable Energy Cluster

HYDROGENi

H2 MARINE

SIEMENS

ASKO

H2 VALLEY
MID-NORWAY

HYDROGEN VALLEY
H2V
CERTIFIED BY MISSION INNOVATION

Meraker Hydrogen

ANEO

NTE

SALMAR
Passion for Salmon

GEXCON

MOEN

equinor

samskip

Moen Marin
A PART OF SCALEAQ

Egil Ulvan Rederi AS

GREENSTAT

FUNDING OF 16 SHIPS ON HYDROGEN/AMMONIA

Hydrogen

- Loran C – Tråler – stoppet
- Topeka – 2 x RoRo-skip
- Egil Ulvan Rederi – 3 x bulkskip
- Thor Dahl – 1 x bulkskip
- Samskip – 2 x containerskip
- Moen Marin - Salmar – 1 x katamaran

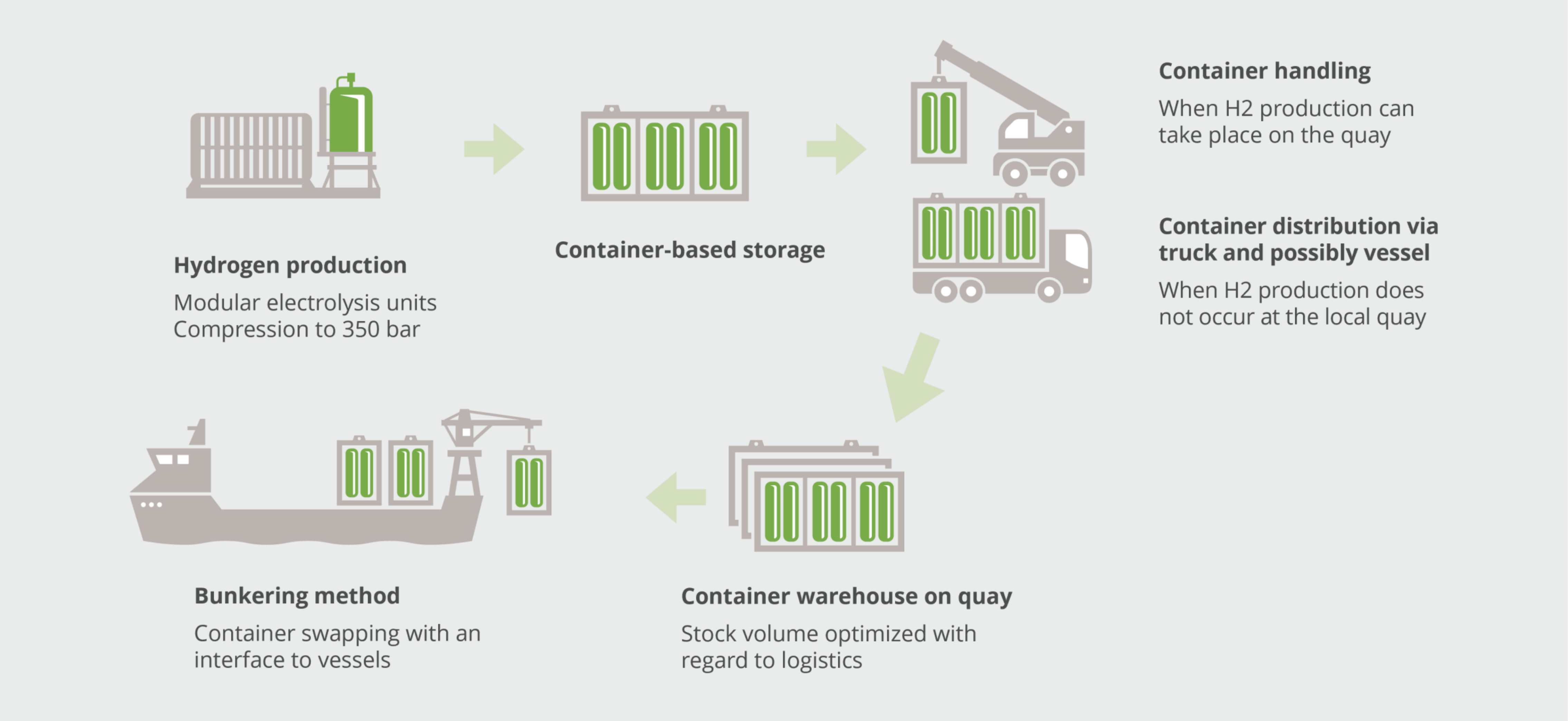
Ammoniakk

- Færder Tankers – 2 x LR 2 tankskip
- Færder Tankers – 2 x bilskip
- Skarv Shipping Solutions – 3 x bulkskip

Hydrogen solutions at the hubs

RENERGY

Compressed hydrogen, infrastructure and logistics



Some R&D challenges that must be solved

RENERGY

- We are building a new energy system, and a new market for new fuels
- The carrier of the energycarrier – Storage on land, on board
- Bunkering systems
- Safety, standards and regulations
- Logistics and transport of the fuel
- Public acceptance of the cost of the energy transition

thomas@renergycluster.no

Ammonia – a renewable fuel for **zero emission** mobility

ABOUT US

Company Profile

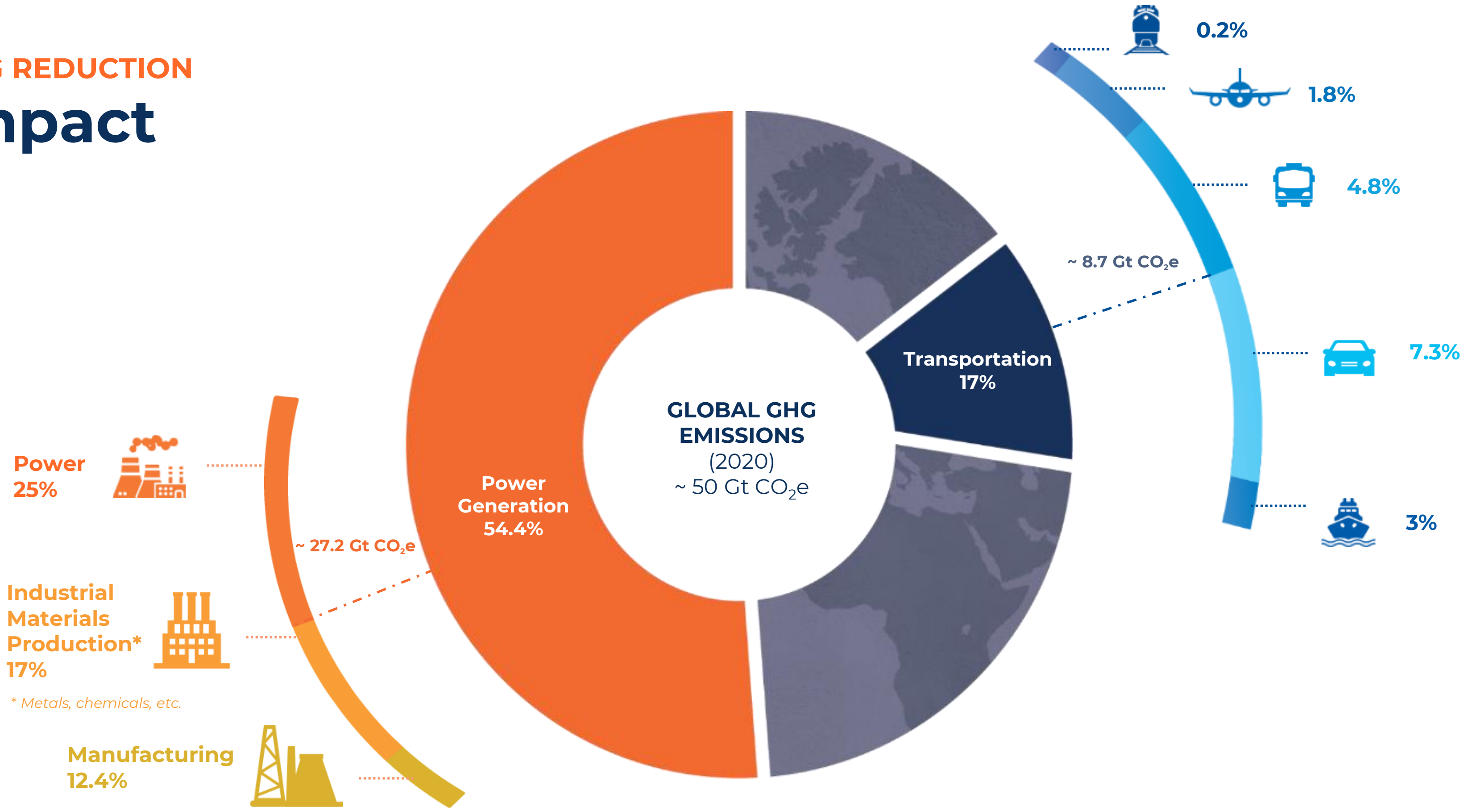
Founded: Nov 2020
Employees: 180+
Funding to date: $220M
Headquarter: Brooklyn, NY
Other Locations: Houston, TX, Norway (Stavanger & Stord) & Singapore

Want more information? Click here.

The Challenge

GHG REDUCTION

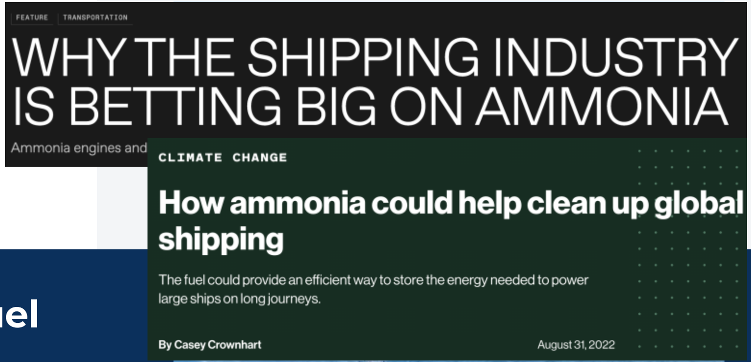
Impact



Source: ourworldindata.org, climatewatchdata.org, CAIT database, International Energy Agency

INDUSTRIES – FIRST MARKET

Shipping


FEATURE TRANSPORTATION

WHY THE SHIPPING INDUSTRY IS BETTING BIG ON AMMONIA

Ammonia engines and

CLIMATE CHANGE

How ammonia could help clean up global shipping

The fuel could provide an efficient way to store the energy needed to power large ships on long journeys.

