Unlocking the Green Hydrogen Revolution

Poul Skjærbæk, Siemens Gamesa Renewable Energy

Smart Energy Systems Conference, 21.09.2021

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Returning to SESAAU – A lot has happened in two years.

Offshore Wind Power & Electrofuels

2019: Outlining the vision…

Unlocking the Green Hydrogen revolution at the sea

Agenda today

- Denmark and Offshore Wind
- SGRE's first Step: Brande Hydrogen
- Next steps to scale Wind-to-Hydrogen systems

2021: Taking the action…

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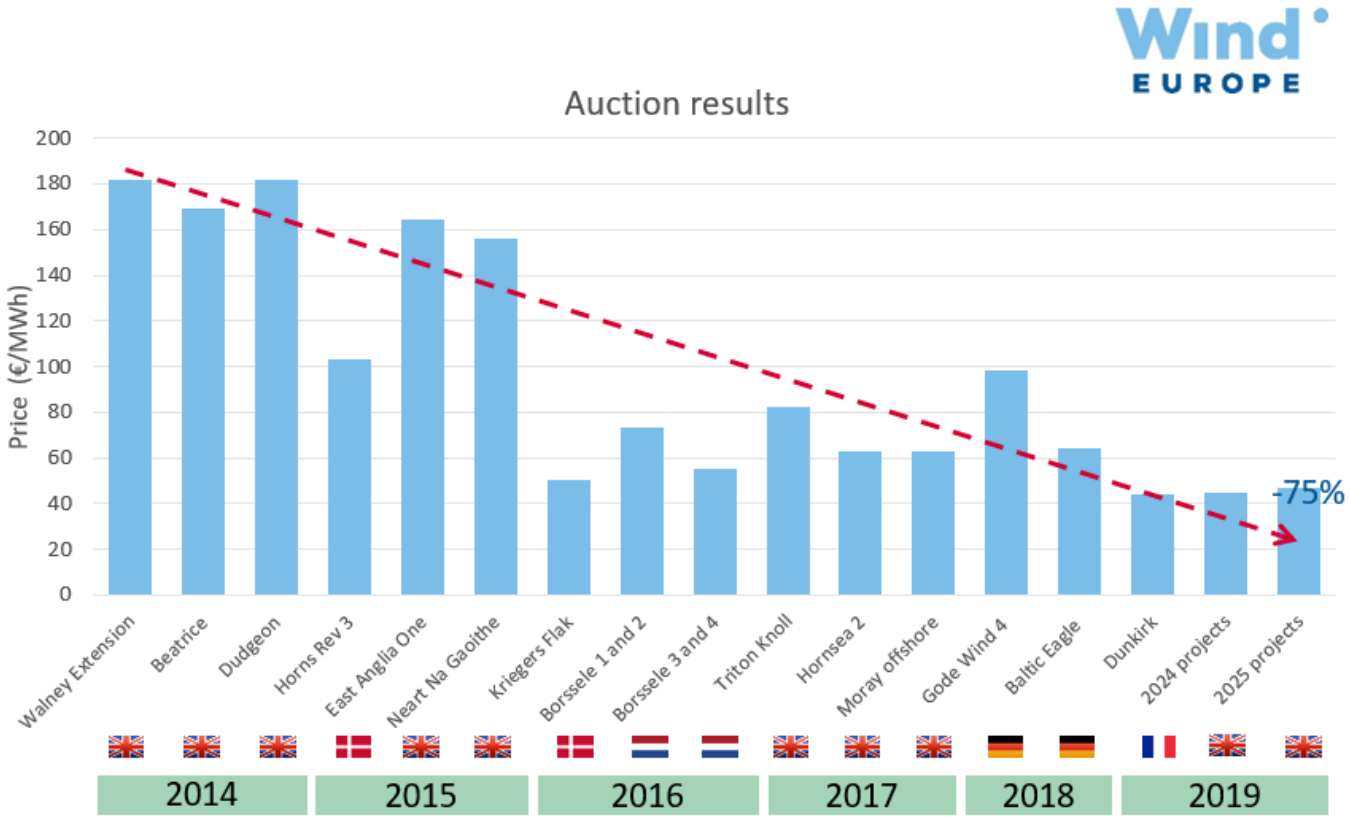
Offshore wind power has scale and cost at a competitive level

A lot has happened in 30 years…

Especially in the last few years…



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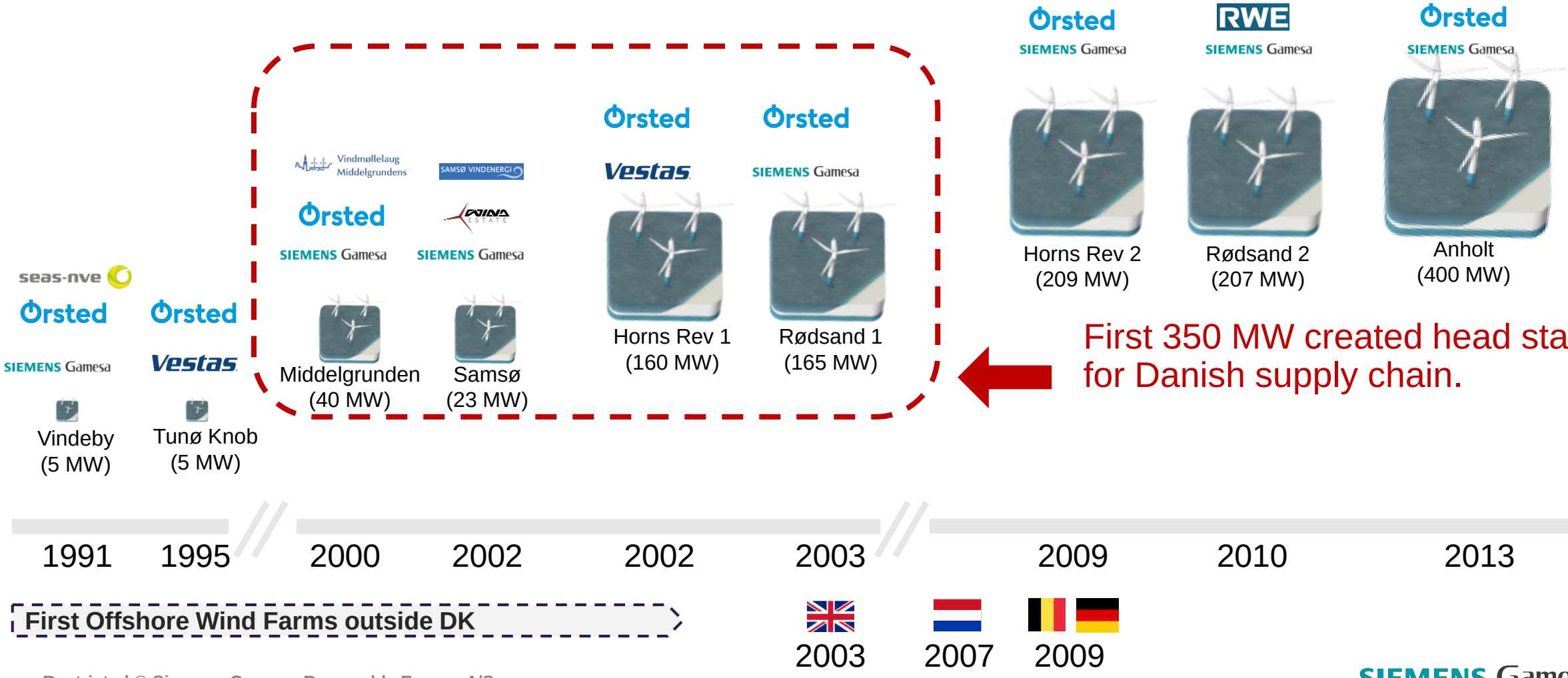
The Danish offshore wind advantage was not born in a lab –
It was made from early projects in the field setting the standards for the world to follow



Note: There are a few other small danish offshore projects not included in this overview: Frederikshavn (7 MW, 2003), Sprogø (21 MW, 2009). All logos are copyrighted to their respective owners.

