North Sea
Wind Power Hub

CONSULTATION SESSION

Stakeholder engagement on first findings and key questions

Amsterdam | 30 November, 2017

SAFETY ANNOUNCEMENT

- No planned safety drills
- In case of fire / evacuation
  - Stay calm, avoid panic
  - Follow instructions from emergency team
  - Go to the assembly point outside the Elicium building, entrance D

PROGRAMME

Introduction, vision and background (Hanne Storm Edlefsen, Energinet)

Modular Hub & Spoke Concept (Rob van der Hage, TenneT \ Henrik Thomsen, Energinet)

Intermezzo (Nicole Versijp, EC DG Energy)

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Power to Gas (Reinalt Nijboer, Gasunie)

What is next and how to get involved

End

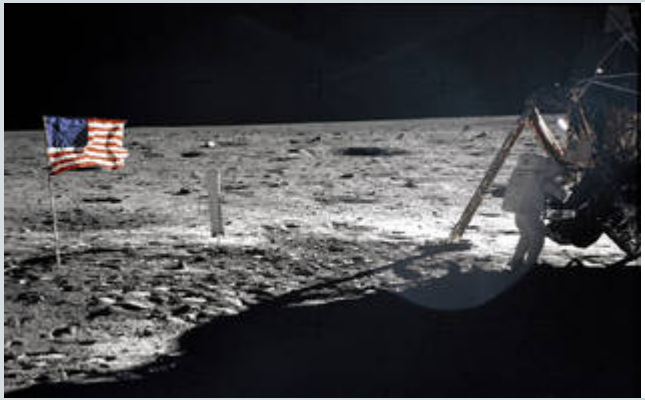
THE VISION

THE VISION

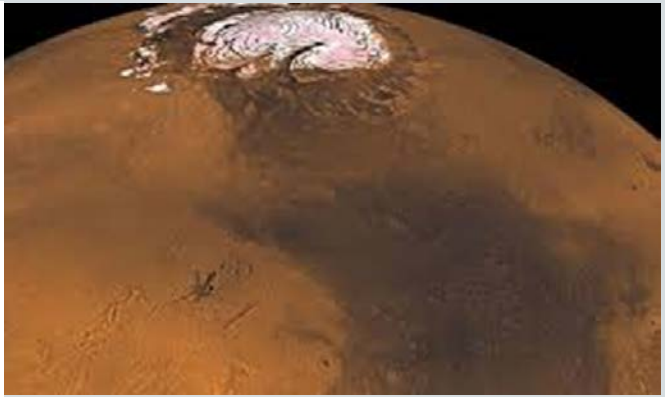
The North Sea Wind Power Hub: a modular approach to facilitate large scale offshore wind at low cost.

- Far shore becomes "near" shore
- Distribution point for different countries
- Space for multiple converters (AC → DC)
- Synergies for Power-to-Gas to contribute to an efficient energy system

IS THIS THE MOON OR THE MARS LANDING OF THE PARIS CLIMATE AGREEMENT?

