Asta Sihvonen-Punkka

The Nordic TSO Strategy Steering Group, Fingrid

Welcome and introduction

Nordic TSO strategy webinar II
15th of October 2021

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The Nordic TSO strategy will look into

→ what do the TSOs need to do

→ **what do the Nordic TSOs need to do together**

Stakeholder webinar
- Nordic TSO strategy
- Solutions report

Agenda for the webinar

9.00 – 9.10	Welcome and opening	Asta Sihvonen-Punkka, Chair of the Nordic TSO strategy steering group
9.10 – 9.50	Nordic TSO strategy for the development of wind and sector integration • Insights to strategy • Summary of stakeholder inputs	Jussi Matilainen, Nordic TSO R&D Daniel Gustafsson, Nordic TSO planning group
9.50 – 10.10	Discussion and questions	All
10.10 – 10.30	Future of offshore wind and energy islands – TSO insights and development	Hanne Storm Edlefsen, Vice President for Energy Islands, Energinet
10.30 – 10.50	Cooperation of wind power and Power to X	Hillevi Priscar, Country Manager, OX2 Sweden
10.50 – 11.00	A short break	
11.00 – 11.20	Hydrogen in steel production and its possibilities in system balancing	Maria Persson Gulda, Chief Project Officer and Chief Technology Officer, H2 Green Steel
11.20 – 11.40	Transition to integrated electricity and hydrogen systems	Magnus Korpås, professor, Norwegian University of Science and Technology
11.40 – 12.00	General discussion and conclusions	Asta Sihvonen-Punkka, Chair of the Nordic TSO strategy steering group

Is something missing?

Should something be taken out?

Webinar guidelines

- All microphones are automatically set to “MUTE”
- All cameras are automatically set to “OFF”
- To comment or pose a question you can either
  - Write in the “CHAT” window
  - Use the “RAISE HAND” feature, your microphone and camera will be available for use accordingly
- When speaking, please
  - Turn your microphone and camera “ON”
  - Start by introducing yourself
  - Remember to turn your microphone and camera “OFF” afterwards
- During the webinar there will be polls using Microsoft Forms

Let’s have a good and interactive webinar!

Jussi Matilainen

Nordic Strategy Group

Draft strategy for the Nordic wind power and sector integration development

15.10.2021

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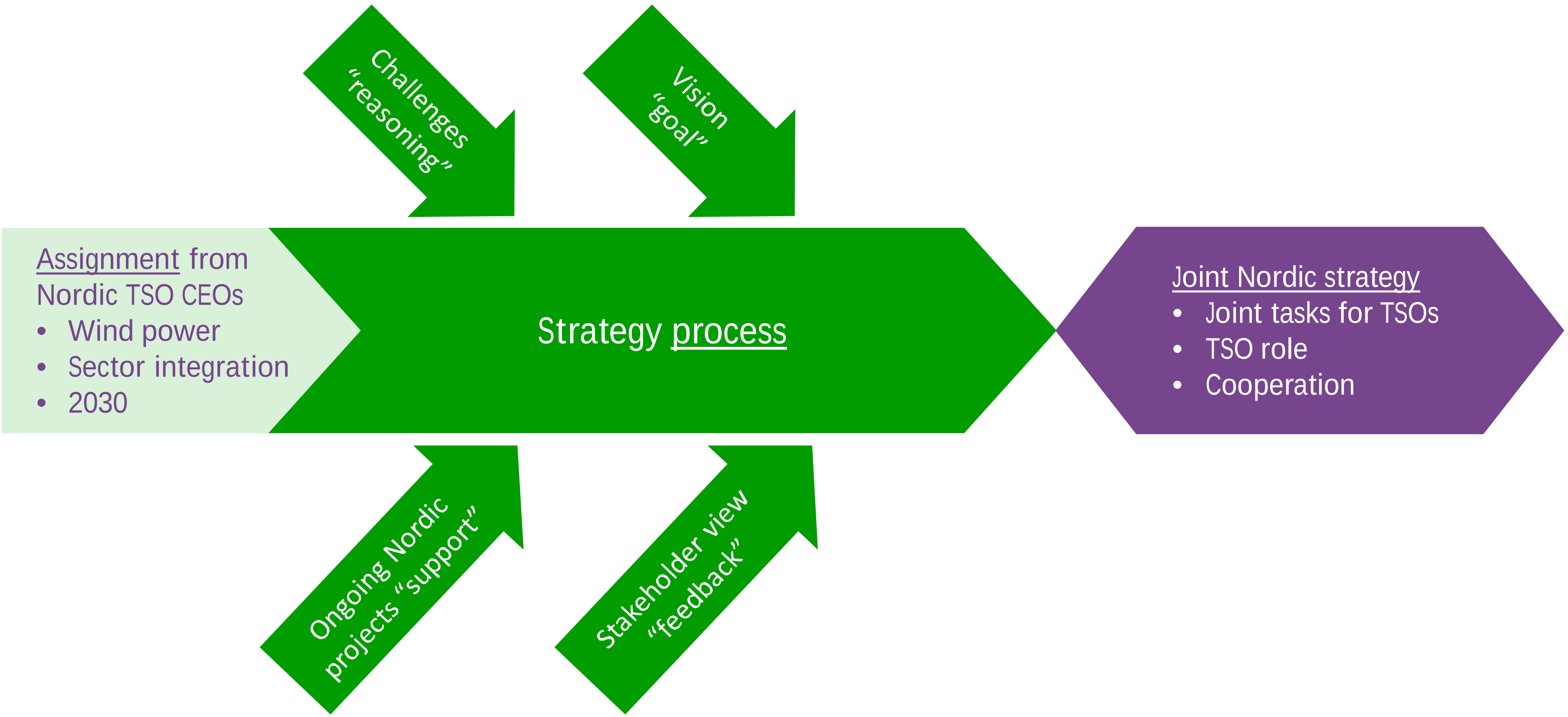
The strategy work: Why and how?



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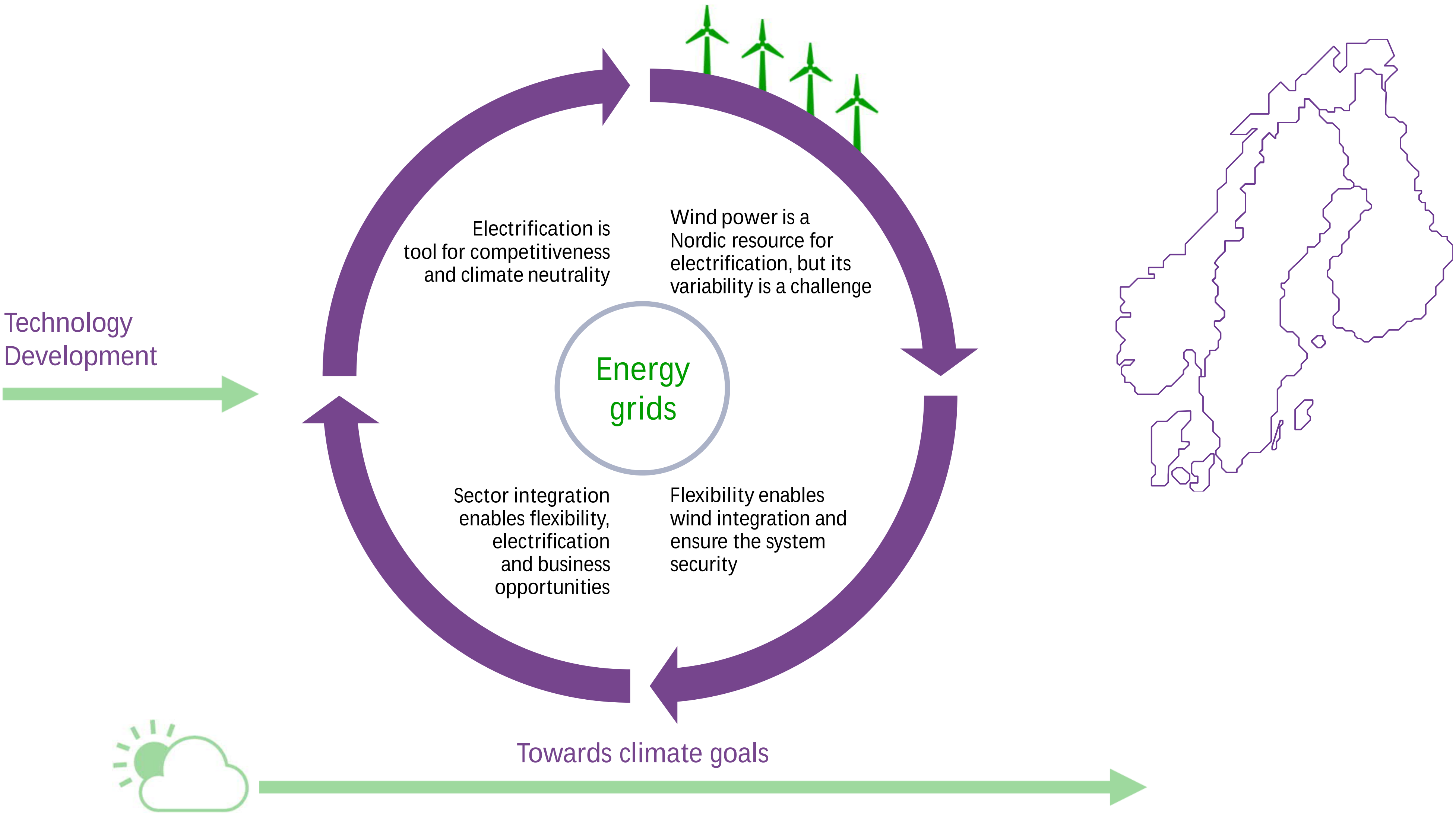

Technology Development
Electrification is tool for competitiveness and climate neutrality
Wind power is a Nordic resource for electrification, but its variability is a challenge
Energy grids
Sector integration enables flexibility, electrification and business opportunities
Flexibility enables wind integration and ensure the system security
Towards climate goals

Nordic vision 2030

Clean and affordable electricity enabling a climate neutral, secure and integrated energy system

Optimized energy system	Integrated market and secure power system	Adequate infrastructure
where infrastructure is based on climate neutral electricity and on the needs of stakeholders	with market design supporting flexibility and secure system operation, and with a level playing field for all technologies	enabling an integrated market for renewable resources as well as direct and indirect electrification

Cross-border cooperation with stakeholders - Shared best practices among TSOs - Excellent conditions for wind - Easy access to advanced markets - Trustworthy location for green investments.

Nordic roadmap 1/3

Vision: Clean and affordable electricity enabling a climate neutral, secure and integrated energy system

Optimized energy system

where infrastructure is based on climate neutral electricity and the needs of stakeholders

How can the Nordic TSOs contribute to the development of optimized energy system?

- Use ambitious wind power and electrification scenarios in the system planning
- Develop tools and create cooperation models for holistic energy system planning

Nordic roadmap 2/3

Vision: Clean and affordable electricity enabling a climate neutral, secure and integrated energy system

Integrated market and secure power system

with market design supporting flexibility and secure system operation, and with a level playing field for all technologies

Nordic roadmap 2/3

How to form integrated energy markets and to ensure system security?

- Ensure market access and financial incentives for all energy resources to provide flexibility and system services
- Introduce offshore bidding zones and integrate offshore solutions in the electricity market
- Develop the requirements for new energy resources to ensure their flexibility and the system security
- Create tools to monitor flexibility and forecast it also at Nordic level

Nordic roadmap 3/3

Vision: Clean and affordable electricity enabling a climate neutral, secure and integrated energy system

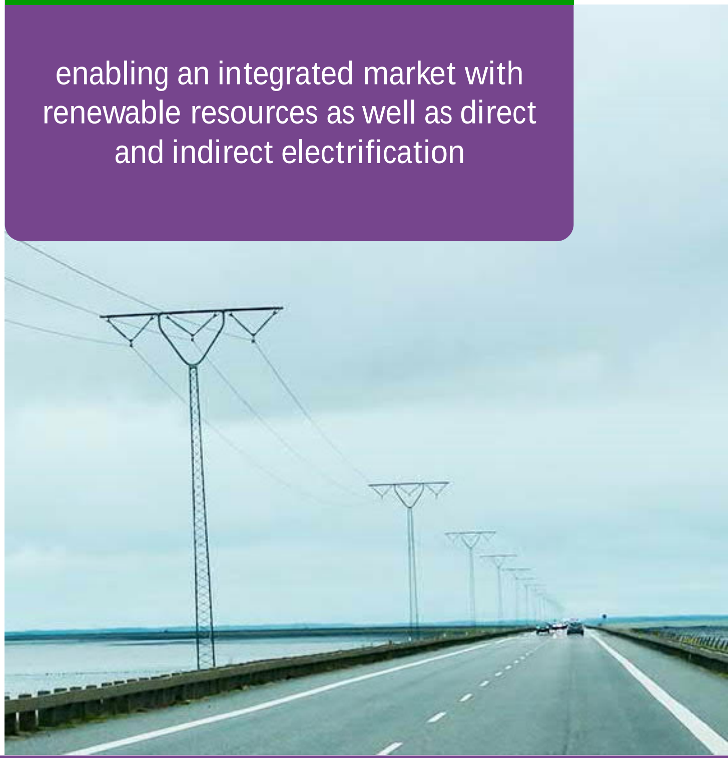
Nordic roadmap 3/3

How to ensure adequate energy infrastructure for all players with a reasonable cost?

- Implement best practices for optimal utilization and performance of existing system
- Use the full transmission technology mix for further grid expansion
- Build adequate infrastructure considering the Baltic Sea & North Sea region
- Speed up connection to grid

Adequate infrastructure

enabling an integrated market with renewable resources as well as direct and indirect electrification



Implementation of the strategy

- First projects from the roadmap focus areas to be launced in 2022
- Regular follow up of the strategy implementation

Optimized energy system

- Use ambitious wind power and electrification scenarios in the system planning
- Develop tools and create cooperation models for holistic energy system planning

Integrated market and secure power system

- Ensure market access and financial incentives for all energy resources to provide flexibility and system services
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Adequate infrastructure

- Implement best practices for optimal utilization and performance of existing system
- Use the full transmission technology mix for further grid expansion
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- Speed up connection to grid

The key messages

- It is vital to have a wide cooperation across all the energy sectors and stakeholders
- Nordic energy system is an attractive area for investors due to easy access to the advanced Nordic electricity markets, competitive electricity price and excellent conditions.
- We develop and maintain adequate infrastructure for efficient markets and renewable energy sources
- Flexibility in consumption, energy storages and dispatchable generation is required for power balancing and grid management
- To unlock flexibility and system services, easy and equal market access and other incentives for all energy resources are required
- We do power system planning, including Baltic Sea & North Sea regions, that considers all energy sectors and infrastructure types enabling optimization of the entire energy system.
- There is a need for a streamlined processes to make grid and connections available in time.

