Danish Outlook

Swedish Hydrogen Development Center

Co-financed by:

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When listening let's try to

1. Keep our microphones off
2. Keep our cameras off
3. Place questions in the chat or raise your hand

Webinar

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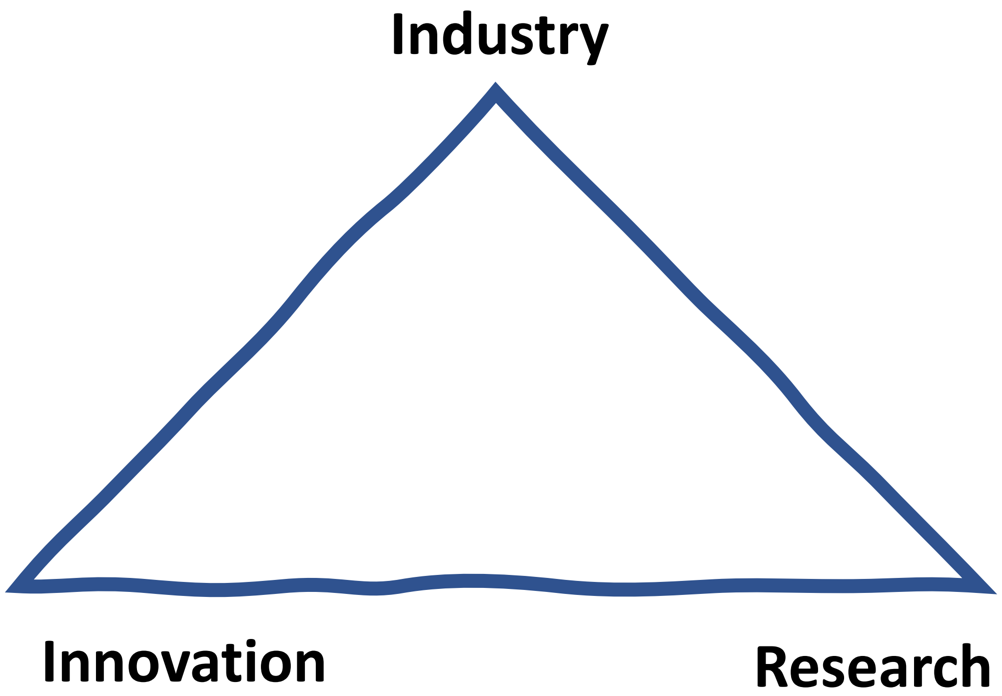
It is worth noting that CEA focuses a significant proportion of its research on defence.

SHDC - network

- Industrial hydrogen and industrial networking in focus.
- SHDC links Industry – Innovation – Research.
- SHDC address the whole value chain, from start ups and technology providers to industrial end users.
- SHDC enables innovation: Technology – Business – System – Policy.



- Workshops
- Webinars
- Newsletter
- Networking

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Events

Events

- Luleå: 24-25 January: *Building the Nordic Hydrogen Economy*
- Online: 21 February : *Hydrogen development in the U.S and Canada*
- Online: 16 May: *Safe hydrogen installations*
- Online: 2 June: *Danish Outlook*

- Stockholm: 18-19 October. *Future in hydrogen production*
- Online: Academic Roadtrip

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Agenda

Danish hydrogen strategy and the role of Energinet Energinet is the TSO in Denmark, i.e. the counterpart to Svenska Kraftnät. However, the task of Energinet includes electricity and gas transmission. We will hear about the Danish Hydrogen Strategy, a forecast on electricity production, and the role of Energinet in this development.	**Energinet** *Nicolai Sørensen, Senior Energy Strategy Advisor*
Danish hydrogen business outlook Business Sweden is jointly owned by the Swedish Government and business sector to support Swedish business development globally. Among their activities is business intelligence and analysis. Let's listen to their findings on the Danish hydrogen sector.	**Business Sweden** *Klas Arvidsson, Project Manager*
The value chain of hydrogen Örsted has made an impressive journey, from a fossil-based energy company to a forerunner in renewables. In Sweden, they have engaged in Liquid Winds project Flagship One. What are their P2X ambition, view on Denmark as a P2X market and their Danish P2X projects?	**Örsted** *Michael Simon Aagaard, Head of Business Development, Power-to-X, Europe*
Short break	
Wind power and hydrogen in the Danish and European context Eurowind is an entrepreneurial wind power developer. How will hydrogen fit in to the wind power development?	**Eurowind** *Henrik Lykke Sørensen, Head of PtX Competence Center*
Danish Energy Islands How will the concept of "energy islands" and especially Bornholm Energy Island support the development? We will get a better understanding of "energy islands" and on Bornholm Energy Islands' effect on and interaction with the local society.	**Bornholm Energi & Forsyning** *Mette Skøt, Project developer · Strategy & Business Development*
Open dialogue with presenters	

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Contact

Contact information

Johan Sandstedt

Johan.Sandstedt@ri.se

+46 72 554 10 80

Anna Tibbelin

Anna.Tibbelin@ri.se

+46 72 356 80 00

Hampus Piehl

hampus.piehl@ri.se

+46 73 050 24 22

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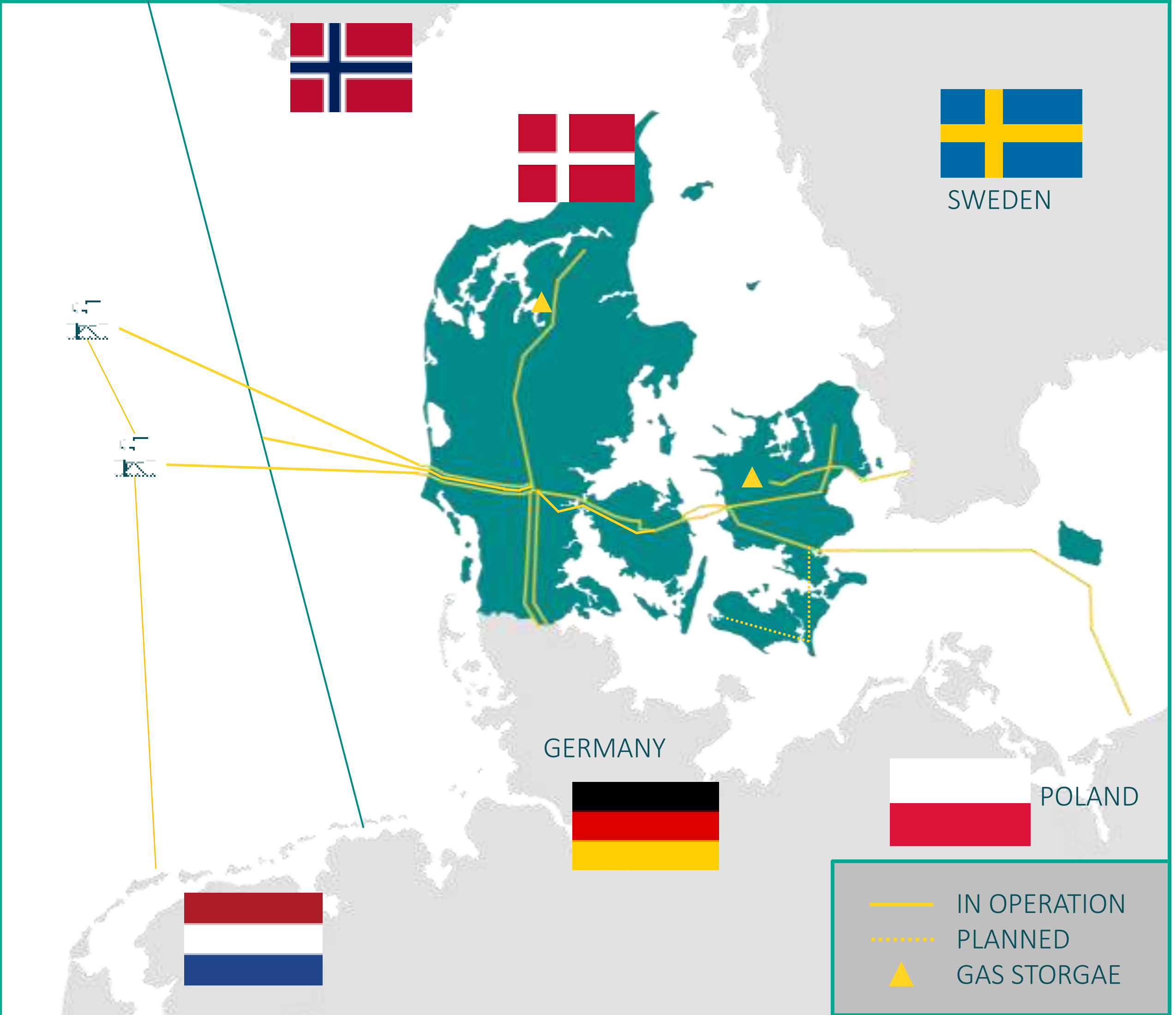
The Danish case

Hydrogen and system integration

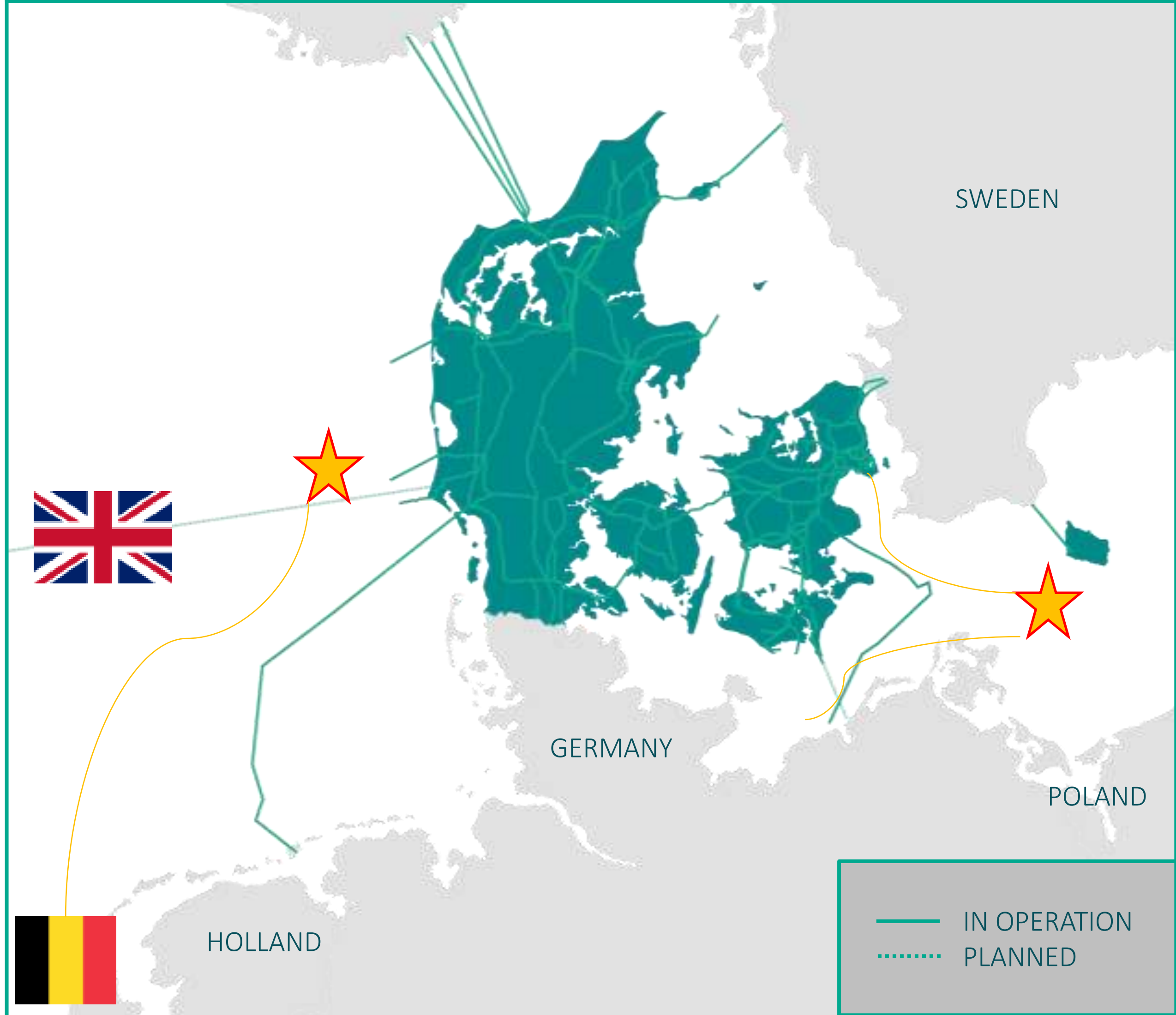
Nicolai Sørensen, Senior Advisor, Energinet System operator

INFRASTRUCTURE

GAS TRANSMISSION SYSTEM

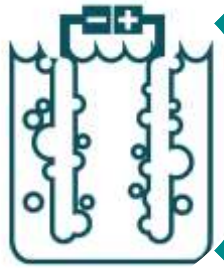


ELECTRICITY TRANSMISSION SYSTEM



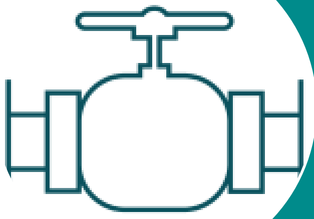
NATIONAL PTX-AGREEMENT (2022)

Highlights



4-6 GW electrolysis in 2030

Net export of green energy



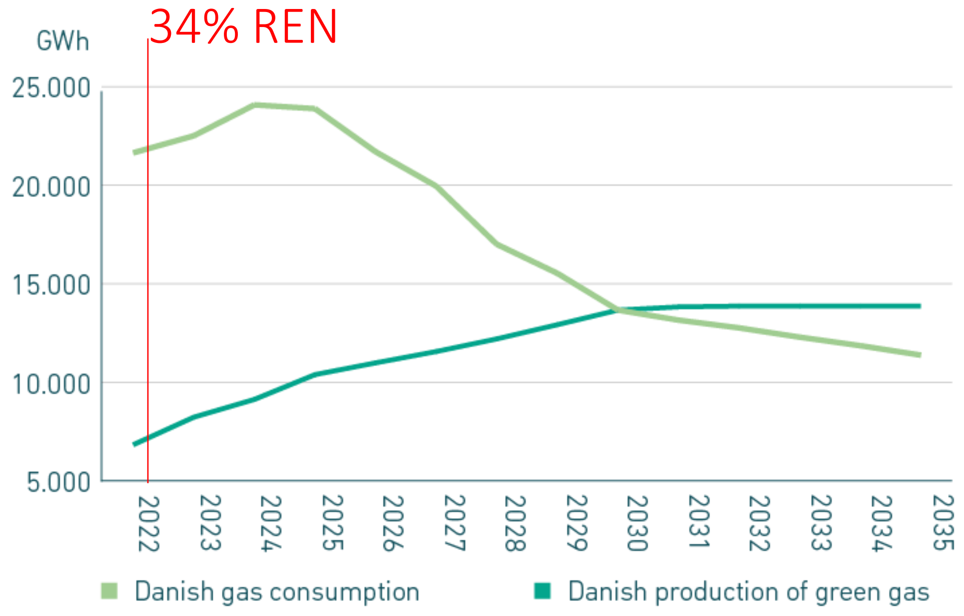
H2-infrastructure

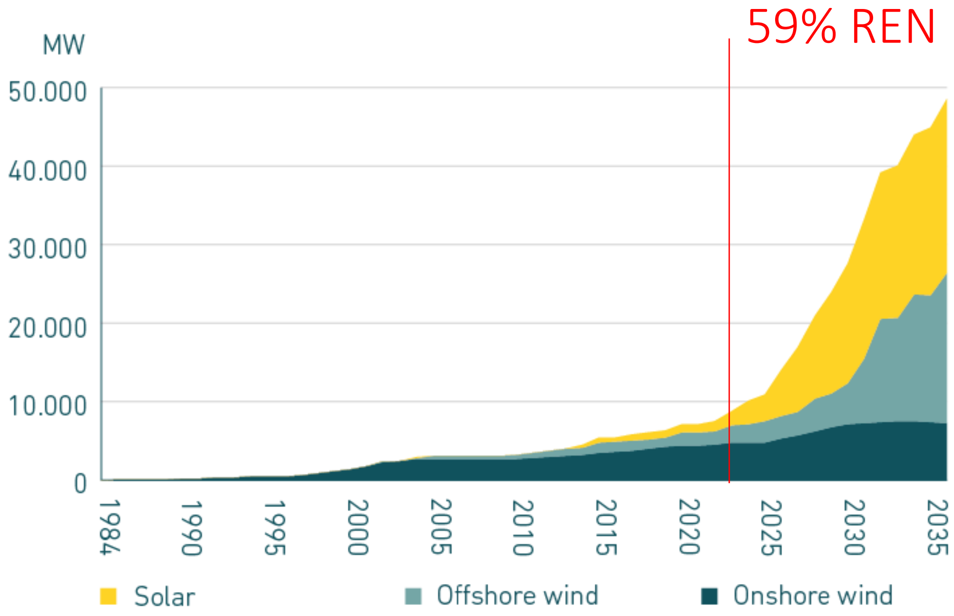
Holistic energy system planning

STRATEGY

ENERGY IN TIME

NEW GOALS – HIGHER PACE





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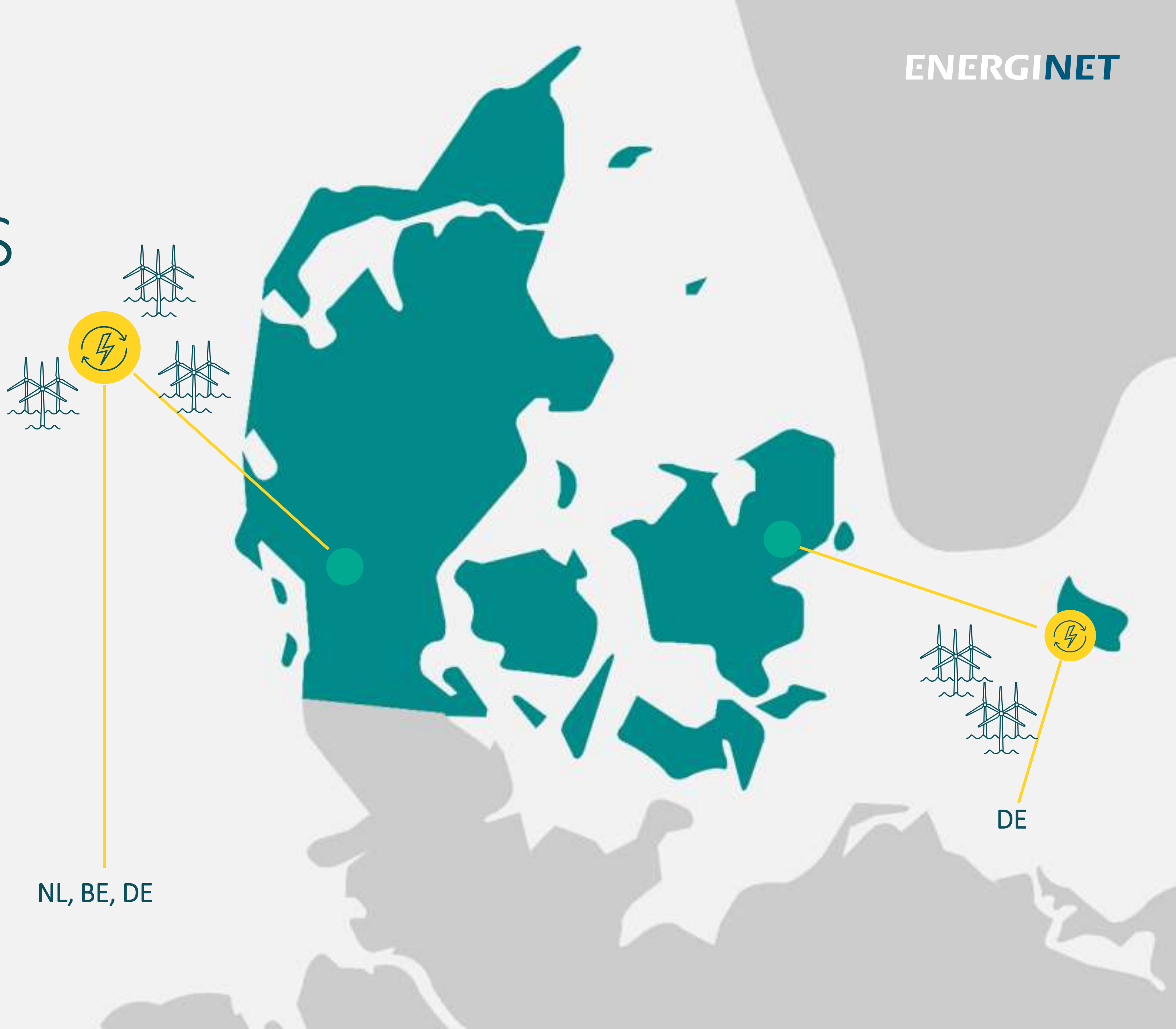
WORLD’S FIRST ENERGY ISLANDS

The North Sea:
3 GW offshore wind by 2033, later 10 GW.