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Pictures from the pioneering days when offshore installation was done for the first time

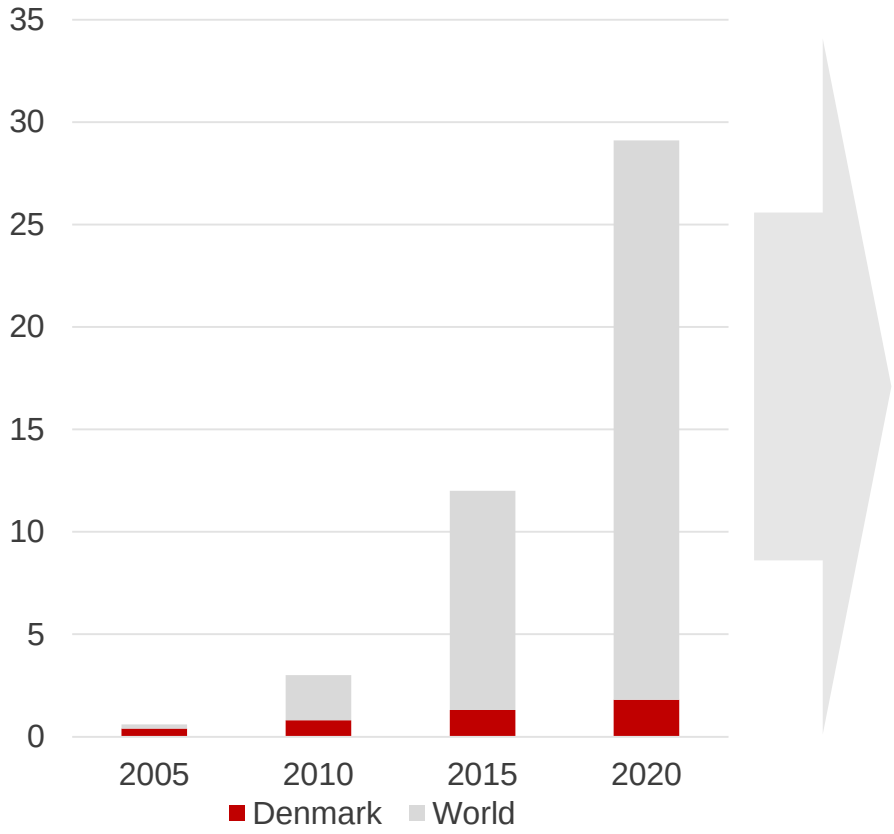
Vindeby
(5 MW - 1991)

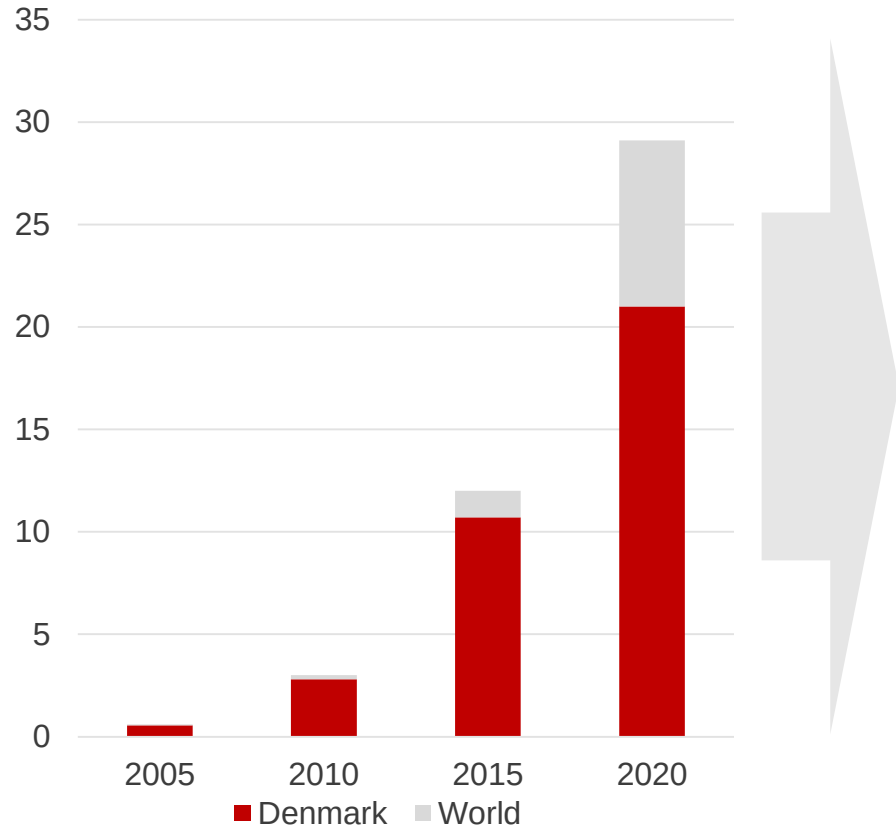
Middelgrunden
(40 MW - 2000)

Rødsand 2
(207 MW - 2010)

Picture Credits: Vindeby: Bonus, Middelgrund & Rødsand 2: SGRE

Denmarks share of the installed offshore wind fleet dropped from 70% to <10% in 15 years… It is a great export story as ~70% of global offshore turbines come from SGRE or Vestas





wind denmark 05.05.2020

Vindeksporten slår rekord

2019 Exports: 66.5 bn. DKK

31.000 Wind employees

13 bn. DKK in tax revenue*

Source: WoodMackenzie: Offshore Project Database, 2019; GWEC OF Wind Report 2020, Mortensen, 2018 – DK Roots means Danish-based companies, Bonus, Siemens SGRE, Vestas, MHI-Vestas. Note: Wind Industry export and employment numbers are based on both onshore and offshore wind turbines.