Thank you!

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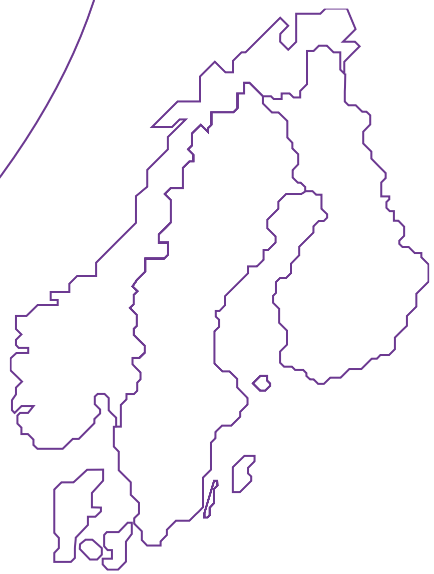
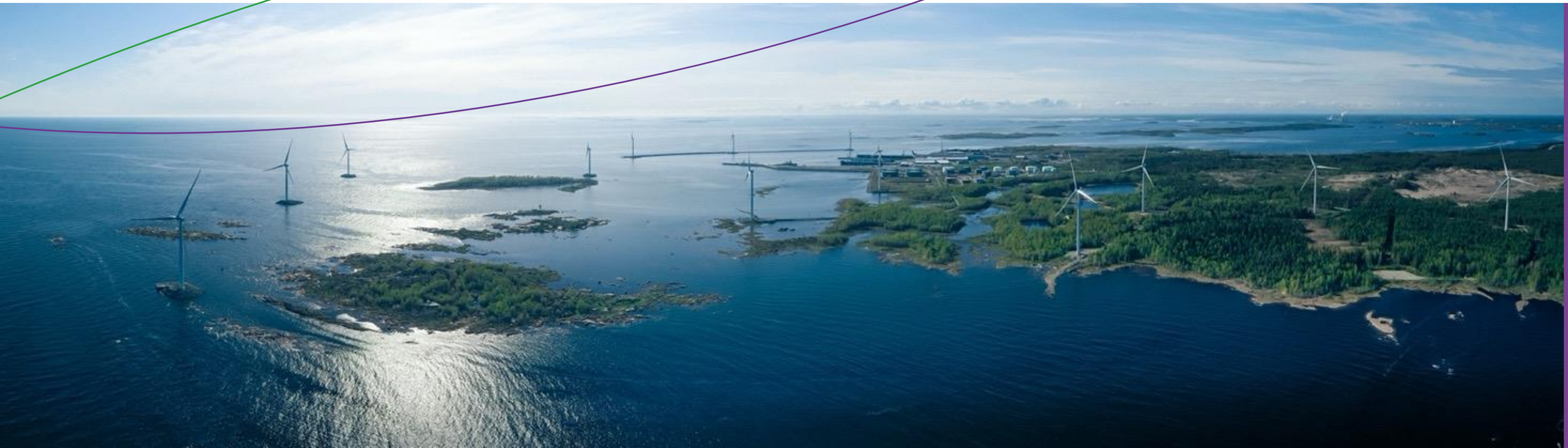
Daniel Gustafsson

Nordic Strategy Group

Joint strategy for the Nordic wind power and sector integration development – Stakeholder involvement





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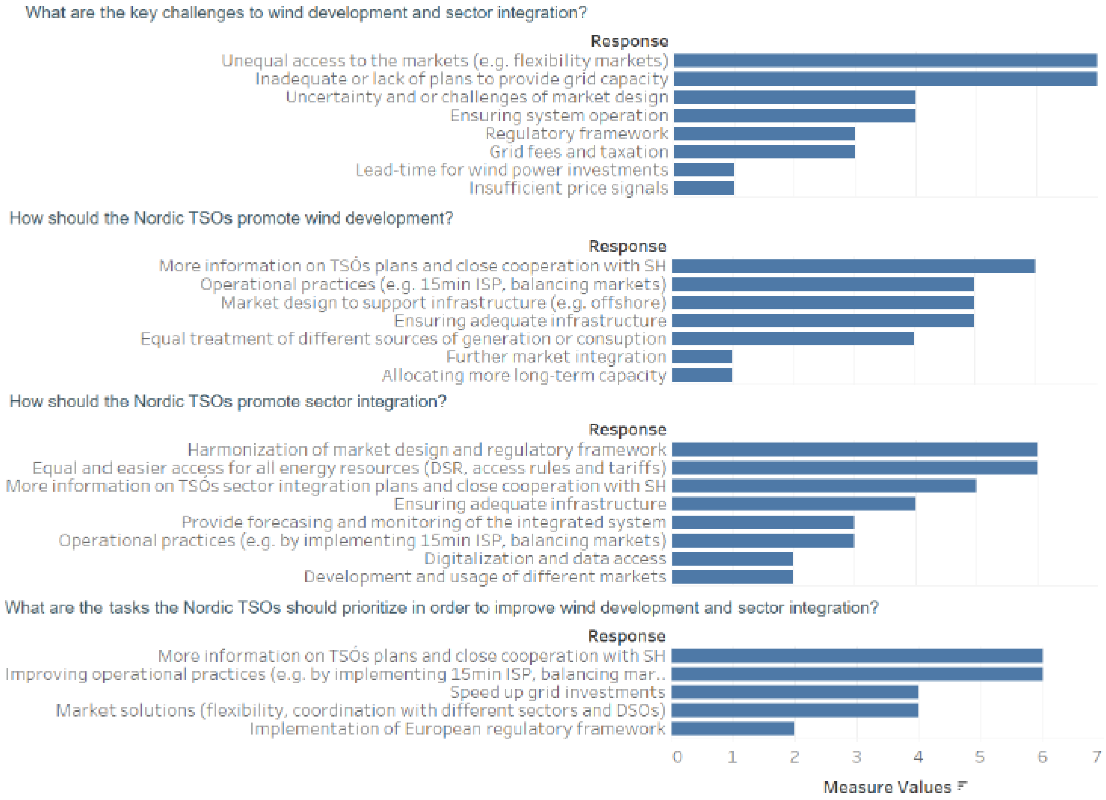
Stakeholder involvement - Process

- Webinars (spring and fall 2021)
- Consultation phase
- Bilateral discussions on national level

Stakeholder involvement - Key findings

- Grid capacity
- Transparency
- Incentives
- Equal conditions



Distribution of written responses.

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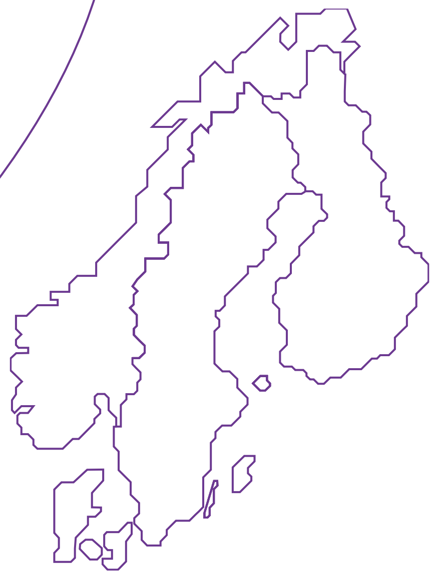

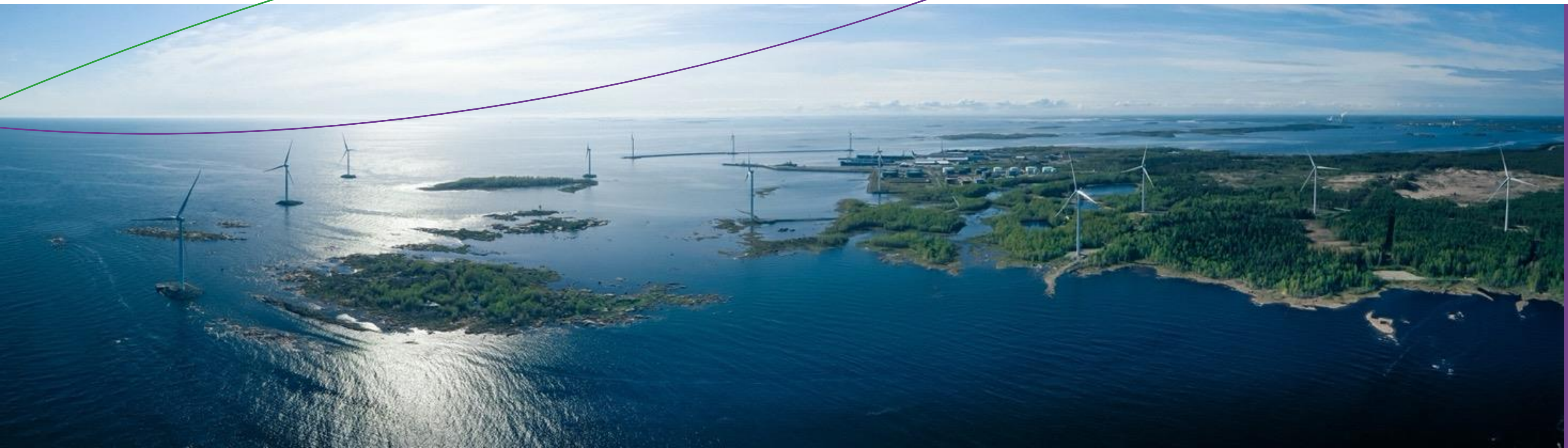

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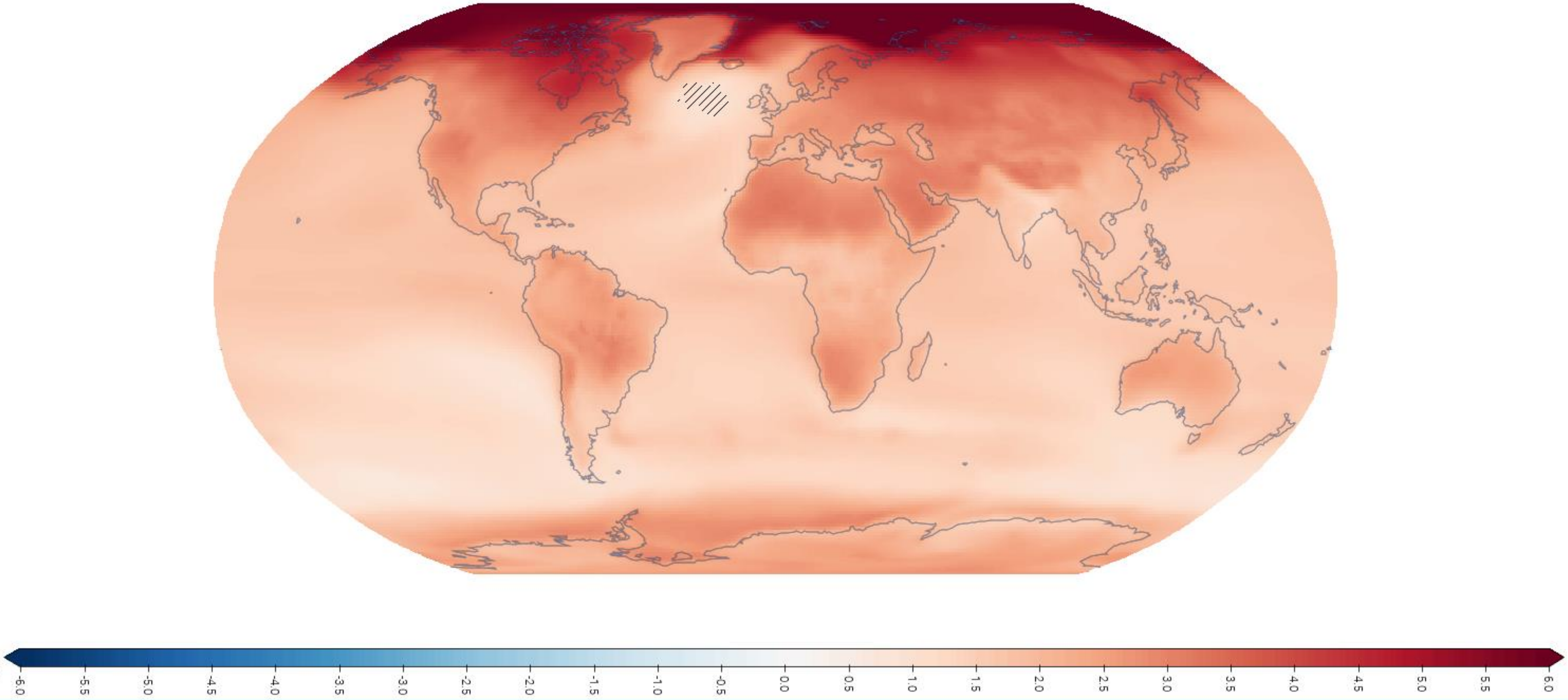
ENERGY ISLANDS