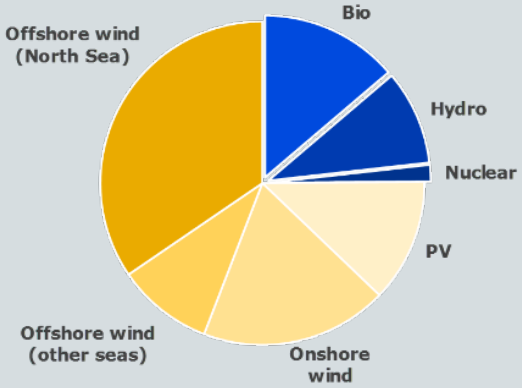


COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE



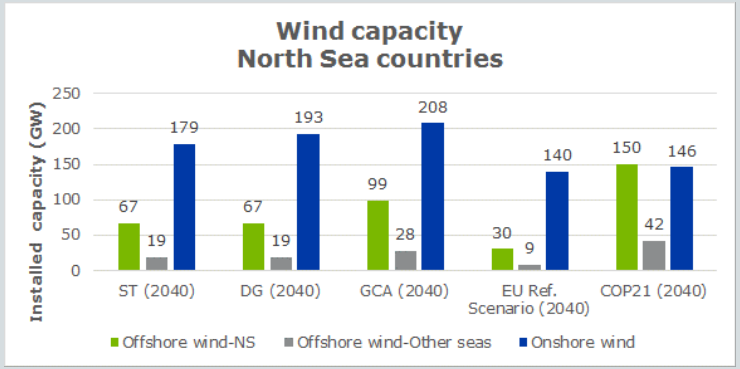
Source: NASA

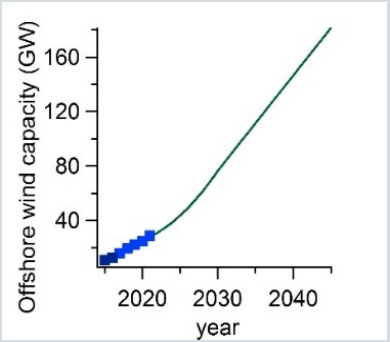
OFFSHORE WIND IS ESSENTIAL TO REALISE 100% DECARBONISATION OF THE ELECTRICITY SUPPLY



Offshore wind will provide a significant share of the RE generation capacity needed for the North Seas countries to meet the Paris Agreement goals

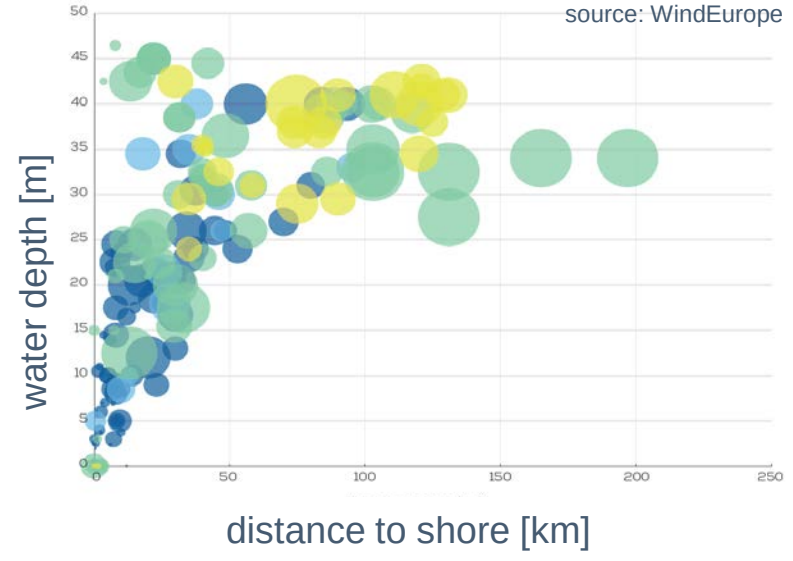
The installed offshore wind capacity for the North Sea countries is expected to grow significantly to an estimated 70-150 GW





The offshore wind deployment rate needs to increase towards 2-7 GW/year over the period 2023-2040

OFFSHORE WIND IS MOVING FURTHER OFFSHORE PUTTING PRESSURE ON COST LEVELS



- Larger distances to shore and deeper waters, due to close to shore spatial constraints (increasing cost for cables, foundations, O&M, ...)
- Increased onshore grid integration cost, due to in-feed of large scale generation and increased share of renewable energy

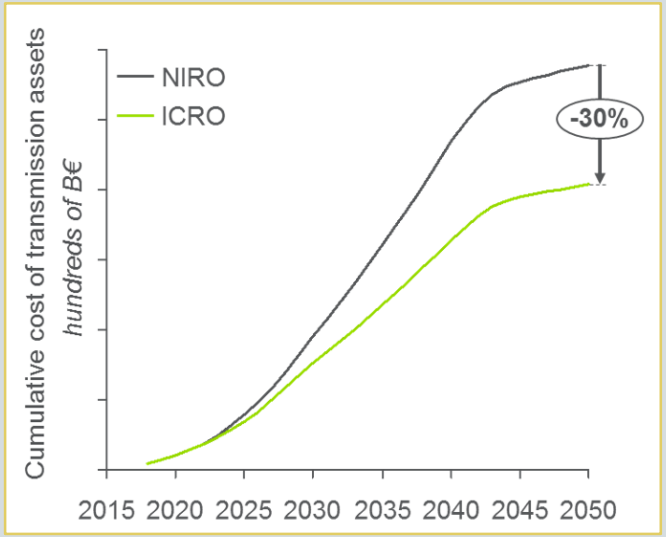
AN INTERNATIONALLY COORDINATED ROLL-OUT CAN SIGNIFICANTLY REDUCE COST

Internationally Coordinated Roll-Out (ICRO) - based on:

- An integrated North Sea infrastructure planning for both offshore wind connection and interconnector capacity
- Coordination of location and timing of wind park sites at a North Sea regional level
- Minimising total energy system costs (wind farm connection, interconnection and onshore grid reinforcement) on a North Sea regional level