***WindDenmark numbers are both onshore and offshore**

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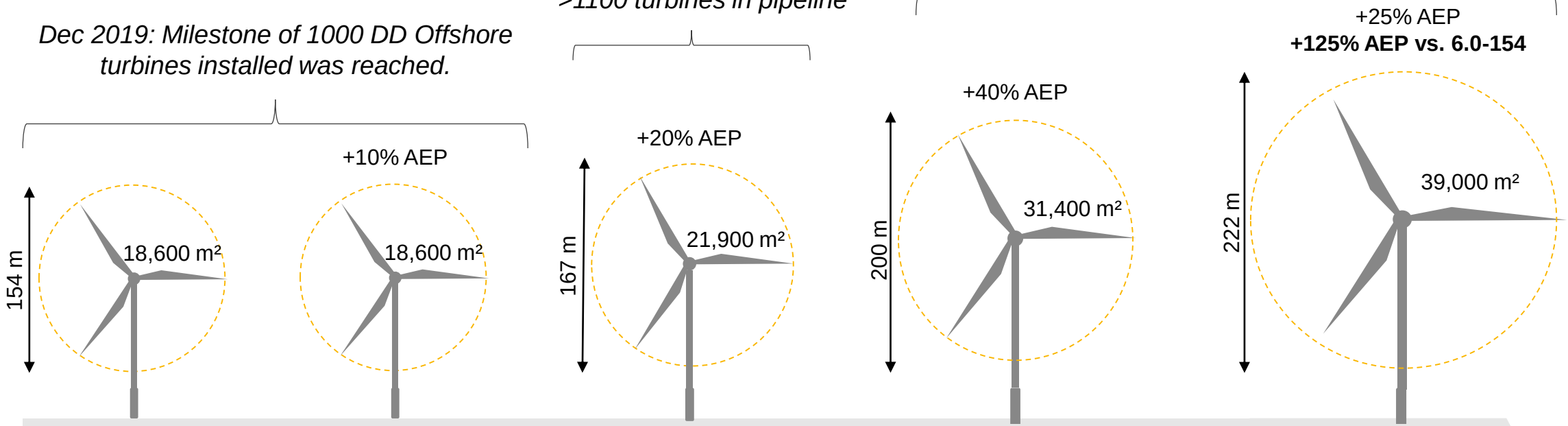
SGRE Offshore wind development of DD machines in the last 10 years show that technology can be scaled quickly when needed – We must scale offshore wind-to-hydrogen even faster.

Dec 2019: Milestone of 1000 DD Offshore turbines installed was reached.

>1100 turbines in pipeline

SG 11 and SG14 to usher in first Subsidy-free wind farms.



SWT-6.0-154	SWT-7.0-154	SG 8.0-167 DD	SG 11.0-200 DD	SG 14-222 DD
Prototype: 2012	2015	2018	2020	2021
Market: 2014	2018	2020	2022	2024

Note: For Comparison of size an international Soccer-field measures 6,400 m², AEP = Annual Energy Production.

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The Brande Hydrogen test site went from investment decision to first test-run in 10 months. The WTG is directly connected to the electrolyzer to be able to test island-mode operations

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Brande Hydrogen Test site – Regulatory Test-Zone awarded 05.05.2021

On 5 May 2021, the Danish Energy Agency has granted GreenLab and Siemens Gamesa's Brande Hydrogen project status as official regulatory test zones.

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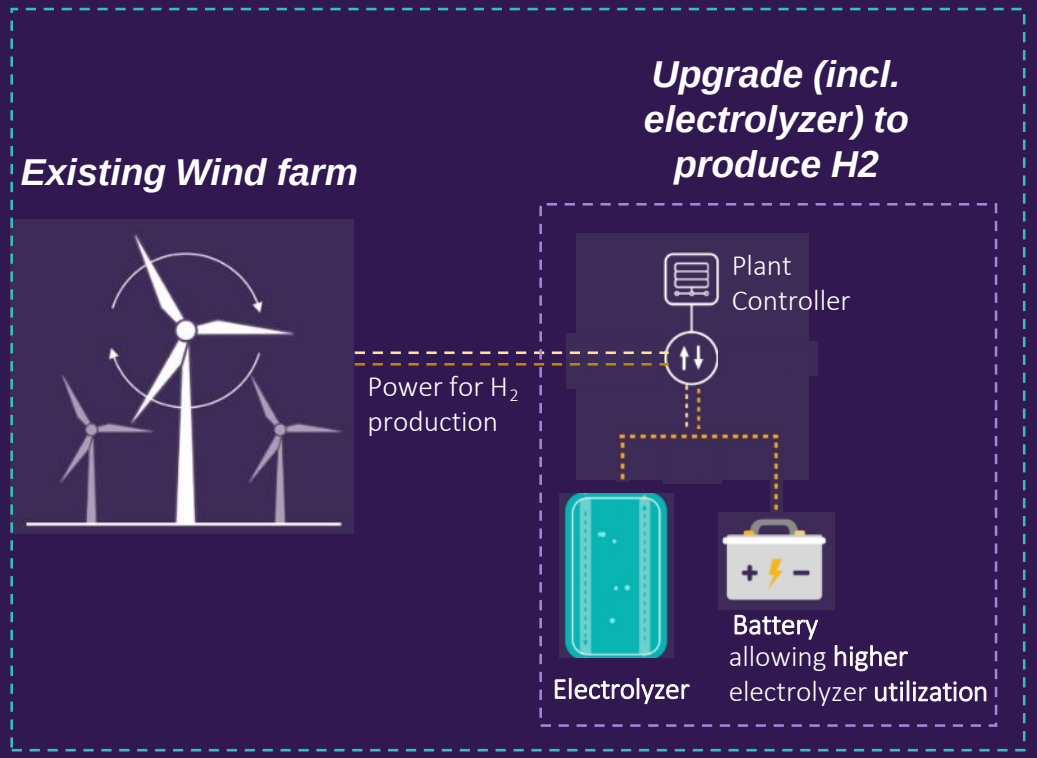
SGRE already taking significant steps in shaping the industry: Brownfield Concept

Renewable H2 Upgrade product integrates an electrolyzer into an existing Wind farm…

Product concept description



… providing sound benefits to existing assets

Benefits

1. Adds a **new value stream** by enabling the generation of **green Hydrogen**
2. **Increases the value of Wind power** by using it **before** it goes to grid
3. Makes the plant **flexible**, allowing the assets to contribute even more to the energy transition

Pilot project

Brande (DK) demonstrator:

3MW onshore turbine
400kW electrolyzer

H_2 output to be used **to be used in mobility sector**

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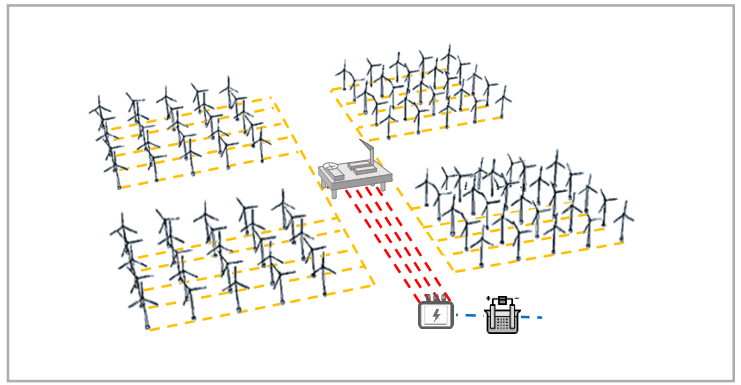
Offshore wind is key to get the scale needed - The three ways to go from electron to molecule

Scenario I: Offshore kWh plant (as-is)