STEPPING STONES FOR LARGE-SCALE RES

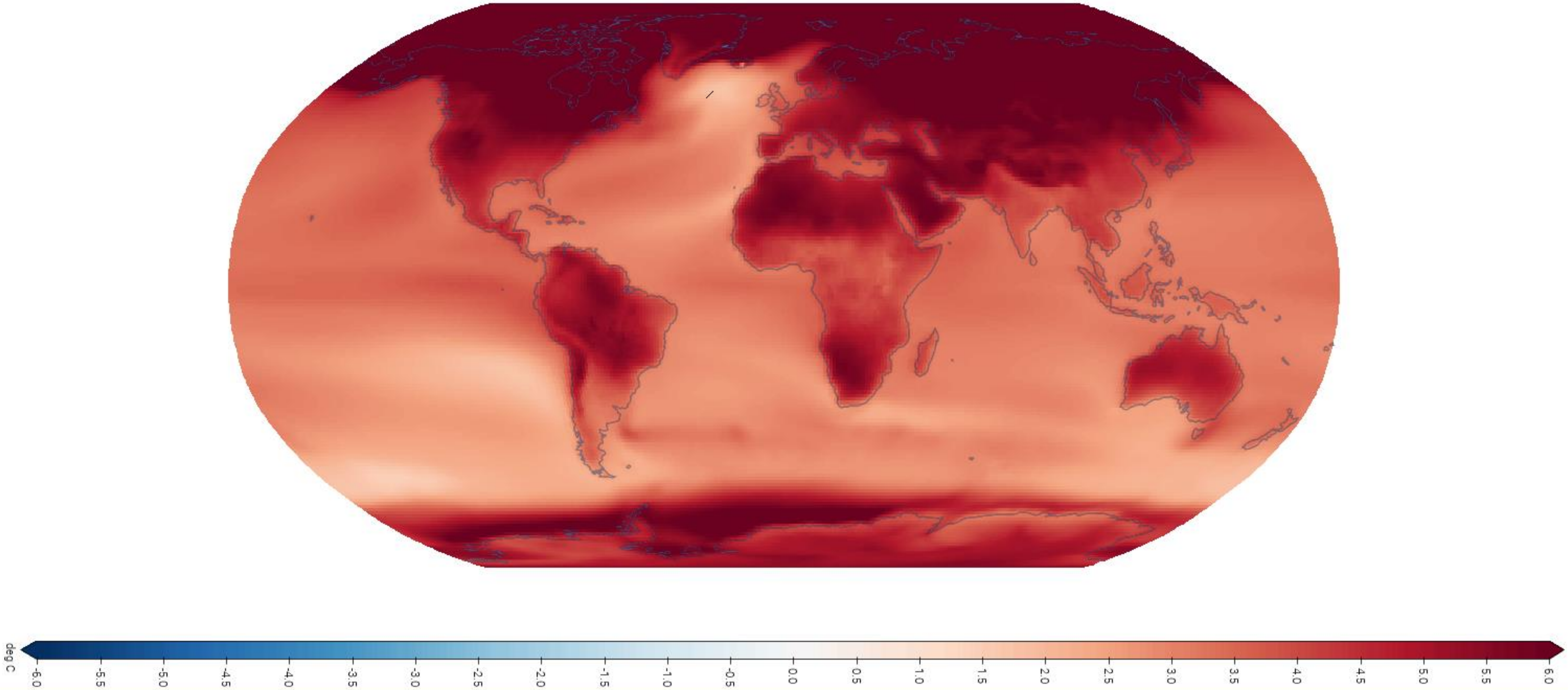
Hanne Storm Edlefsen, Vice President



Mean temperature (T) - Change (deg C)
Warming 2°C (SSP5-8.5) (rel. to 1850-1900)
CMIP6 - Annual (34 models)

High agreement
Low agreement

INTERGOVERNMENTAL PANEL ON climate change



Mean temperature (T) - Change (deg C)
Warming 4°C (SSP5-8.5) (rel. to 1850-1900)
CMIP6 - Annual (20 models)

High agreement
Low agreement

INTERGOVERNMENTAL PANEL ON climate change

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OFFSHORE WIND IN EU

003

3 % of the space at sea in Europe is needed for offshore RES in 2050

030

Europe’s currently installed capacity of offshore RES need to grow almost 30 times before 2050

300

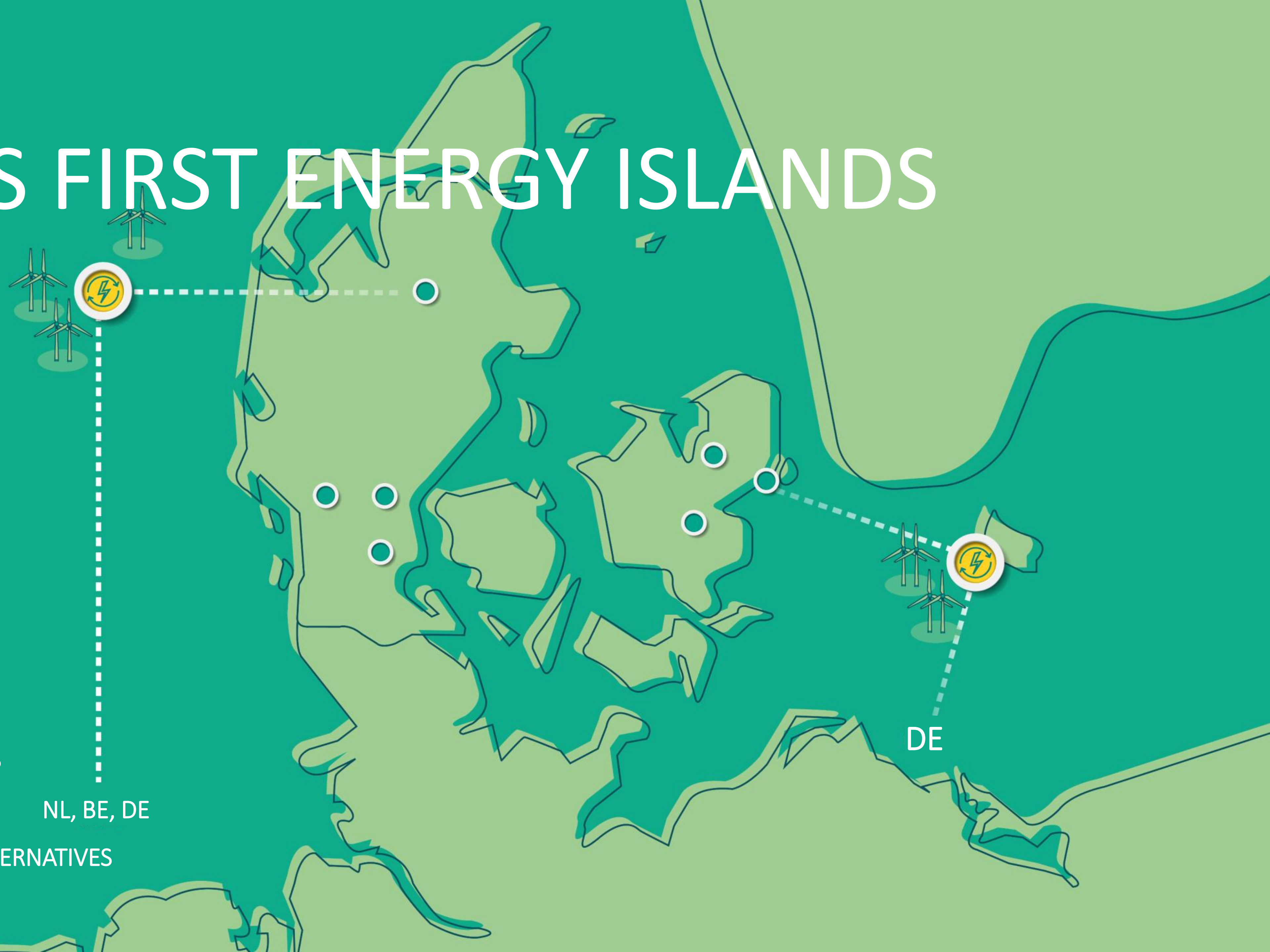
300 GW of offshore RES in 2050 is the target put forward by the European Commission.

WORLD’S FIRST ENERGY ISLANDS

The North Sea:
3 GW offshore wind by 2030, later 10 GW.

The Baltic Sea:
2 GW offshore wind by 2030.

(or 1 GW by 2030 and afterwards stepwise build-out.)



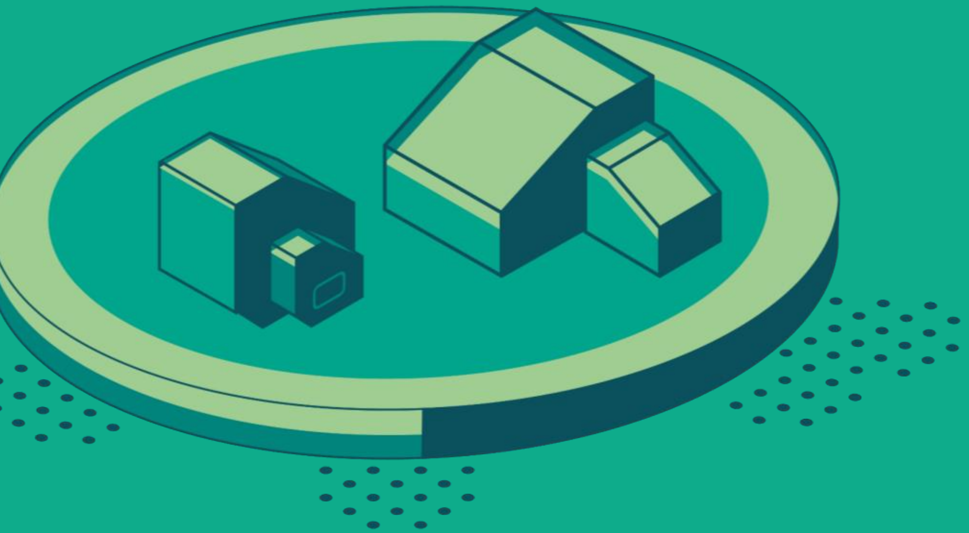
- NEW OFFSHORE WIND FARMS
- ENERGY ISLAND
- ONSHORE CONNECTIONS, ALTERNATIVES

Illustration: Danish Energy Agency

ARTIFICIAL ISLAND IN THE NORTH SEA

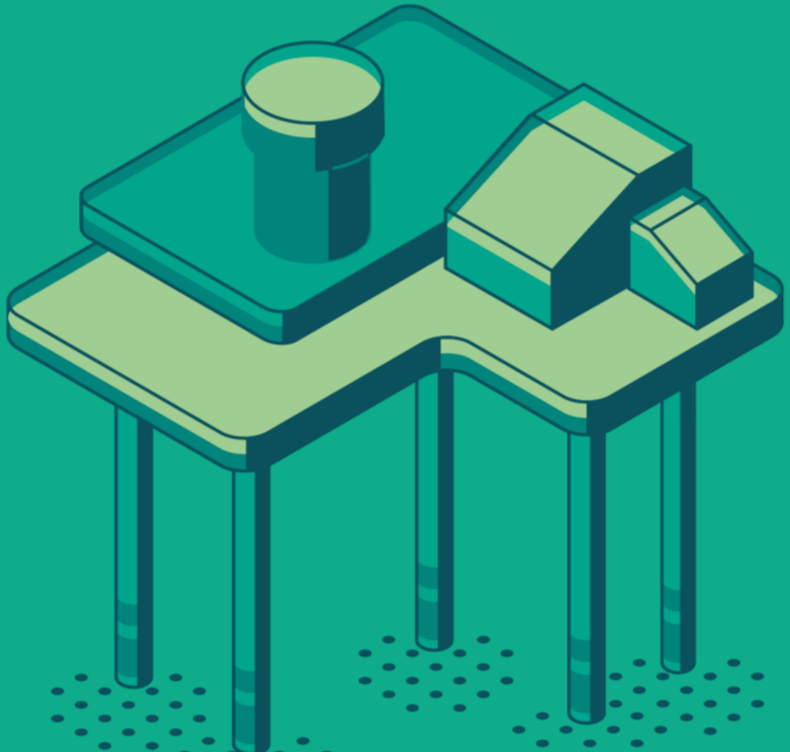
- 80 km from the shore of the peninsula Jutland
- 3 GW growing to 10 GW (3-10 million european households)
- EUR 28 billion, including 10 GW wind farms, electrical installations and power cables
- Public private partnership

3 ENERGY ISLAND TYPES



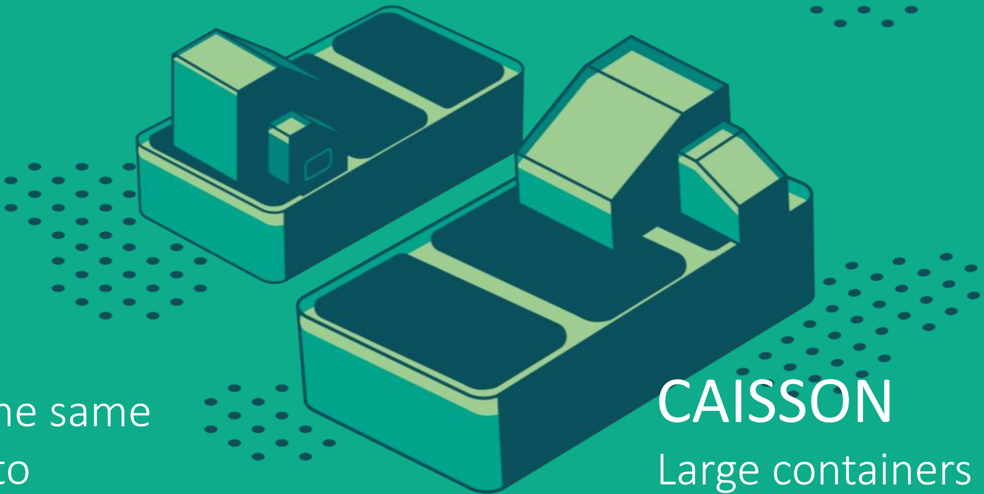
SANDFILLED ISLAND

Where the sea is not too deep, energy islands can be sandfilled islands.



PLATFORMS

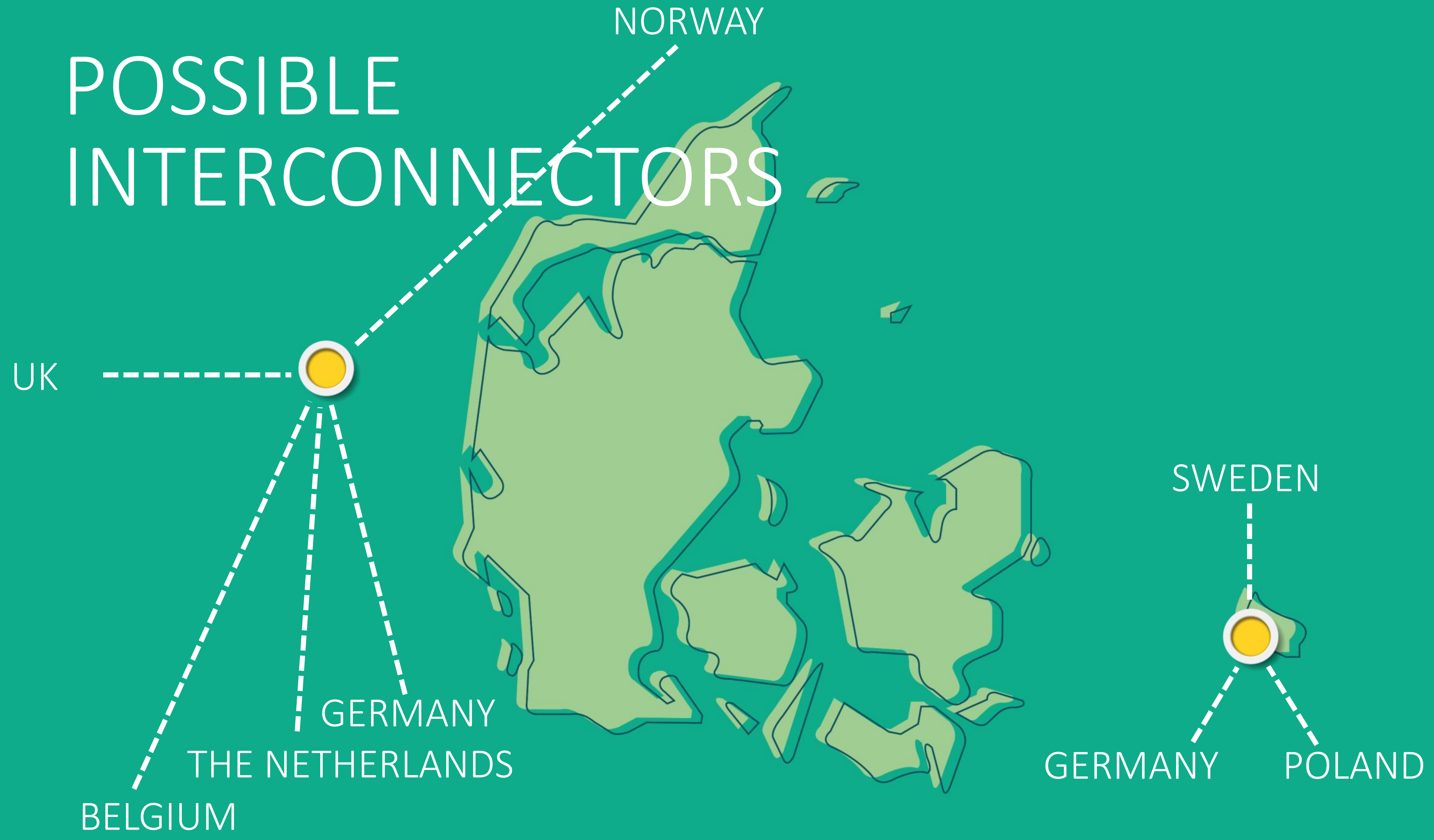
Hubs made of large steel-platforms. The same kind of platforms that are used today to collect power from offshore windfarms.