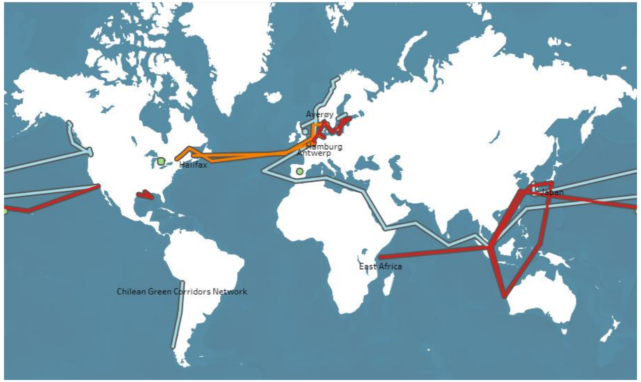
By Casey Crownhart August 31, 2022

IMO targets create an urgent need for zero-emission fuel

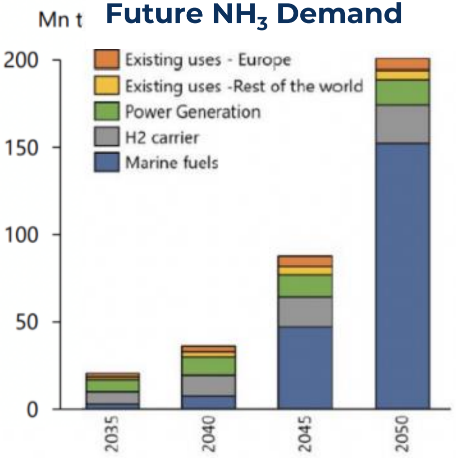
100% CO_2 reduction by 2050

Industry is ready for an efficient, proven ammonia-based solution

Green Shipping Corridors Initiatives



Future NH_3 Demand



Argus Green Ammonia Strategy Report, 2021

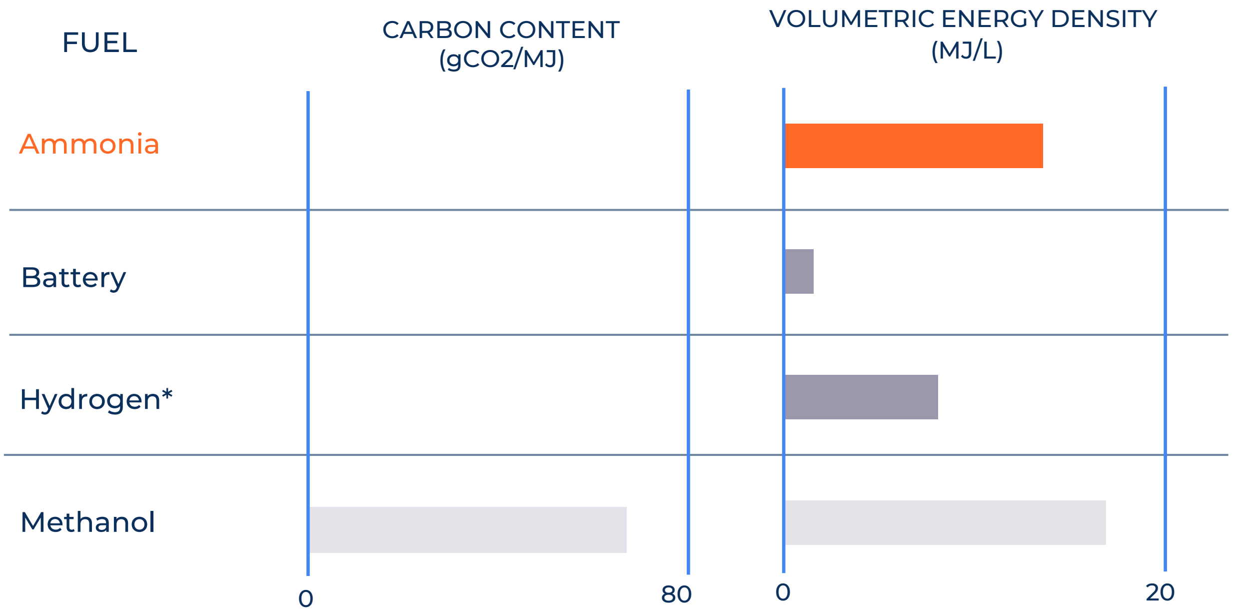
AMOGY

HEAVY INDUSTRY ENERGY TRANSITION

Everyone is looking for a way to decarbonize...

BUT ONE STANDS OUT...

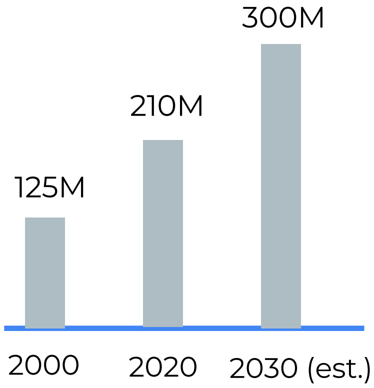
Ammonia



AMMONIA TODAY

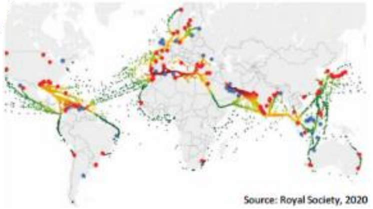
Ammonia Infrastructure

Scaled Production
Ammonia production, tons



Available Infrastructure
Ammonia pipeline in U.S. corn belt

~200 Ammonia ports worldwide



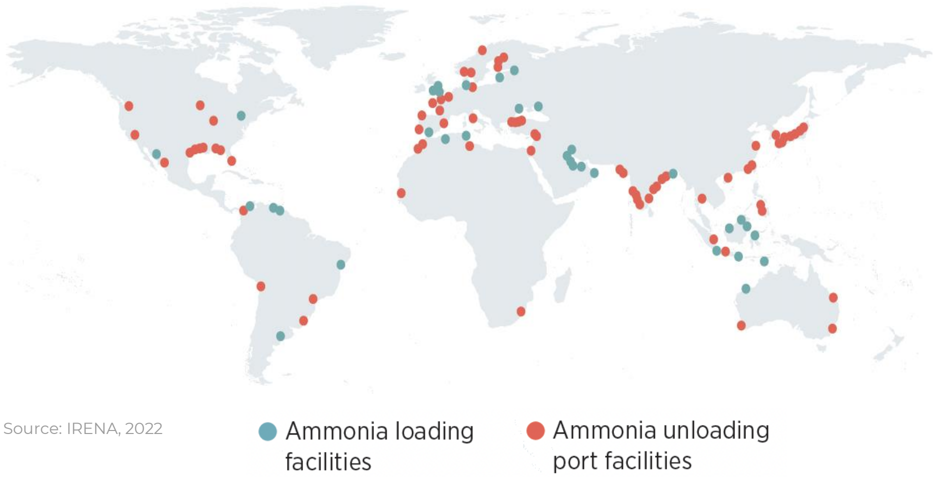
100+ yrs. scaled industrial use, however,
no ammonia-to-power technology available yet

AMOGY

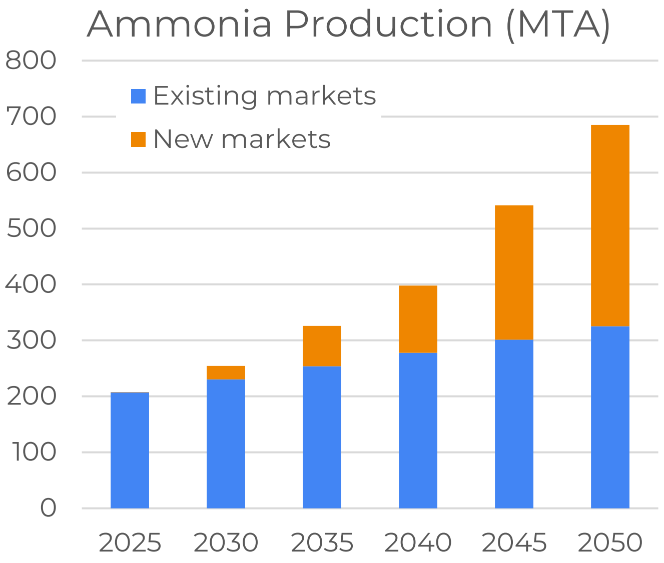
AMMONIA MARKETS

Worldwide demand projected to grow 3x by 2050

- Ammonia is the world's 2nd most traded chemical with a global, mature, low-cost distribution infrastructure in place
- New uses (fuel, H_2 carrier, power) will 3x demand by 2050



Source: IRENA, 2022



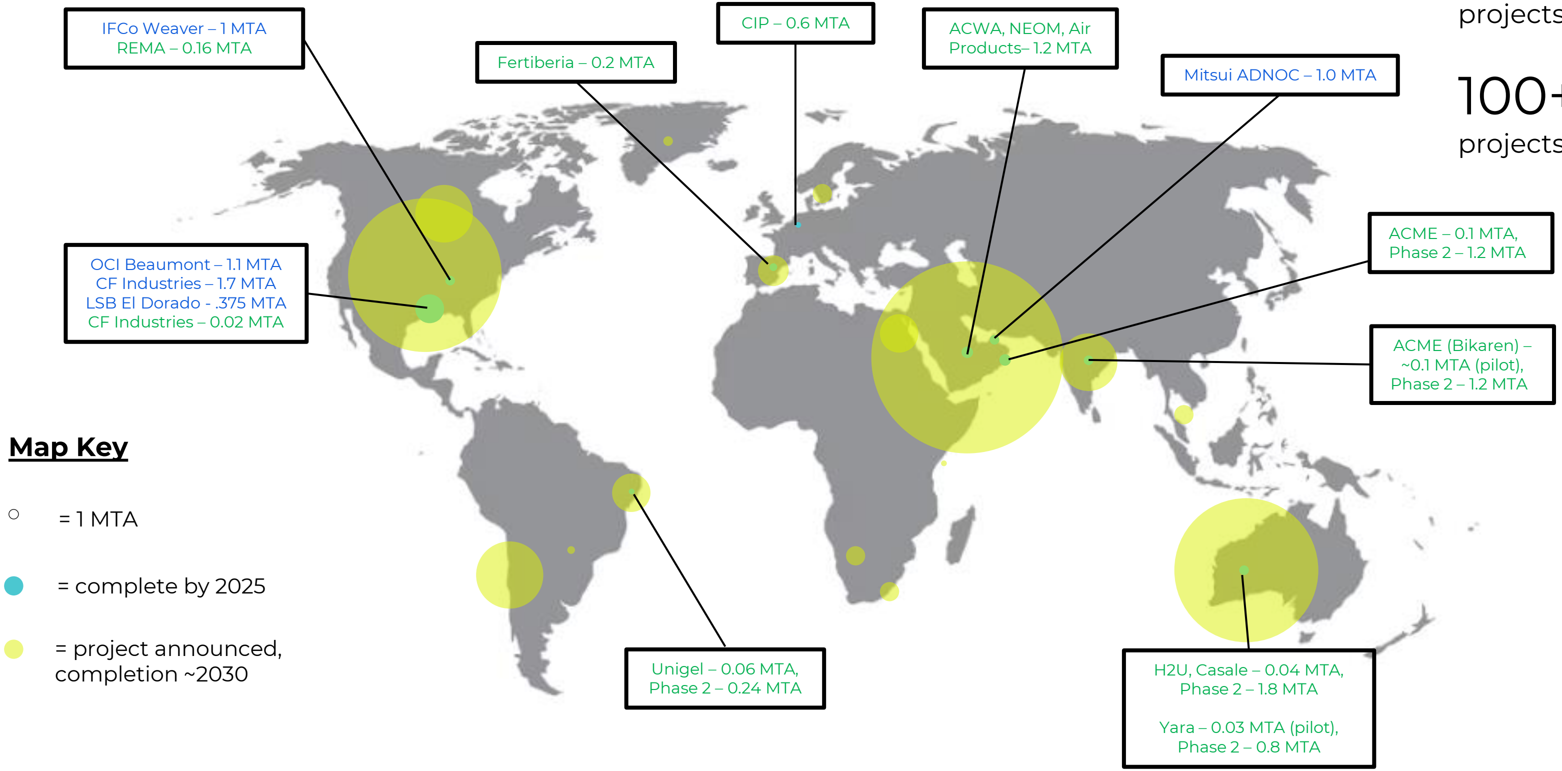
Source: IRENA, 2022
MTA: Million metric tons annually