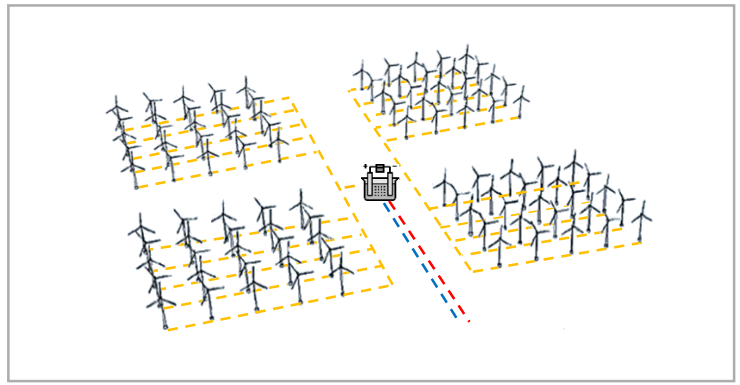
Berlingske 25.09.2019

Ørsted foreslår kæmpe vindmøllepark ud for Bornholm

Berlingske 19.08.2020

Gigantisk brintfabrik i København rykker tættere på første spadestik: Søger kæmpe beløb hos statsfond

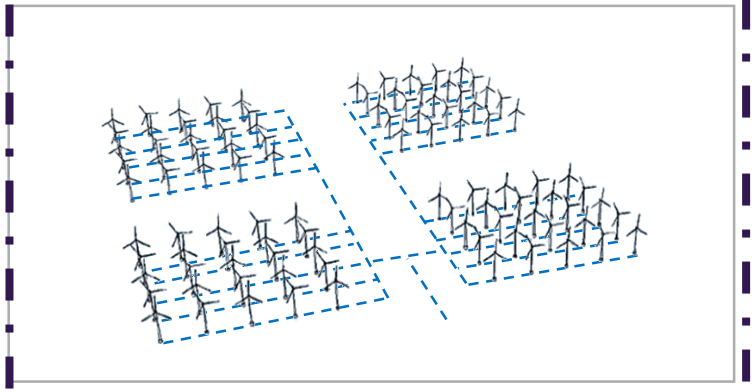
Scenario II: Offshore H_2 plant



BYENS Ejendom Videnscenter for Byudvikling 05.06.2020

PFA, PensionDanmark og SEAS-NVE vil bygge 250.000 kvm ø med beton-sænkekasser

Scenario III: Decentralised H_2



RECHARGE Global news and intelligence for the Energy Transition 08.09.2020

Siemens Gamesa wind turbine pilot targets 'cheapest green hydrogen'

Flexibility

Cost Parity

kWh – 66KV kWh – 220KV H_2 – Hydrogen (Pipeline incl. auxiliary power

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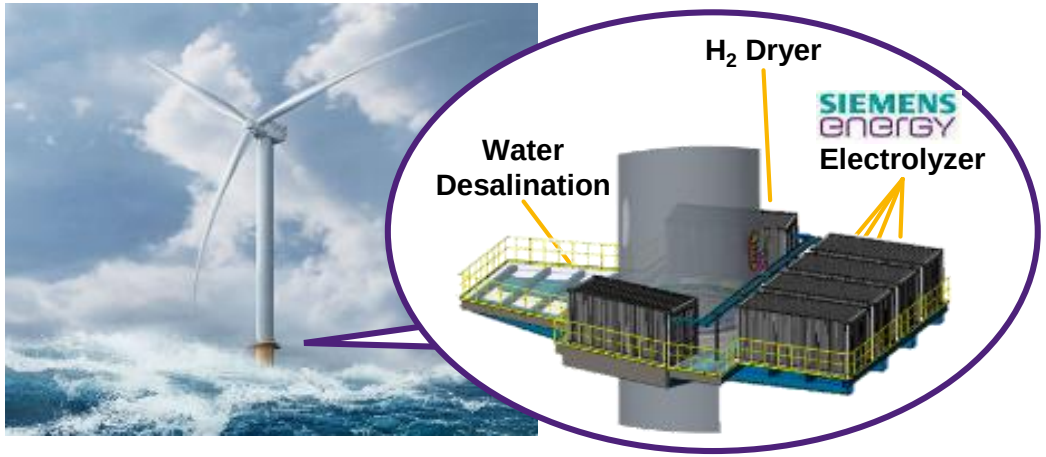
SGRE already taking significant steps in shaping the industry: Decentralized offshore solution

Offshore decentralized solution description



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Wind turbine

Modified WTG to produce H_2 at turbine level

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Electrolyzer

Plug & play containerized solution on a platform located at sea level

Advantages taking us to Cost-Parity

- **High utilization of off-grid electrolyzer**
- **Electrical CAPEX savings**
- **Cost-out through modularity in scale**

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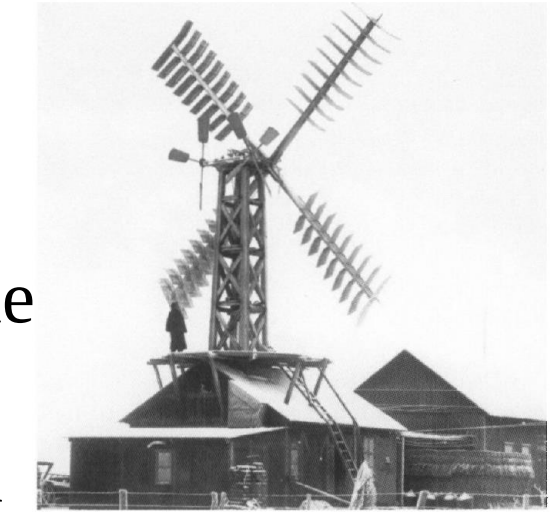
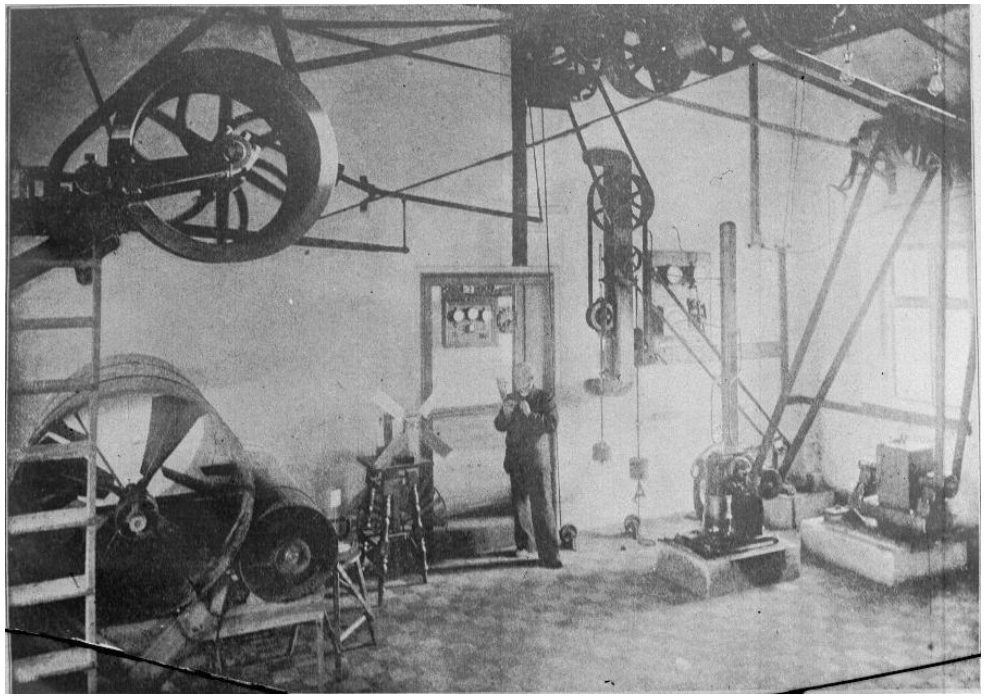
Poul La Cour's first test turbine in 1891 became a hydrogen production unit already in 1894.