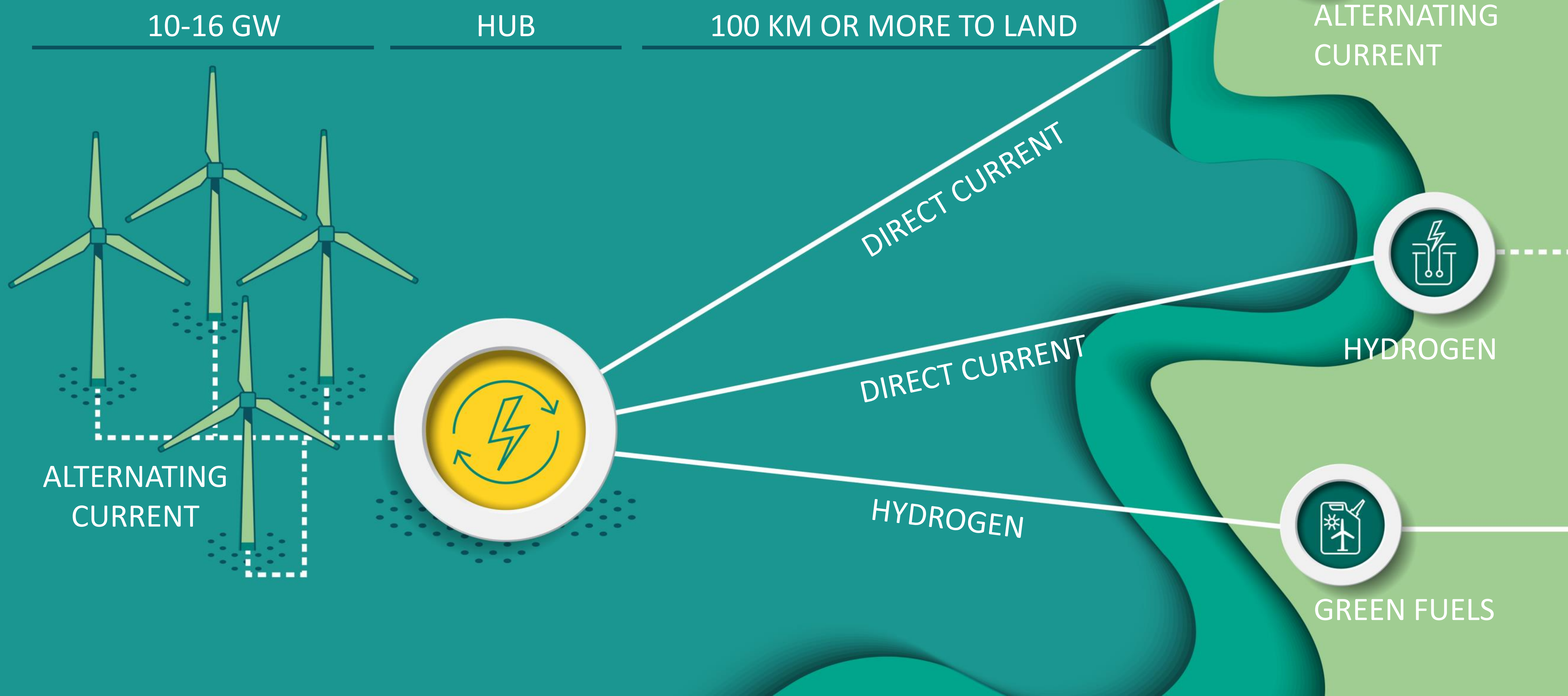
CAISSON

Large containers made of steel or concrete that are filled with stone- or other materials.

POSSIBLE INTERCONNECTORS



ENERGI ISLANDS OR HUBS



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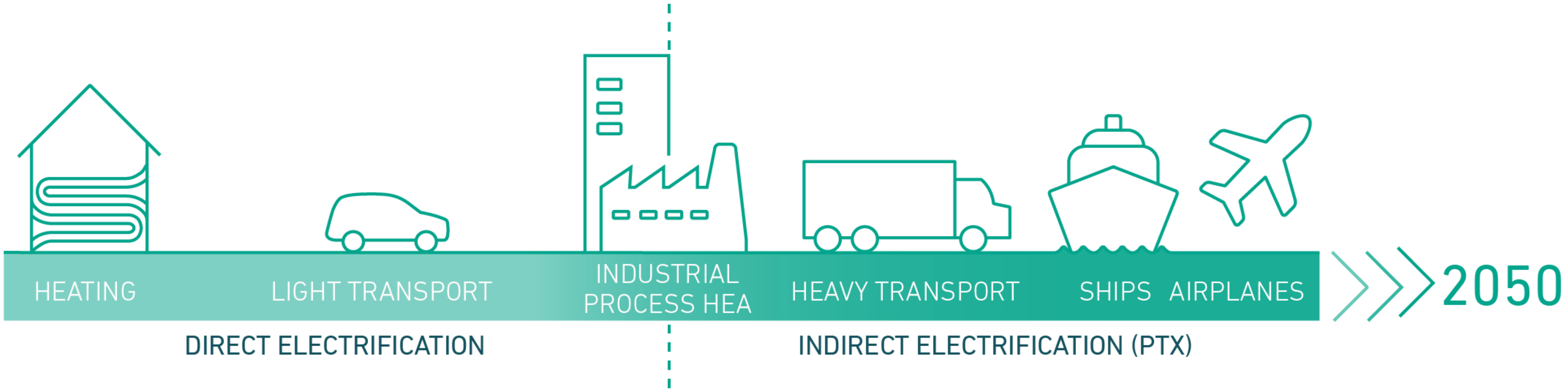
ELECTRIFICATION AND POWER TO X

The huge RE-potentials can be utilized to electrifications and to indirect electrification via power to X for sectors that cannot run on electricity.



SURVEY VESSELS

- Geophysical studies
- Seismic mapping of seabed
- 100 meters below sea floor
- Foundation solutions
- Designs for cables on seabed

Photo: Fugro

TIMELINE – ENERGY ISLAND IN THE NORTH SEA

2021

Preliminary studies, country outreachs & co-ownership tender

2024

Preparing and building the island, converters etc. onshore and international connections (IC) offshore

2028

Island ready for energy-infrastructure. Continuated establisment of IC & onshore infrastructure. Offshore windfarms are being set up

2031

Grid-connection, tests and buffer

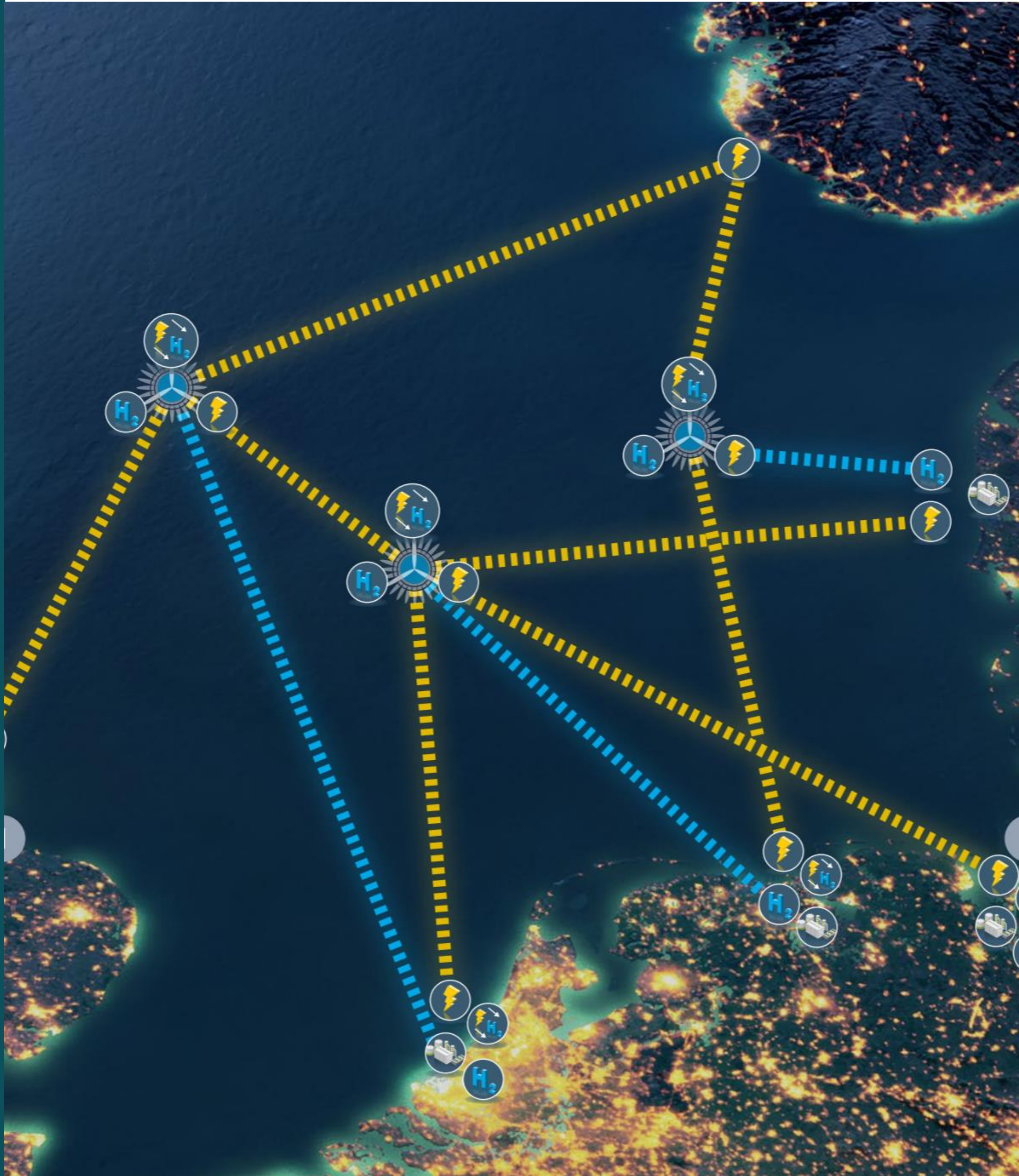
FOLLOW OUR WORK

NSWPH:

https://northseawindpowerhub.eu/

Energinet:
https://en.energinet.dk/Green-Transition/Energy-Islands

Danish Energy Agency:
https://ens.dk/ansvarsomraader/vindenergi/udbud-paa-havvindmoelleomraadet/danmarks-energioeer



OFFSHORE WIND

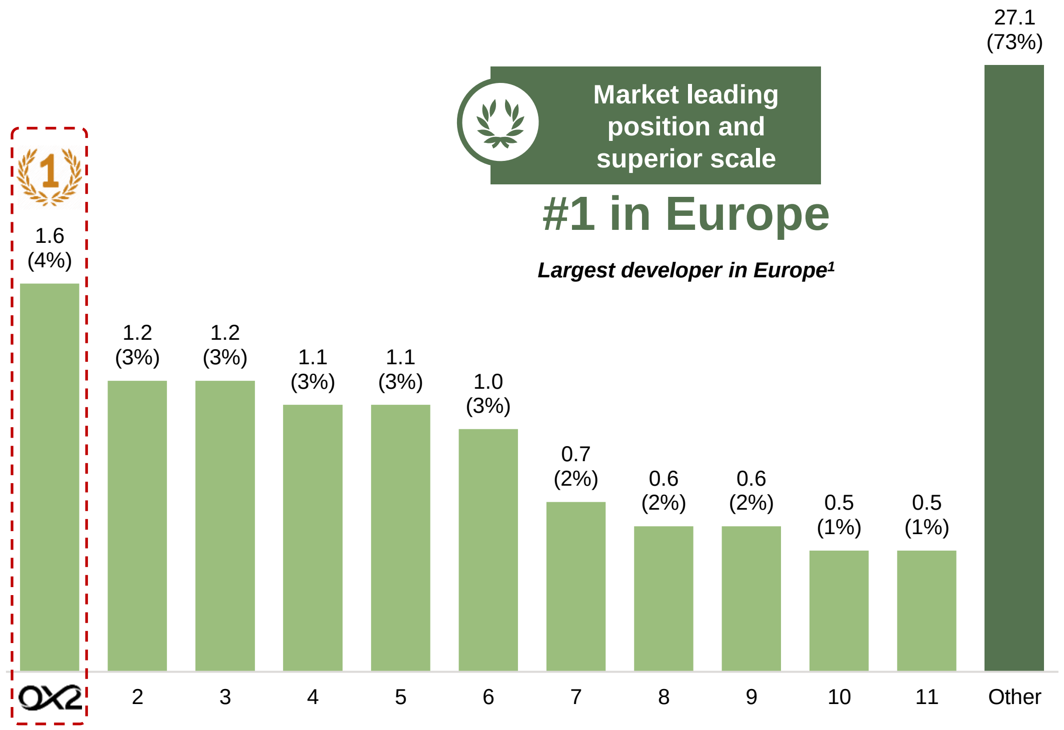
Creating a Fossil-free Energy Hub in Northern Europe