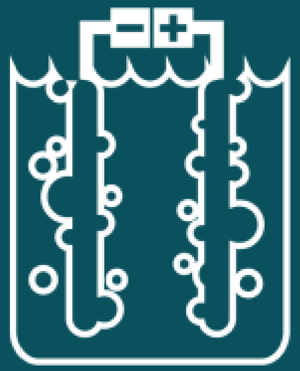
The Baltic Sea:
3 GW offshore wind by 2030.



ENERGY ISLAND

ONSHORE CONNECTIONS, ALTERNATIVES

NEW OFFSHORE WIND FARMS



THE NEED FOR SYSTEM INTEGRATION

CHANGES IN THE PROVIDER PORTFOLIO

ENERGINET

HIGH RES

Renewables
Dominating direction : ↓↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

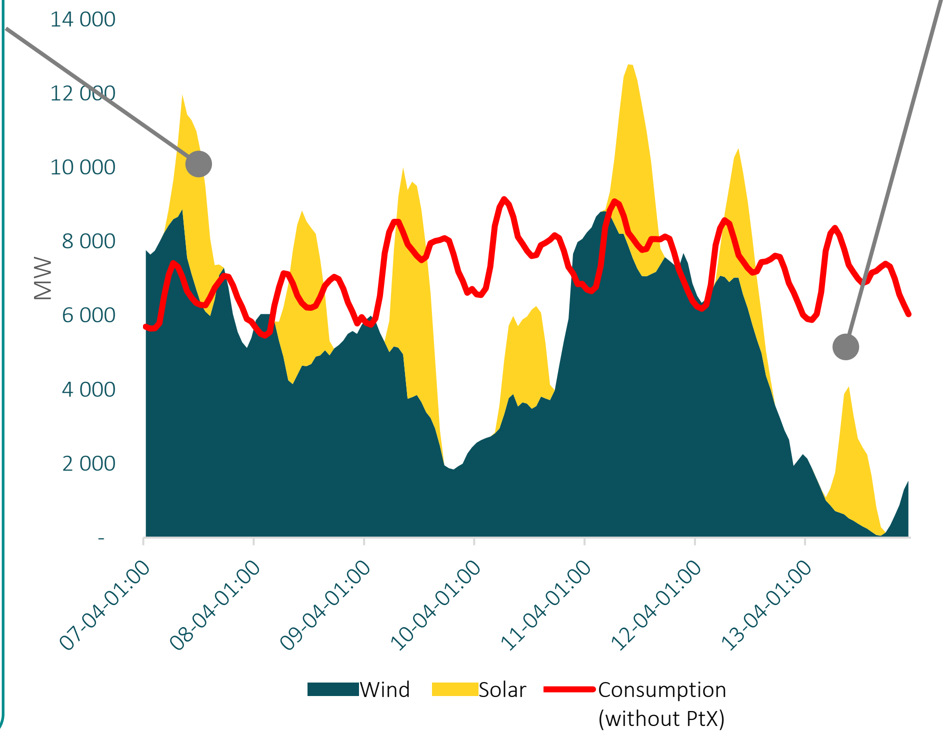
Ptx
Dominating direction: ↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

Classic consumption (flexible)
Dominating direction: ↑
Frequency services: Fine
aFRR: Limited energy
mFRR: Limited energy

Batteries (discharge)
Dominating direction: ↓
Frequency services: Fine
aFRR: Limited energy
mFRR: Limited energy

Electric boiler
Dominating direction: ↓↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

Heat pumps
Dominating direction: ↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine



LOW RES

CHP's
Dominating direction : ↓↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

Heat pumps
Dominating direction : ↑
Frequency services: Fine
aFRR: Fine
mFRR: Fine

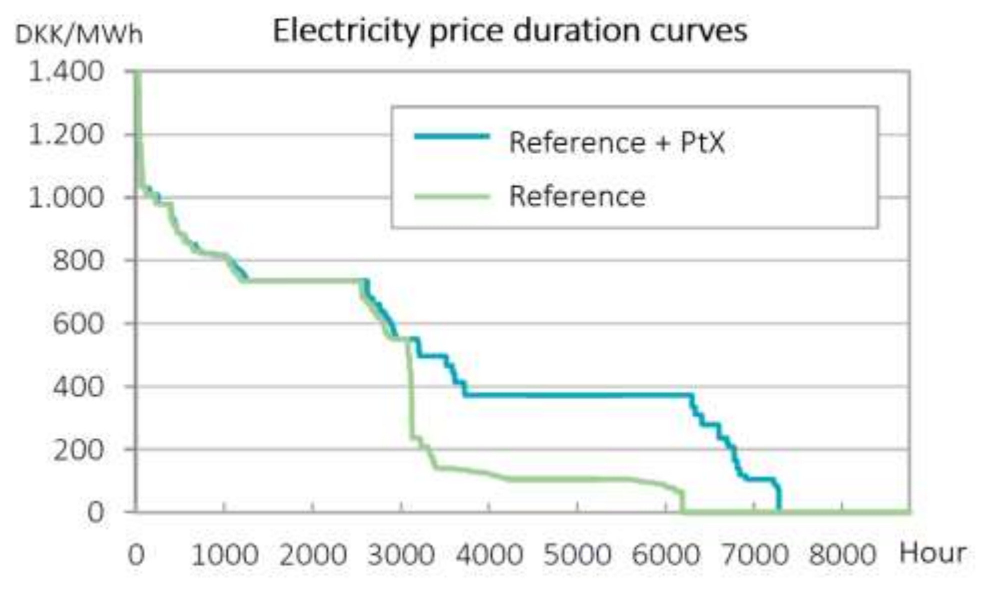
Classic consumption (flexible)
Dominating direction : ↑
Frequency services: Fine
aFRR: Limited energy
mFRR: Limited energy

Batteries (discharge)
Dominating direction : ↑
Frequency services: Fine
aFRR: Limited energy
mFRR: Limited energy

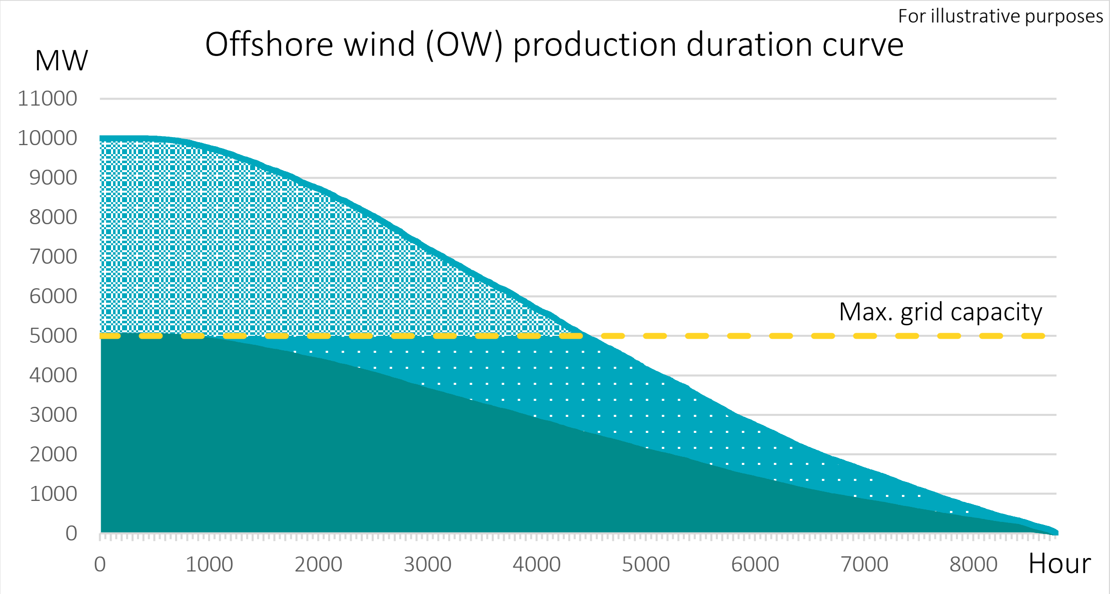
Electric boiler
Dominating direction: ↓
Frequency services: Fine
aFRR: Fine
mFRR: Fine

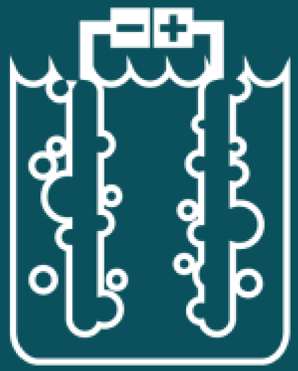
POWER-TO-X LEADS TO MORE RENEWABLE ENERGY

PTX IS AN EFFECTFUL MEAN OF "LIFTING" THE ELECTRICITY PRICE IN HOURS WITH A HIGH SHARE OF RENEWABLE ENERGY PRODUCTION (HEDGING)



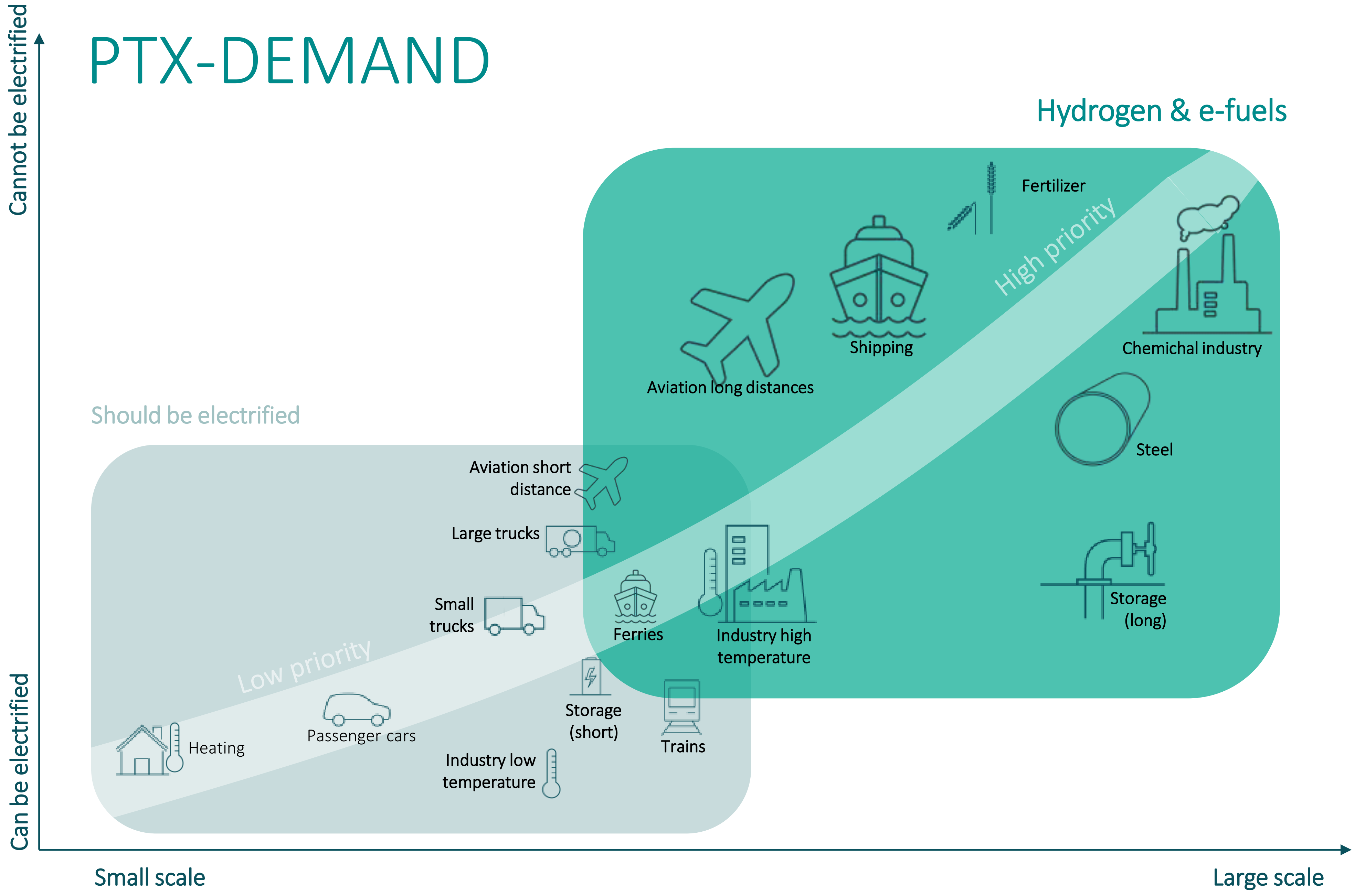
... AND INCREASE THE SHARE OF FLUCTUATING RENEWABLE ENERGY INTEGRATED TO THE ELECTRICITY SYSTEM



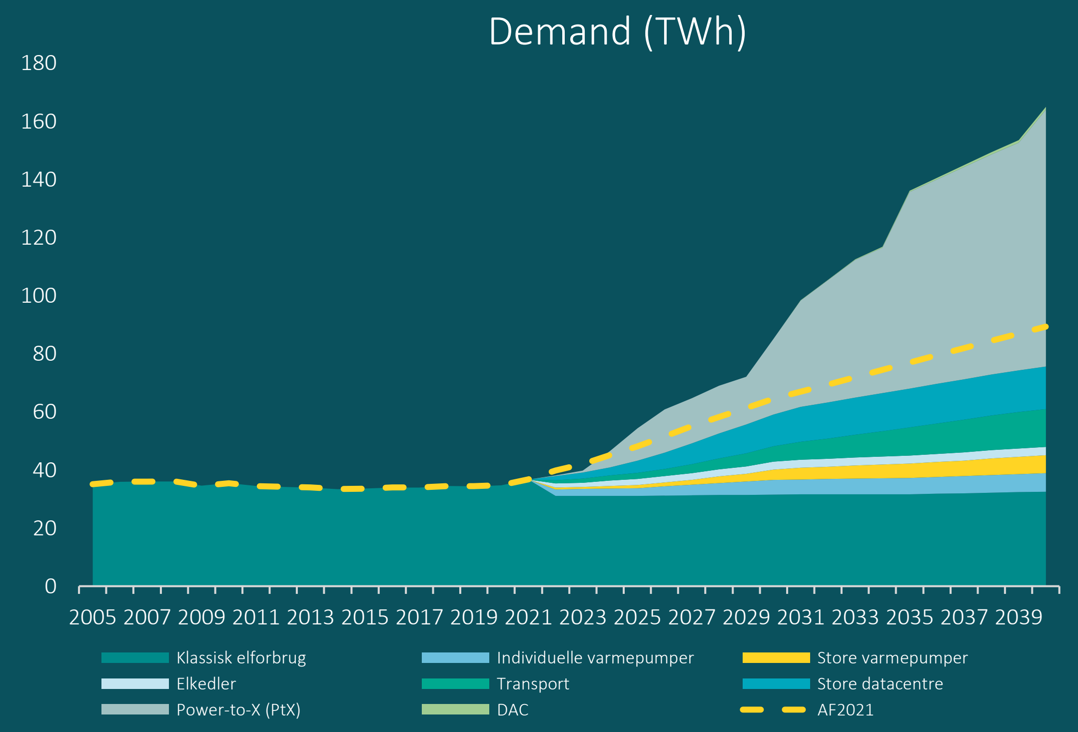


PTX-POTENTIALS IN DENMARK

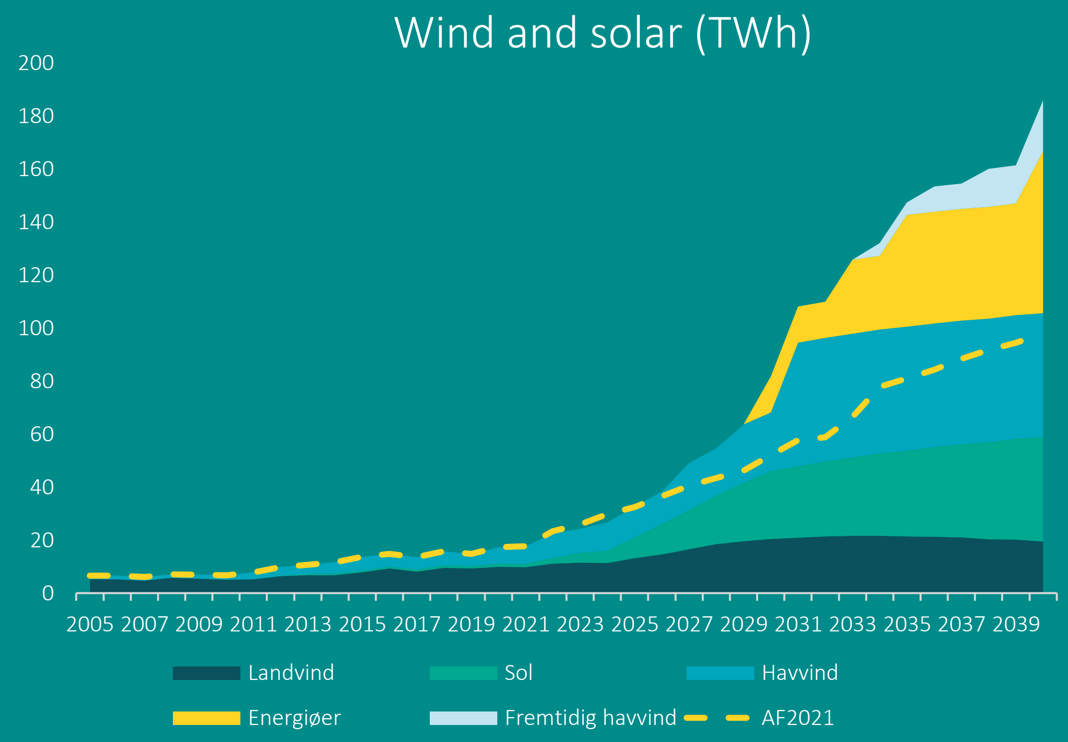
PTX-DEMAND


Cannot be electrified
Can be electrified
Small scale
Large scale
Hydrogen & e-fuels
Should be electrified
High priority
Low priority
Fertilizer
Shipping
Aviation long distances
Chemichal industry
Steel
Storage (long)
Aviation short distance
Large trucks
Small trucks
Ferries
Industry high temperature
Storage (short)
Trains
Heating
Passenger cars
Industry low temperature