LOW CARBON AMMONIA PLANTS

Global Production Outlook

11+MTA
projects by 2025

100+MTA
projects announced

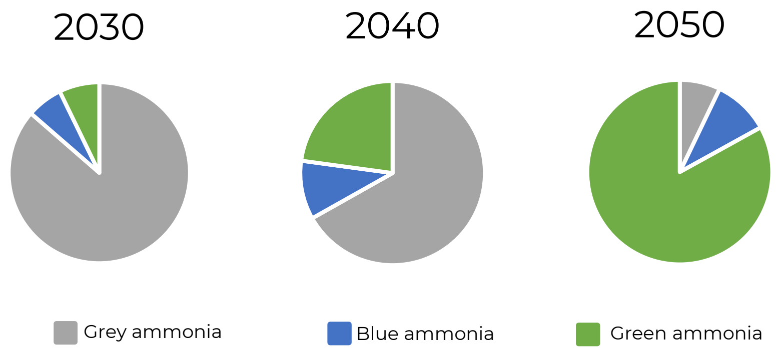


Boxes mark mature projects (completion expected by 2025) based on the Argus Monthly Ammonia Outlook – May 2023 and Amogy's internal database.
Green text represents green ammonia production (electrolysis-based); **blue** represents blue ammonia facilities (natural gas + CCS).

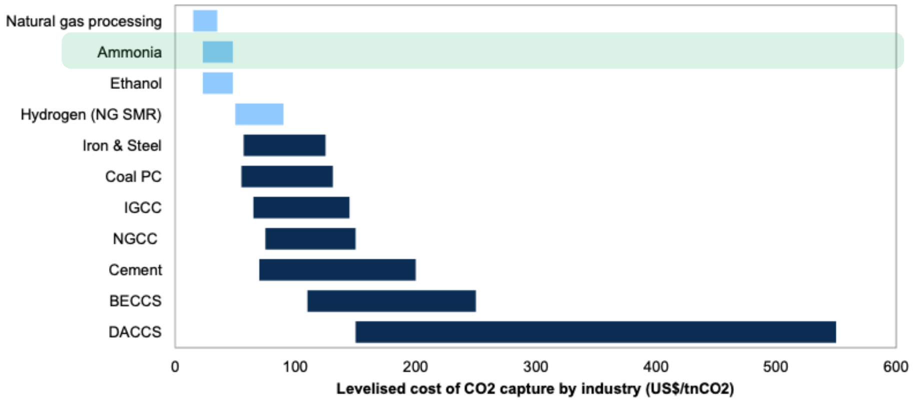
AMMONIA MARKETS

Decarbonization of ammonia production

Projected ammonia supply



Levelized cost of CO_2 capture by industry



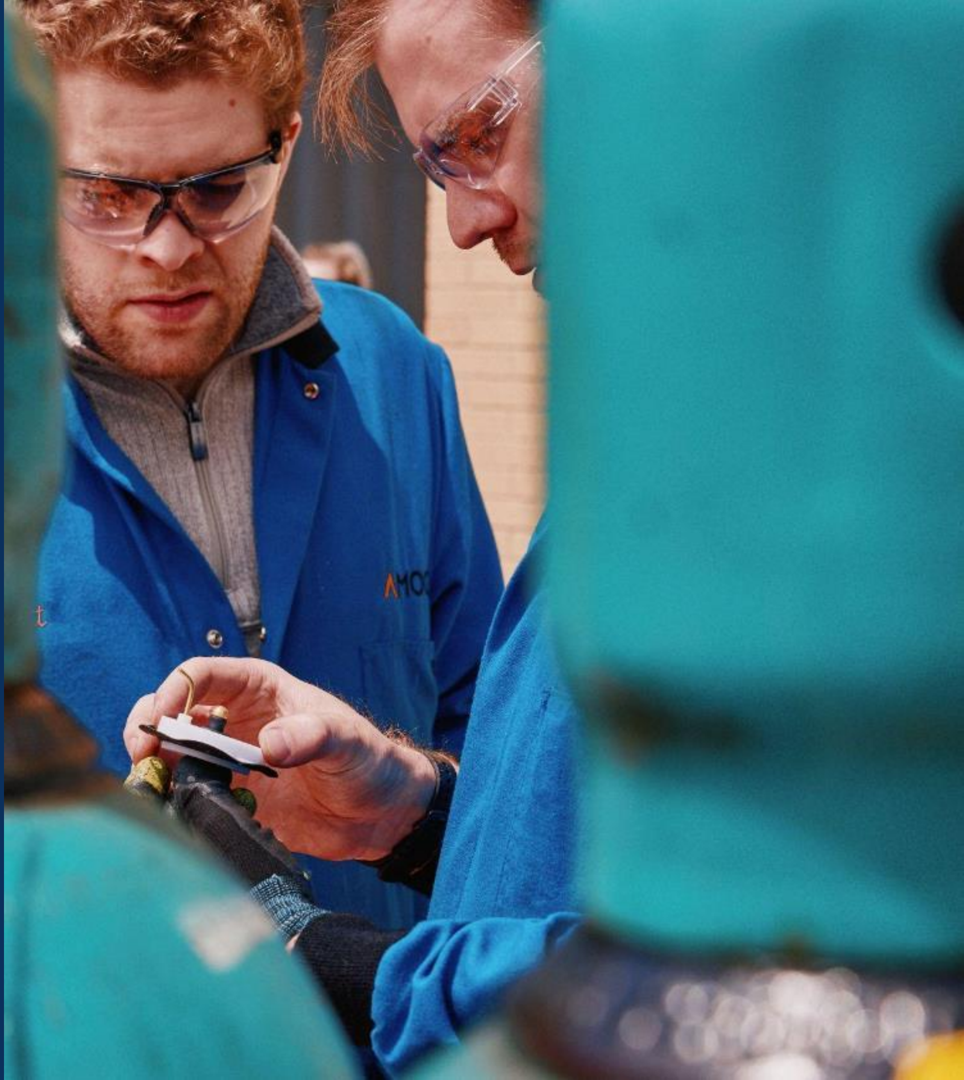
Source: Goldman Sachs Equity Research, 2022

Decarbonization of ammonia production predicted at 70-90% by 2050, <u>higher than any other large-scale H_2 application</u>:

- Blue ammonia will be a bridge between conventional and renewable production as technology develops
- >50% of ammonia demand in 2050 is projected to come from new applications, mostly as shipping fuel given the IMO emission reduction targets
- High CO_2 concentration lowers capture cost
- Near-shore production allows low-cost storage

Projected ammonia supply: adapted from IRENA and AEA 2022. **Levelized cost of CO_2 capture by industry:** Goldman Sachs Equity Research, 2022