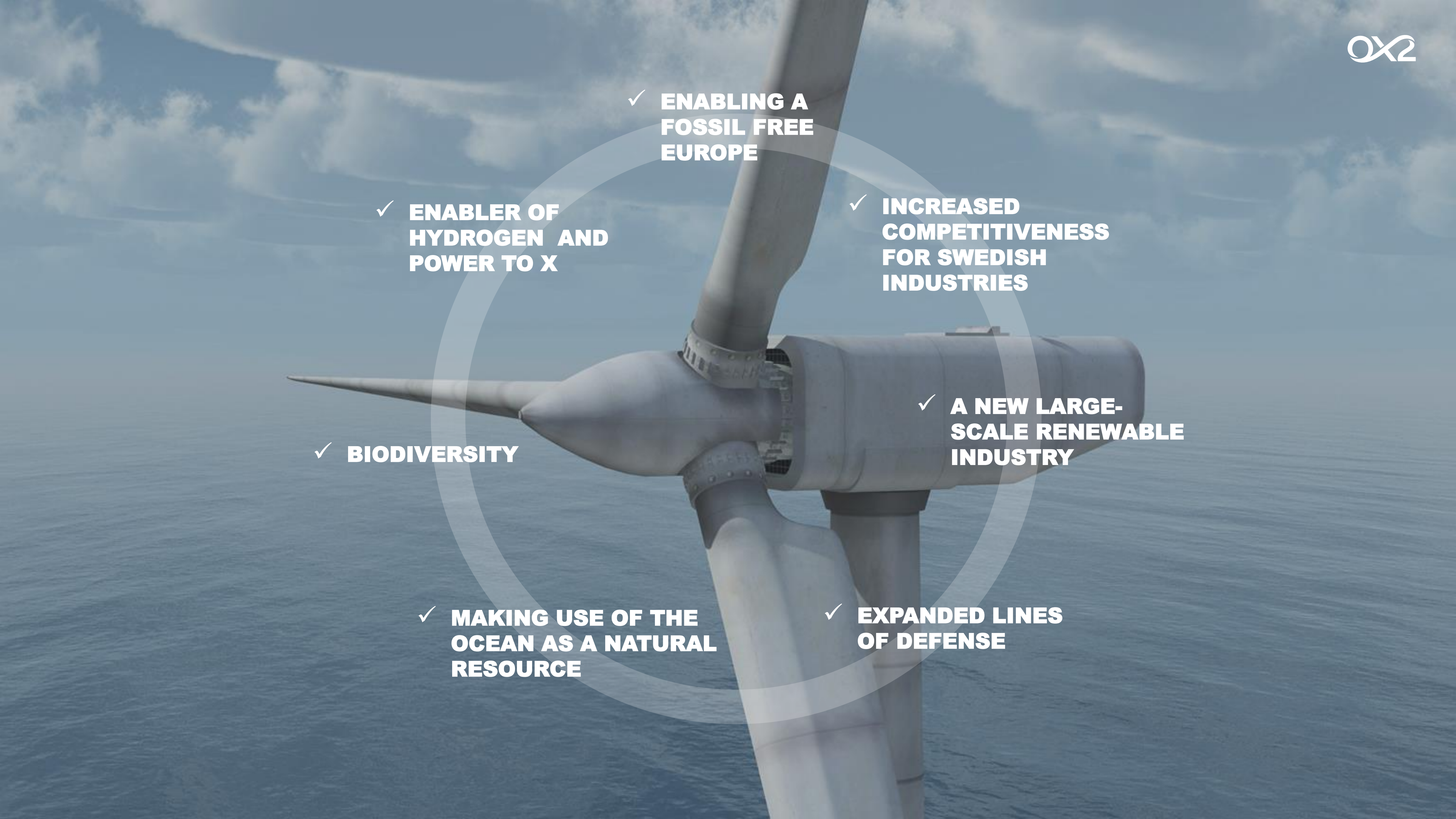
A NECESSARY SHIFT

Nordics can become a leader in the shift to fossil free industries. And wind power can be developed cost-effectively, in large-scale and quickly enough to make it happen.

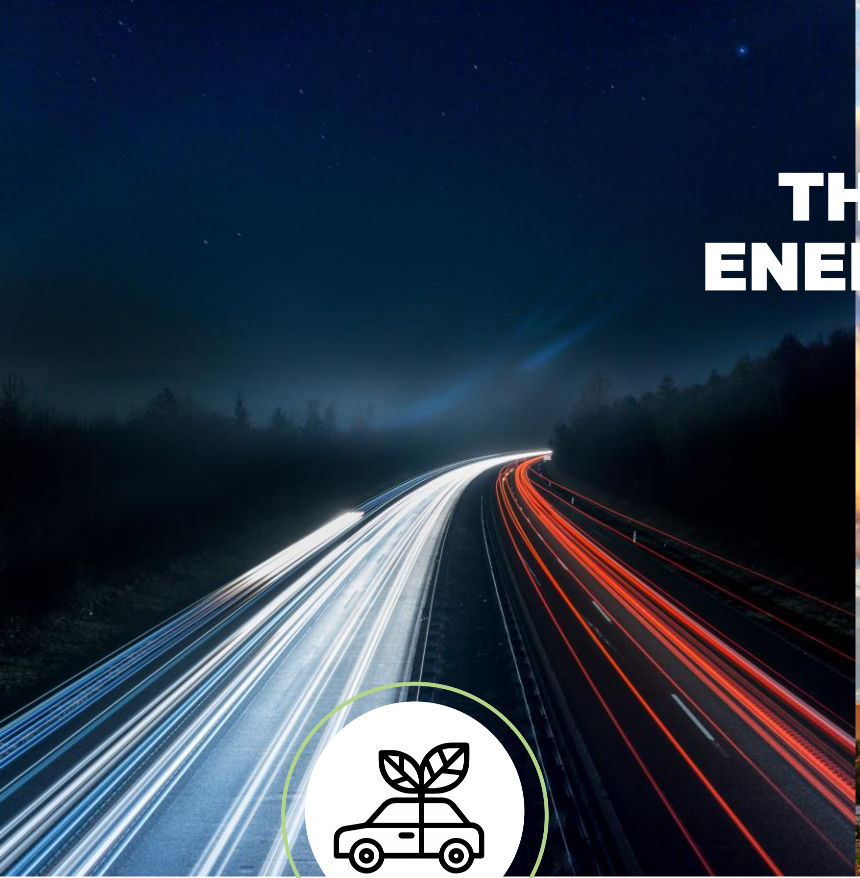
Combined with onshore wind, hydropower and hydrogen development, offshore development in the Baltic Sea and Kattegat can make Sweden the renewable energy hub of Northern Europe.

After taking a #1 position in Europe in onshore wind, OX2 is now dedicated to expand in offshore.




OX2
✓ ENABLING A FOSSIL FREE EUROPE
✓ ENABLER OF HYDROGEN AND POWER TO X
✓ INCREASED COMPETITIVENESS FOR SWEDISH INDUSTRIES
✓ A NEW LARGE-SCALE RENEWABLE INDUSTRY
✓ BIODIVERSITY
✓ MAKING USE OF THE OCEAN AS A NATURAL RESOURCE
✓ EXPANDED LINES OF DEFENSE

THE NEED FOR FOSSIL FREE ENERGY INCREASES DAY-BY-DAY



ELECTRIFICATION

Millions of cars and transports will run on green, fossil-free energy.

INDUSTRY TRANSFORMATION

Mining, steel, concrete and other energy-intensive industries are making the shift to renewable energy. Sweden is also becoming a hub for data centers, battery production and other new industries.

DIGITALIZATION & GROWTH IN POPULATION

More people and more connected devices increase our energy needs.

MARKET OUTLOOK

1st

The **EU** to become **the world's first climate neutral** region by 2050.

x25

The **EU** plans for a **25-fold increase** in offshore wind by 2050.

€800B

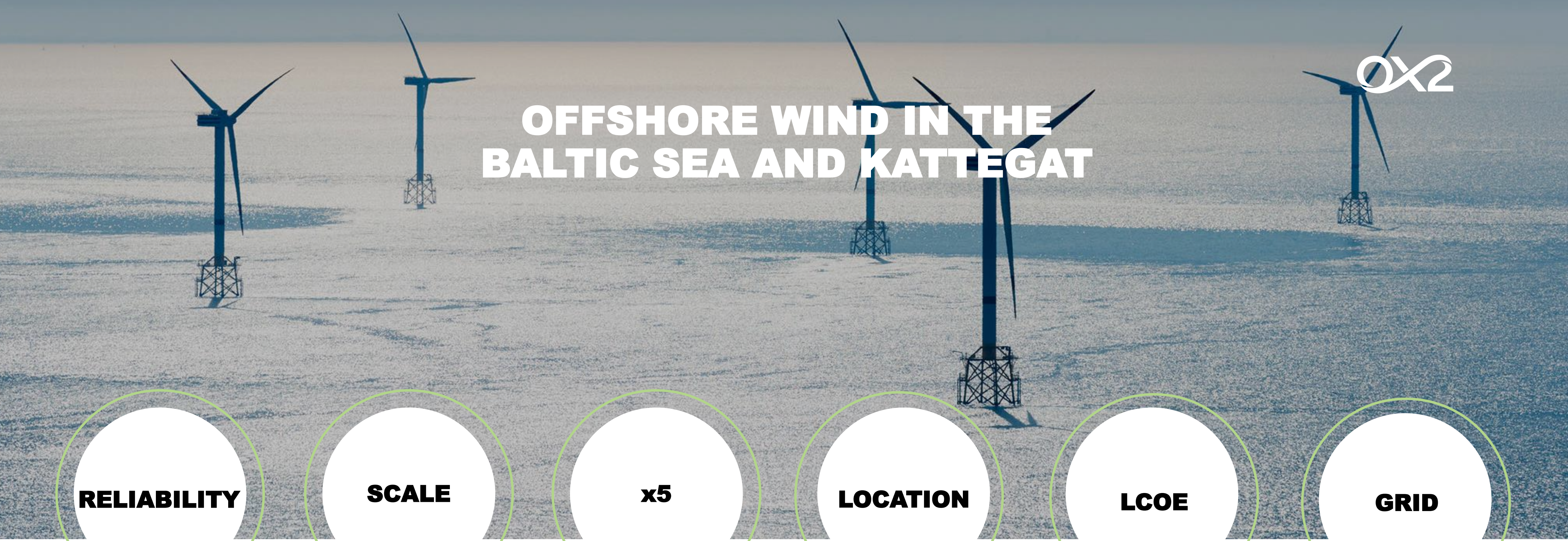
Expanding offshore renewable energy in Europe will require investment worth nearly **800 billion euros**.

100 %

Sweden to have **100 percent renewable energy** by 2040.

Market driven by **decreasing tech. costs**, **green wave** and **investor interest**

Source: European Commission.



OFFSHORE WIND IN THE BALTIC SEA AND KATTEGAT

RELIABILITY

Favorable conditions with **steady and strong winds**.

SCALE

Offshore allows for **larger turbines** and **bigger parks**.

x5

Galatea-Galene alone will produce close to **five times as much energy** as the Porjus hydropower plant.

LOCATION

Energy will be produced in Southern Sweden, close to demand.

LCOE

Highly competitive levelized cost of energy.

GRID

Opportunity to build an interconnected Baltic offshore grid.

NORDIC DEFENSE – POWERED BY WIND

The nordic defense has become more encouraging to the expansion of offshore wind in the Baltic Sea and Kattegat.

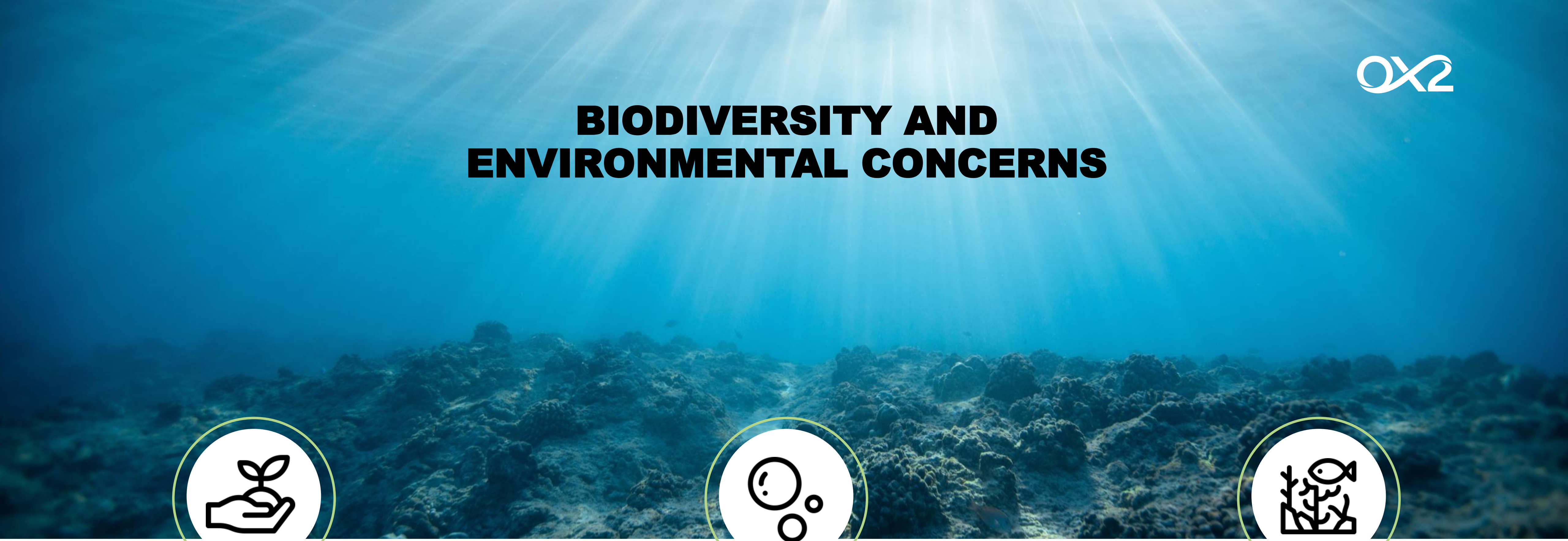
- ✔ Becomes less vulnerable with a diversified energy system, on and offshore.
- ✔ Expanded lines of defense are more protective
- ✔ The defense becomes self-sufficient in fossil free fuel
- ✔ Preparing for a hydrogen fleet
- ✔ A letter for regulation commissions the Swedish defense to enable the expansion of offshore wind

POWER TO X

With expanded offshore wind, Nordic countries will at certain times have a significant surplus of electricity. With Power-to-X technologies, this surplus can be converted into hydrogen, ammonia, synthetic fuel etc.