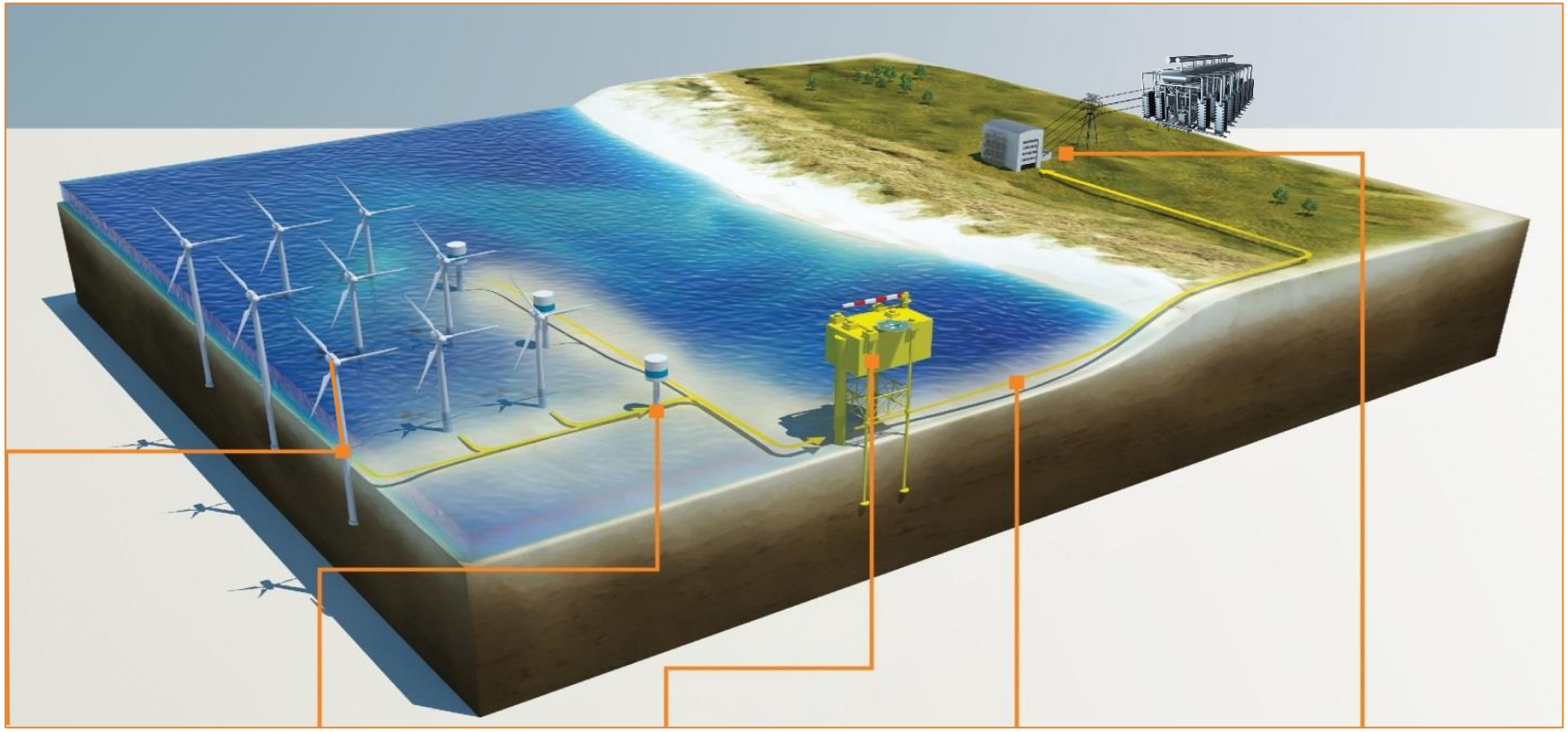
Poul La Cour's 1891 test turbine was in 1894 connected to an Electrolyzer array from the Italian inventor Pompeo Garuti. The turbine would pull a dynamo which powered water separation in 10 electrolysis chambers in the basement.





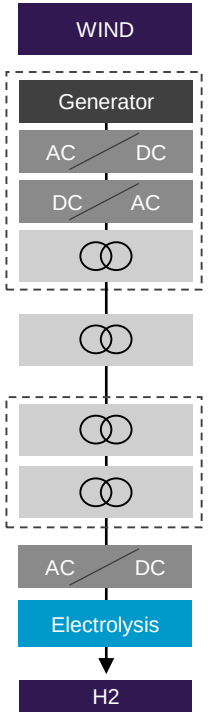
Picture: Steffen M. Søndergaard, 2002: Poul la Cours forsøgsmolle og mølleforsøgene i Askov, p. 35 & Poul La Cour Museet Introduktion, 2012, p. 6 & 18.

120 years later we have achieved scale of our wind resources by going offshore…



WTG Transformer steps | Array Cables | OF Substation | Export Cable | ON Substation & Grid