ELECTRICITY DEMAND



RES-PRODUCTION



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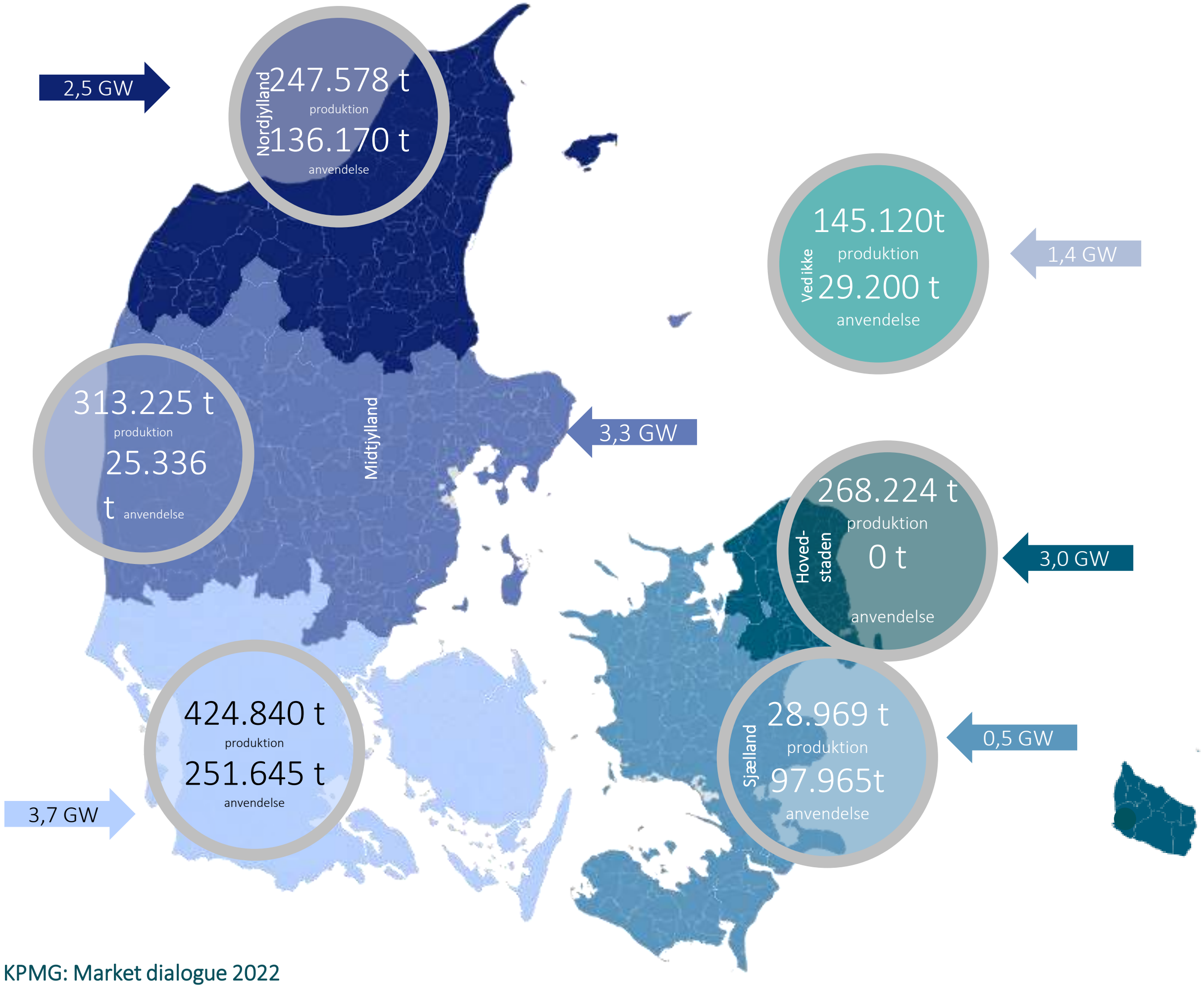
MARKET SURVEY 2022

- 87 % of H2 to be transported via pipelines in 2030
- The 8 largest production projects (with +1 GW electrolysis capacity) expects to export the hydrogen via pipelines.
- Electrolysis capacity in DK in 2030 if all the projects are realized: 14 GW, producing 1,4 mt. H2/year
- H2 network significantly improves business cases
- 50% of the expected H2 production in 2030 is unlikely to be realized without a H2 network
- Lack of knowledge about H2 infrastructure as the greatest uncertainty in relation to further investment decisions.

Expected geographical allocation of demand and production centers in 2030

Production, demand and electrolysis capacity (tons H2)



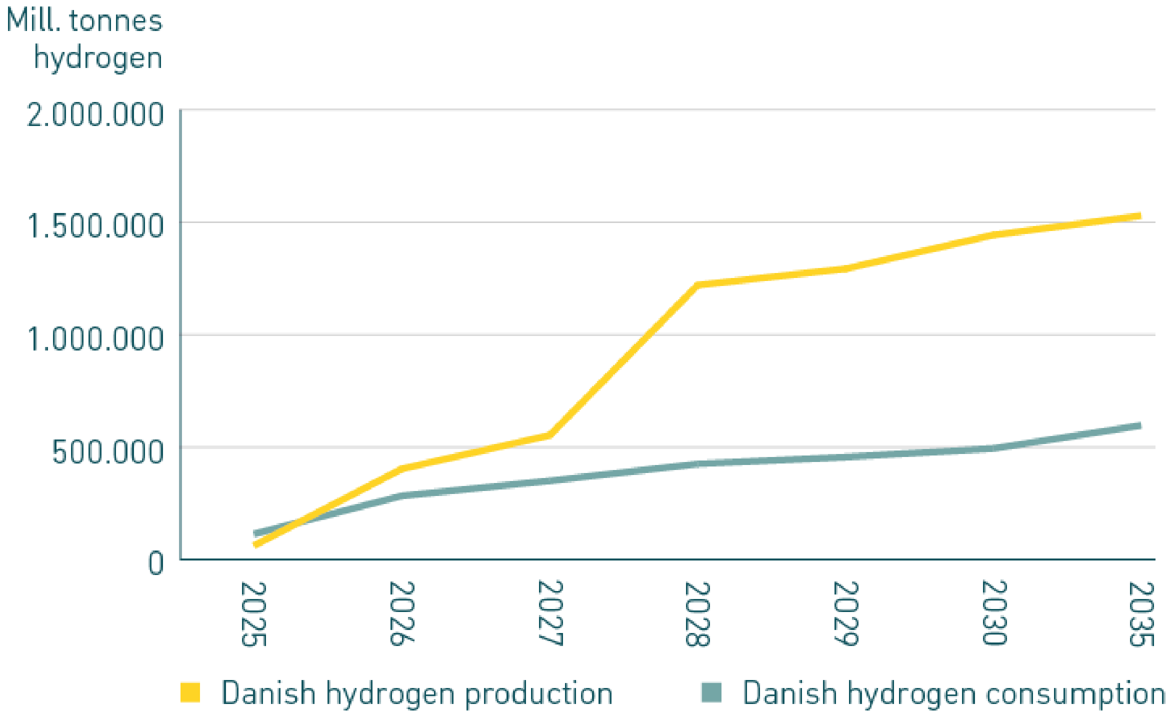
KPMG: Market dialogue 2022

HYDROGEN FOR EXPORTS

Hydrogen is an important element in a green energy system characterised by security of supply.

Hydrogen also has a large potential for exports to Europe.

This presupposes that it can be traded across borders.



H_2 Network Germany & Denmark

Hyperlink 3 (PCI) + Danish backbone West (PCI)

March 2023

ENERGINET gasunie

MATURE INFRASTRUCTURE STRETCHING TOWARDS ALL DIRECTIONS IN 2040

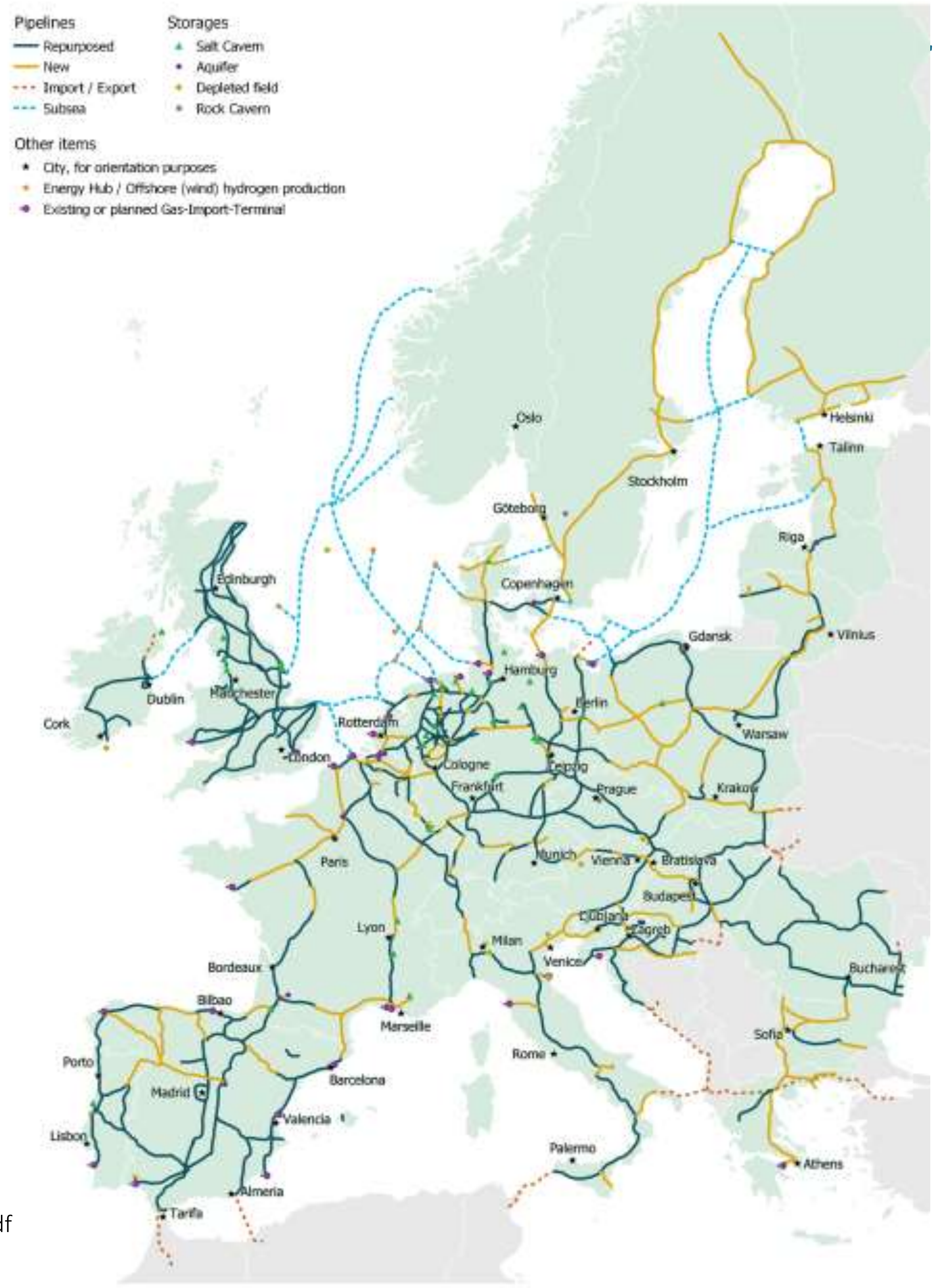
The report published shows a vision for a

~53,000 km hydrogen pipeline infrastructure

In **28** countries by 2040

over **60%** of which is based on repurposed existing natural gas pipelines

Making it possible to create the European Hydrogen Backbone at affordable costs



https://gasforclimate2050.eu/wp-content/uploads/2022/04/EHB-A-European-hydrogen-infrastructure-vision-covering-28-countries.pdf

VISION

GREEN ENERGY FOR A BETTER WORLD

Hydrogen Business Outlook – Denmark

Business Sweden

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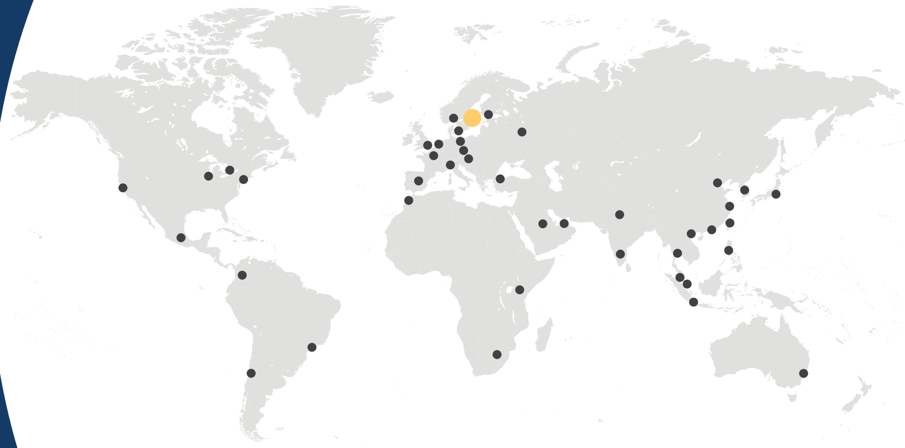
- INDUSTRY & MATERIALS
- LIFE SCIENCE



We shorten time to market, find new revenue streams and minimise risks

40+ MARKETS	450+ PEOPLE	45+ YEARS
From Helsinki to Hong Kong, Moscow to Mexico City – our business developers offer strategic advice and hands-on support	Our multinational team collaborate across the globe with expertise rooted in local business cultures and network	With a vast experience we help Swedish companies grow global sales and international companies invest and expand in Sweden

CONSULTING SERVICES

MARKET EXPANSION

- Market Selection Analysis
- Market Analysis
- Product & Customer Mix
- Sales Channel Setup
- Global Operations Footprint
- Mergers & Acquisitions

SALES ACCELERATION

- Customer Acquisition
- Partner search & Selection
- Sales & Partner Performance management
- Deal & Tender Support

BUSINESS TO GOVERNMENT

- Business to Government Strategy
- Stakeholder Analysis
- Strategic Messaging & Communications
- Stakeholder Engagement

BUSINESS INCUBATION & OPERATIONS

- Incorporations & Registrations
- Co-Working Space
- Employment & HR Services

GOVERNMENT ENABLED SERVICES

- INVEST PROMOTION & ADVISORY
- ECOSYSTEM GROWTH PROGRAMS
- SMALL BUSINESS PROGRAM
- BUSINESS DELEGATIONS & EVENTS
- TRADE & INVEST FACILITATION

Business Sweden invites you to join our events and promotional initiatives around the world

	2023			2024
	Q2	Q3	Q4	Q1
Americas			Canada: **Sweden-Canada Innovation Day** (Oct 4-5)	USA: **US hydrogen company delegation to Sweden** (TBA, 24Q1)
Asia	India: **India-Sweden Green Hydrogen Cluster** (Q2-Q4) Taiwan: **Swedish Renewable Energy Alliance** (12/6/2023)	S Korea: **H2 Meet seminar & roundtable** (Sept) China: **Pioneer the possible** – Support Swe companies to reach CO2 goals & promote their solutions (Q3-Q4)	Japan: **Hydrogen Society Network 2023** (Q3-Q4) Australia: **NSW Renewable Energy Zones** – support to position Swe companies	
EMEA	France: **Hydrogen Invest France 2023 – s**ymposium with French investors, delegation from MEDEF to Sweden (May 2023)	UK: **Hydrogen Event** – bringing together both SWE and UK hydrogen players (Q3/Q4)	Spain: **Sweden + Spain Green Alliance** – Roundtable and positioning of Swe solutions towards 3 smart city opportunities (TBA) Netherlands: **Smart Energy Netherlands** + World H2 summit Rotterdam (Oct)	

Anticipated investments in **green electricity & availability of water,** gives Denmark a favourable conditions for the development of green hydrogen economy