In contrast to **National Incremental Roll-Out (NIRO)** - based on:

- National approach with radial connections
- Incrementally improved grid connection technology changes



HIGHER LEVELS OF RENEWABLE ENERGY SOURCES REQUIRE INCREASED FLEXIBILITY OPTIONS

- A higher share of variable sources, with strongly reduced levels of dispatchable generation, requires increased use of flexibility options.
- Higher level of interconnectivity across the North Sea are needed for flexibility options and markets to function
- Cost efficient flexibility options, such as demand response, small/large-scale storage and power-to-gas, will become essential

REALISING COST EFFICIENT OFFSHORE WIND CAPACITY REQUIRES A CROSS BORDER STRATEGIC APPROACH

A regional view on resource use, deployment and operation based on a common sustainability commitment and an integrated market to balance:

- Preservation of an important nature area
- Facilitating intense use by a wide variety of economic sectors
- Cost efficient roll-out

From a stepwise development - starting from bi-national hybrid connections, towards large scale (10-30 GW) offshore wind collection hubs feeding and connecting multiple North Sea counties.

WHY TSO INVOLVEMENT ?

- We have a public responsibility to ensure a high level of security of supply at lowest possible socio-economic cost in a future scenario with more renewables.

- Our aim is to make the overall energy transition both feasible and affordable by planning for possible future scenarios today.

WE WELCOME YOUR FEEDBACK

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- Today's presentations
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Feedback