Technology outlook and AMOGY



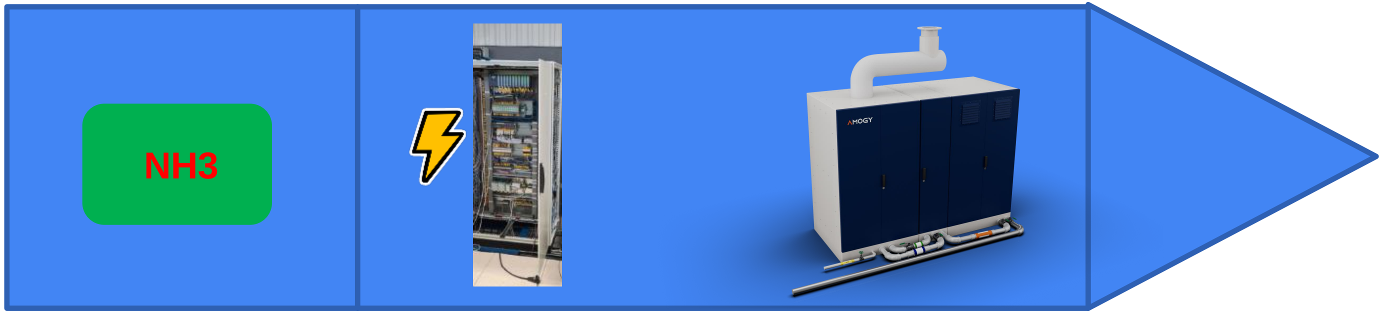
Energy House – Stord Norway

Energy House Test Facility

NH3 tank +
feeding system +
safety equipment

Electrical
Integration

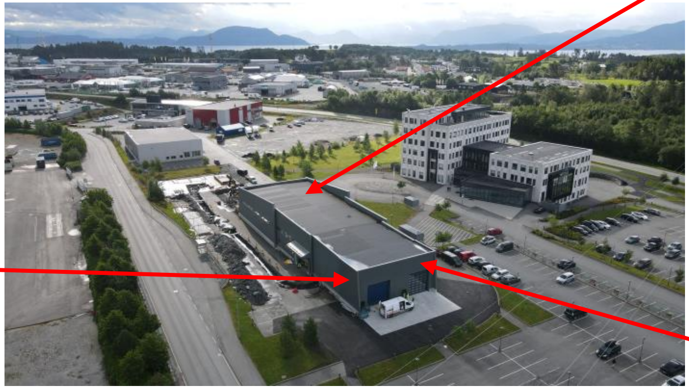
Power generation
technology



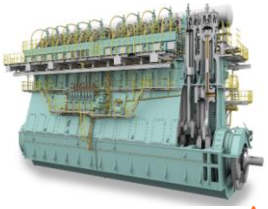
Energy House – Stord Norway

3 key players in one location

Alma

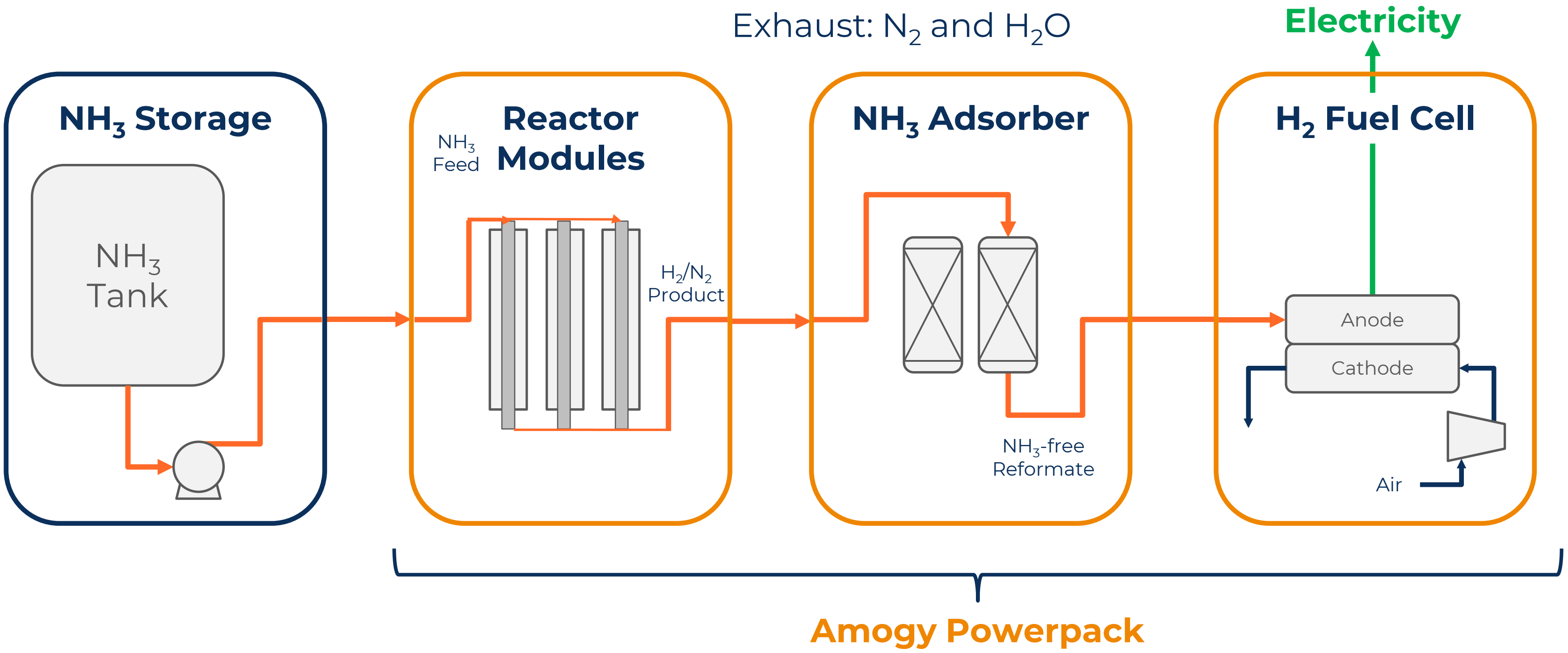


WÄRTSILÄ



TECHNOLOGY

Ammonia (NH_3) to Electrical Power



Product

Amogy System Module

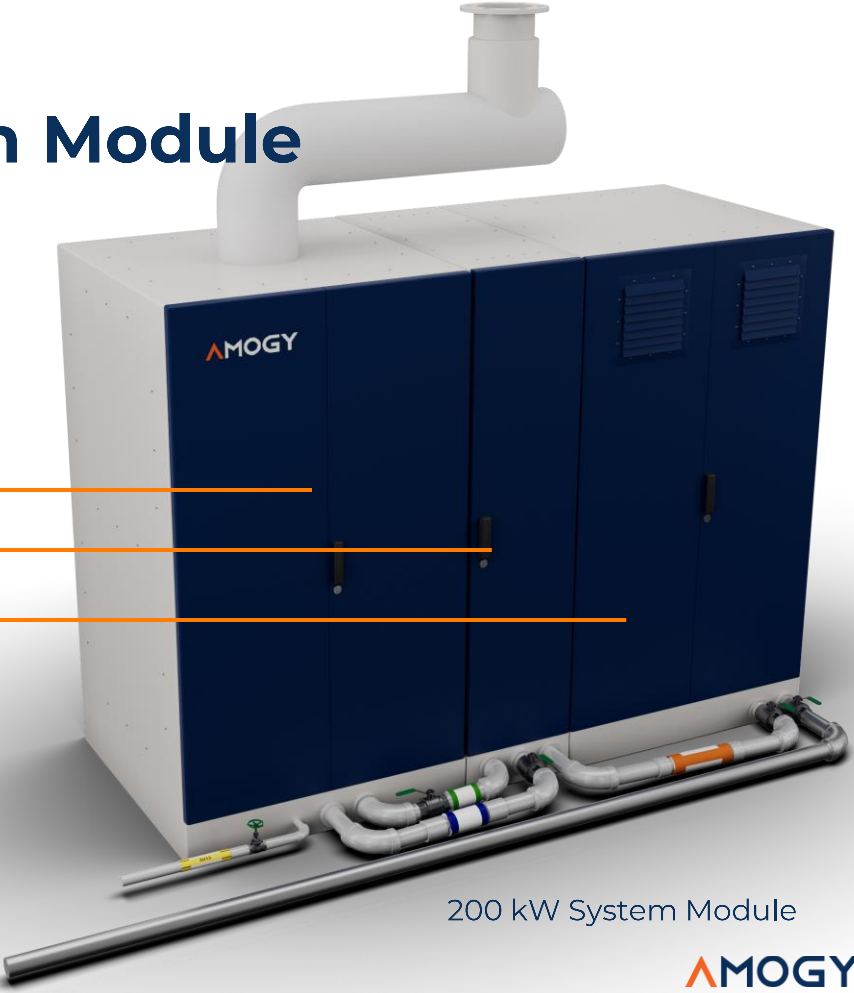
Our Powerpack converts ammonia into a clean energy source with zero emissions at the point of use.

REACTOR MODULE

ADSORBER MODULE

FUEL CELL MODULE

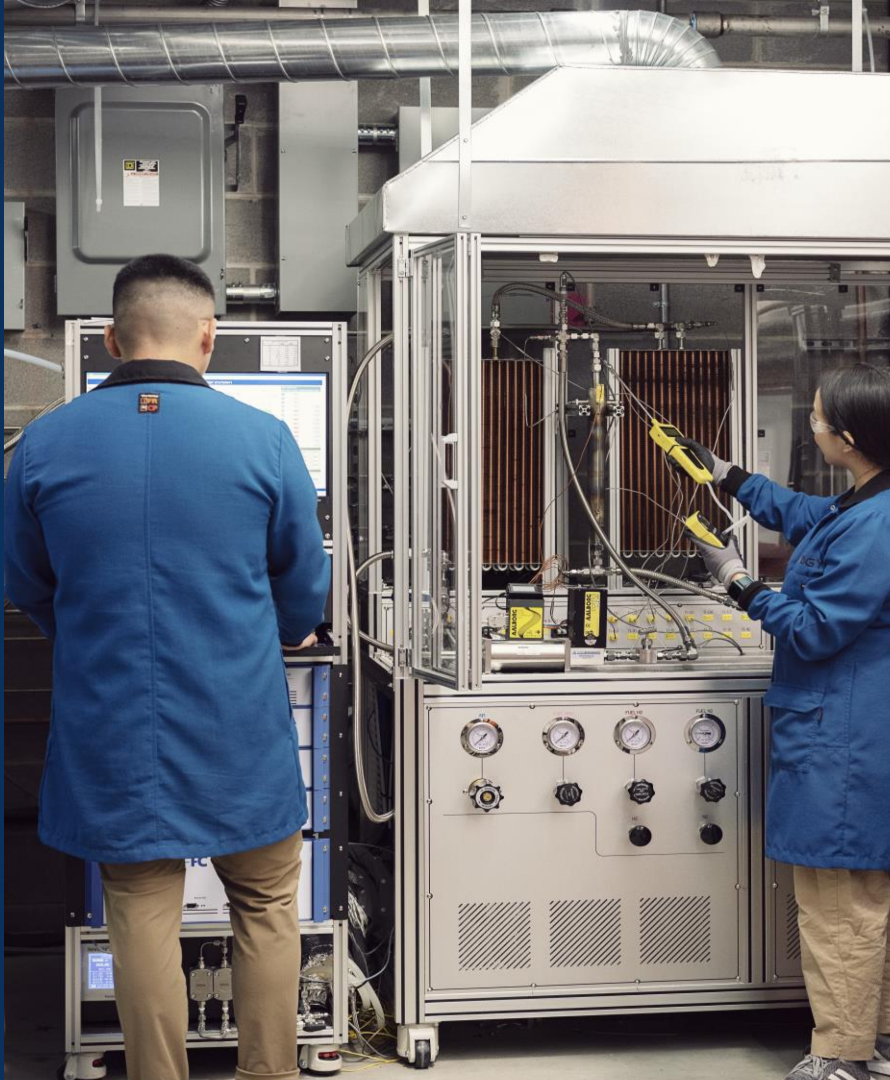
Download our Technical Datasheet.