Low electricity prices - with 90% of the OPEX in an electrolyser project arising from the electricity price, this is a necessity

Green electricity– massive investments in offshore wind power in Denmark have the potential to supply the energy needed to produce hydrogen

Water supply – to produce 1kg of H2 requires 9 litres of water. Sufficient and low cost supply of water (that does not require extra costs for desalination or extensive purification) is another competitive advantage

Denmark has favourable pre-conditions for a low carbon hydrogen value chain

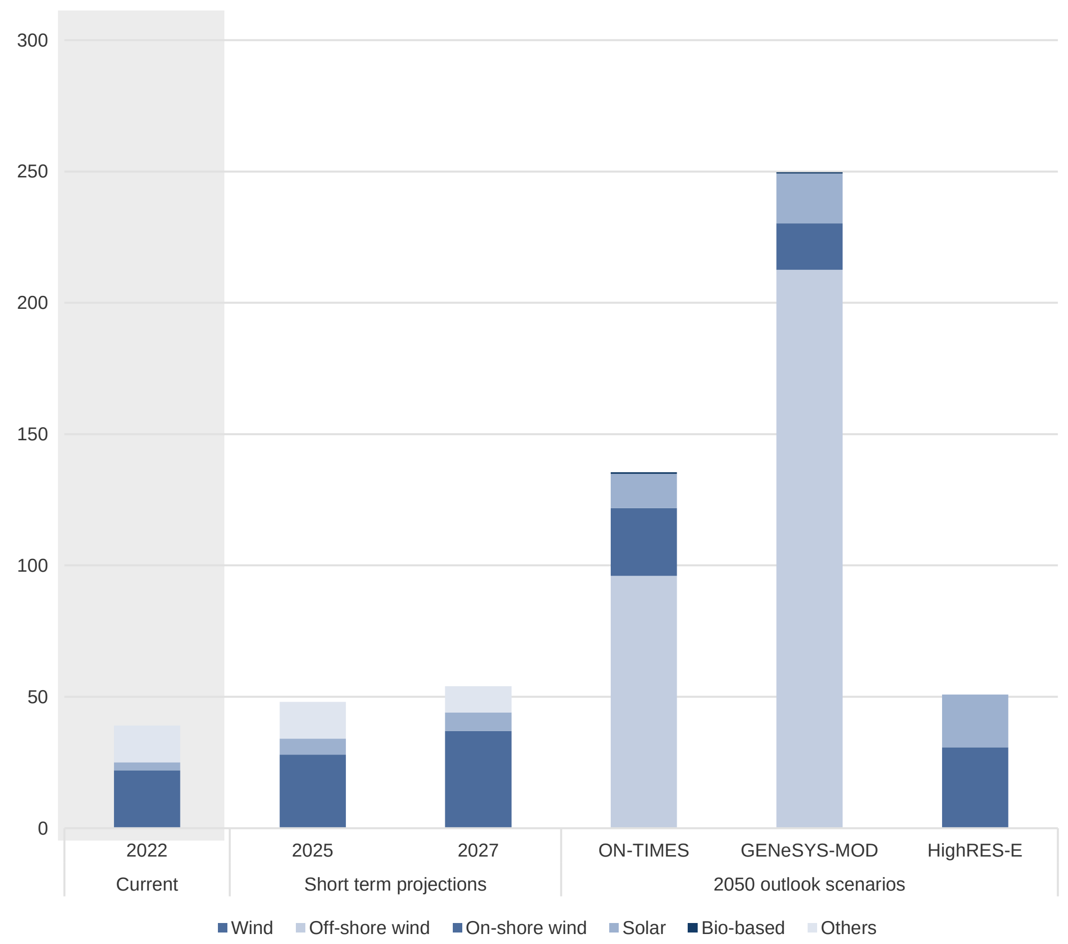
Fossil free power system	• Ambitious targets and plans to increase renewable power generation • Comprehensive gas grid infrastructure
Access to biogenic carbon	• Denmark has potential for captured and biogenic carbon from biogas production based on agricultural waste • Combined with low carbon hydrogen supply, gives Denmark the possibility to produce any Power-to-X fuel and feed-stock
Leading energy and industrial ecosystem	• Strong developers with access to funding • Industry actors matching the needs of the hydrogen value chain with actors ready to lead the way and open for new partnerships
Sustainability leaders and innovation pioneers	• Denmark has a highly skilled workforce and a competence base drawing from oil and gas and other industries • Denmark's leading global energy players within wind shows the potential in energy exports and job creation
Favorable business climate, stable society, collaborative culture	• Denmark, along with the other Nordic countries is top ranked on all parameters providing the basis for driving a cross-sectorial technology and business model shift such as democracy, resilience, corruption perception, digital competitiveness and network readiness
Political support	• A Hydrogen strategy with the objective of reaching a 4-6 gigawatt of electrolysis capacity by 2030 • The Government work to establish a common European hydrogen infrastructure so that Denmark can export green hydrogen • The Government plans to invest DKK 1.25 billion through a Power-to-X tender to support the industrialization of Power-to-X

But there is still a lot of uncertainty of costs, investments and what comes first – supply or demand

Source: Report interviews and analysis of statistics

25% of the current Danish electricity mix is still fossil based and will have to be gradually phased out in the coming years

Power generation mix developments in Denmark 2022-2050, by source and model (in TWh)



The Danish electricity mix has the highest share of wind in the world

- Fossil sources constituted over 25 % of the power generation mix in 2022
- Onshore and offshore wind already constitute almost 50 % of the Danish electricity mix, which is the highest share of intermittent electricity generation in the world
- On- and offshore wind is being hailed in Denmark as the primary driver to new electricity production, in addition to solar
- Thermal generation, which is marginal, is likely to stay stagnant

Electricity demand could potentially double over the next three decades

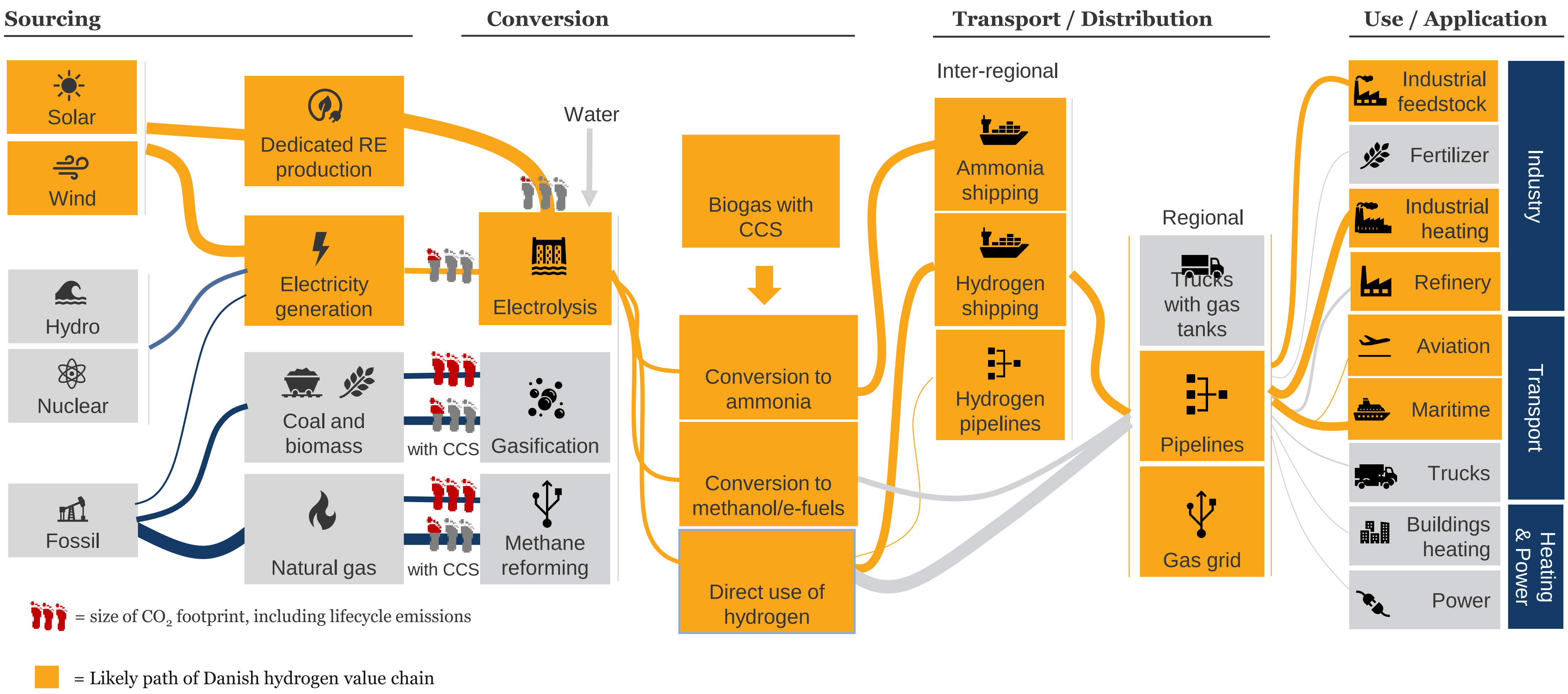
- Demand is projected to be primarily driven by Power-to-X (Power-to-X), data center establishments and the electrification of the transportation sector

Sector coupling across the energy sector is needed to integrate the huge amounts of intermittent electricity production

- Hydrogen is one of the solutions Denmark turns to for utilising wind and solar when production exceeds demand in the electricity system

Source: Nordic Energy Research report August 2022: NEOFinalreportWP2-1.pdf; Statnett's Short-Term Market Analysis for the period 2022 - 2027 (KMA): kortsiktig-markedsanalyse-kma-2022-2027---nokkeltall.xlsx **Note**: Others refers to Fossil fuels in the graph

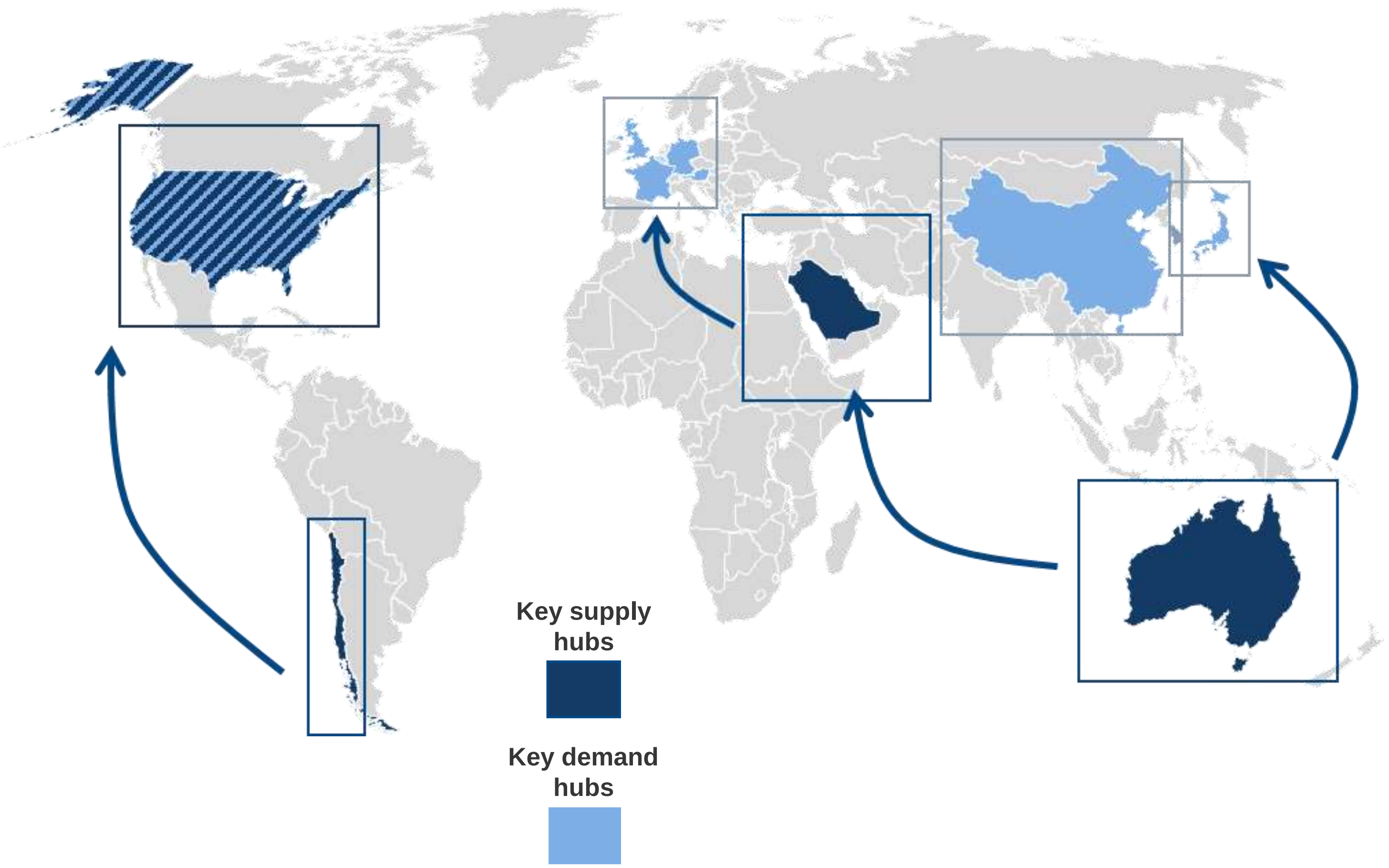
Denmark has an attractive value proposition in multiple areas of the hydrogen value chain, utilising renewable energy and biogas to produce fuels



Source: Hydrogen value chain DNV Hydrogen Forecast 2022 to 2050, Report analysis

Hydrogen will be shipped from optimal supply locations to demand centers globally

Supply and demand hubs including key supply routes (Illustrative)



- Access to cost-effective renewable energy and shipping routes will influence which nations become key supply hubs, while the USA, Asia and Europe drive demand
- By 2030, hydrogen could be shipped from supply hubs such as Australia, Chile and Saudi Arabia to projected demand centres in Asia, Europe and USA
  - Supply hubs, or **optimal hydrogen production countries**, like Australia, Saudi Arabia and Chile, will have access to wind and solar power
- While the **feasibility** of long-distance hydrogen transportation choice will differ depending on end-use, **shipping** will help unlock demand globally

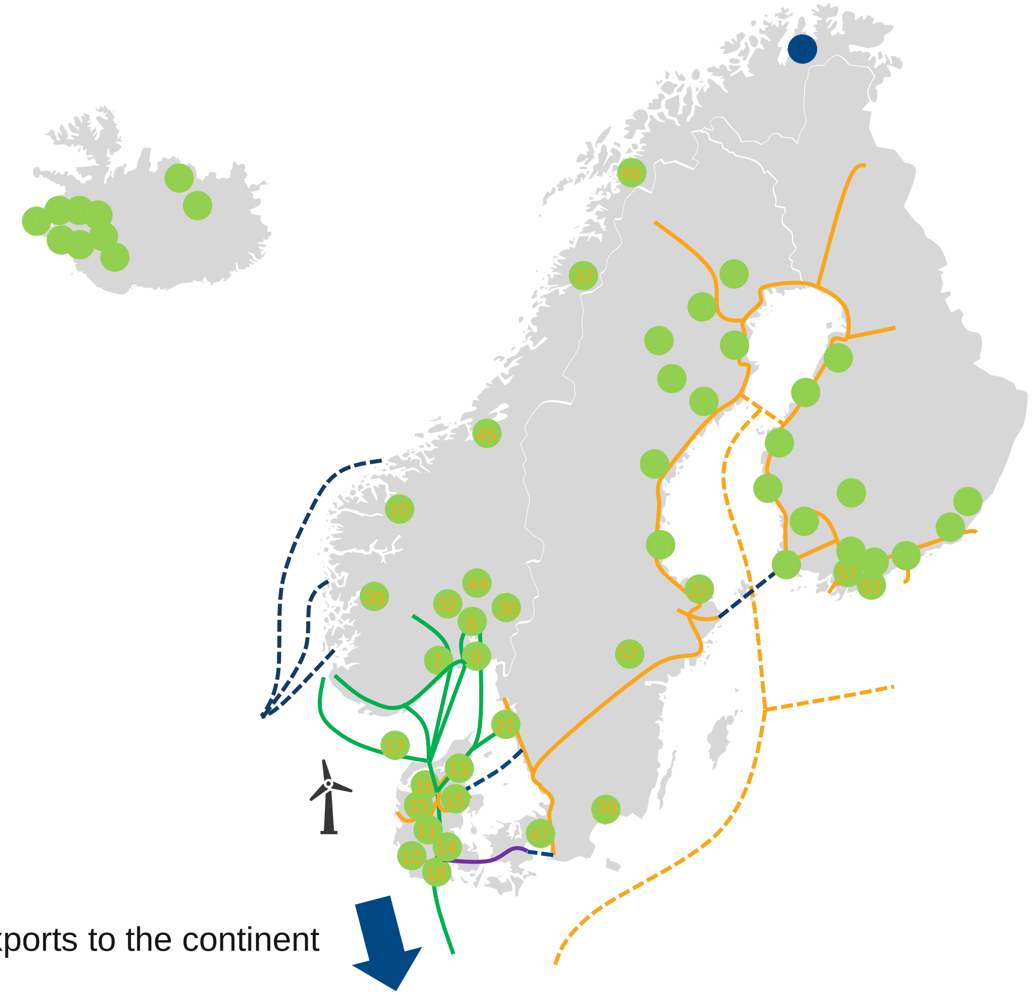
Note: US is expected to be a key demand hub with some supply going to export
Source: Report analysis, Hydrogen Council, IEA, Fitch Solutions, Wood Mackenzie

Denmark is strategically positioned close to the German market and the rest of Scandinavia

- Low carbon-based
- Electrolysis-based

Hydrogen routes by 2040:

- Existing natural gas pipelines
- Planned Jylland Corridor
- Existing pipeline that will be repurposed
- Planned European Hydrogen Backbone Connections
- Baltic Sea Hydrogen Collector



Exports to the continent

- **Denmark has the advantage of being geographically close to demand hub Germany** and northern continental Europe wich will allow for **exports through pipelines**

Source: Report analysis; Company websites

Note: The overview is illustrative and not exhaustive. Highlighted projects are presumed to be mature, e.g. under construction at the time of the report (January 2023), an extension of existing operations, and/or have reached FID * No projects identified under Power and Heating

The Danish hydrogen ecosystem spans across the entire value chain with green fuels being a core theme amongst market players