Conventional WTG to Hydrogen



100%

57%

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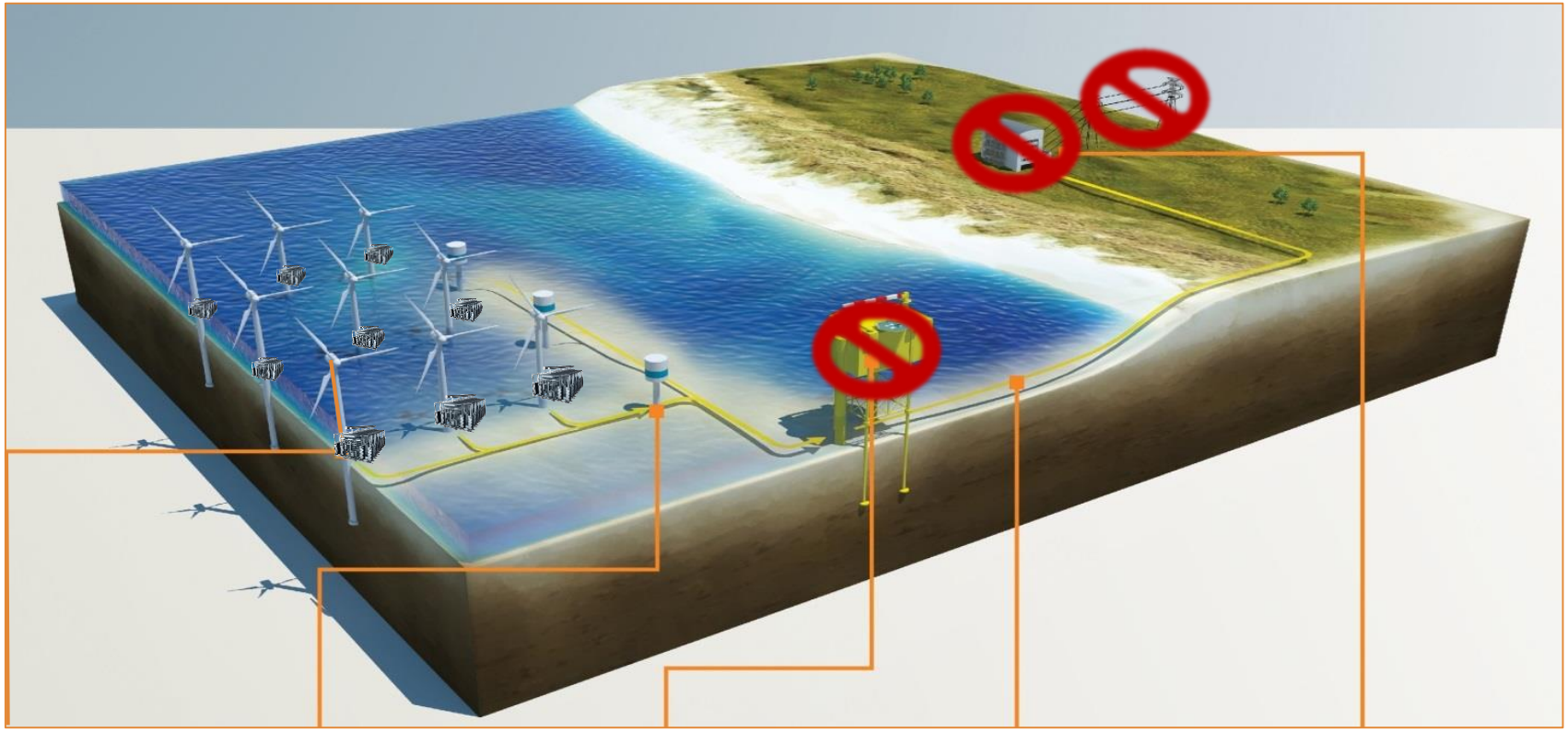
Our concept follows the original logic – Move conversion as close to the source as possible. This lowers conversion losses, minimizes the disturbance to wildlife and people.



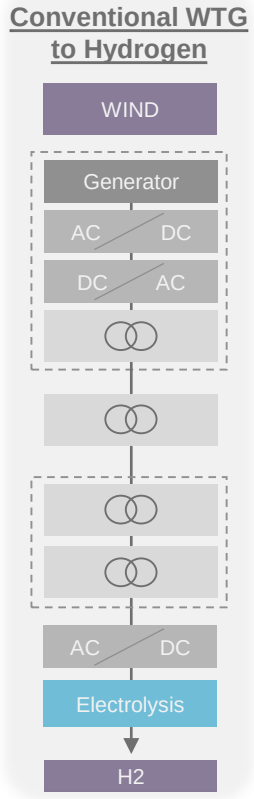
WTG Transformer steps

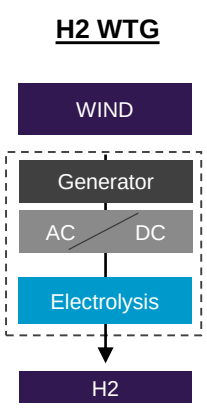
Array ~~Cables~~ Pipes

~~OF Substation~~

Export ~~Cable~~ Pipe

~~ON Substation & Grid~~





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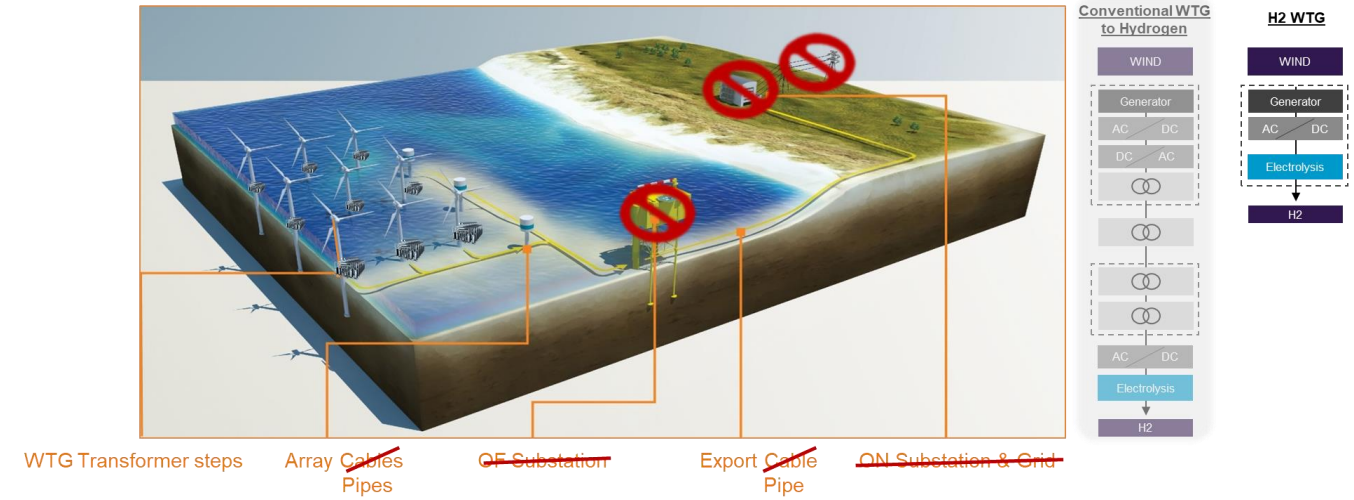
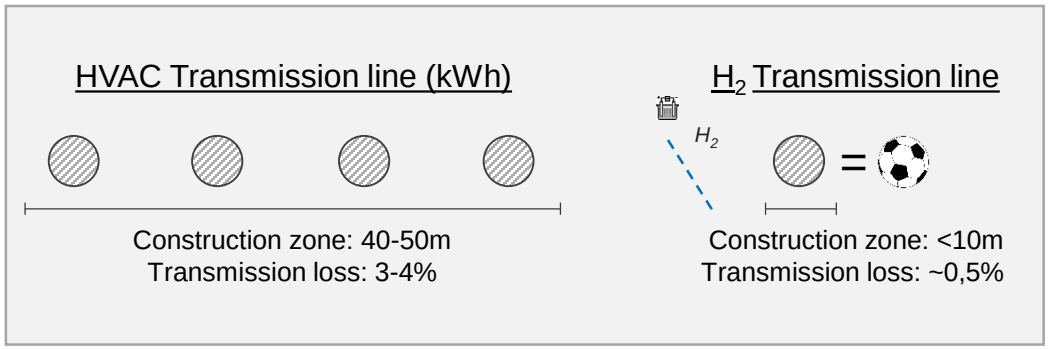
Our concept follows the original logic – Move conversion as close to the source as possible.