200 kW System Module

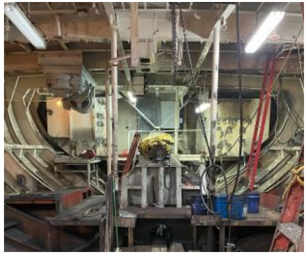
AMOGY

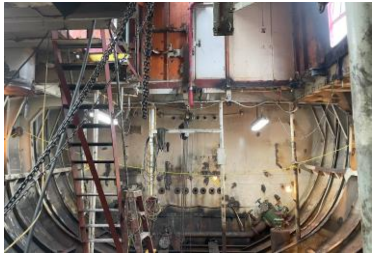
Learning by doing

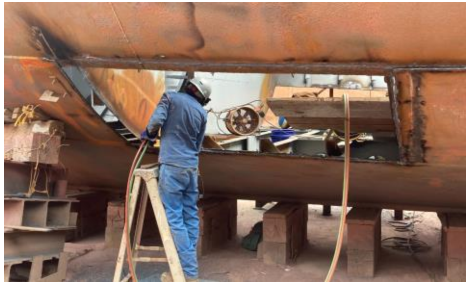


Technology demonstration

Tugboat

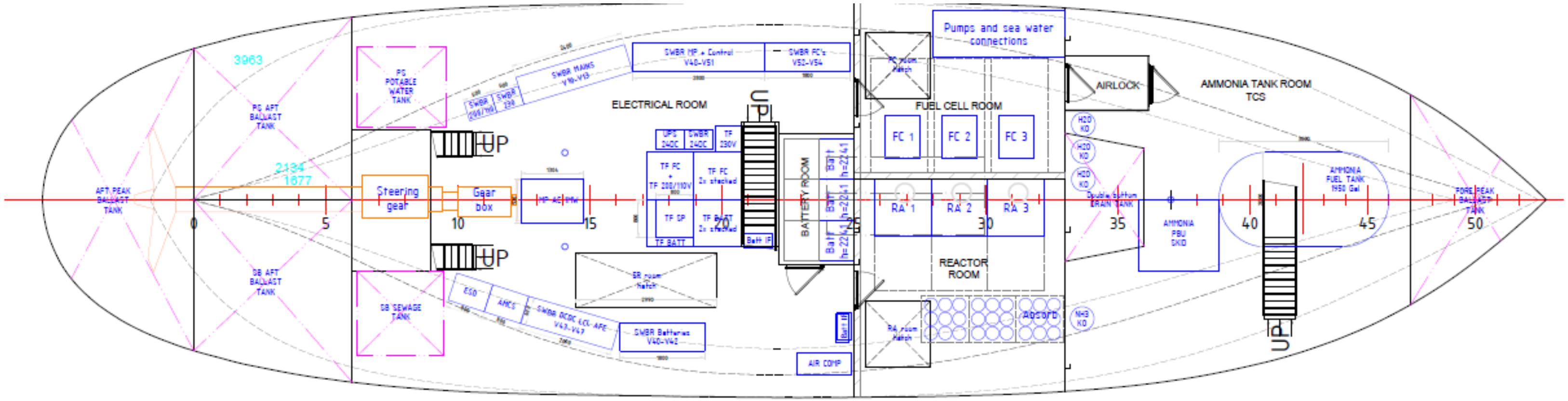


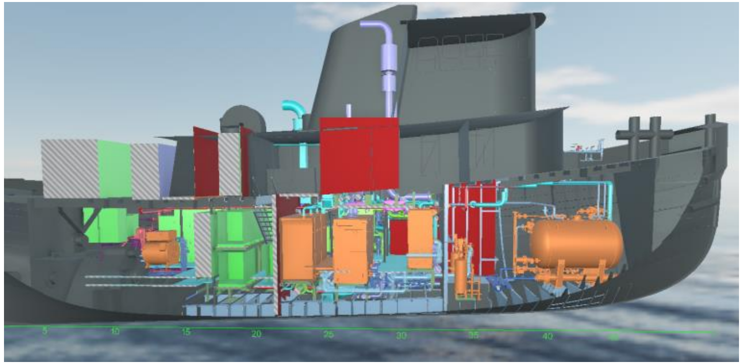




BETWEEN RETROFIT and NEW BUILD

1MW Tugboat





AMOGY

1 MW TUGBOAT DEMONSTRATION

The World's First Ammonia-Powered Vessel

AMOGY

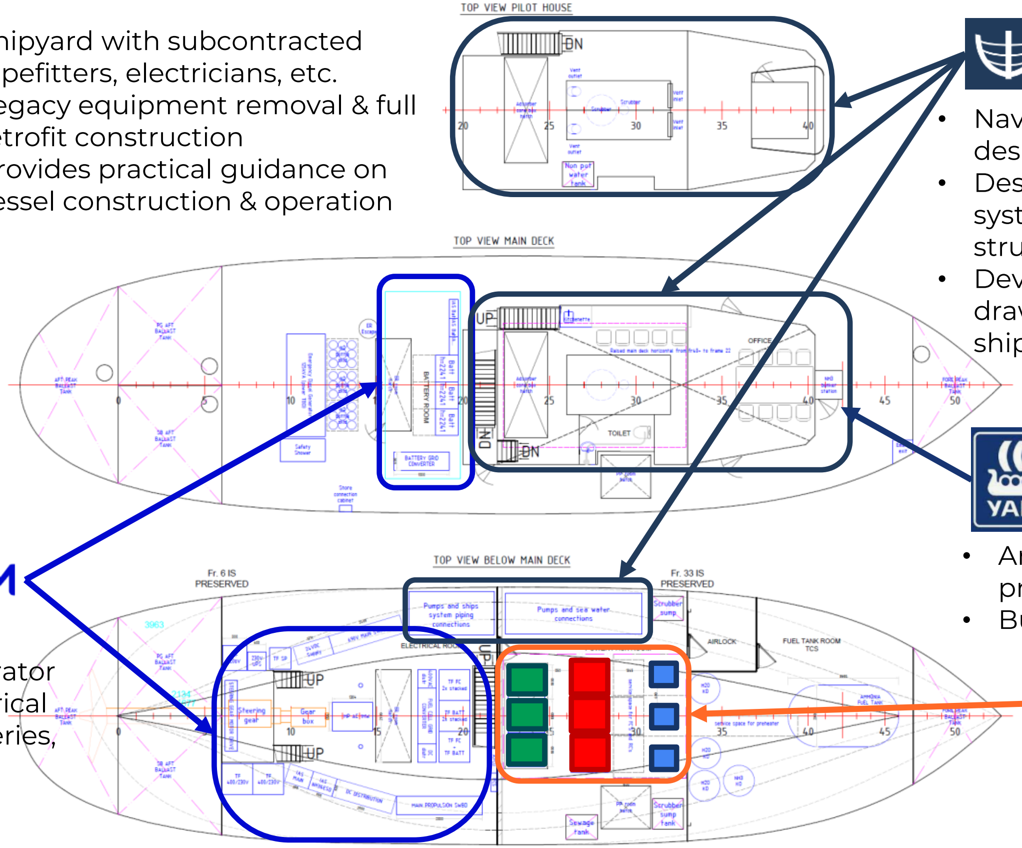
DNV · SEAM · Lloyd's Register · C-JOB

Vessel procurement & partnerships	Safety and regulatory reviews & procurement	Detailed engineering & vessel construction	System install	First NH_3-powered tugboat
2022	***Q1 '23***	***Q2 '23***	***Q3 '23***	***Q1 '24***

AMOGY - 1MW TUGBOAT DEMO

Partnership & Collaborations

- Shipyard with subcontracted pipefitters, electricians, etc.
- Legacy equipment removal & full retrofit construction
- Provides practical guidance on vessel construction & operation



C-JOB

- Naval architect & vessel designer
- Designs vessel auxiliary systems & overall structures
- Develops construction drawings for the shipyard to execute

DNV / USCG

- DNV – ship classification society
- USCG – regulatory agency
- Provides risk-based guidance on design & operating requirements

Vector Systems, Inc. / Macrotek

- VSI – tank & feed system vendor
- Macrotek – scrubber vendor
- Other vendors for subsystems, nitrogen, etc.

YARA / Tanner Industries, Inc.

- Ammonia fuel provider
- Bunkering operator

SEAM

- Electrical & controls integrator
- Supplies electrical cabinets, batteries, & motor

AMOGY

- Power provider
- 3 x 200kW powerpacks

Technology demonstration

Amogy - NH3 KRAKEN

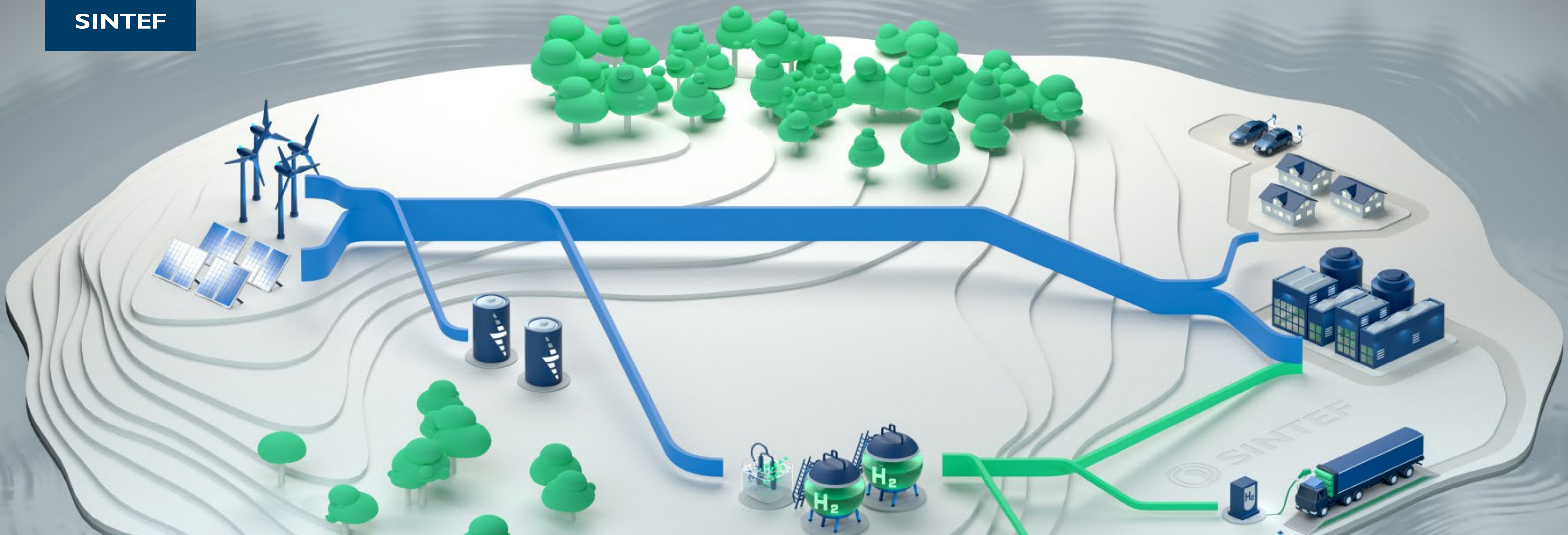
AMOGY

Web: amogy.co

Email: contact@amogy.co

CEO: Seonghoon Woo

SINTEF



The role of hydrogen research and innovation in decarbonization of the Nordics

Sigrid Lædre, SINTEF

Nordic Hydrogen Valleys Conference October 4th

SINTEF

Hydrogen on everyone’s lips

French trio TotalEnergies, Air Liquide and Vinci to create $1.7 billion hydrogen fund

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Home › Clean fuel ›

New hydrogen projects achieve record numbers; investments must triple to $700 bln by 2030 to hit net-zero target, report shows

H2Accelerate TRUCKS

HYDROGEN ECONOMY

€3bn Europe Hydrogen Bank Announced

September 14, 2022 · Add comment · 2 min read

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Department of Energy

Biden-Harris Administration Announces $750 Million to Advance Clean Hydrogen Technologies

MARCH 15, 2023

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In-depth

Biden’s Inflation Reduction Act is great news for green hydrogen

Myriad new tax credits make the USA one of the world’s most promising markets for electrolyser and hydrogen-fuelling technology – and set the country on course to reduce CO2 emissions by 40% compared to 2005 levels.