Hydrogen value chain

	1. Sourcing	2. Conversion	3. Transport and distribution	4. Use/Application areas
Process owner	andel, Ørsted, Vattenfall, European Energy, RWE, HOFOR, Eurowind Energy, BeGreen, be	H2 Energy, Topsoe, CIP, Everfuel, Crossbridge Energy Fredericia, REintegrate	Energinet, Norlys, evida, ADPT	Danish Crown, DSV, DAT, Maersk, OK, Arla, Circle K, DFDS, Everfuel, Esvagt, Copenhagen Airports
Technology provider	Vestas, Siemens Gamesa Renewable Energy	nel, Topsoe, A2X, Dynelectro, Electric Hydrogen, Danfoss, Estech, Green Hydrogen Systems	Corre Energy, Danfoss, Grundfos, Air Liquide, nel, Everfuel	Eltronic FuelTech, MAN, Geely, Advent, MAN Energy Solutions, Blue World Technologies, Alfa Laval, Nordhavn Power Solutions
Academia and institutes	DTU Danmarks Tekniske Universitet, SDU, Aalborg Universitet, Danish Technological Institute	DTU Danmarks Tekniske Universitet, SDU, Aalborg Universitet, Danish Technological Institute	DTU Danmarks Tekniske Universitet, SDU, Aalborg Universitet, Danish Technological Institute	DTU Danmarks Tekniske Universitet, SDU, Aalborg Universitet, Danish Technological Institute
Public organisations	DI Energi, Green Power Denmark, Danish Ministry of Energy, Utilities and Climate, Energy Cluster Denmark	Brintbranchen, DI Energi, DaCES, Hydrogen Valley, Green Hydrogen Hub Denmark	Danish Ministry of Energy, Utilities and Climate, DaCES	Drivkraft Danmark, Energy Cluster Denmark, Københavns Kommune, DaCES

Many companies are active in more than one part of the value which shows a highly integrated value chain

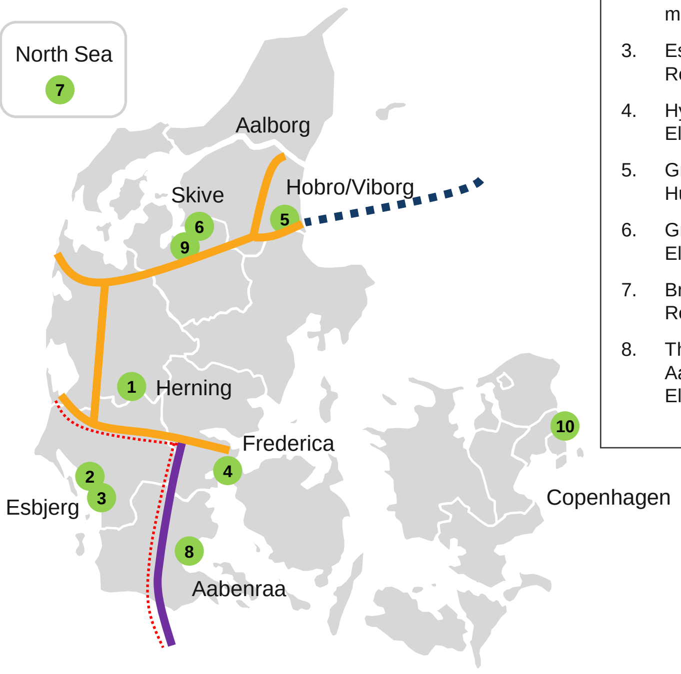
Source: Company Websites **Note**: Example companies

Denmark has more than 70 identified projects with most being in the feasibility or pre-feasibility stage

Overview of a few notable projects

Electrolysis-based

Hydrogen routes by 2040:
- Existing natural gas pipelines
- Planned Jylland Corridor
- Existing pipeline that will be repurposed
- Planned European Hydrogen Backbone Connections
- Planned route for future exports to neighboring countries



Sourcing → *Conversion* → *Transport and distribution* → *Use/Application areas*

Sourcing / Conversion	Transport and distribution	Use/Application areas
1. Topsoe electrolyser manufacturing plant | Electrolysis 2. Høst | Conversion to ammonium, methanol/e-fuels 3. Esbjerg Harbor | Renewables 4. HySynergy | Electrolysis 5. Green Hydrogen Hub | Electrolysis 6. GreenHyScale | Electrolysis 7. BrintØ project | Renewables (Wind) 8. The port of Aabenraa | Electrolysis	9. ClusterNorthH2 | Storage	**Industrial heat** **Industrial feedstock** **Transports** 10. Green Fuels for Denmark | Transport **Power and Heating**

Summary

- 70 hydrogen have been identified in Denmark, with more than 28 companies involved
- Hydrogen production is expected to increase sharply and become significantly larger than the domestic use after 2025
- If the announced projects are realised, total Danish electrolysis capacity will be of over 14 GW in 2030 and 21 GW in 2040. Some of these projects can me found on the map to the left
- In Denmark focus lies exclusively on producing green hydrogen. Large-scale Power-to-X projects have already been launched that will produce large quantities of green hydrogen and fuels by 2030
- Status on some of the bigger projects in Denmark:
  - The BrintØ project will be in full operation 2030 with 10 GW of offshore wind power and a production capacity of 1 M tonnes of green hydrogen
  - Green Fuels for Denmark’s electrolysis plant with a capacity of 1,3 GW by 2030
  - HØST will be in full operation by 2027 with a capacity of 1 GW
  - Topsoe Electrolyser plant will be in full operation by 2024 with a capacity of 500MW, up to 5GW long term

Realisation of the planned large-scale projects could make Denmark an exporter of hydrogen to and electrolyses to neighbouring countries

Source: Markedsdialogen om brintinfrastruktur, Company websites, Strategi for Power-to-X

Denmark’s great ambitions in renewable energy generation can lay the foundation for large scale hydrogen production

Hydrogen value chain

1. Sourcing — Renewables, Fossil energy, Fossil feedstock, Nuclear
2. Conversion — Electrolysis, Methane/Reforming/Gasification, CCS/CCU, Biogen CO2, E-fuels
3. Transport and distribution — Storage, Pipeline, Shipping, Trucking
4. Use/Application areas — Industrial heat, Industrial feedstock, Transports, Power and Heating

Potential

- Denmark has the potential to **utilise the wind and solar power** resources that are becoming more widely available on market terms
  - Broad **political support is backing quadrupling** of solar and wind energy production on land and **increasing offshore wind five times until 2030**
  - Denmark has the potential of becoming a **net exporter of offshore wind energy by 2050** considering the already assigned zones for offshore wind farms, in the North Sea
- Green gas and **conversion of electricity to hydrogen**, heating and **RE-based fuels** will be essential to **climate impact reductions** in sectors such as **agriculture and transport**
- Any **renewable energy** not used domestically can be exported as electricity or be used to **produce hydrogen and green fuels**. Here the **Nordics can take a lead** in showing the potential in an integrated energy system across boarders

Needs expressed by the industry

- The **energy system must be transformed** dramatically in the coming years
  - **Sector coupling** across the energy sector is important
  - **Frameworks needed for storing green energy** in line with hydrogen infrastructure
- **Cheap green electricity** is a prerequisite for prices of hydrogen to come down
- Showcase the **Nordics as a model for an integrated energy system**

It is possible for Denmark to contribute to an integrated Nordic green energy system if sector coupling and frameworks are aligned with market demands

Source: Report analysis

Political support and a strong and integrated ecosystem within Power-to-X create a good foundation for developing the industry

Hydrogen value chain

1. Sourcing	2. Conversion	3. Transport and distribution	4. Use/Application areas
Renewables, Fossil energy, Fossil feedstock, Nuclear	Electrolysis, Methane/Reforming/Gasification, CCS/CCU, Biogen CO2, E-fuels	Storage, Pipeline, Shipping, Trucking	Industrial heat, Industrial feedstock, Transports, Power and Heating

Potential

- The Power-to-X strategy and high ambitions to turn Denmark into climate-neutral society could put **Denmark in a global leading position** in the **technology for conversion of green electricity**
  - Competence exists to make Denmark a forerunner in hydrogen technology, and many Danish companies are **actively engaged in the conversation step** of the value chain both nationally and internationally
  - Denmark can become an **export of hydrogen and green fuels** to Nordic users within industry and transport
- There is potential for even more **collaboration across the Nordics**
  - Danish companies are already making **hydrogen investments in the other Nordics countries**, with potential for further investments
  - **Danish technology could be used in Nordic solutions** from conversion to application

Needs expressed by the industry

- **Technology development** and lowering of reduction of hydrogen costs
  - **Better knowledge** about production costs and hydrogen price
  - **Industrialisation** of electrolyser equipment
  - **Significant R&D need,** particularly in relation to advanced Power-to-X products
- **Political frameworks** development is crucial
  - In order to prevent Europe from being overrun by the United States, Europe needs **active government support** and a level playing field for investments
  - **Clarity on regulation**
- **Higher visibility of the Nordics in EU** contexts and more active use of EU funding

The emergence of a strong value chain is on it's way but there is still much uncertainty associated with the future market for hydrogen

Source: Report analysis

Domestic and cross-boarder pipeline infrastructure is important to enable planned projects and export potential of hydrogen

Hydrogen value chain	1. Sourcing	2. Conversion	3. Transport and distribution	4. Use/Application areas
	Renewables, Fossil energy, Fossil feedstock, Nuclear	Electrolysis, Methane/Reforming/Gasification, CCS/CCU, Biogen CO2, E-fuels	Storage, Pipeline, Shipping, Trucking	Industrial heat, Industrial feedstock, Transports, Power and Heating

Potential

- The establishment of domestic **pipeline infrastructure is a prerequisite for many projects** and allows for transport of hydrogen between hydrogen production to production of methanol, ammonia and other fuels
- **Connecting Denmark to the rest of Europe** enables exports of hydrogen to Germany and other countries
- By connecting the rest of the Nordics with Denmark, **hydrogen could be transported to and from the continent through Denmark**

Needs expressed by the industry

- Better knowledge of the **placement of the hydrogen infrastructure** and commissioning
- **Speed up the process** of implementation of initiatives and establishment of promised infrastructure
- Establish a **clear governance model for the hydrogen infrastructure** and secure **public funding** for both vehicles and infrastructure

A Nordic hydrogen pipeline infrastructure is an opportunity to even further integrating the Nordic energy system and become more self-sufficient

Source: Report analysis

Green fuels for transports could be realised through collaboration between market leading players and policy measures

Hydrogen value chain

1. Sourcing	2. Conversion	3. Transport and distribution	4. Use/Application areas
Renewables, Fossil energy, Fossil feedstock, Nuclear	Electrolysis, Methane/Reforming/Gasification, CCS/CCU, Biogen CO2, E-fuels	Storage, Pipeline, Shipping, Trucking	Industrial heat, Industrial feedstock, **Transports**, Power and Heating

Potential

- **Great conditions** for successfully developing e-fuels
  - Key players within **maritime, air and road transport** work together to develop production facilities to produce sustainable fuels as they are **establishing a market for green fuels**
  - Even more **strategic partnerships** could secure the volumes of needed for methanol driven vessels and vehicles
- Ongoing projects could drive the maturation of sustainable fuels, and **create jobs** supporting Denmark's role as a **green energy leader**

Needs expressed by the industry

- The hydrogen strategy needs to be followed up with **strategies and actions for the transport sector**
- Maturing the **downstream distribution of hydrogen**
  - Safety **standards** and standardised specifications
  - **Storage** for hydrogen and fuelling stations to support the different modes of transport
- **Collaboration and partnerships** to secure the need for new sustainable transport solutions; airplanes, ships, busses among others

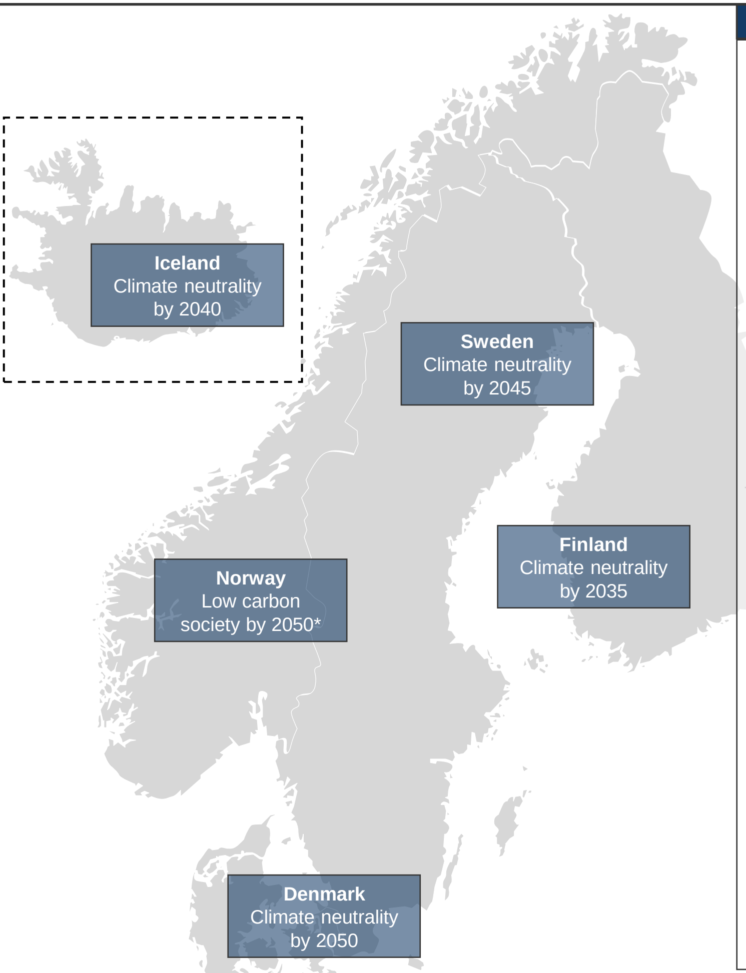
Companies are taking the lead in creating new green transport solutions but policy action is needed for the market to kick-off

Source: Report analysis

The story of the Nordics builds on leadership sustainability and complementary industrial and energy legacy

A joint point of departure

- The Nordic markets have a joint point of departure as global climate leaders
    - Hydrogen is identified to play a key roll in the Nordic markets green transition
    - The Nordics have access to fossil free cost efficient energy
    - Rank at the top of innovation and collaboration leaders in the world
- In parallel, the Nordics offer a complementary aspects as
    - Access to natural resources such as natural gas, forest and farmland
    - Industrial legacy – all key industries in need of decarbonisation where low carbon hydrogen can be key
    - Gas legacy, such as pipeline infrastructure
- Together, the Nordics offer favourable preconditions throughout the value chain, from sourcing of green energy supply, conversion initiatives for low carbon hydrogen, and potential offtakers such as steel and maritime



The Nordic prerequisites

Low carbon hydrogen identified to play key roll in the green transition	✓	✓	✓	✓	✓
Access to fossil free cost efficient energy	✓	✓	✓	✓	✓
Natural gas legacy	✓	✓		✓	
Natural resources	✓	✓	✓	✓	✓
Industrial heritage					
Steel industry	✓		✓		
Maritime		✓		✓	✓
Refinery	✓	✓	✓		
Pulp and Paper	✓		✓		
Fertiliser		✓		✓	
EU member state	✓		✓	✓	✓
Atlantic / Baltic sea access	✓	✓	✓	✓	✓

The Nordic offer in hard-to-abate industries provides an opportunity for climate impact both in the extended home market, in Europe and globally

Source: Report analysis; EHB.eu; government.is; FN.no; Global Innovation Index 2022 ***** Climate emissions reduced by 90-95% compared to 1990

Introduction to Ørsted P2X

Presentation for the Swedish Hydrogen Development Center

2 June 2023

Ørsted

Agenda

1. **Introduction to Ørsted's P2X business**
2. Danish P2X deep-dive

Ørsted at a glance

Offshore wind

- Global leader in offshore wind
- Ambition to reach ~30 GW installed capacity by 2030

Onshore renewables

- Strong presence in the United States and Europe
- Ambition to reach ~17.5 GW installed capacity by 2030

Bioenergy & other

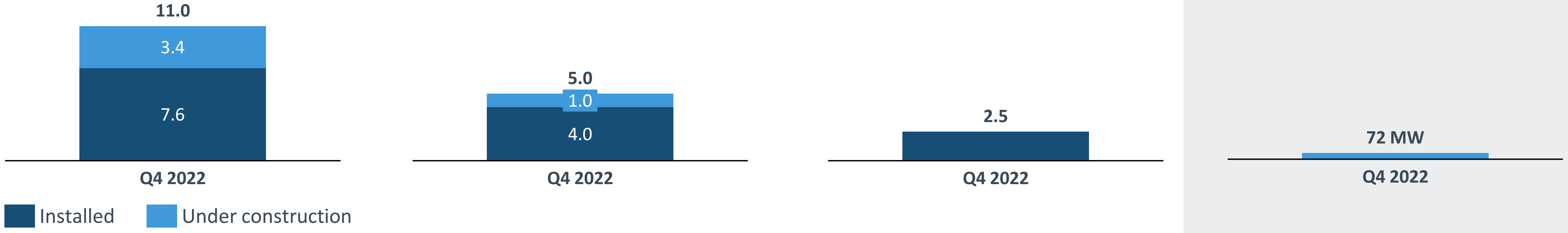
- Presence in Europe, including bioenergy and heat plants, legacy gas activities and patented waste-to-energy technology

Power-to-X

- Emerging platform with 10 pipeline projects (+3 GW) mainly in Europe
- Ambition to become a global leader in renewable hydrogen and green fuels by 2030

Capacity

GW



Our aspiration for 2030 is to become the world's leading green energy major

One of the world's largest green electricity producers

- Global no. 1 in offshore
- Global top 10 in onshore
- A global leader in renewable H_2 & green fuels

One of the world's largest and most value creating deployers of capital into the green transformation

The world's leading talent platform in renewable energy

A globally recognised sustainability leader

A core contributor and catalyst for change towards a world running entirely on green energy

1. Execute and expand **current pipeline of +3 GW** in close collaboration with key offtake partners
2. **Pursue global opportunities** across our growth platform in Europe and USA
3. **Lean forward into selected value chains** to drive deep decarbonization together with key offtake partners

Ørsted offers credible access to P2X products with an industry leading track record and ambition that ensures reliable delivery of competitive projects

Why Ørsted?