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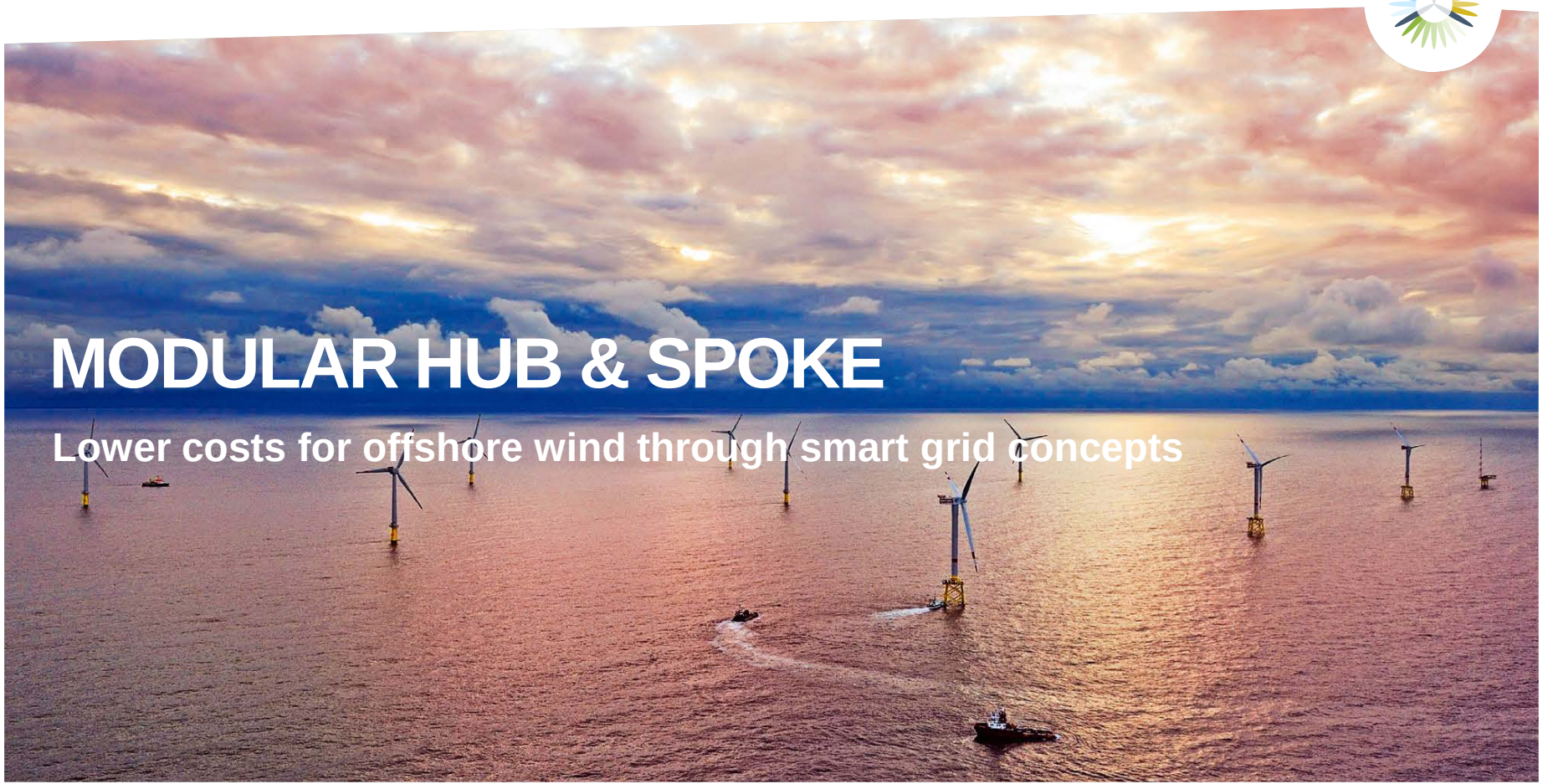
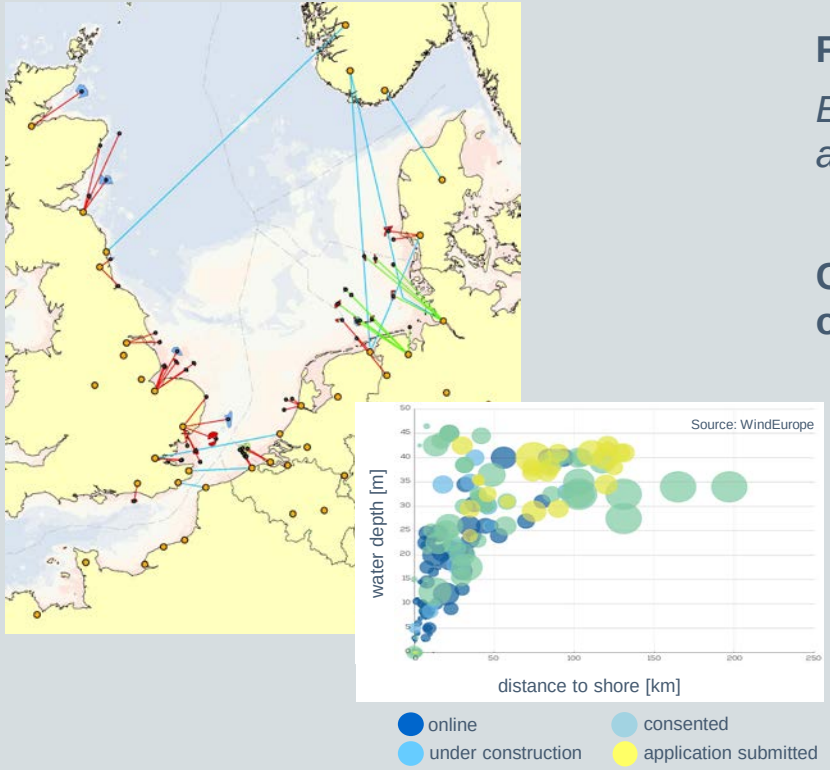


MODULAR HUB & SPOKE

Lower costs for offshore wind through smart grid concepts

CHALLENGE FOR OFFSHORE WIND ENERGY



Far offshore wind at large scale is needed

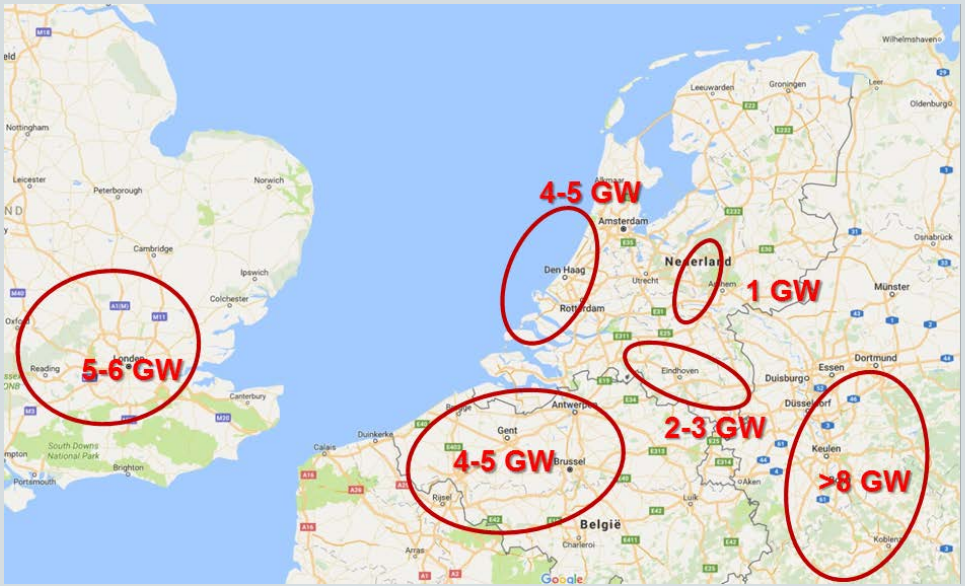
Estimated capacity approximately 70-150 GW in 2040 and possibly 180 GW by 2045 (translate COP21 scenario)