Technology for a better society

EU

Detailed assessment supported by scenario analysis

	Electrification (ELEC)	Hydrogen (H2)	Power-to-X (P2X)	Energy Efficiency (EE)	Circular Economy (CIRC)	Combination (COMBO)	1.5°C Technical (1.5TECH)	1.5°C Sustainable Lifestyles (1.5LIFE)
Main Drivers		Hydrogen in industry, transport and buildings						
GHG target in 2050		-8 [“v						
Major Common Assumptions		gy efficiency post 20 of sustainable, adv rcular economy me n						
Power sector		Power esponse, storage, in						
Industry		Use of H2 in targeted applications						
Buildings		Deployment of H2 for heating						
Transport sector		H2 deployment for HDVs and some for LDVs						
Other Drivers		H2 in gas distribution grid						

"The green energy transition is not an option but a necessity. I see a pivotal role for clean hydrogen.."
(Frans Timmermans, First Vice-President EC, November 2019)

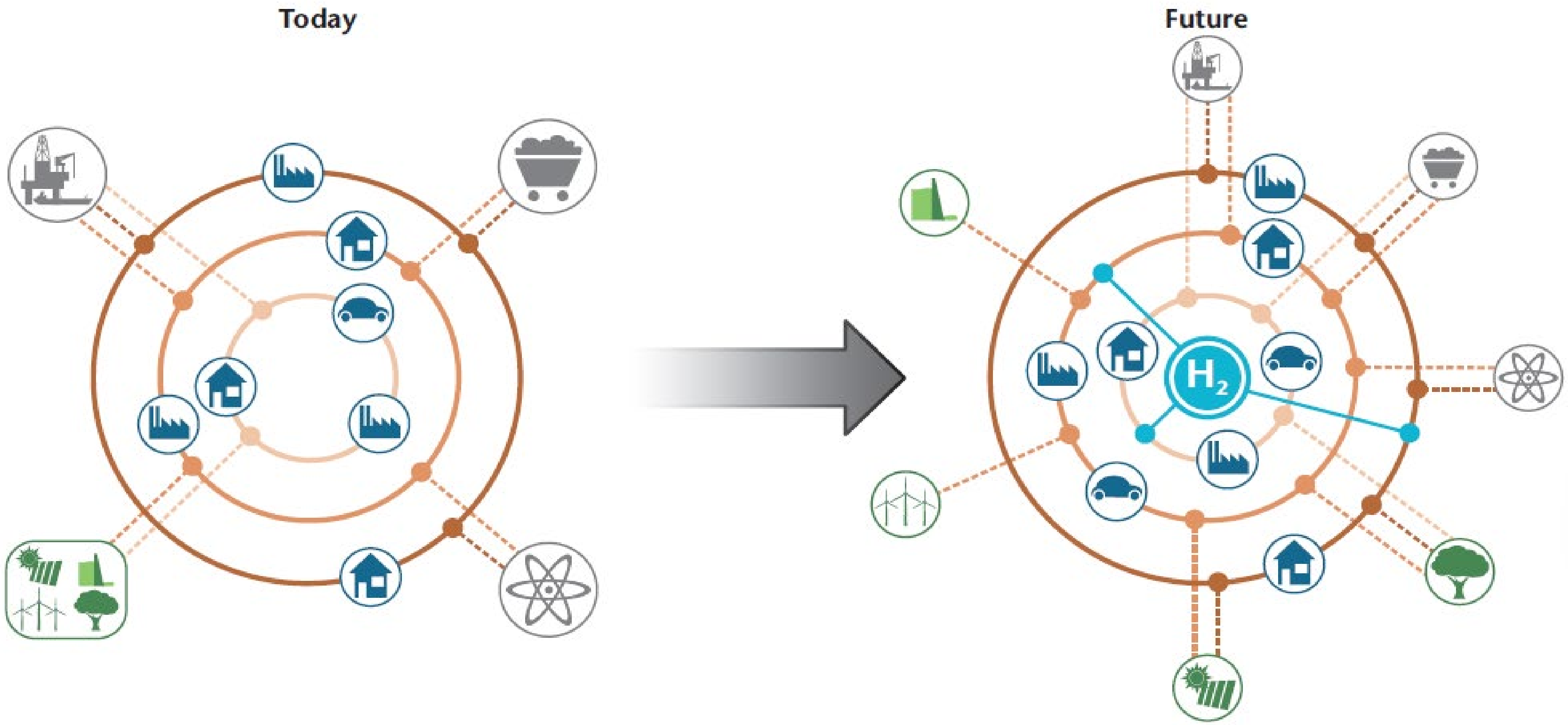
Brussels, November 2018

European Green Deal

Hydrogen Europe

SINTEF

Hydrogen´s role in the energy transition

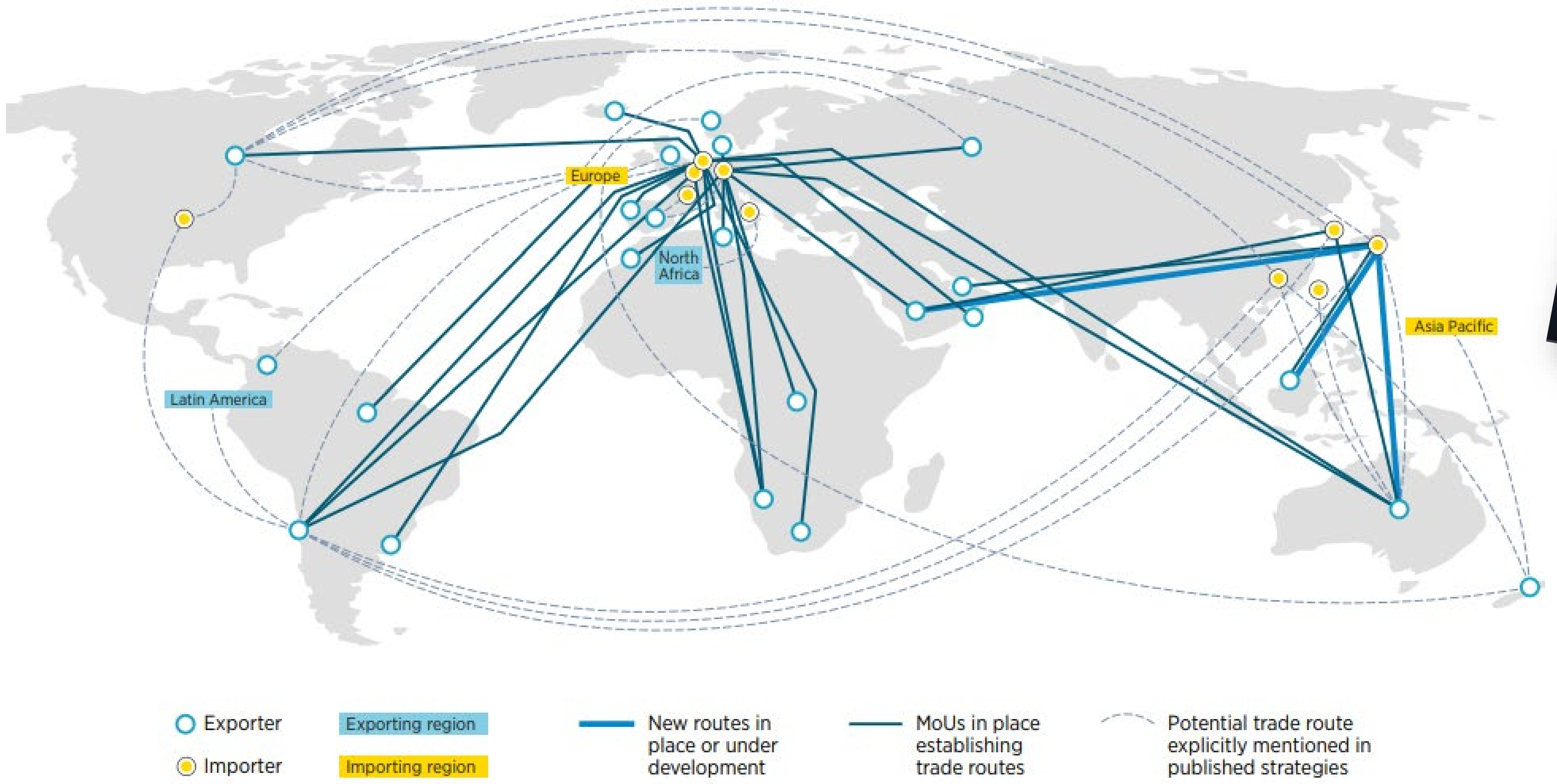


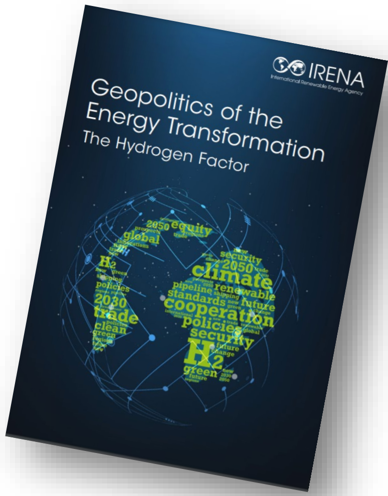
Hydrogen can link different energy sectors and thus increase the operational flexibilility in future low-carbon energy systems

"Sector coupling"

Source: https://www.iea.org/reports/technology-roadmap-hydrogen-and-fuel-cells

A global hydrogen market under development





Hydrogen in Norway

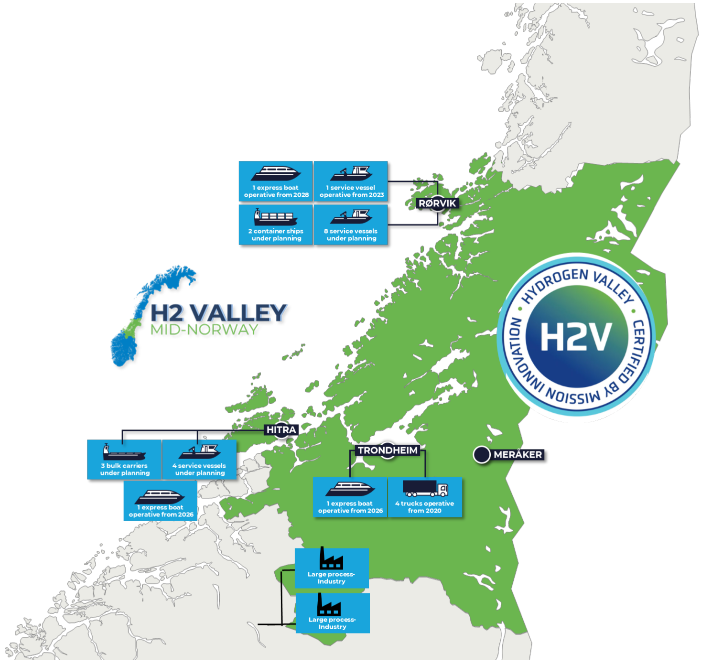
Business Norway
Menu

Renewable energy flows through Norway

Norway is primarily powered by hydropower. Norwegian innovators are, however, also developing other renewables and the technology to make them work.

Published 14 March 2023

Tre industriprosjekter mottar milliardstøtte



ENOVA

Enova supports hydrogen projects in the maritime sector with NOK 1.12 billion

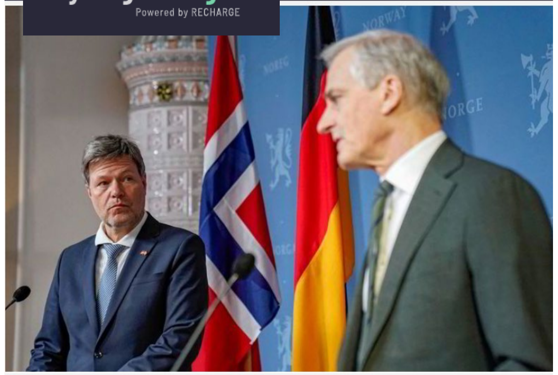
23.6.2022 12:01:00 CEST | Enova

Del

Hydrogen can be a key climate solution in tomorrow's Norway. This is especially true for the maritime sector and industry.