Track record: Ørsted led the industrialization of offshore wind and is well positioned to lead the scale-up of P2X with leading positions in Offshore, Onshore, Solar PV and Bioenergy

Committed: A project with Ørsted will be designed and developed with completion in mind – showcased by Ørsted taking FID on one of the global first commercial scale P2X projects

Oversized portfolio: Ørsted is developing an oversized global portfolio providing flexibility to execute on our best available options and deliver competitive P2X products to customers

Shaping market conditions: Vast experience in shaping market conditions for emerging and maturing green technologies - incl. working closely with regulators, policy markets and involvement in advisory councils

Sustainability champion: Lead role in energy transition and ranked world's most sustainable energy company from 2019-2022

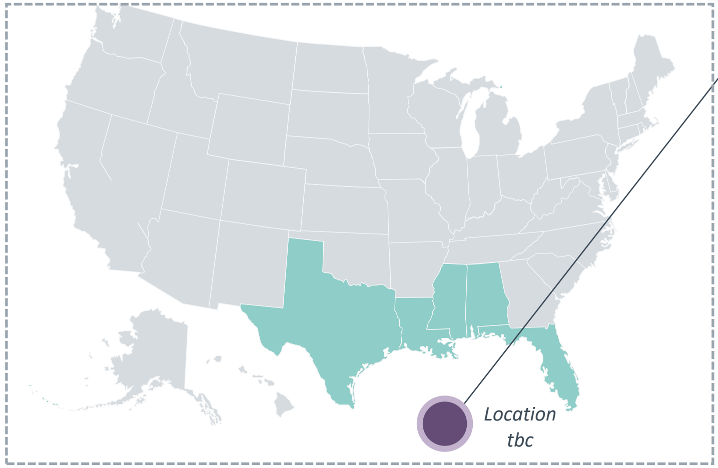
Levelised cost of electricity
EUR/MWh

Ørsted has a diverse range of global projects and a pipeline of +3GW involving many partners and key stakeholders

Product: Hydrogen eMethanol Multiple

Deep-dive

Offtake segment(s): Heavy transport Refineries Chemicals & fertilizers Steel



Project Star
- 675 MW

Ørsted MAERSK

Idomlund
- 150 MW

Ørsted SKOVGAARD ENERGY

FlagshipONE
- 70 MW

Ørsted

GFDK[1]
- 1.3 GW

MAERSK DFDS SAS DSV Ørsted TOPSOE Everfuel COWI BCG nel

H2RES
- 2 MW

Brintbranchen DSV ENERGINET Everfuel nel Ørsted

WK100[2]
- 30 MW

Ørsted Holcim hynamics

Gigastack
- 100 MW

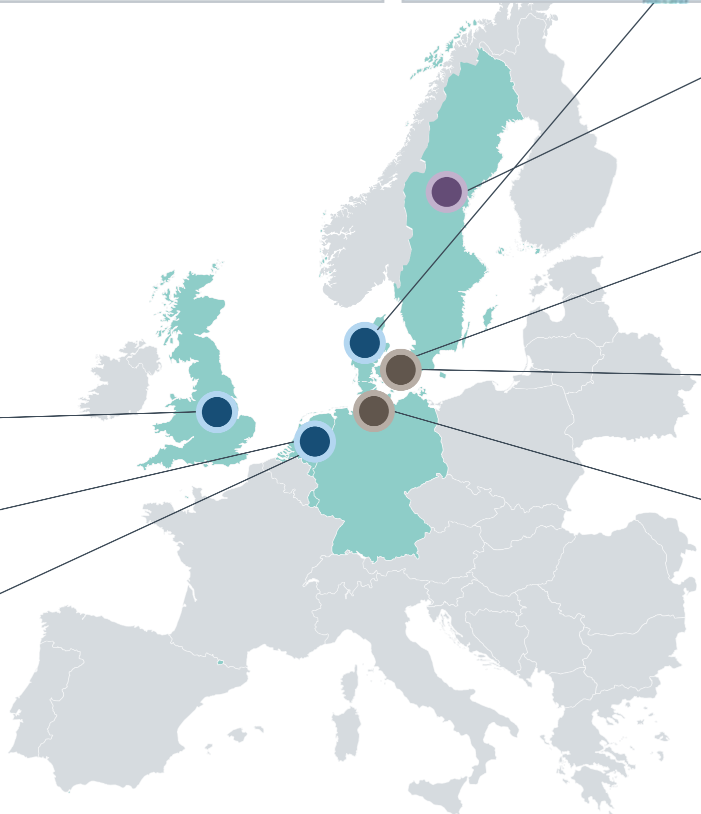
PHILLIPS 66 Ørsted

SeaH2Land
- 1000 MW

Ørsted

Haddock (Sluiskil)
- 100 MW

YARA Ørsted



1. Green Fuels for Denmark (GFDK) 2. Westküste 100

Agenda

1 Introduction to Ørsted's P2X business

2 Danish P2X deep-dive

Danish P2X market fundamentals

1 **Production fundamentals**

- Favorable economics from onshore wind, solar PV and offshore wind implying H_2 production costs that are competitive in Europe

2 **Power supply**

- By 2030, Denmark is forecasted to have a substantial renewable energy surplus, predominantly driven by the planned offshore wind build-out in the North Sea, which can be utilized for P2X production

3 **Infrastructure**

- European H_2 Backbone to provide the required transport infrastructure within Denmark and first export routes to Germany by late 2020s

4 **Regulatory support & funding schemes**

- Danish Energy Agency has launched a PtX tender to develop and promote renewable H_2 and green fuels with a funding pool of DKKbn 1.25

Green Fuels for Denmark is a flagship project targeting a 1.3GW electrolyser in post 2030 decarbonising heavy transport through sustainable eFuels production

Project ambition and partners

This pioneering project brings together leading Danish companies on the demand and supply side of sustainable eFuels

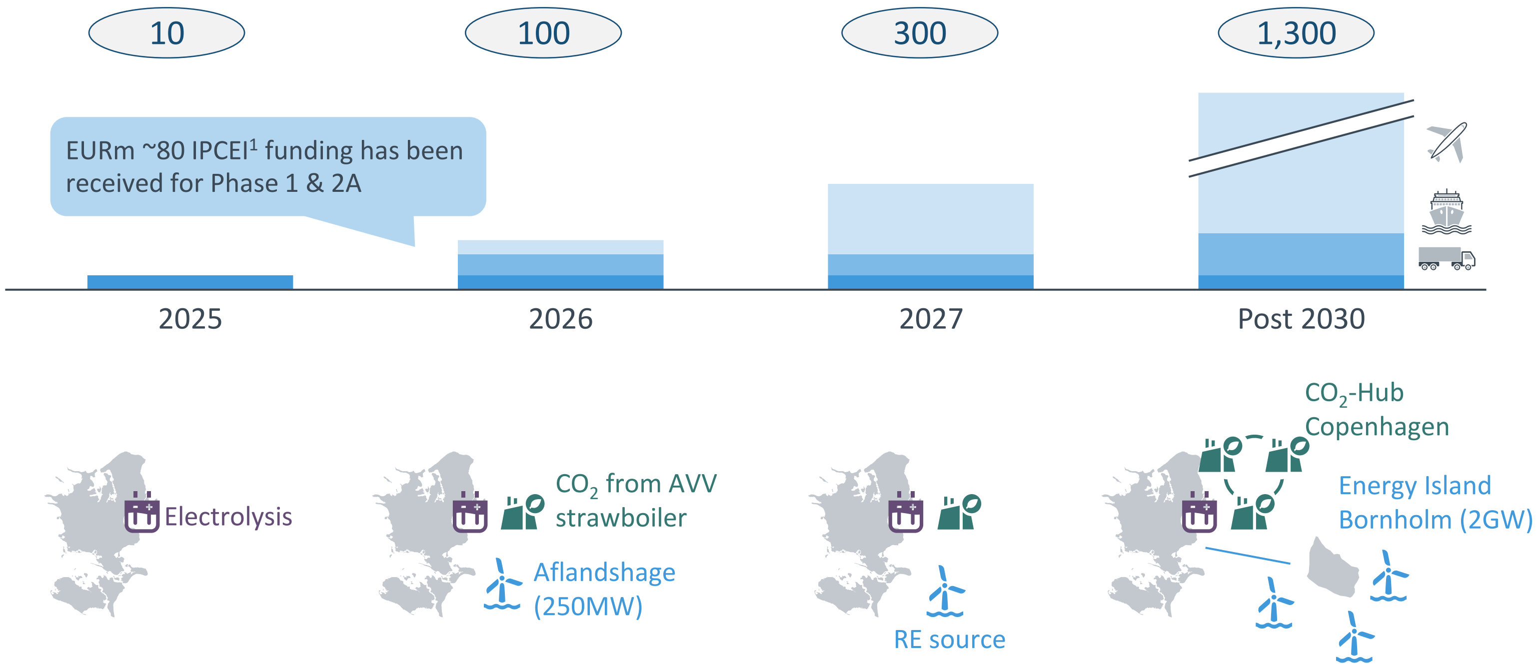
The project is being developed by Ørsted, but leverages the expertise and market positions of a diverse group all committed to drive change

Ørsted, SAS, TOPSOE, DFDS, MAERSK, Copenhagen Airports CPH, DSV, nel, MOLSLINJEN, Region Hovedstaden, Everfuel

Key project highlights

Cumulative electrolyzer size, MW

Phase 1	Phase 2A	Phase 2b	Phase 3
Build H_2 production capabilities	Build eMethanol production and demon-strate jet fuel production	Scale-up eFuel capacity, scale-up jet fuel production	Scale and drive cost parity by meeting large potential demand in aviation



1. Important Project of Common European Interest

IDOMLUND | Ørsted and Skovgaard Energy have joined forces to develop a large-scale P2X facility in Western Denmark

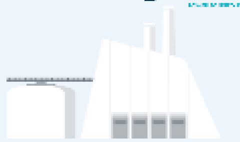
Project well positioned for large scale offshore wind build out

Power generation

Ørsted	Skovgaard Energy	Skovgaard Energy
Offshore wind	Onshore wind	Solar PV

Hydrogen Production

Ørsted | Skovgaard Energy



Project phase	Electrolyser capacity
Phase 1 (2028)	*150MW*
Phase 2 (2030)	*550 GMW*
Phase 3 (2033)	*1,7 GW*
Phase 4 (2036)	*3 GW+*

Idomlund phase 1 at a glance

- Developed together with Skovgaard Energy which has a strong track record in onshore wind and solar PV
- Project site is strategically located near transformer station, a point of connection (POC) for multiple upcoming offshore wind farms
- European Hydrogen Backbone connection, expected by 2030, enables export to Jutland and Continental Europe
- Phase 1 electrons to be sourced from Bur site combining 200MW solar and 60 MW onshore wind

Visualisation of project set-up

Q&A?

Short break

Swedish Hydrogen Development Center

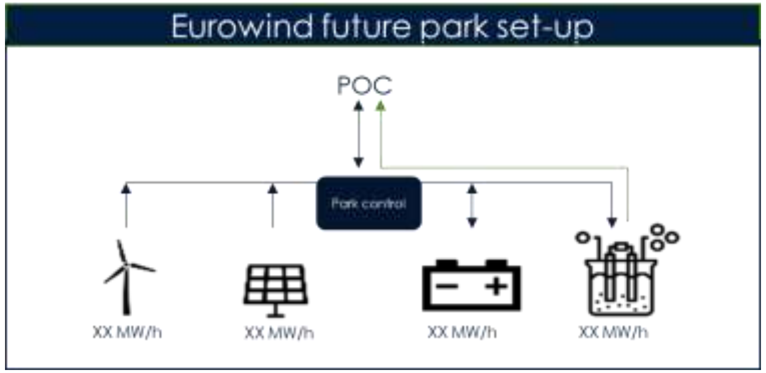
Co-financed by:

Swedish Energy Agency

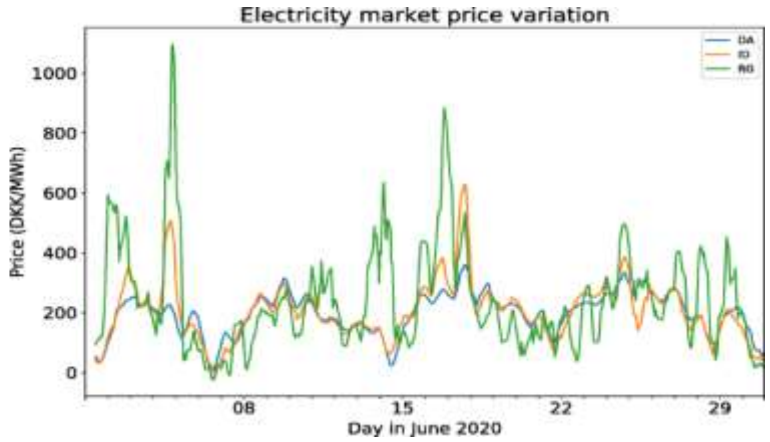
Ørsted


Eurowind Energy™
How will hydrogen fit into the wind development

PtX as Business Strategy



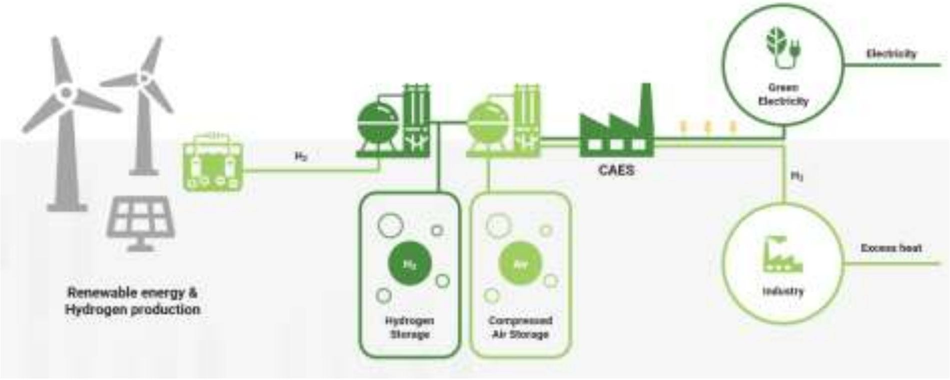
- Wind and solar projects is the pivotal enabler for PtX business development. Potential co-location to PtX off-takers is the sweet spots to competitive advantage.
- PtX enablers can be different in various regions. For regions with no grid or low grid capacity, PtX is an opportunity to bring WTG/PV projects to the market.



Eurowind Energy

Green Hydrogen Hub

Green Hydrogen Hub DENMARK

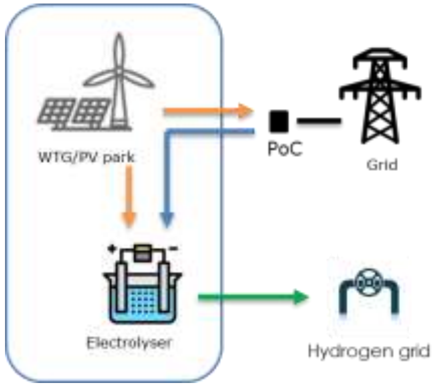


GHH Vision

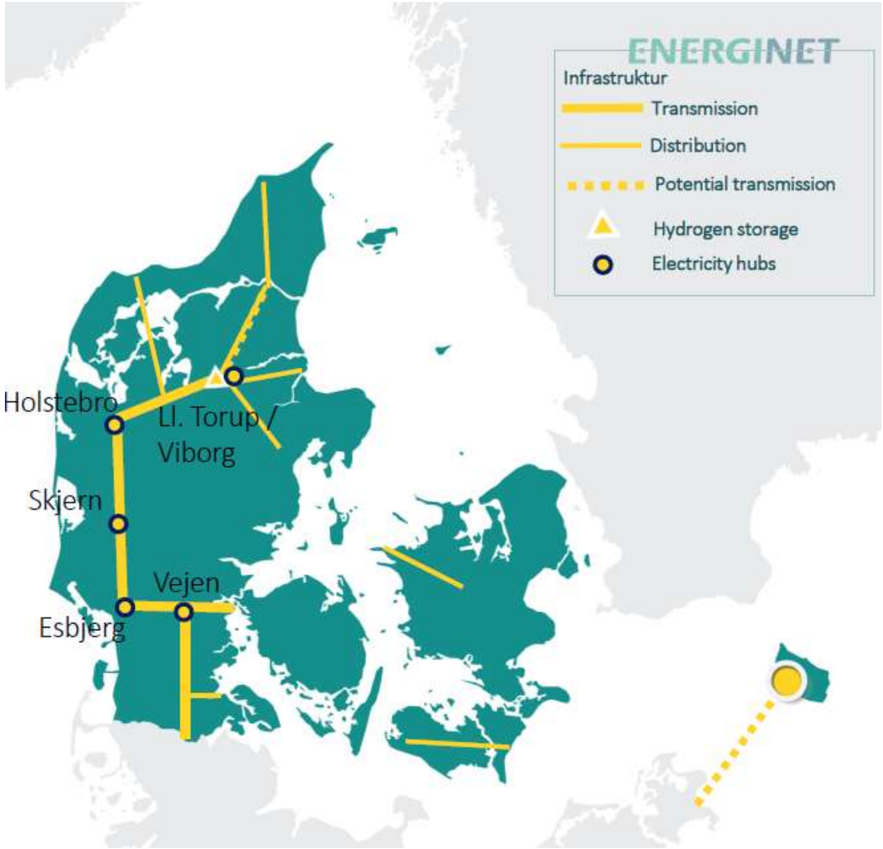
The vision is to create the world's first co-located scheme to combine large-scale electrolysis, hydrogen storage and hydrogen-fueled Compressed Air Energy Storage (CAES)

GHH Master Plan

- 2022 Concept Design
- 2025 Detailed Design
- 2025 FID & EPC
- 2028 Commission & Operation



Co-location for electricity production and PtX production is optimum setup for ancillary service and grid power balance