Current connection concepts lead to increasing costs for far offshore wind farms

- Wind energy on land
- Wind energy near shore
- Wind energy far offshore
  - Construction (expensive)
  - Maintenance (expensive)
  - Infrastructure (expensive)

CHALLENGE FOR ONSHORE GRID INTEGRATION

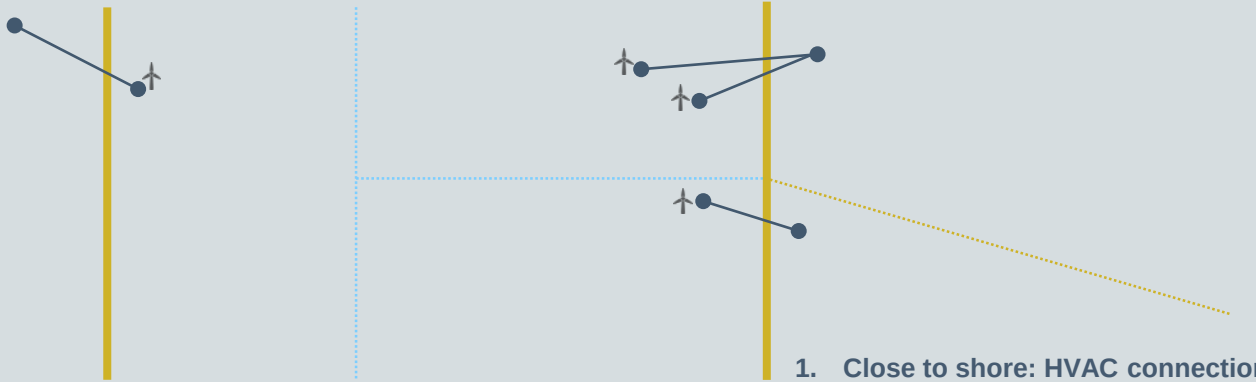
Connecting wind power to load pockets



NIRO

National Incremental Roll-Out leads to cost increase for far offshore wind

- National targets
- National approach with radial connections

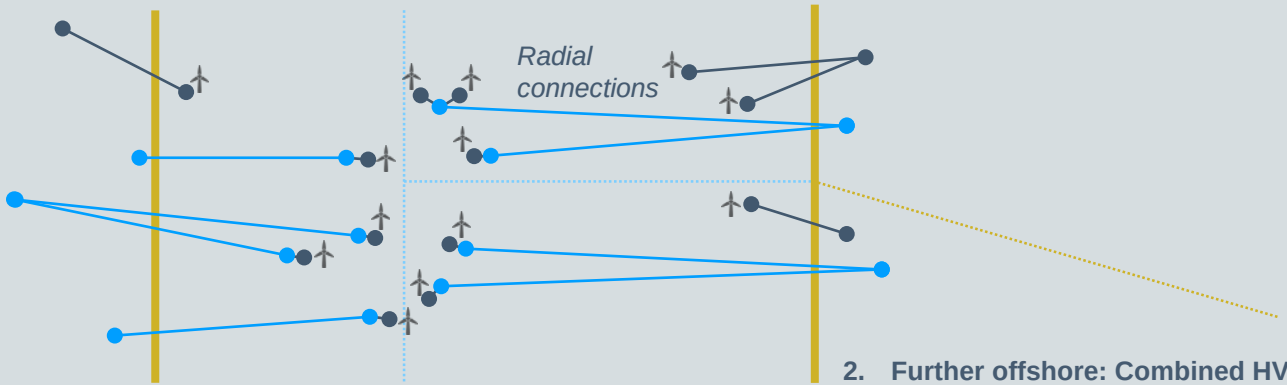


1. **Close to shore: HVAC connections**

NIRO

National Incremental Roll-Out leads to cost increase for far offshore wind

- National targets
- National approach with radial connections
- Incrementally improved grid connection technology