Advantages of moving to Pipes

- Lower Conversion losses
- Eliminates overhead cables
- Minimizes disturbance to wildlife





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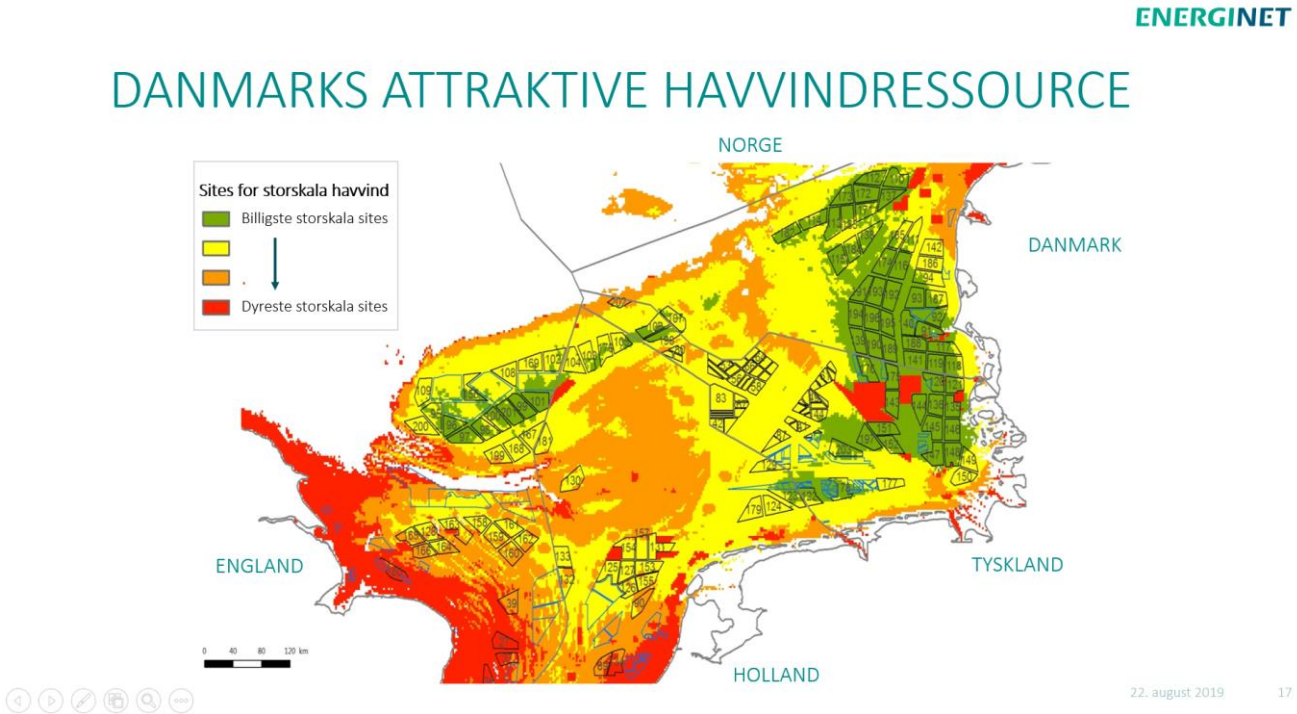
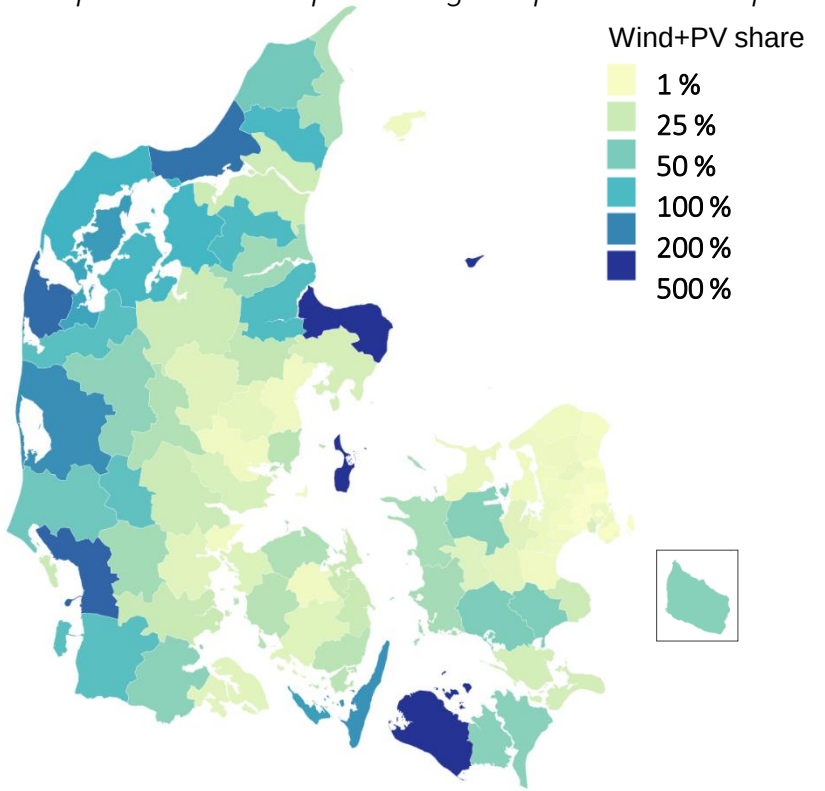
Denmark has ~40 GW of attractive offshore wind sites, but currently only electrical capacity for 4-6 GW more on the grid – Western municipalities are already above 100% RE share.



Wind+PV share at municipality level in Denmark (2017)

VRE production compared to gross power consumption



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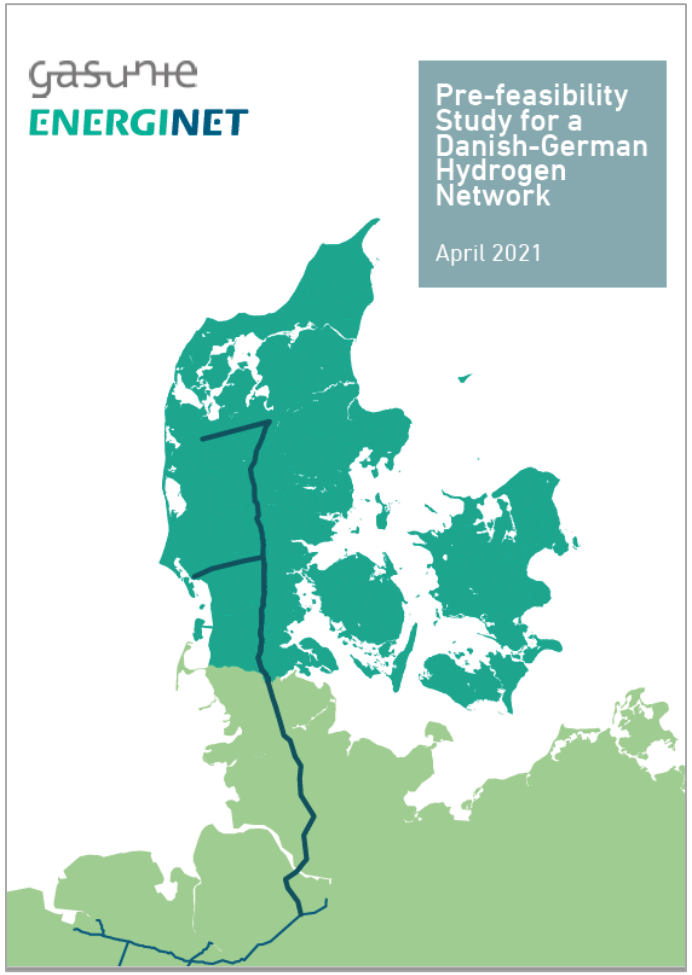
Denmark and Germany should establish a joint-hydrogen infrastructure in the next 10 years