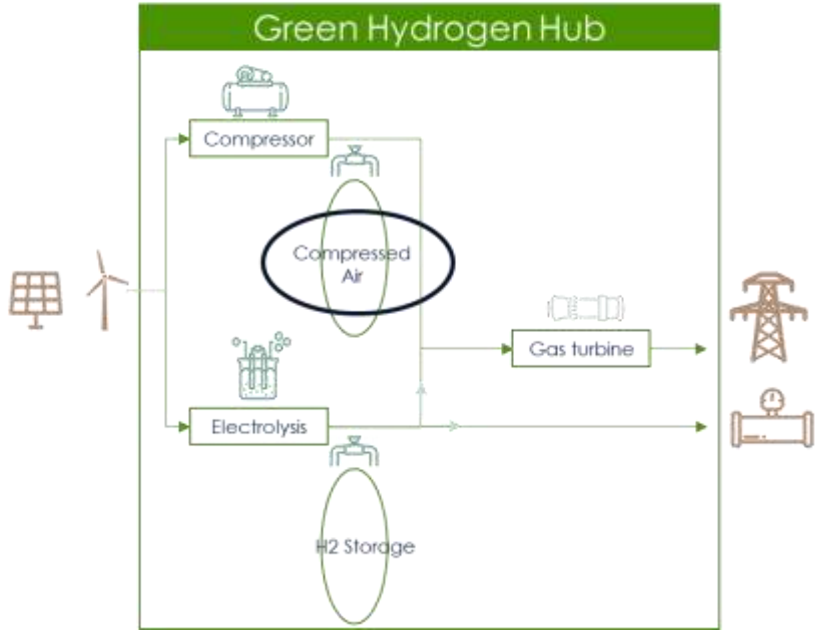


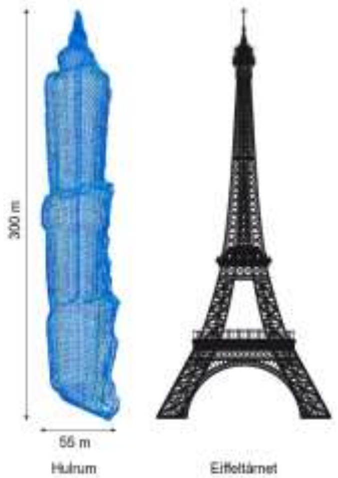
Conceptual study of new hydrogen infrastructure
Fremtidens gasinfrastruktur banker på (evida.dk)

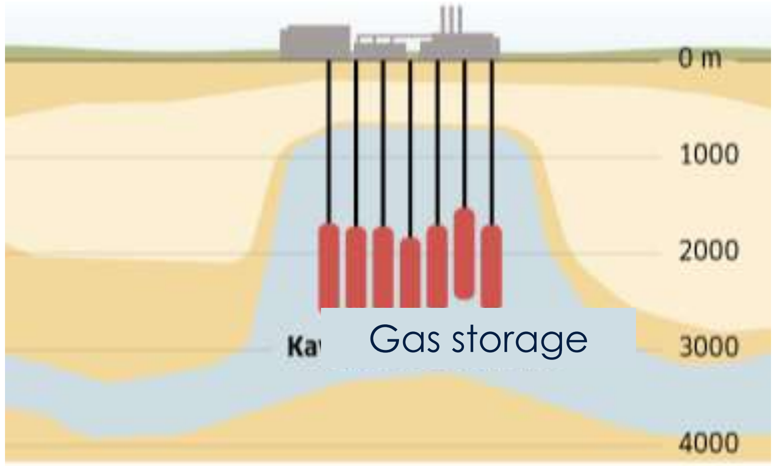
corre.energy GAS STORAGE DENMARK Eurowind Energy https://greenhydrogenhub.dk/

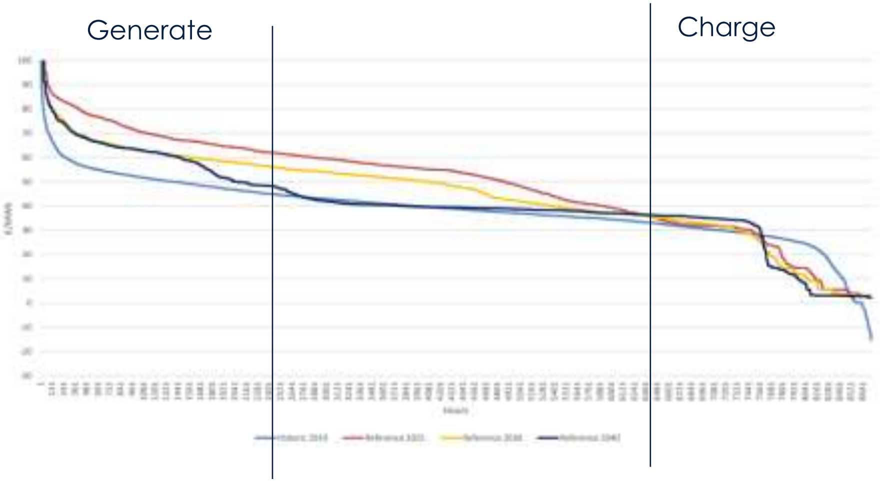
GHH provides balance to the Energy system

Project Type	Green Hydrogen Hub
Location	Lille Torup, Denmark
CAES Capacity	200 GWh
CAES Generator	320 MW
H_2 Capacity	117 GWh
Electrolyze Capacity	180 MW
Financial Close	2025
Operational From	2028





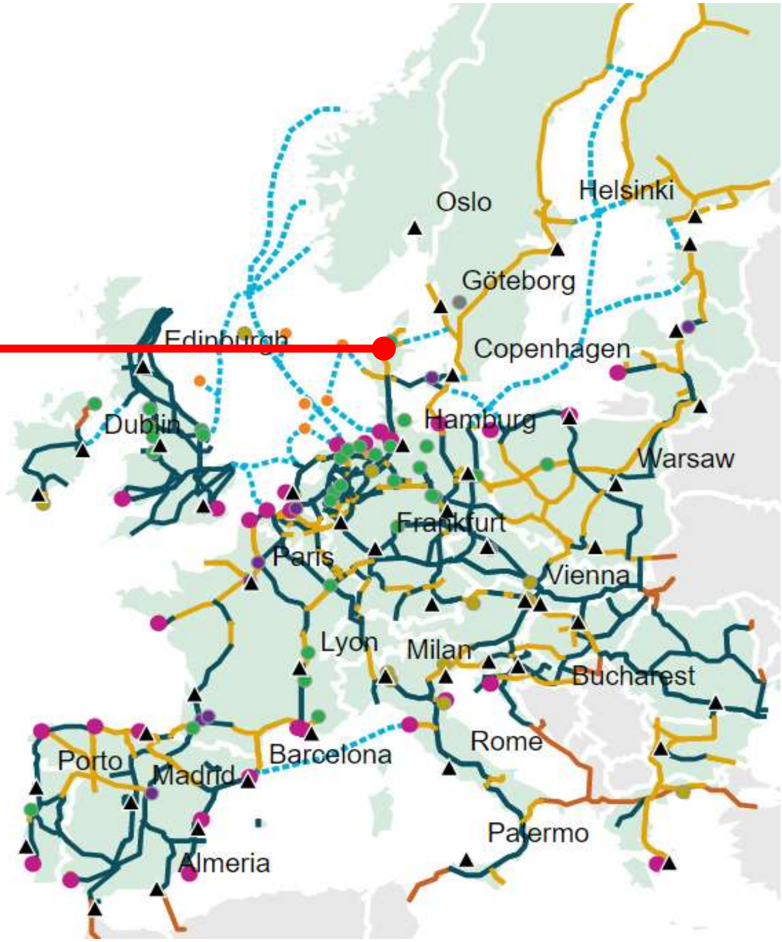




Excellent location within the European Hydrogen Backbone

The use of underground salt caverns for hydrogen storage, which the electrolyser and CAES facility are connected to, are of strategic interest to the Danish state and managed by GHH-participant Gas Storage Denmark, a subsidiary of Energinet [TSO]

Figure 10. Danish transmission power grid (2020)
... approximate locations.

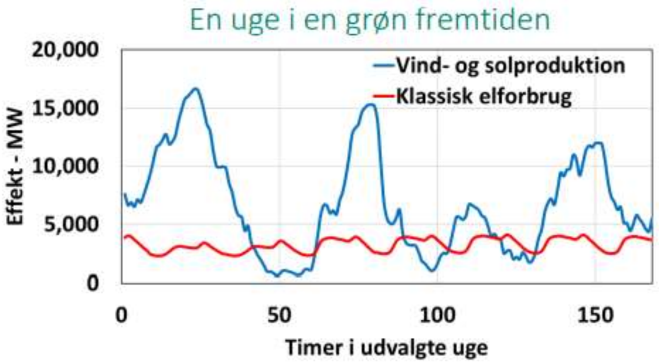


https://www.ehb.eu/maps/202209/index.html

Large Scale Energy Storage

Green Hydrogen Hub DENMARK

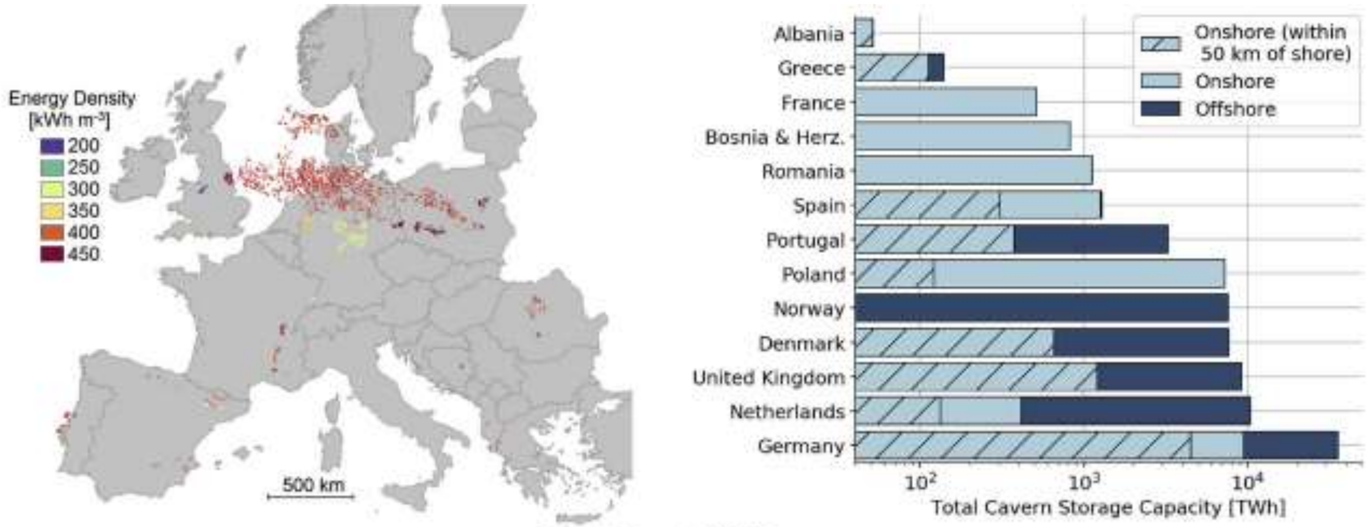
Large scale underground hydrogen storage is pivotal for developing the European market and enable the green transition.



Estimated capacity demand*):

- 70 TWh in 2030
- 450 TWh in 2050

LCOS for salt kaverne: 0.18 – 1.34 EUR/kg H2



Source: Caglayan et al. (2020).[15]

Distribution of potential salt cavern sites across Europe with their corresponding energy densities (cavern storage potential divided by the volume)

The full technical caverns storage capacity in EU is Approx 50.000 TWh.

*) guidehouse_gie_report_draft-1

preprints201910.0187.v1.cleaned.pdf

H2 in the underground: Are salt caverns the future of hydrogen storage? | ENGIE Innovation

Eurowind Energy

Green Hydrogen Hub

Infrastructure development

Green Hydrogen Hub DENMARK

ClusterNorthH2

evida

GreenLab

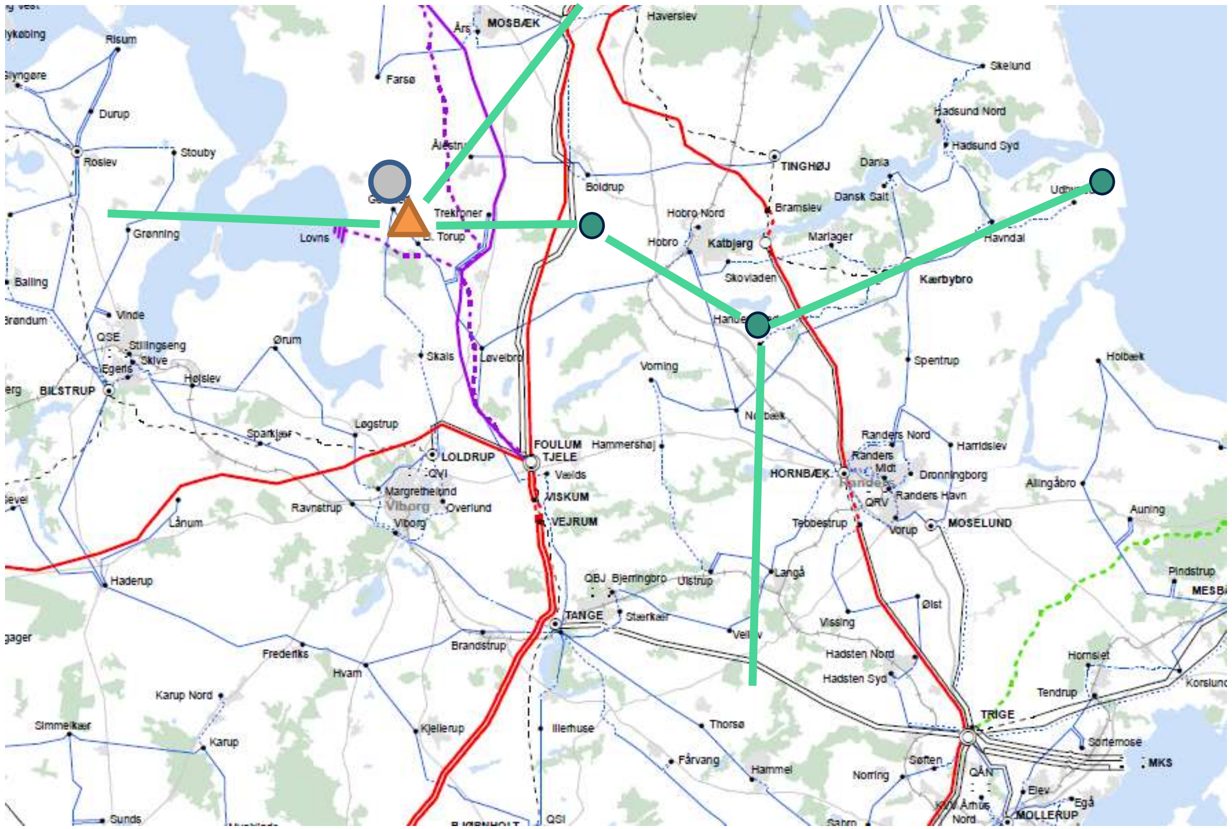
Eurowind Energy

GAS STORAGE DENMARK

HYDROGEN VALLEY

Electrolyser capacity co-located with wind/solar sites

	Location	Park Capacity [MW]	AEP [GWh]	Electrolysis Capacity
A	Overgaard	93,6 WTG 400 PV	861	120 MW 10.000 ton/y
B	Handest Hede	21,6 WTG 75 PV	172	30 MW 3.000 ton/y
C	Hejring	15 WTG 67 PV	134	30 MW 3.000 tons/y
SUM		**671**	**1.167**	**16.000 tons/Y**



DSO hydrogen pipeline

Electrolyze co-located with wind/solar sites

GSD Hydrogen Storage at Lille Thorup

CASE at Lille Thorup

Summary

Hydrogen Production, Transport and Storage

- Co-placing hydrogen production with renewable power production unlock the full wind/PV potential.
- Large scale underground hydrogen storage enable to split the concurrency for energy demand with energy production.
- Developing hydrogen infrastructure is pivotal for accelerating green hydrogen production.

Levers to pull

- Incitements for H2 storage.
- Predictably plans for hydrogen infrastructure development.
- Stable regulatory framework.