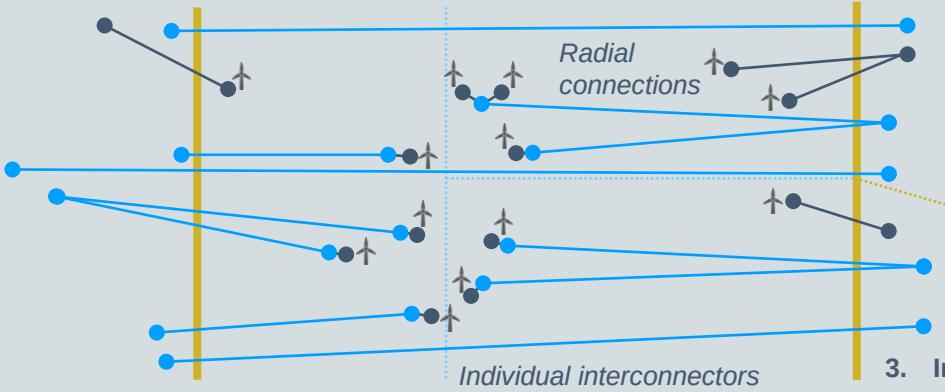


2. **Further offshore: Combined HVAC/HVDC equipment**

NIRO

National Incremental Roll-Out leads to cost increase for far offshore wind

- National targets
- National approach with radial connections
- Incrementally improved grid connection technology
- Offshore grid and interconnection from a national costs perspective