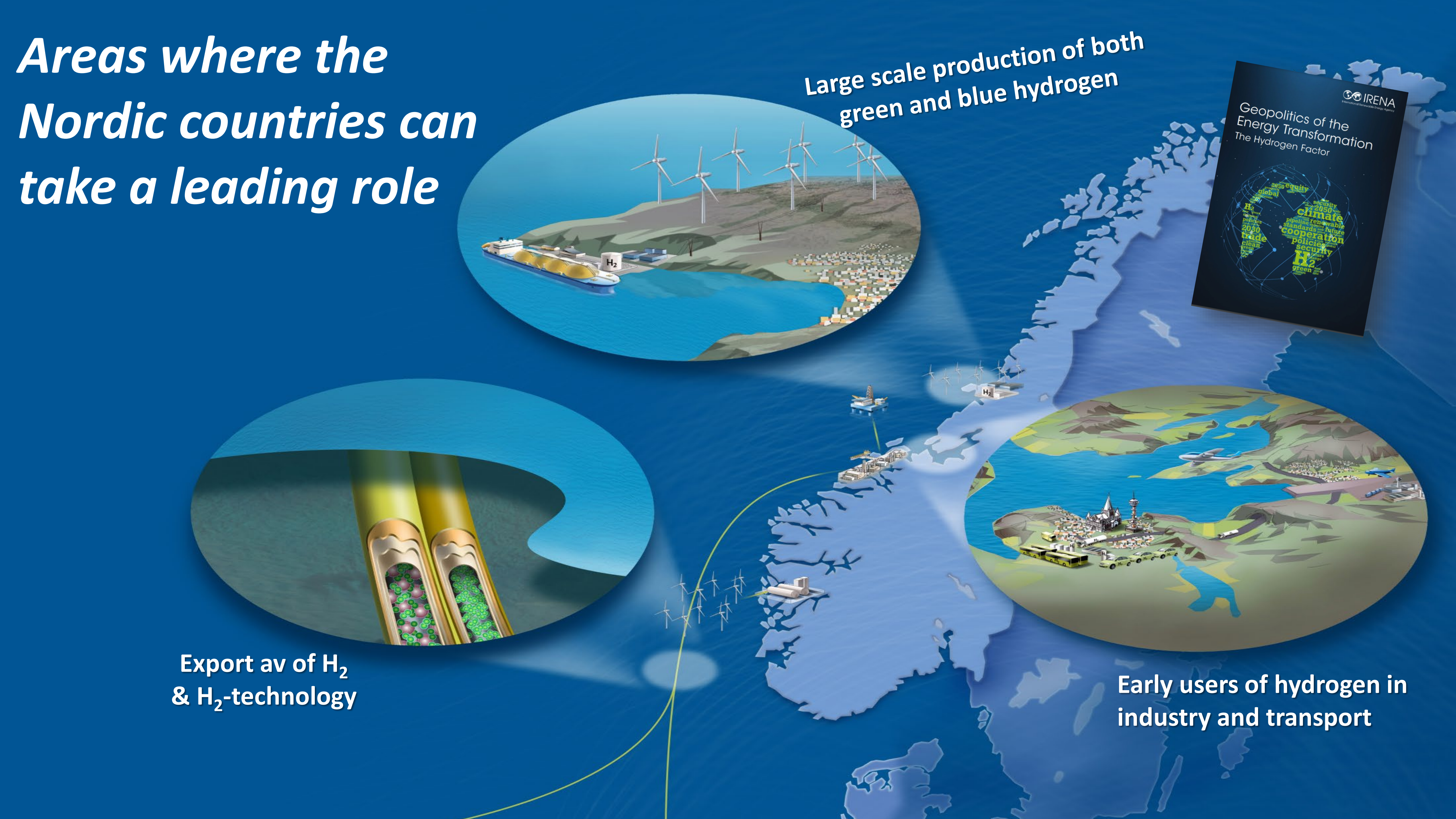
Thor Dahl Shipping hydrogen-powered bulk carrier is one of the vessels that receive fundings from Enova. (Ill: Thor Dahl Shipping)

Hydrogeninsight
Powered by RECHARGE

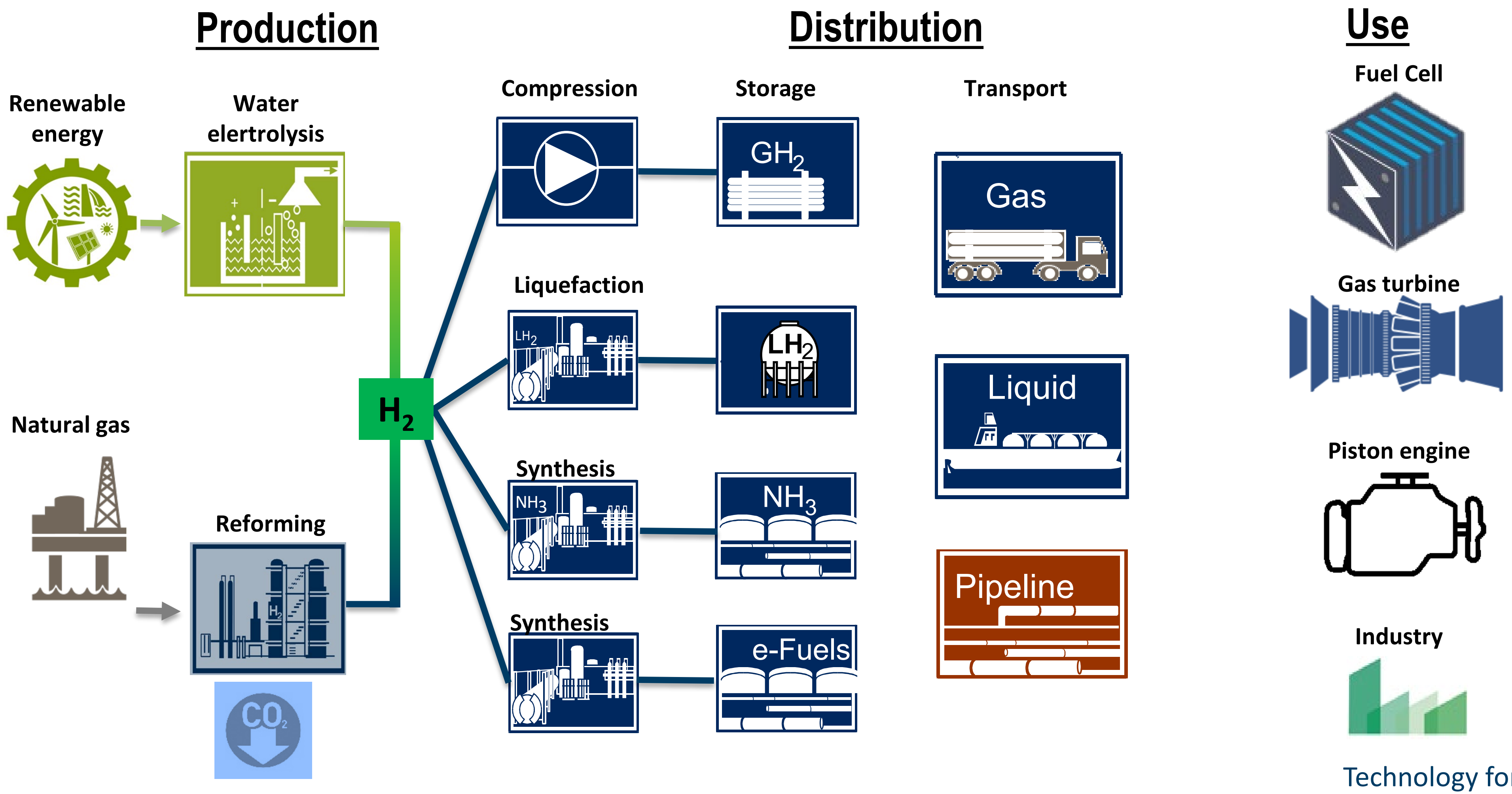


Norway and Germany announce plan to build hydrogen pipeline between the two countries by 2030

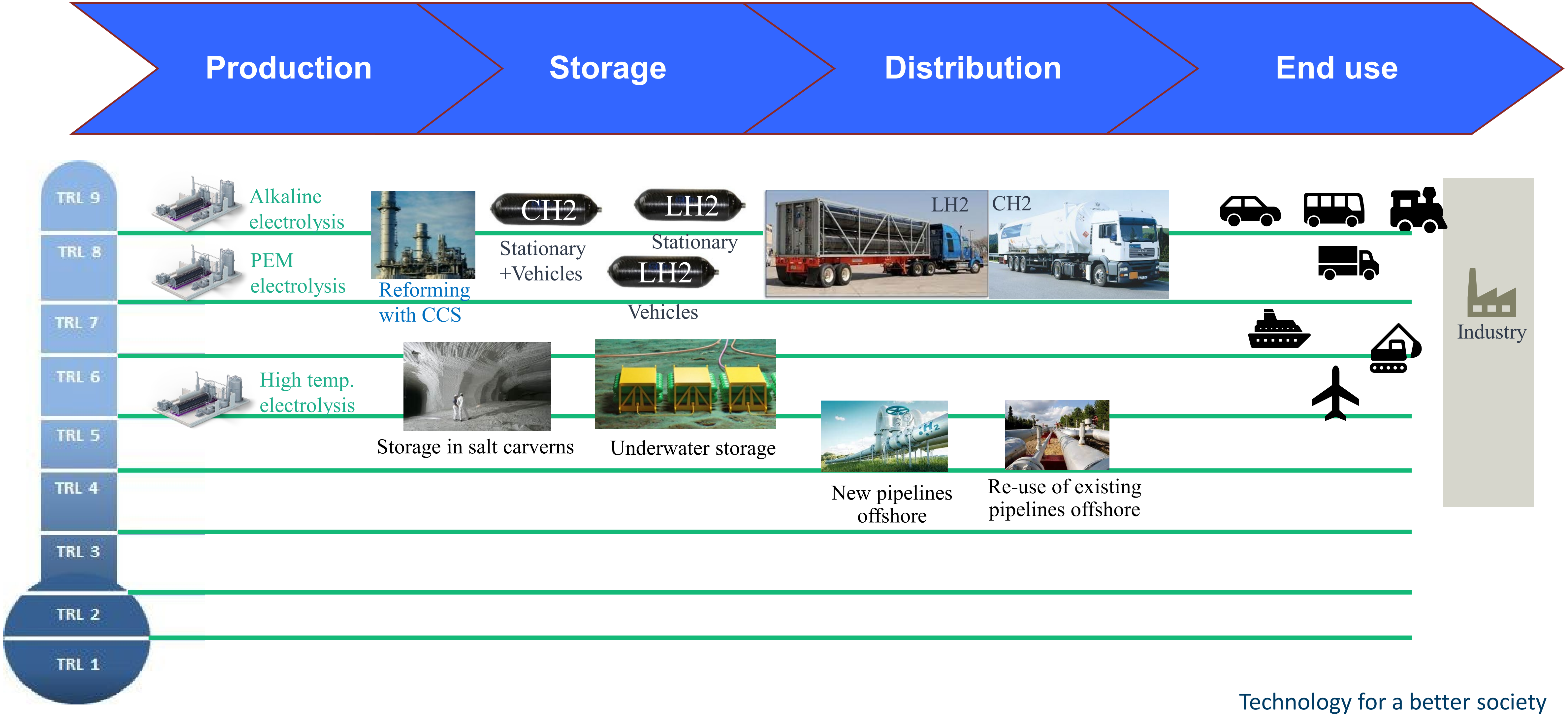
Technology for a better society


Areas where the Nordic countries can take a leading role
Large scale production of both green and blue hydrogen
IRENA
Geopolitics of the Energy Transformation
The Hydrogen Factor
Export av of H_2
& H_2-technology
Early users of hydrogen in industry and transport