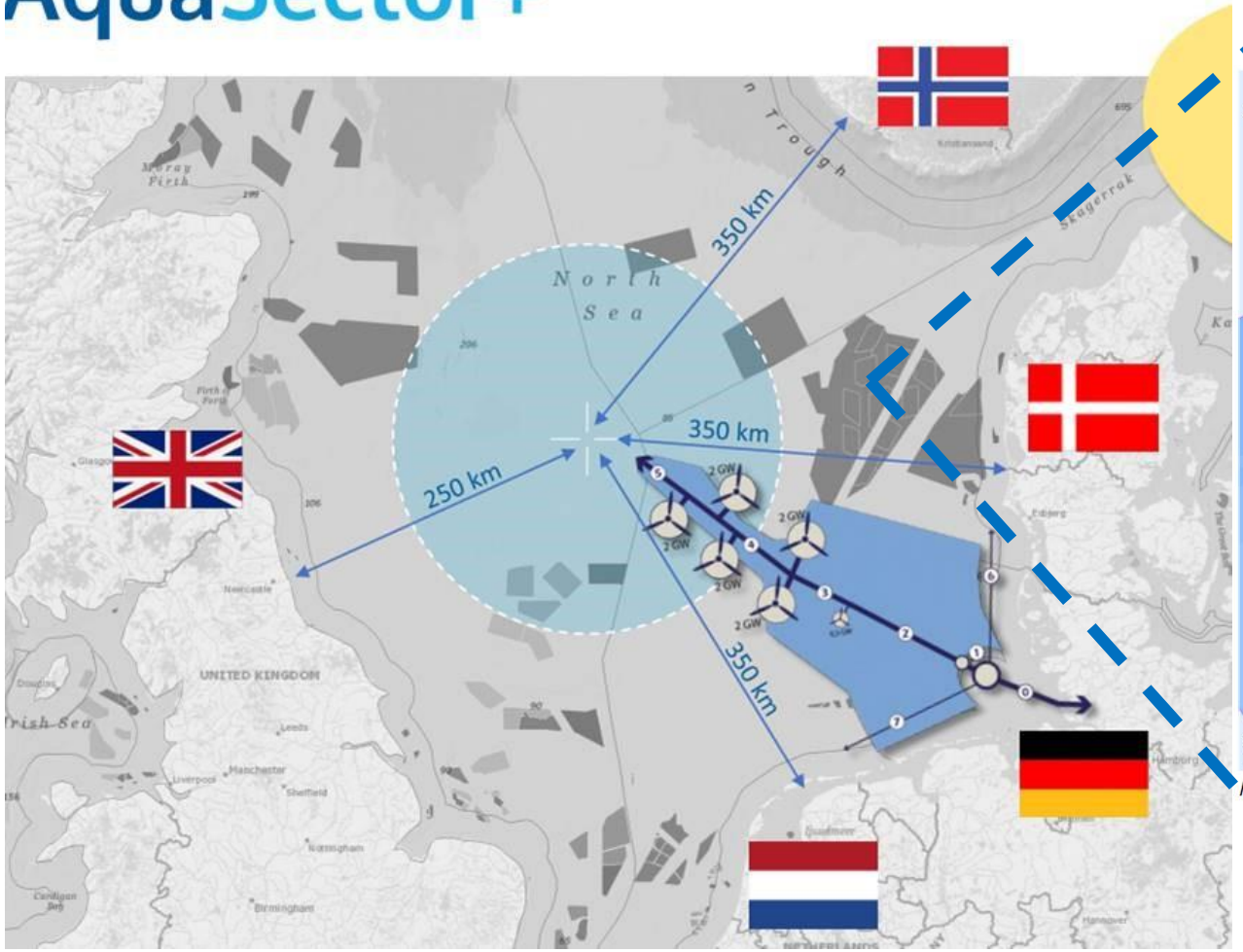
"From a cost perspective, we find that a transport corridor between Denmark and Germany can be realized rather quickly…

However, from a financing perspective, clear market signals and regulation will need to be in place before it is possible to move forward and make final investment decisions."

Source: Gasunie, Energinet: Pre-feasibility study, 2021 p. 35.

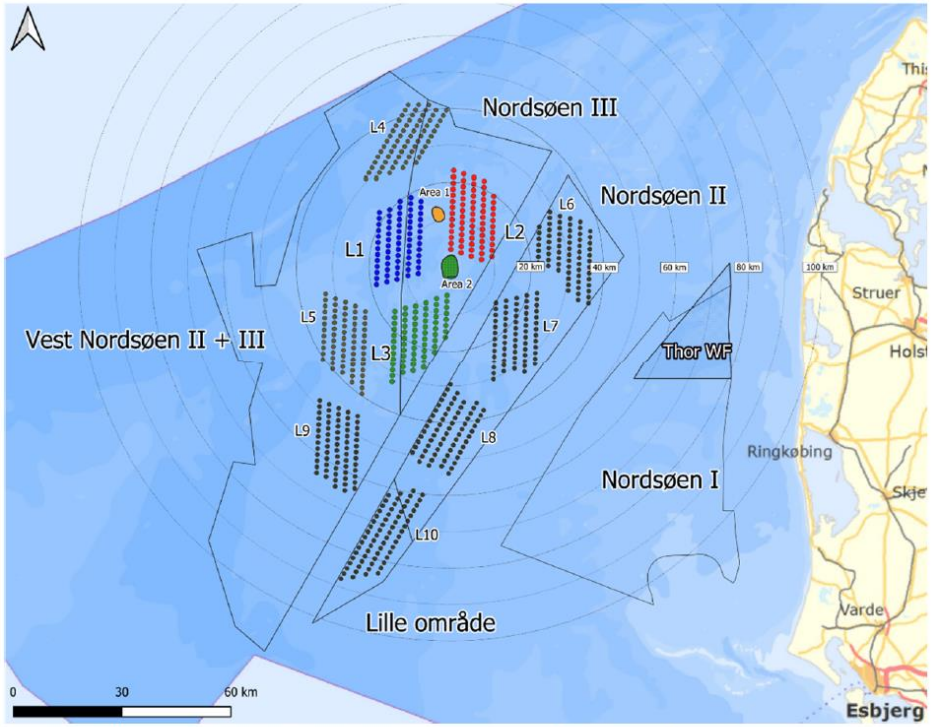
The AquaSector + placement fits well with the planned Energy Island.

AquaSector+



Cost benefit analyse og klimaaftryk af energiøer i Nordsøen og Østersøen

COWI



Figur 6-1 Placering af ti vindmølleparker og energiø i Nordsøen (Area 2).

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Conclusion: Offshore wind coupled to hydrogen can deliver the scale needed to decarbonize ‘hard-to-abate sectors’ such as shipping, aviation and steel manufacturing

- The EU is a leader in offshore wind, because of the first large projects.
- As with offshore innovation, visibility of H2 project pipeline is key.
- 2030: Infrastructure and GW-scale sites for hydrogen production is needed.
- We again have the opportunity to set the global standard – **Let’s seize it!**

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Thank you.

Questions?