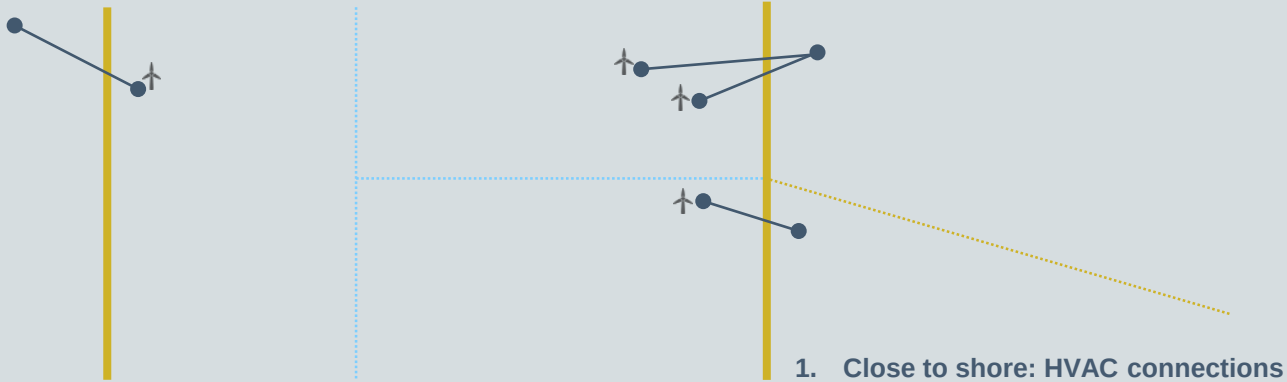


3. **Individual ICs – no synergies with transmission assets**

ICRO

International Coordinated Roll-Out provides several cost reduction factors

- National targets
- National approach with radial connections

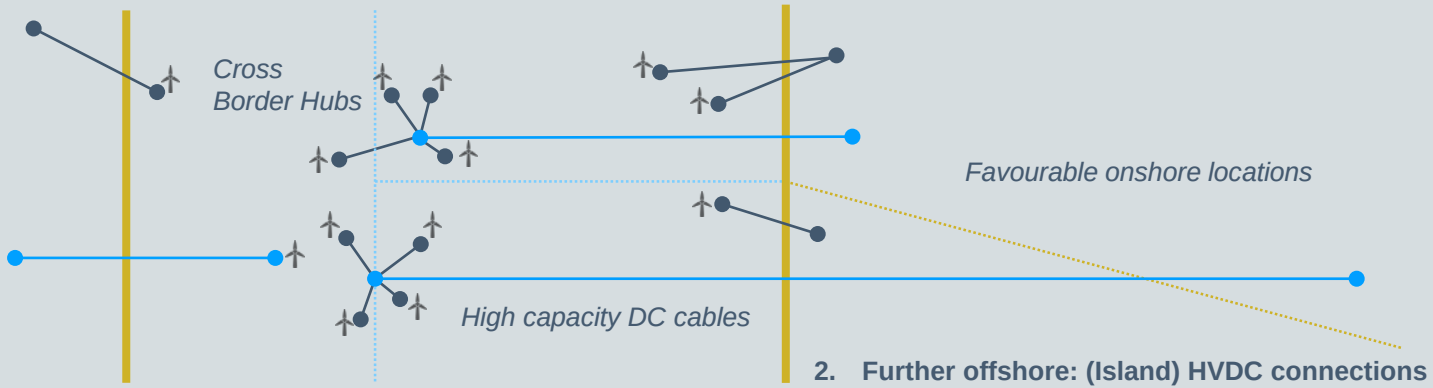


1. **Close to shore: HVAC connections**

ICRO

International Coordinated Roll-Out provides several cost reduction factors

- National targets, Integrated planning
- National approach with radial connections, Coordination of location and timing
- Connection to favourable onshore locations

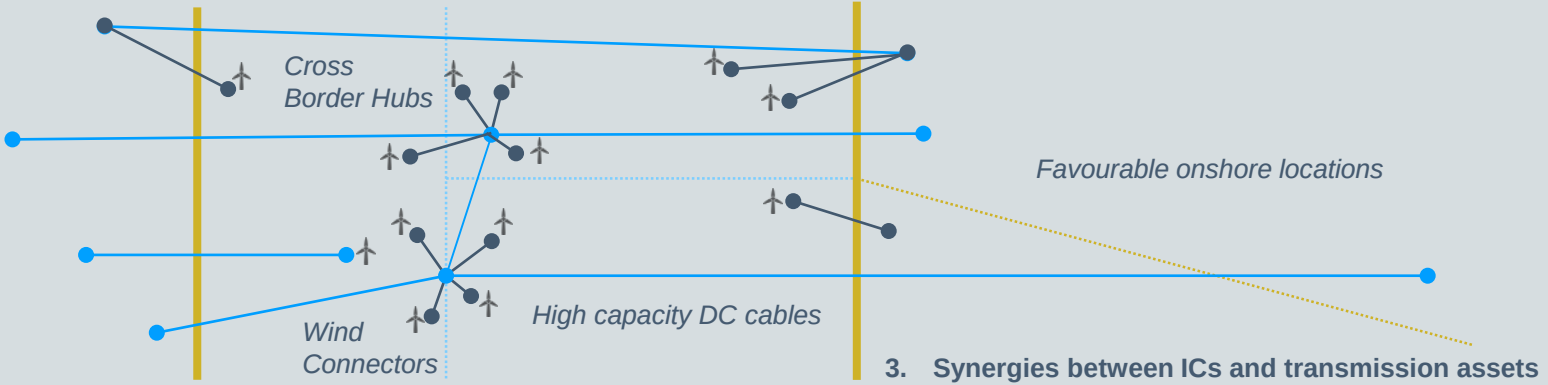


2. Further offshore: (Island) HVDC connections

ICRO

International Coordinated Roll-Out provides several cost reduction factors

- National targets, Integrated planning
- National approach with radial connections, Coordination of location and timing
- Connection to favourable onshore locations
- Regional system cost perspective
- Allocation of benefits i.e. RES targets

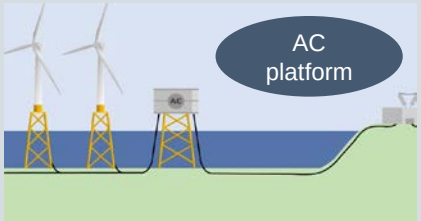


3. Synergies between ICs and transmission assets

ICRO COMBINES DIFFERENT TRANSMISSION ASSET CONCEPTS TO ACHIEVE MAXIMUM BENEFITS

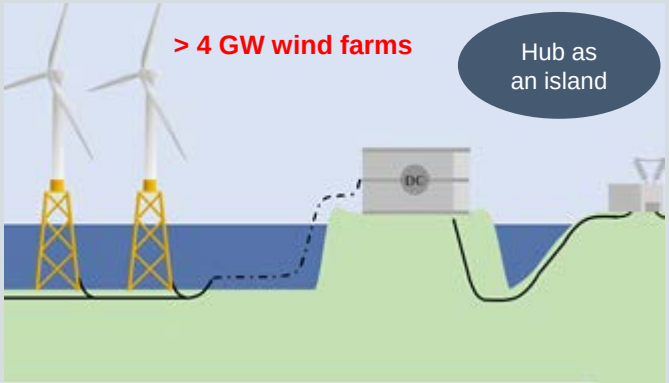
- Different (modular) transmission grid concepts
- Deploy at appropriate times and location
- In a coordinated, step-by-step roll-out