- **Enables green hydrogen as a power source for ships, airplanes, trucks and industries**
- **Enables new industries and operation in harbors and costal towns**
- **Allows for storage and transportation of energy**

BIODIVERSITY AND ENVIRONMENTAL CONCERNS



ENVIRONMENTAL CONCERNS

Sensitive locations are avoided. Screening and development always take place with great regard for wildlife and environmental interests.

OXYGENATION

As oxygen is a by-product of hydrogen production, each wind turbine can help oxygenate the seabed, and thereby contribute to healthier marine environments.

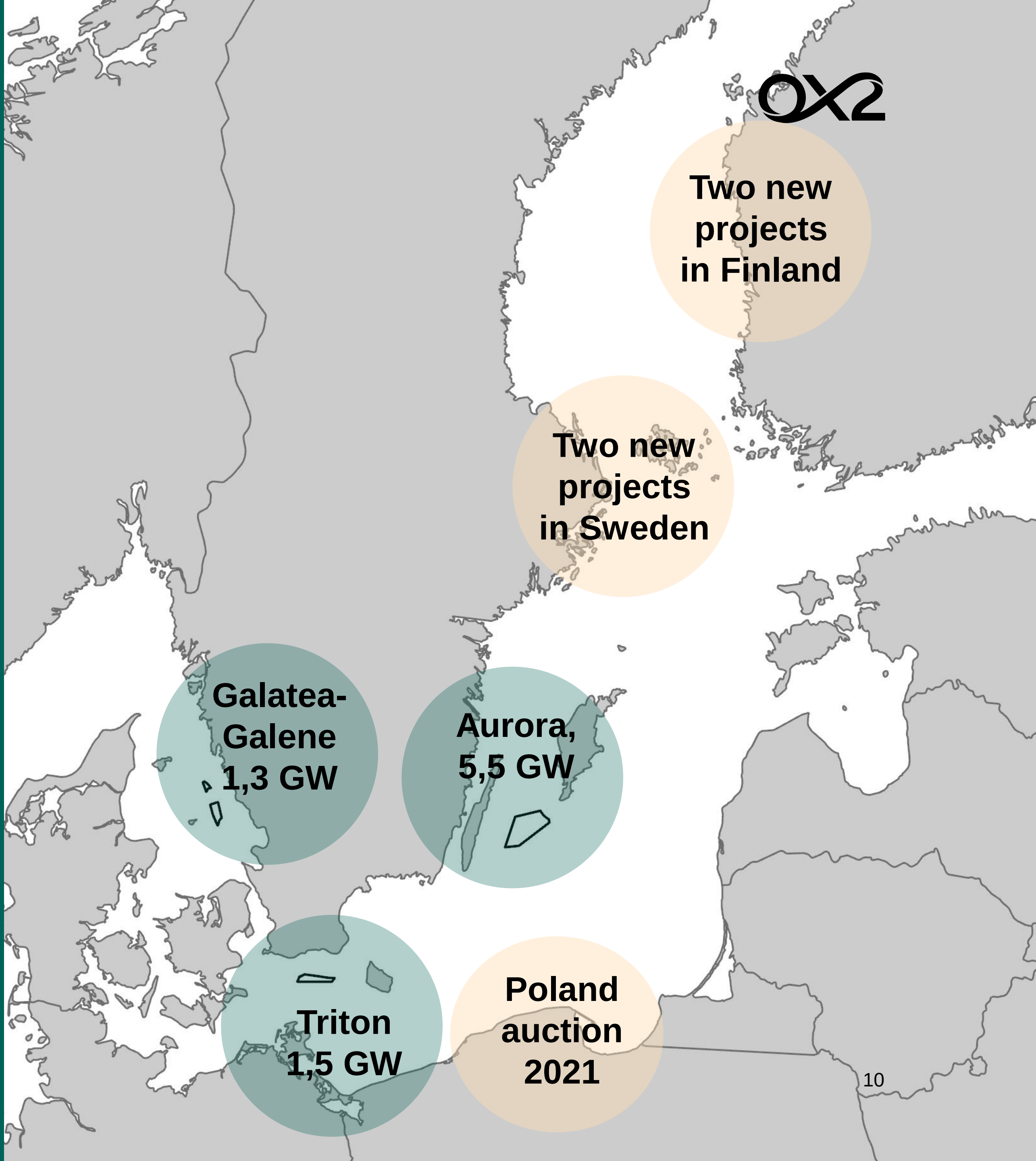
REEFS AND BANKS

Every offshore foundation provides the opportunity to create mussel and alga beds, with the capacity to purify water, provide a safe zone for fish populations and deliver healthy and ecological food for humans.

OX2'S OFFSHORE PIPELINE

OX2 targets to further accelerate our existing offshore portfolio while expanding with new opportunities in existing and new geographies.

- **50+ people team**
- **8,3 GW announced portfolio (three Swedish projects)**
- **Four new projects with started permitting work (two in Sweden and two in Finland)**
- **Ready to participate in 2021 seabed auction in Poland**
- **Expanding portfolio in existing as well as new geographies**



AURORA

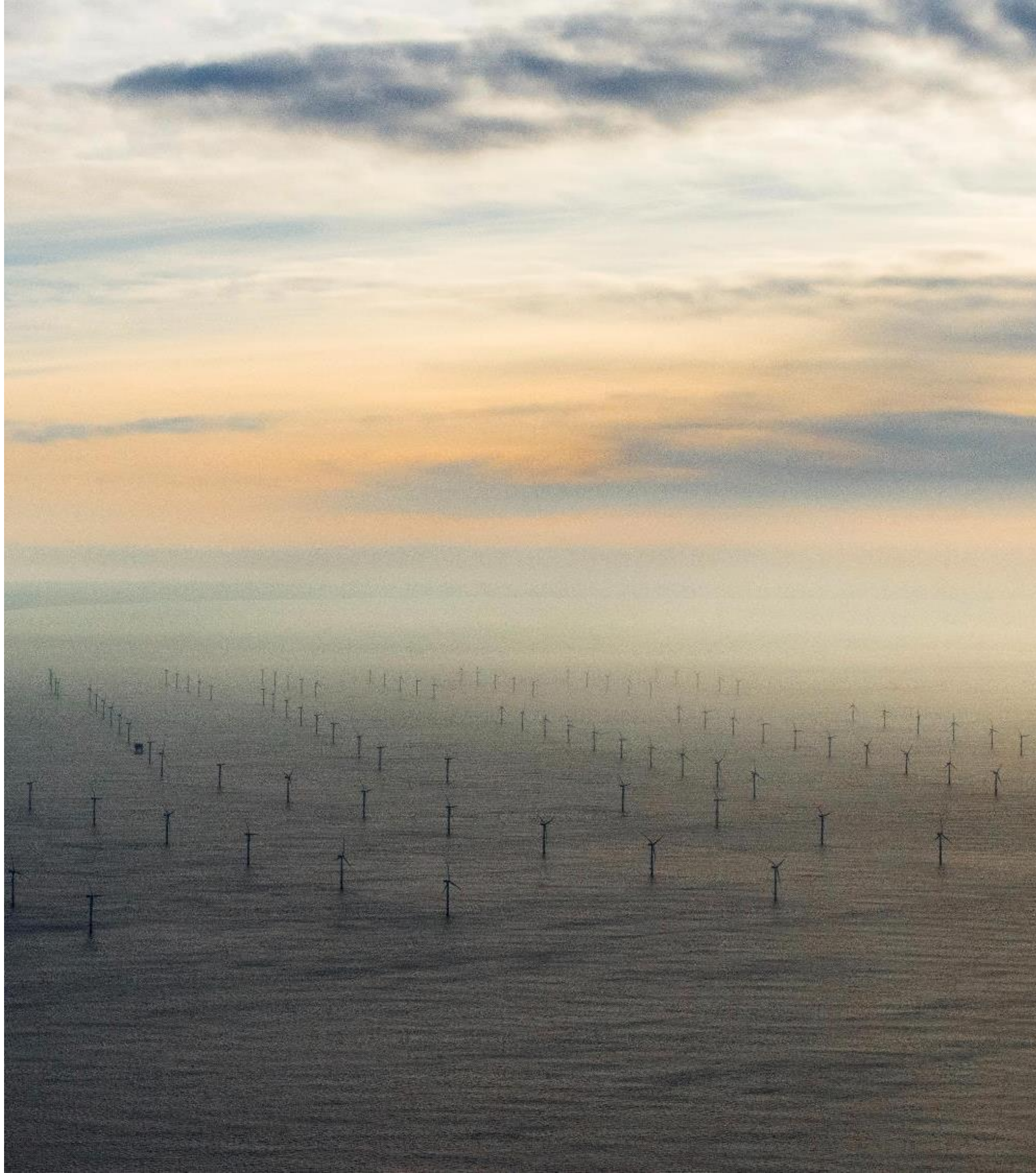
- East of Öland, South of Gotland
- 220 – 370 turbines, up to 370 m high
- 24 TWh/year ≈ 2 x O3 Oskarshamn ≈ 11 X Harsprånget ≈ 5 M households
- Up to 100,000 t of hydrogen production offshore possible within the park
- Grid connection at Nybro, Oskarshamn or Gotland
- Opportunity to build a Baltic grid
- Hydrogen demo in Burgsvik in collaboration with IVL Svenska Miljöinstitutet
- Puts Gotland on the Green Map

GALATEA-GALENE

- West of Falkenberg by the Halland coastline
- 68 – 101 turbines, up to 340 m high
- 2-3 km distance between turbines allow for outdoor life in the park
- Grid connection near Ringhals
- 6 TWh/year ≈ Ringhals 2 ≈ 5 x Porjus
- Puts Halland on the Green Map

TRITON

- South of Beddingestrand and Smygehuk by the Skåne coastline
- 68 – 129 turbines, up to 370 m high
- A direct answer to the severe lack of capacity in the region
- 7,5 TWh/year ≈ energy consumption for 1,5 M households
- Up to 100,000 t of hydrogen production offshore possible within the park
- Proximity to Trelleborg's RoRo port and Ystad's ferry node, where the demand for green electricity and fuels will only increase
- Puts Skåne on the Green Map



Next step
Create new ways of working
Buiness models
Legislation

THANK YOU!

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Transition to integrated electricity and hydrogen systems

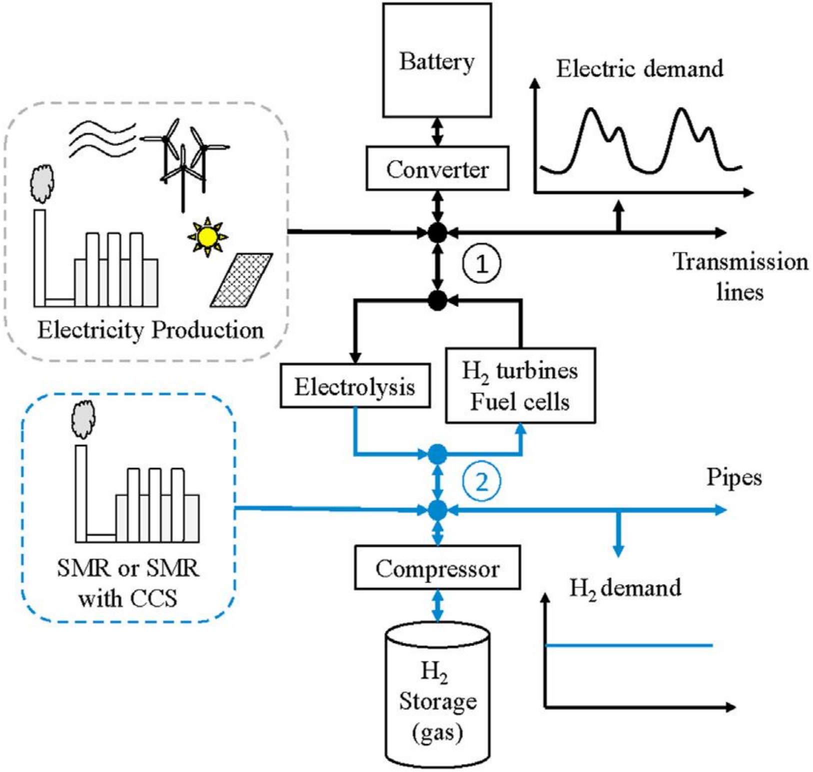
Magnus Korpås, Professor

Espen Flo Bødal, Phd Candidate

Dept of Electric Power Engineering

NTNU

Nordic TSO Strategy Webinar, Oct 2021



Hydrogen for mitigation of CO_2-emissions

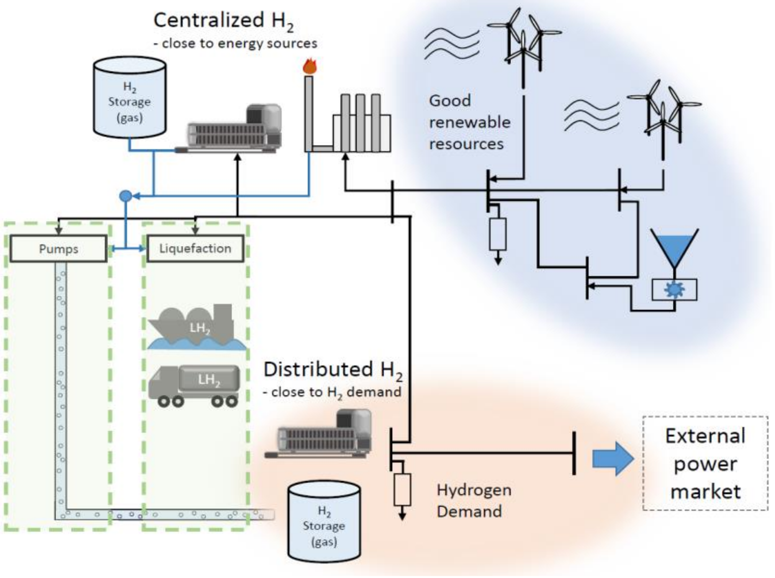
- Efforts to reduce global CO_2-emissions requires substituting fossil energy sources with clean alternatives
  - Significant electrification and integration of renewable energy
  - Hydrogen may be necessary to enable 100% mitigation of CO2-emissions in sectors such as transport and many industry processes
- 96 % of hydrogen produced today is from natural gas
  - Carbon capture and storage (CCS) can reduce the carbon footprint by 90%, from 9.26 to 0.93 kg CO_2/ kg H_2
  - Must be centralized due to the CCS
- Hydrogen can also be produced by electrolysis using electricity from renewables
  - Zero plant emissions
  - Costs of wind and solar has dropped significantly the last years
  - Can be both centralized and distributed
  - Two main technologies: PEM and Alkaline