Hydrogen as an energy carrier, synthesis



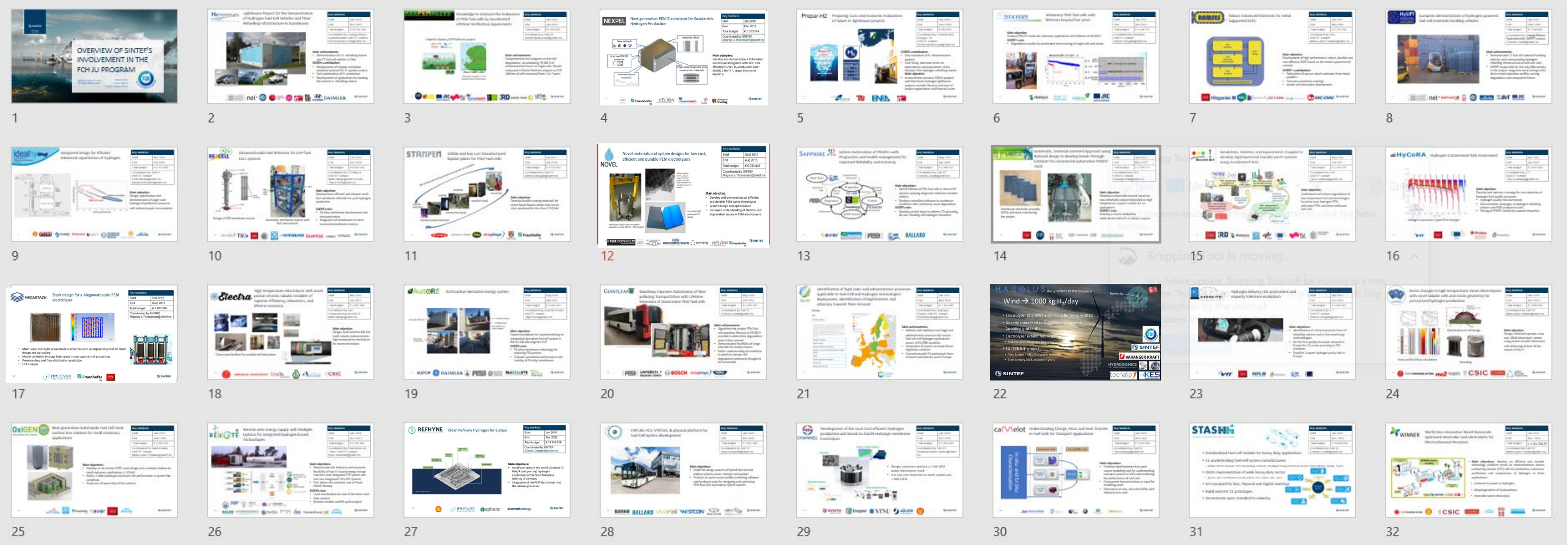
H_2-technologies – TRL along the value chain



SINTEF

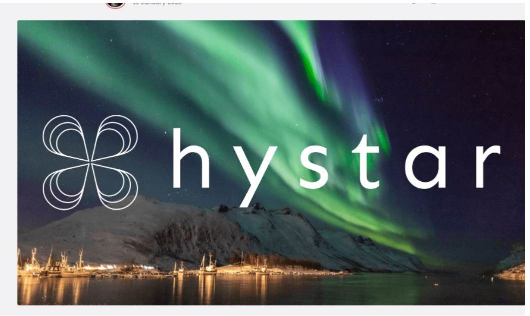
SINTEF's EU-project portfolio (2010-2021)

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING



PEM Water Electrolysis @ SINTEF

- SINTEF-coordinated EU funded projects (2010 → 2027)
  Materials development → Up-scaling → Market deployment



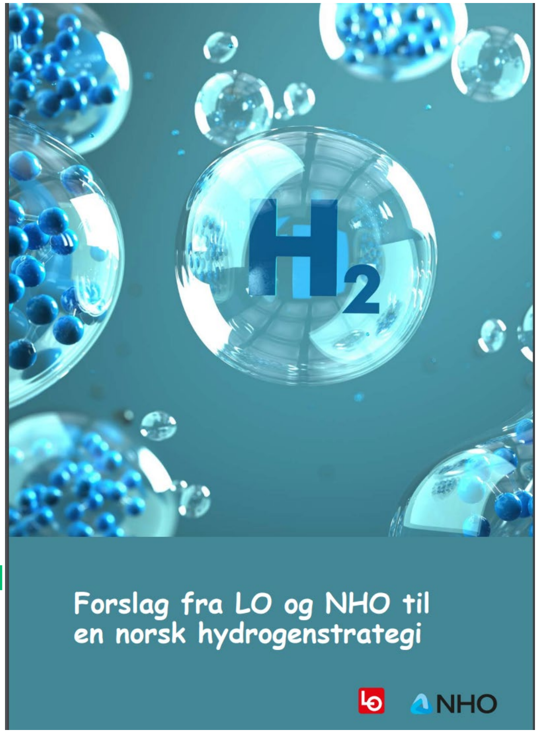
Technology for a better society

SINTEF

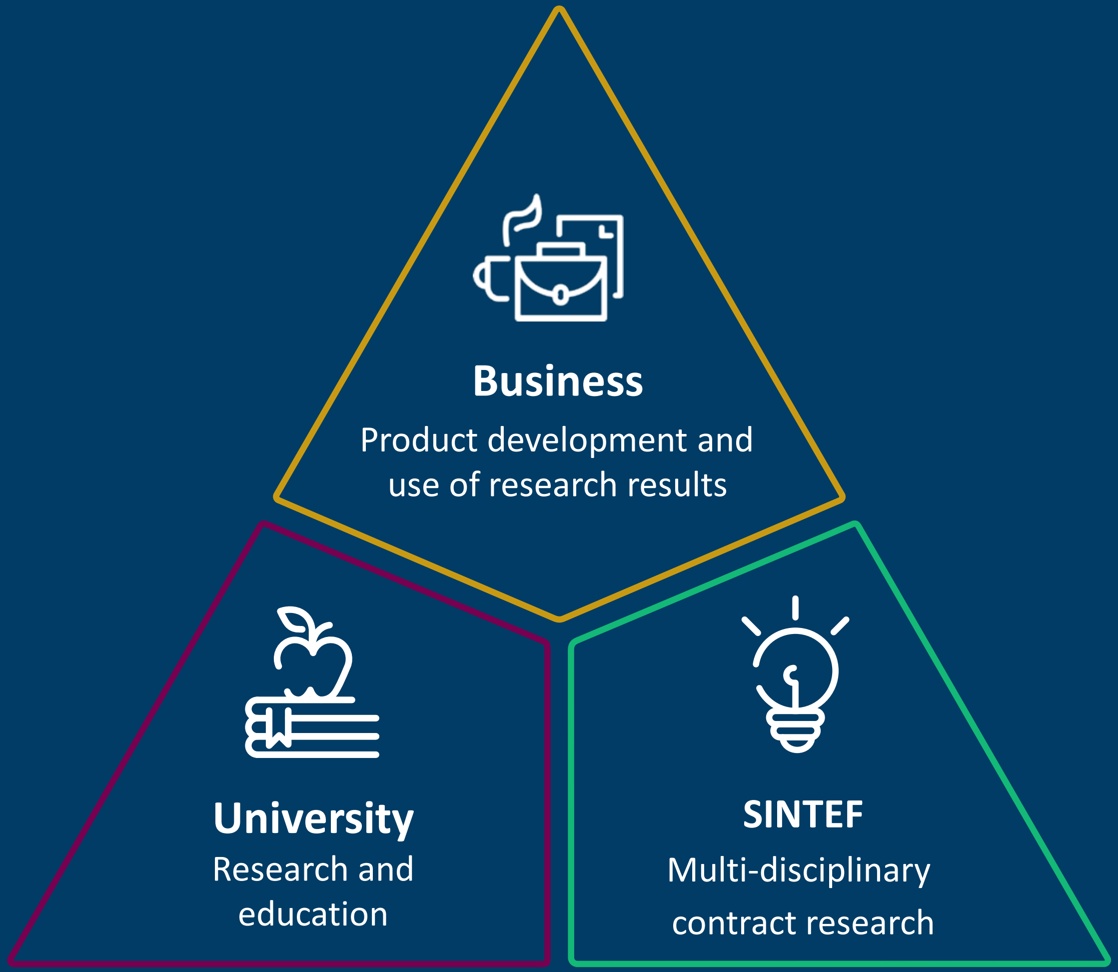
Research, standardization and CFDs

- The technologies are available, but there is still a need for technology development within several sectors
- Standards need to be developed
- Public funding for research and implementation is necessary
- Hydrogen will compete with other sustainable solutions due to scarcity on electrical power, work force and land area

- Norway has resources and competence we can use to take a leading role in Europe's hydrogen industry
- Need similar incentives as those launched in EU and USA
- Incentives like Contracts for Difference (CFDs), support for building of infrastructure and increase in CO_2 taxes



Innovation through co-operation and expertise



COLLABORATION IN AN ECOSYSTEM OF INNOVATION

- where new businesses play a bigger part

SINTEF

Applied research projects

REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE

Solar powered Hydrogen heavy duty trucks & forklifts

Safe hydrogen fuel handling and use for efficient implementation

SH2IFT

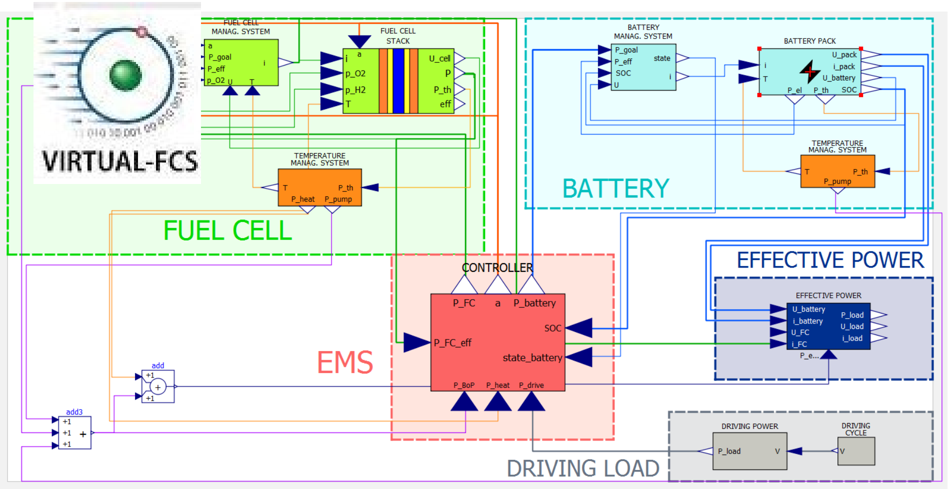
SH2IFT II

Aquaculture vessel + hydrogen production

ZERO KYST

12 million Euro for building of Fishing boats

VIRTUAL & physical platform for Fuel Cell System development



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Hydrogen can play an important role in the decarbonization of Nordic countries,

But only if governmental incentives are strengthened, and further research is supported