Eurowind Energy™

Henrik Lykke Sørensen
Head of PtX Competence Center
hls@ewe.dk
+45 51962365

BALTIC ENERGY ISLAND

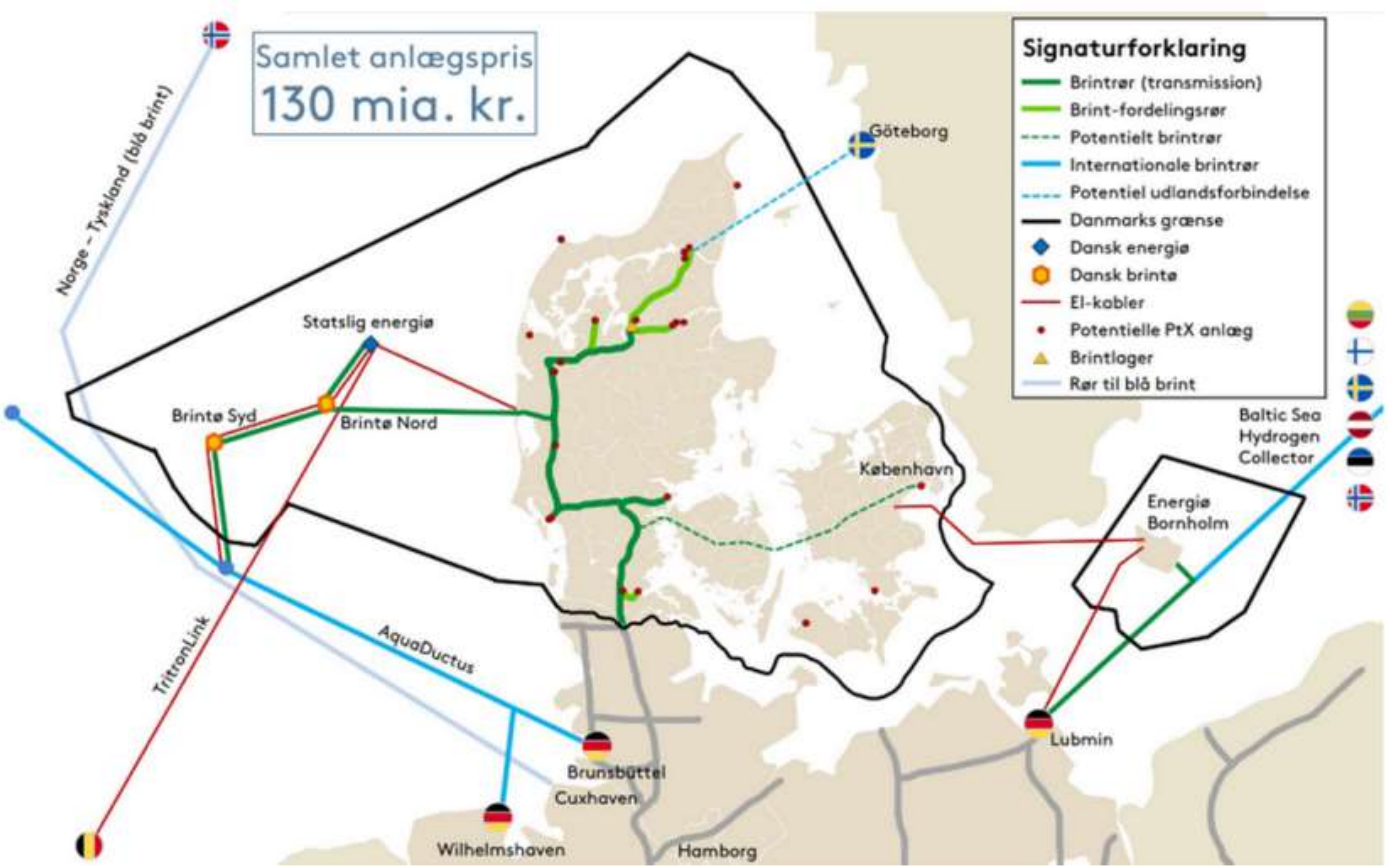
Energy Island Bornholm

Mette Skøt
Strategic partnerships, Baltic Energy Island


134 GW
by 2030
+300 GW
by 2050
+90 GW
Potential
19,6 GW
by 2030

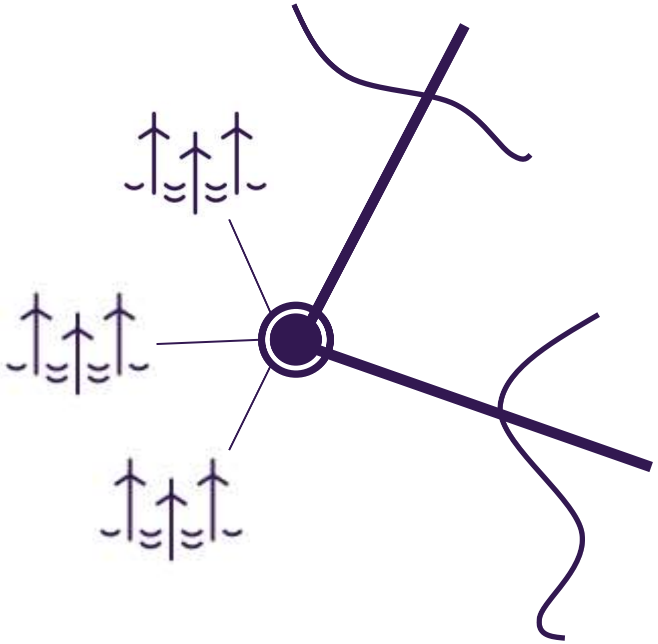
Sundsvall
Tampere
Turku
Helsinki
Uppsala
SWEDEN
STOCKHOLM
Tallinn
ESTONIA
Linköping
Jönköping
Riga
LATVIA
Liepaja
Daugavpils
Copenhagen
KALININGRAD OBLAST
Gdansk
MECKLENBURG-VORPOMMERN
Demand Centers
Energy Islands
Offshore Wind Zones
Backbone

Hot off the press…. Recommendations for the Danish state




ENERGINET
50hertz
| Elia Group

Third generation of wind energy



1980s

Onshore Wind Energy

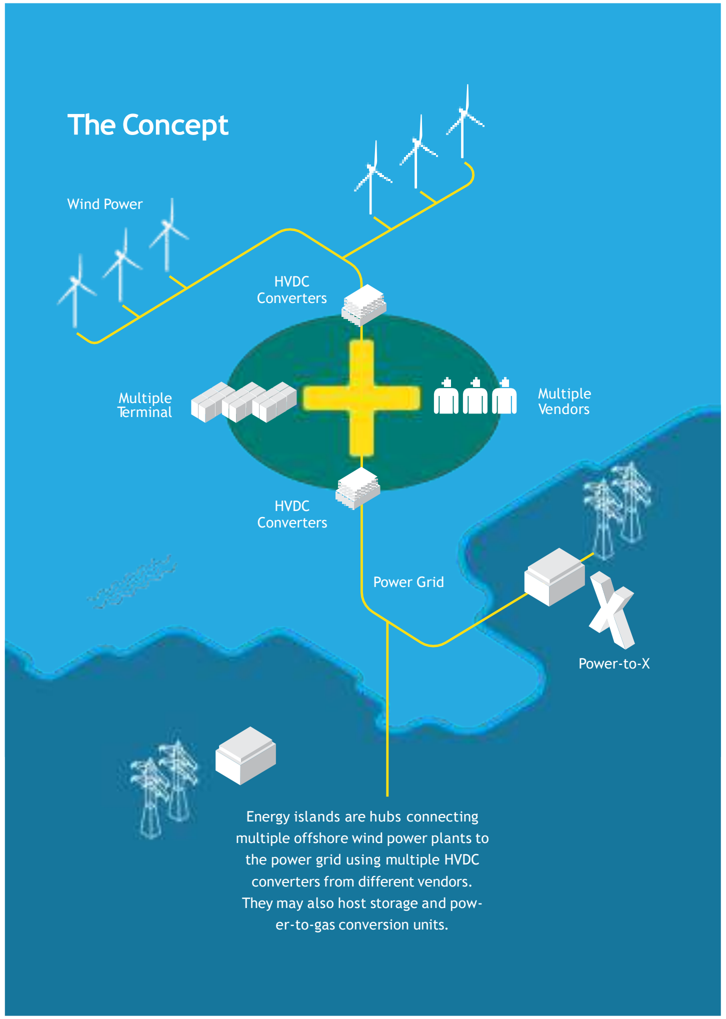
2000s

Offshore Wind Energy

2030s

Offshore Energy Hubs

The concept for energy islands



Energy islands:

- hubs that collects energy from *multiple* offshore wind power plants, typically far from the shore
- use HVDC-connections to transfer the energy to *multiple* neighboring power grids
- They may also host storage and power-to-gas conversion units

Bornholm is a special energy island - because people live there

Energy production

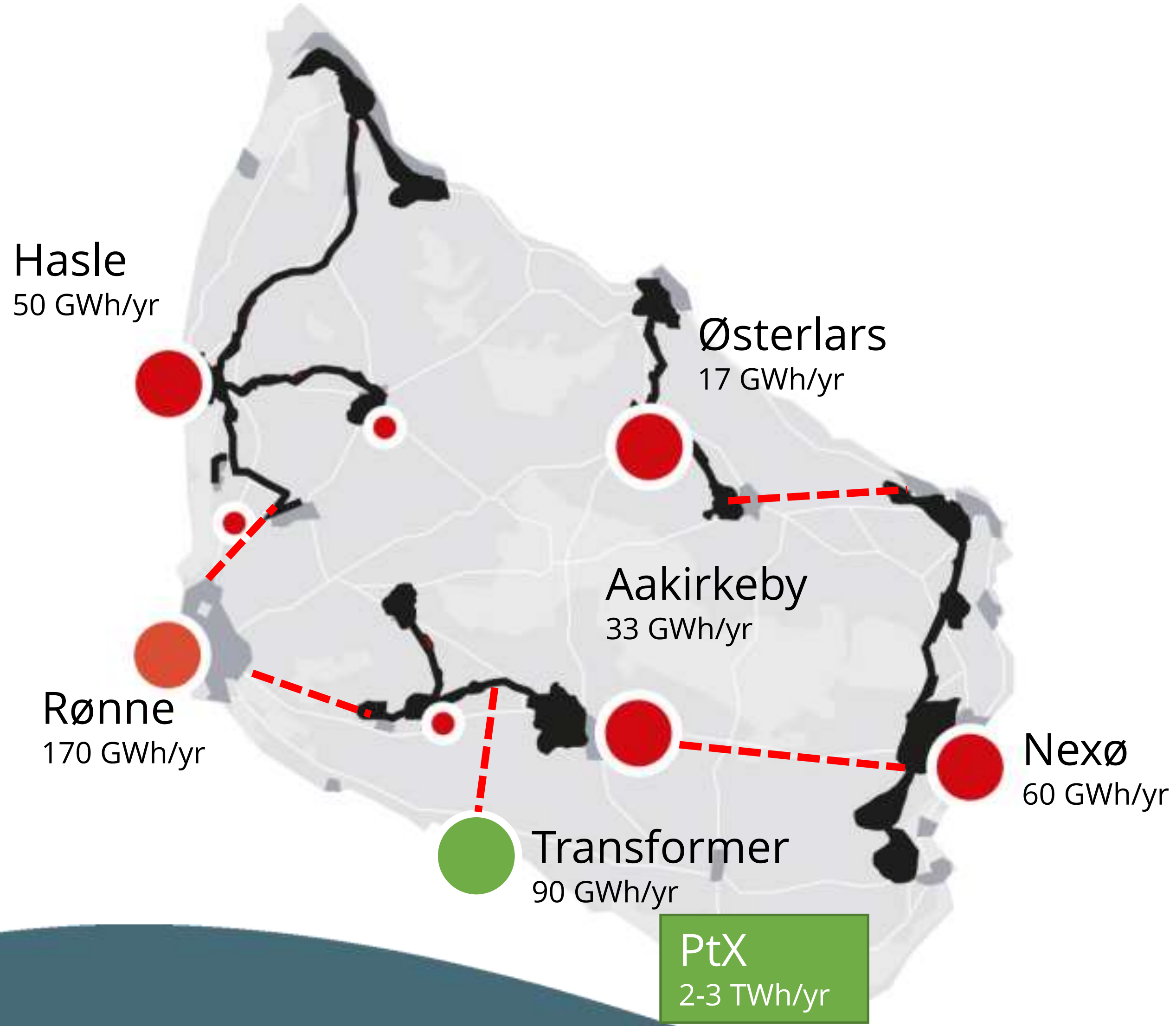
Energy Island Bornholm
3,2-3,8 Gw

CIP / Ørsted
3,0 GW (for PtX)

Bornholms Havvind
0,1 GW

Surplus heat from transformer and PtX
2-3 Twh/år equivalent to 6-9 times the district heating consumption on Bornholm

BALTIC ENERGY ISLAND



BORNHOLMS ENERGI & FORSYNING

SURPLUS HEAT

Likely input of **90 GWh** surplus heat from transformer

A robust and **interconnected energy system** will be essential to capture the value of this

Additional interconnectors and wind farms connected to the energy island will further enhance the potential

PtX production in connection with the project will be a game changer and result in new business opportunities

Local value for Bornholm

With the energy island, Bornholm looks into a bright future with great potential for development. This also includes businesses outside the energy industry. The existing business community has the opportunity to become greener. While the energy island's derived potentials can be seized by entrepreneurs and companies who see opportunities where others see legwork.

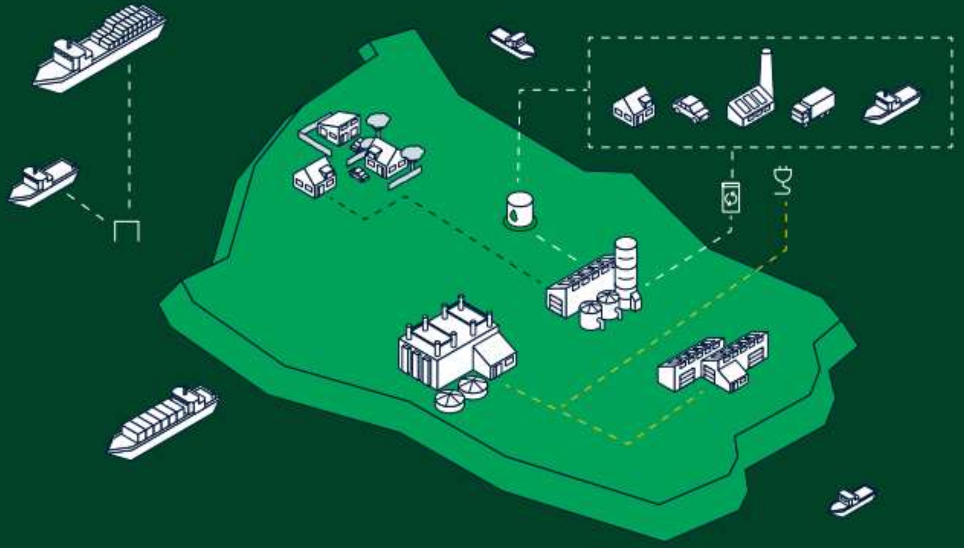
Installation port
The Port of Rønne will be able to function as an installation port for the wind turbines.

Bunkerhub
The Port of Rønne is investigating the possibilities of supplying green fuels and servicing to the 60,000 ships that pass Bornholm every year.

Service port
The many wind turbines need to be serviced to ensure the production of green electricity. It is expected to take place from a port on Bornholm and will provide many new jobs.

New green businesses
The large amounts of green electricity and surplus heat as well as oxygen from PtX can form the background for new green industries. It can be food production, aquaculture, water parks and other businesses that need heat, oxygen and green electricity.

PtX facility
If PtX is established on Bornholm, both the construction and production phases will provide jobs and development opportunities.



Energinet's onshore facility
Energinet's onshore facility will employ up to 2,000 positions per year on Bornholm during the construction phase.

Test site
In connection with the onshore facility, a test site is planned, which will attract even more researchers, students and companies.

Centre for development of new technologies and green businesses

Bornholm is the place in Denmark where the sun rises first. A head start that can be seen as a symbol for the energy island, which puts Bornholm into play in an international context, as a center for green energy in the Baltic Sea.

The project will create value locally on Bornholm in the form of new job, educational and societal opportunities, and it will open up a sea of new potential both technologically and energy-wise.

Test island and test site

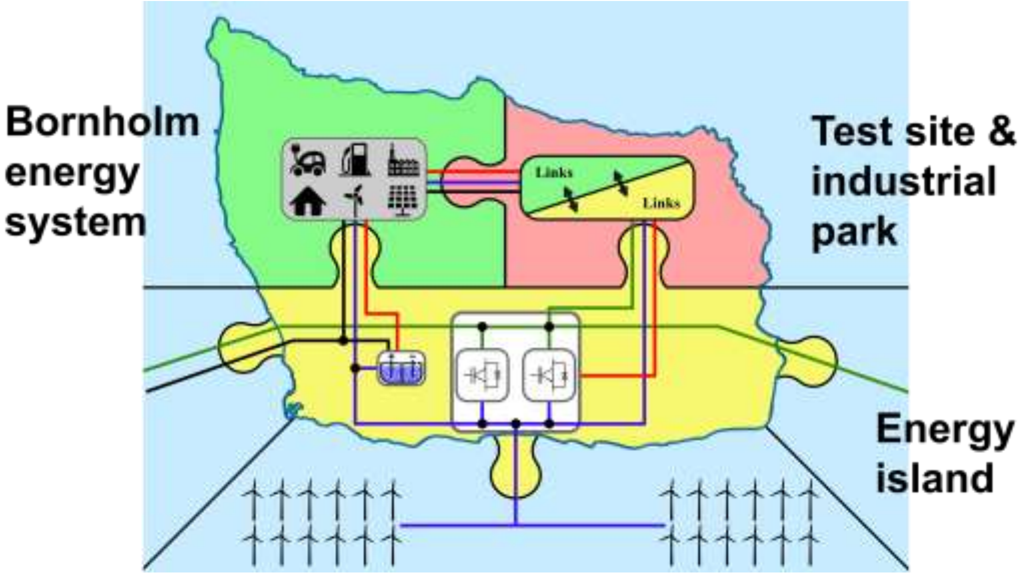
Test island. Prototype Island. Living lab. Over the past 10-15 years, Bornholm has been successful as a green test island. The geographical isolation makes the island perfect for testing new technology on a small scale before it is rolled out to the world.

With the energy island, the island of Bornholm, together with universities and companies, has an even greater opportunity to be a society that is at the forefront of the development of the green solutions of the future.

The ambition is that, together with Energy Island Bornholm, a test site will be built that will enable companies and universities, for example, to test new electrical components for future energy islands.

Why is a test site necessary?

- Security of supply
- De-risking energy island technologies
- PtX system integration and optimisation
- Greentech-innovation



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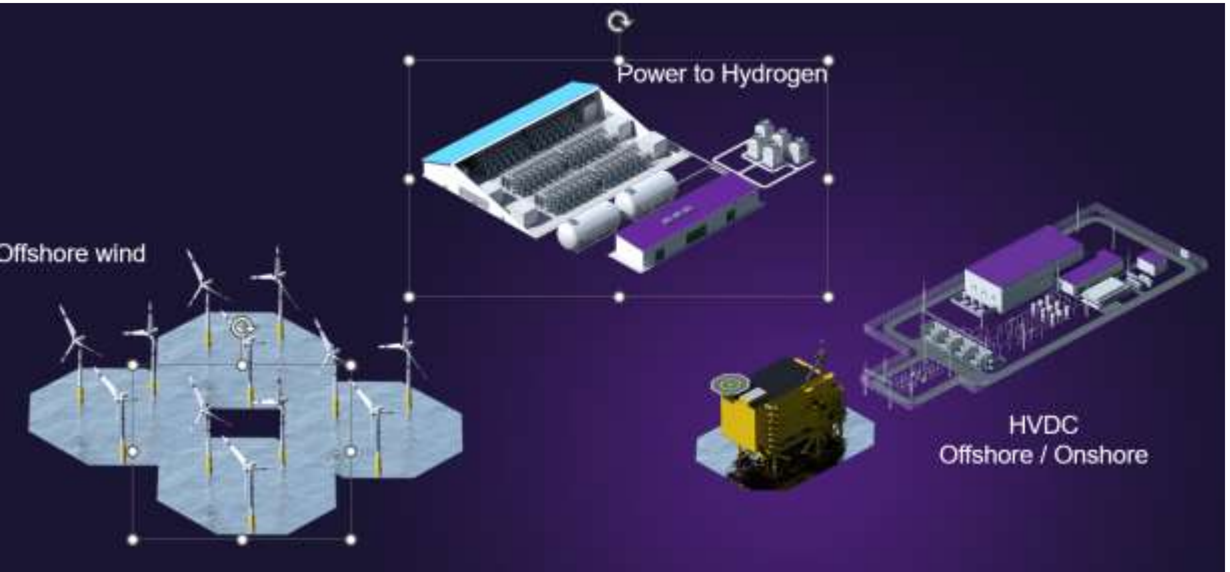
- Capturing and efficient use of waste heat
- Integrating waste water treatment - use of resources
- BunkerHub for green fuels



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Thank you
for your attention !

BALTIC
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ISLAND

Open session – with speakers

Swedish Hydrogen Development Center

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