Electricity-hydrogen systems research background

- Phd-thesis Magnus Korpås (2004)
  - Distributed Energy Systems with Wind Power and Energy Storage, NTNU.
  - Statkraft collaboration.
- Phd-thesis Christopher Greiner (2010)
  - Sizing and Operation of Wind-Hydrogen Energy Systems, NTNU.
  - Statkraft+Equinor Collaboration.
- Phd-thesis Espen Flo Bødal (2021)
  - Hydrogen Production from Wind and Hydro Power in Constrained Transmission Grids.
  - SINTEF+Equinor mm collaboration.
- NTNU-MIT Collaboration (ongoing)
  - Modelling and Optimizing Integrated Electricity-Hydrogen Systems

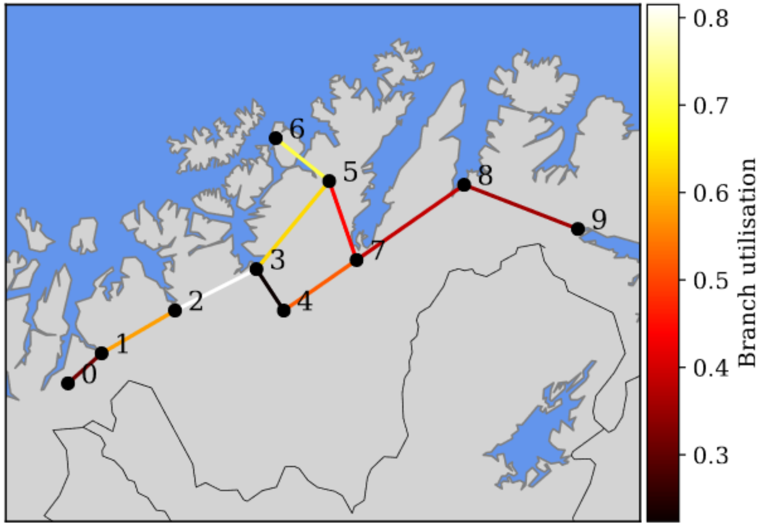
Pathways for serving different levels of hydrogen demand

- Often regions with good renewable resources are located far away from the energy demand
- Hydrogen can be produced:
  - Centralized - close to the energy source, either from natural gas or electricity and transported by pipes, trucks or ships
  - Distributed - from electricity close to the energy demand
- How should the system develop for different levels of hydrogen demand?
  - Where would the hydrogen be produced?
  - From which energy source would hydrogen be produced? Natural gas or electrolysis?



Case Study: Northern Norway

- Existing LNG facility
- Suitable site for H2 prod from NG
- Very good wind potential
- Some existing hydro power
- Limitations in transmission grid
- Liquification alone requires significant electric power



- Electrolyser options

Maximize electrolyzer utilization (and minimizing need for hydrogen storage)

OR Install overcapacity in electrolyser and hydrogen storage (Increase flexibility)

Model of regional power system

- Centralized optimization
  - Maximize profit from power exchange
  - Minimize investment cost
  - One year horizon, hourly time stages
- Storage balance
  - Hydro power and hydrogen storage
- Energy balance
- DC power flow
  - Common power system linearization method used by system operators
- Max and min capacities
  - Power plant capacities, electrolyser and storages

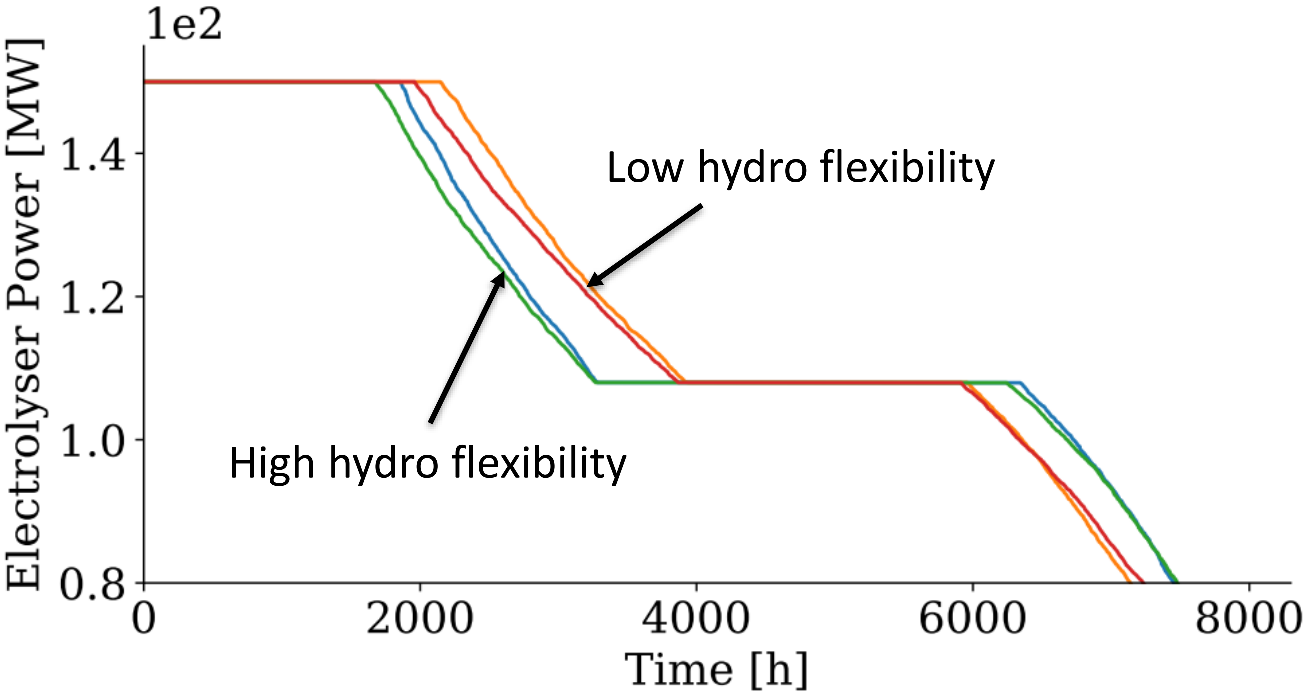
GUROBI OPTIMIZATION

python™

Flexible or continous H2 production in contstrained power grids?

- Local H2 demand is a strong investment signal for more wind
- Even flexible H2 production leads to **high degree of H2 storage utilization** and requires additional electrolysers
  - From 108 MW to 130 MW capacity for 10 hour storage)
- H2 Flexibility is important to **avoid load curtailment** due to the new demand from the H2 system (liquification+electrolysis)
- H2 Flexibility helps **integrate more wind power** without high levels of curtailment
- A strong grid favors continuous H2 production

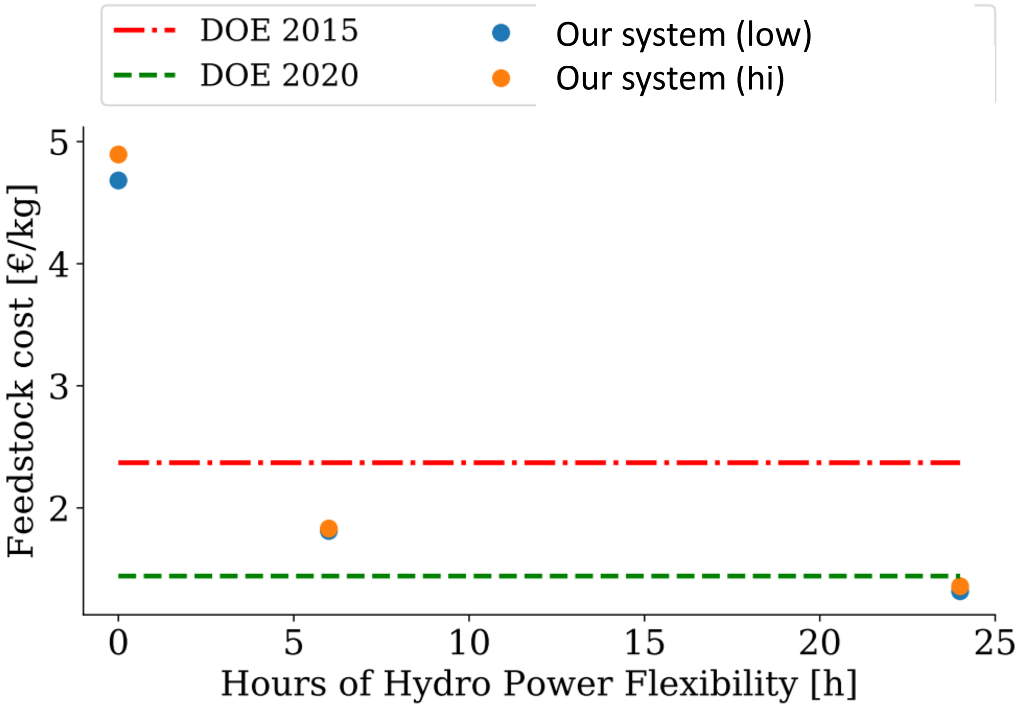
More hydro flexibility gives more stable H2 production



Flexible hydro production reduces H2 costs in constrained grids

-> Reduces the need for costly H2 storage

	Current	Future	DOE - 2020
Capital [€/kg]	0.72	0.31	0.41
Feedstock [€/kg]	1.32	1.32	1.46
Fixed O&M [€/kg]	0.53	0.26	0.21
Total [€/kg]	2.57	1.89	2.08

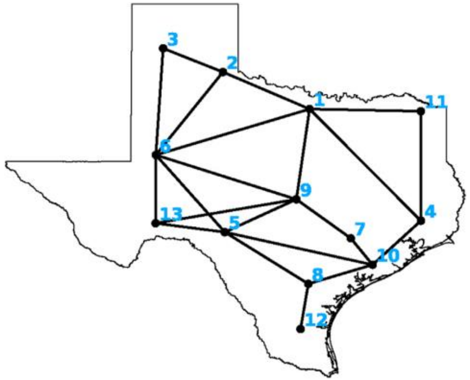


Wind-hydro-hydrogen

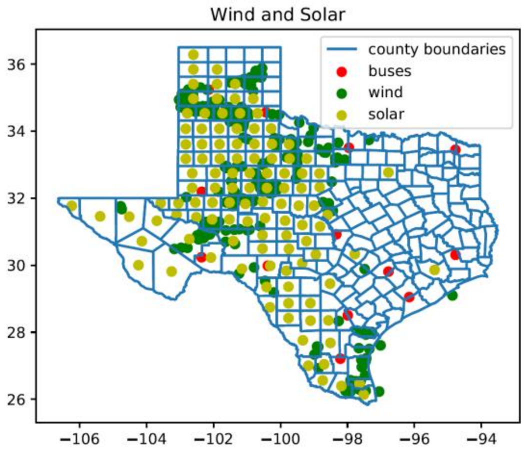
- Hydrogen makes wind more profitable -> more investments
- When hydro power is flexible
  - Total system costs and prices are lower
  - Hydrogen production is cheaper about 12-13 %
  - Feedstock cost is fulfilling to DoE targets with more wind power development and regional grid expansions
- When hydro power is not flexible:
  - Hydrogen plant is more important source of flexibility
  - H_2 storage is used more frequently and is more valuable
  - More H_2 storage is beneficial for reducing system and balancing costs

Case study: Texas

- We model the Texas electric power system 2050 using a 13-bus system with transport constraints [4]
- The electric power system is dominated by natural gas
- Significant wind power is developed the latest years
- Texas has high potential for development of renewables
  - Located in the north-west or south
  - Most energy demand is in the east
- Already high H2 demand in industry
- H2 demand scenarios for transportation [0.7 7.0 35.0] mmt/yr
  - Corresponds to [23 230 1133] TWh/yr LHV
  - From NG w/wo CSS and/or EL
- Electricity demand 492 TWh (42% increase from 2018)
- Tech costs mainly from NREL 2050 scenarios



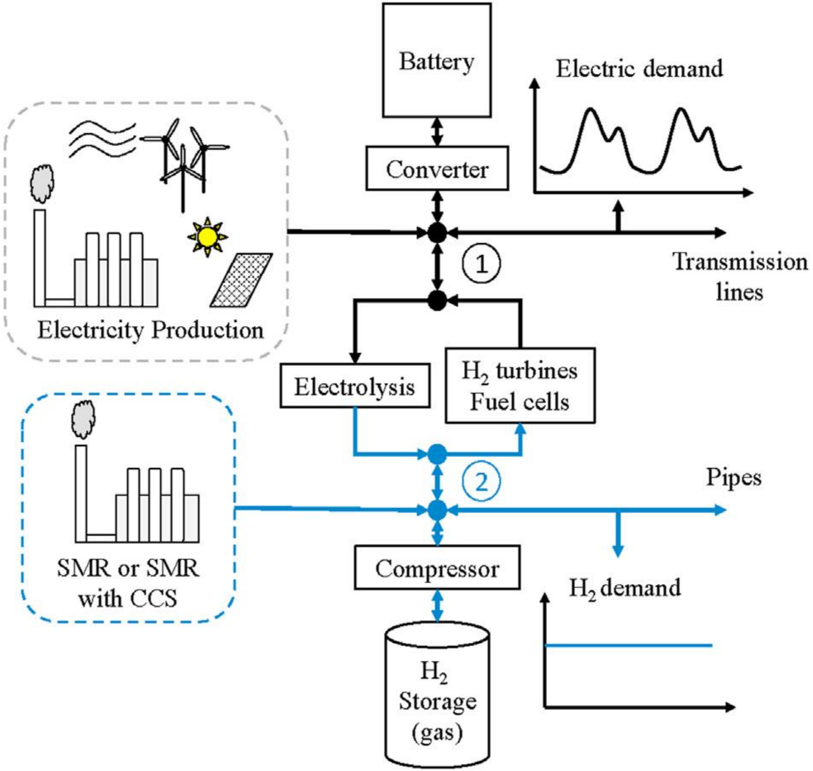
13-bus model of Texas power system [2]



Potential wind and solar sites in Texas

[4] M. Majidi-Qadikolai and R. Baldick, “Stochastic Transmission Capacity Expansion Planning with Special Scenario Selection for Integrating n-1 Contingency Analysis,” *IEEE Trans. Power Syst.*, 2016.

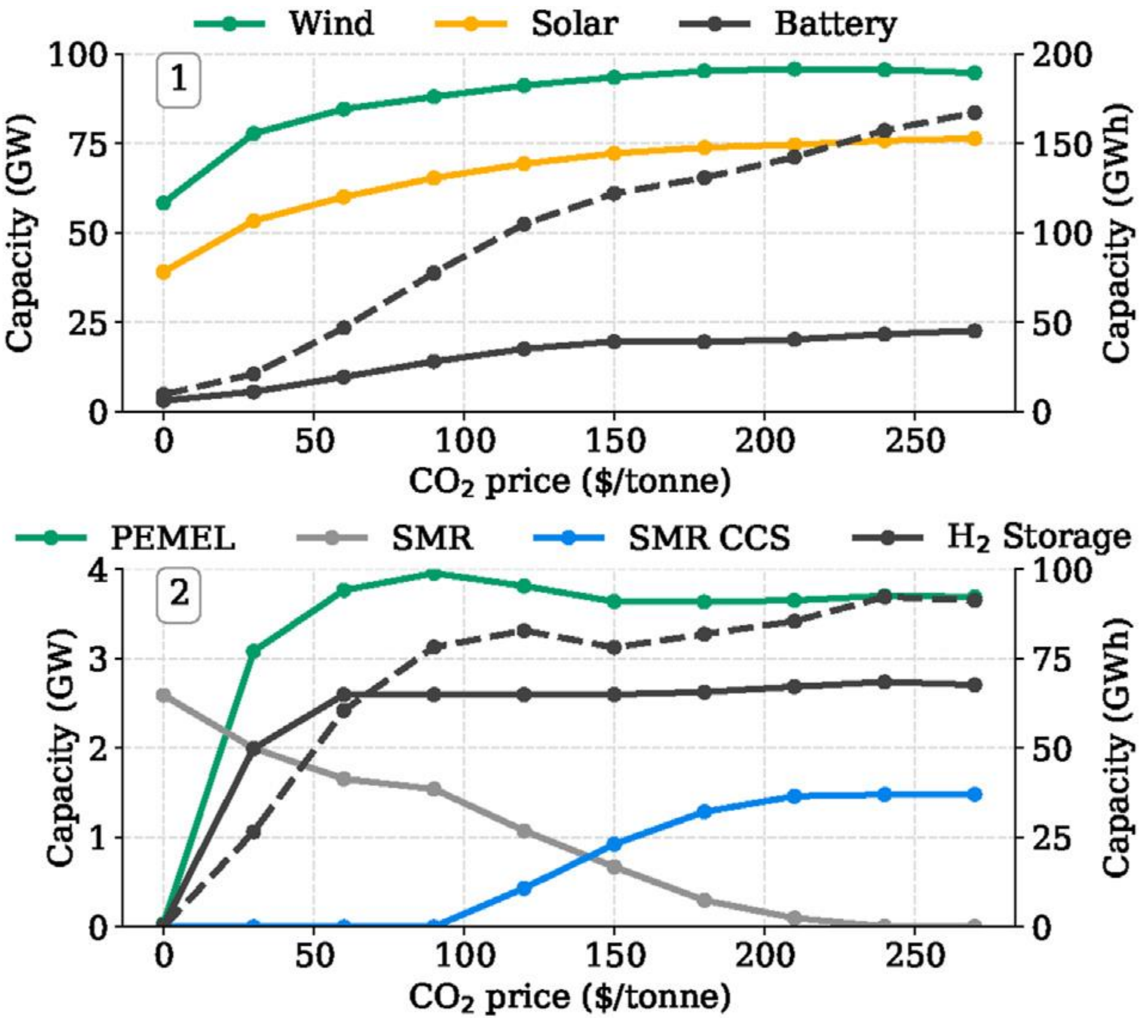
Optimization model for EL-H2 system



- Minimize sum of investment, retirement, fixed and variable operation cost
- Separate power and energy capacities of storage
- Simplified power grid and H2 grid representation
- 1 year with 1hour timestep.
- H2 demand and power demand both have VOLL cost

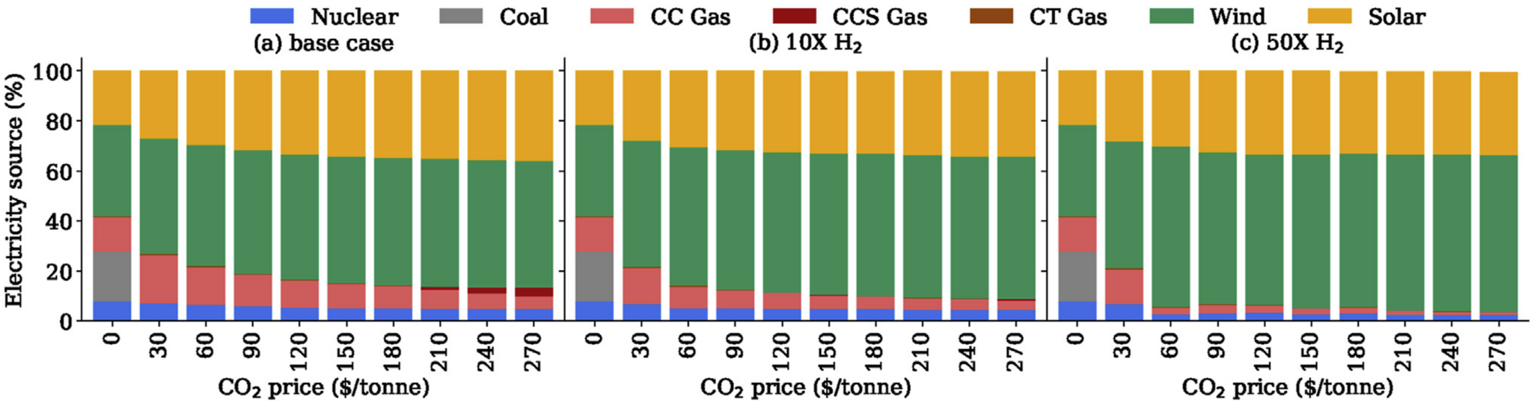
- Programmed in Python/Pyomo

Capacity development



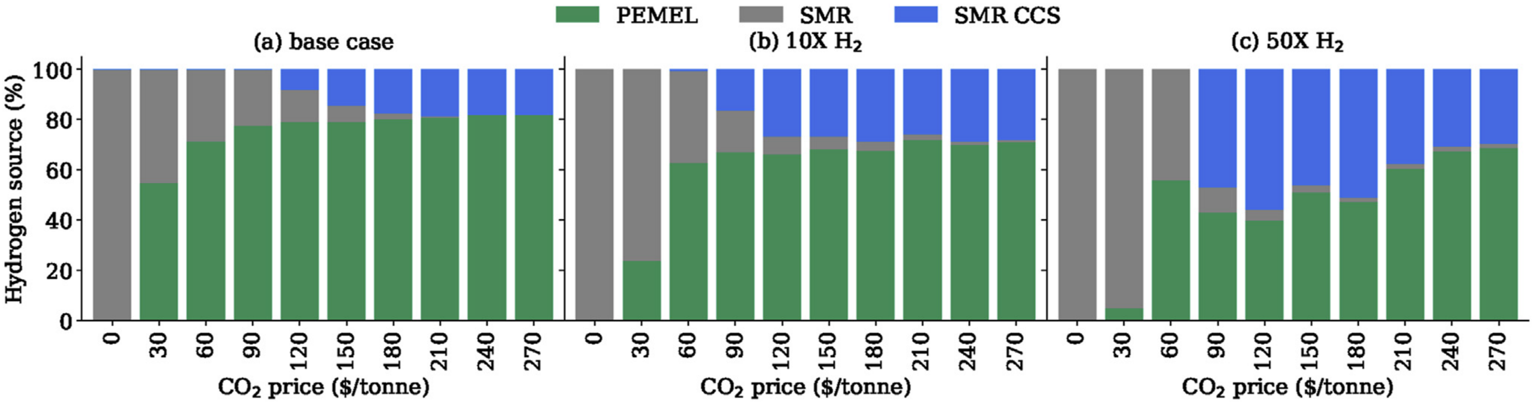
NTNU

Supply mix



(1) Electricity produced by technology for the different CO_2 prices and H_2 demands.

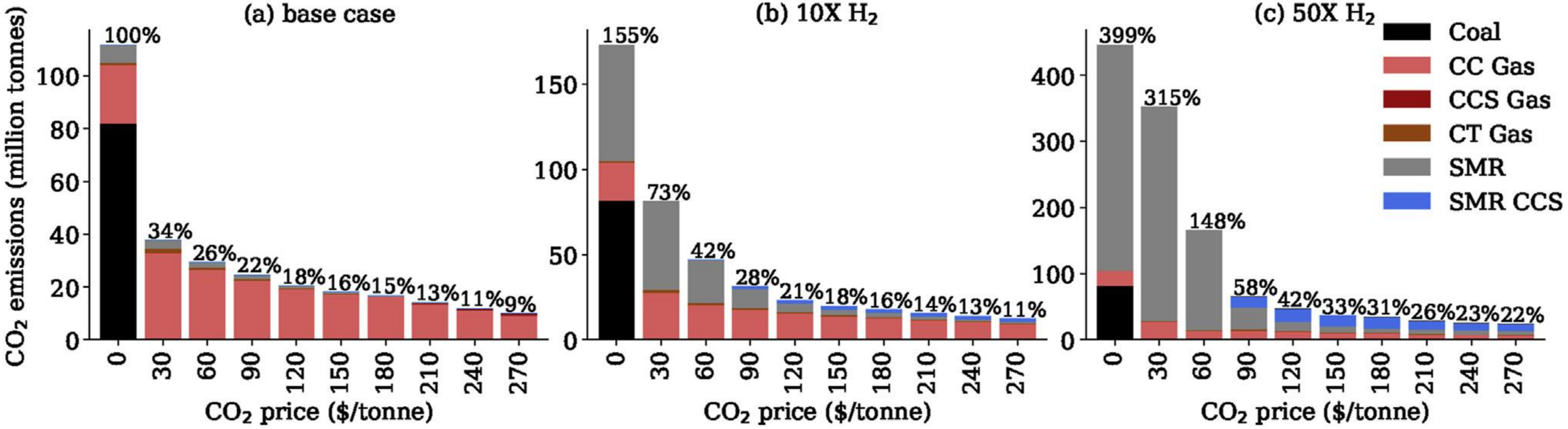
EL



(2) Share of H_2 demand by production technology for the different H_2 demand scenarios.

H2

CO2 emissions



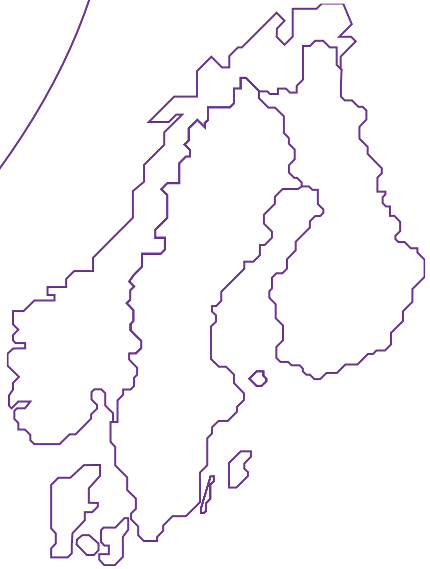
Conclusions from Texas study

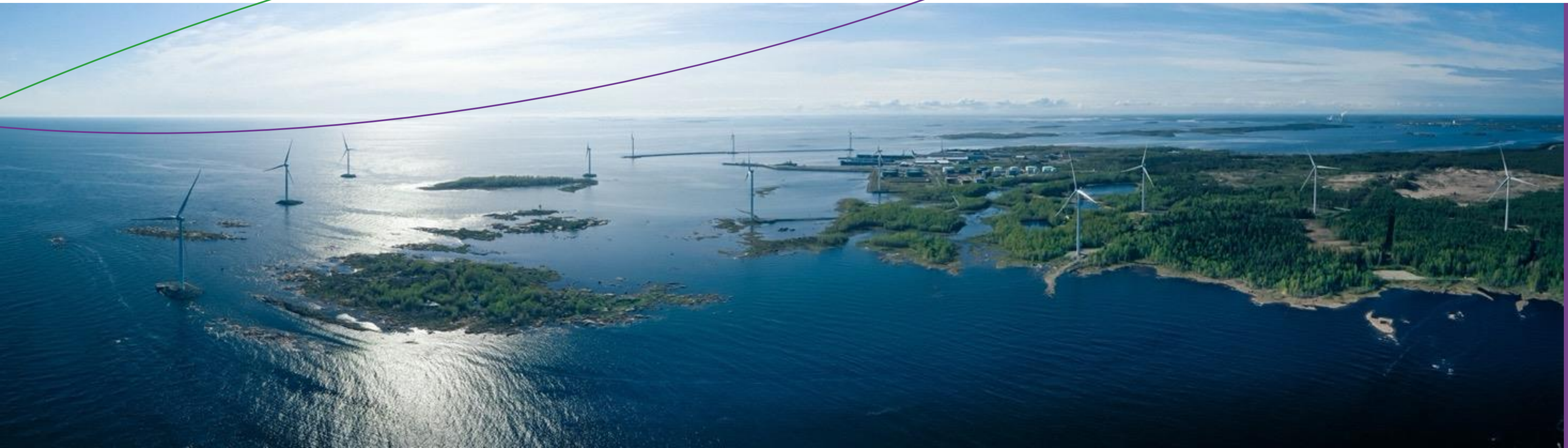
- Demand-side flexibility provided by hydrogen production allows for phasing out of natural gas for electricity production.
  - Higher RES shares in the generation mix
  - Hydrogen deliver flexibility on longer time-scales than batteries and allows for greater renewable shares at lower CO_2 prices
  - More hydrogen demand results in less need for batteries
  - Re-electrification of hydrogen in fuel cells does is limited due to high costs and low-round-trip efficiency
- CCS is profitable at lower CO_2 prices for natural gas-based hydrogen production than for natural gas-based electricity production.
- Higher CO_2 prices favor electrolytic hydrogen, while higher hydrogen demands favor hydrogen from natural gas with CCS.
- Hydrogen is used as energy storage and for transporting energy from surplus to deficit regions (west to east in Texas)

Asta Sihvonen-Punkka

Nordic TSO Strategy Steering Group

Conclusions and next steps





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Take-aways

- The strategy will be a guiding document for the Nordic TSO projects in the coming years
- Power and energy security
- Åland!
- Financing of the grid to enable offshore wind development
- How to ensure cost-efficiency as heavy investments are needed?
- Inclusion of gas TSOs? Next step? Long-term storage of energy from wind electricity? Hydro…
- Available transmission capacity between and inside countries
- Both speed and scale need to be increased! Need to create new ways of working
- Baltic Sea and North Sea regions in the focus
- Important to include research into the strategy work and discussions

Final steps of the strategy process

- The inputs received will be analysed and the document amended accordingly
- The approval of the strategy document is planned to take place at the beginning February 2022.
- The strategy document will be published on the TSO websites.
- **A webinar covering both strategy and the Solutions report will be organized in spring 2022 (date to be published later).**

Thank you for your participation and contributions!

ENERGINET Statnett FINGRID SVENSKA KRAFTNÄT