Close to shore



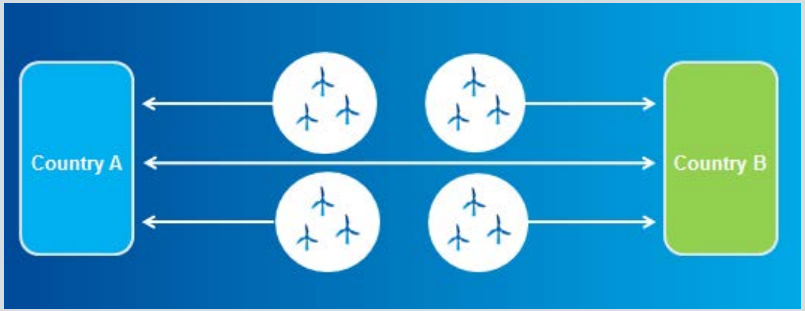
Far from shore

Large scale far from shore

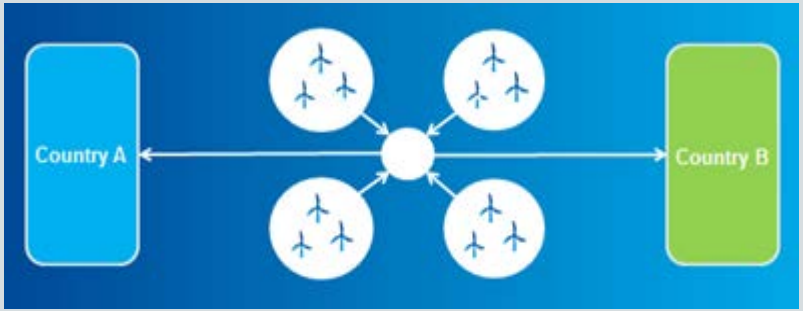


INTERNATIONAL ROADMAP IS CRUCIAL

ICRO USES HYBRID CONNECTIONS FOR OPTIMAL USE OF CABLES



Current situation: wind infrastructure is radially connected to each individual country. Separate interconnector cables between countries.

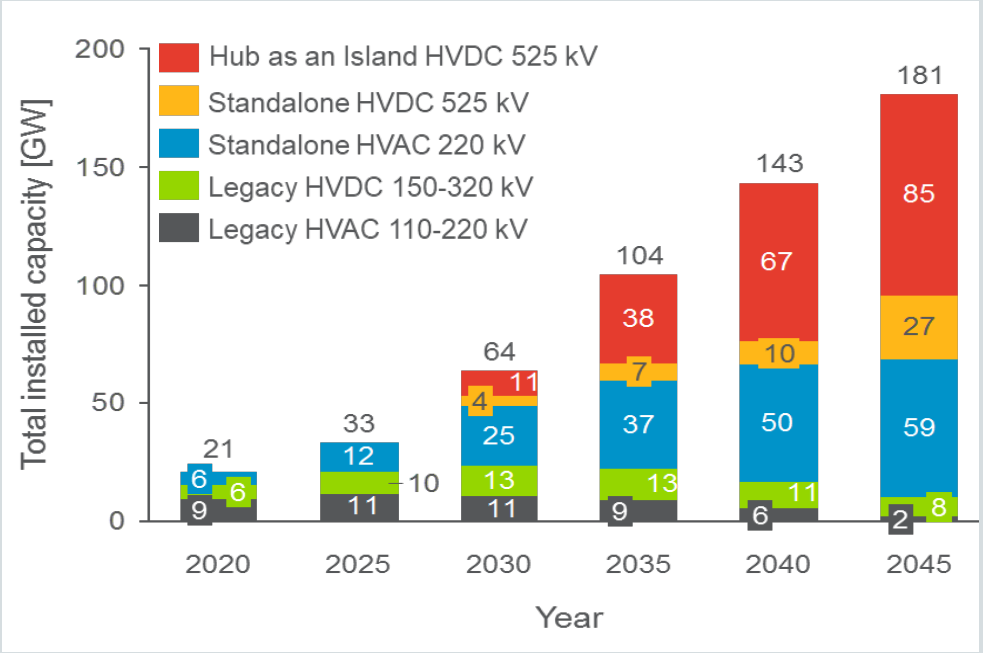


The ‘wind-connector’: wind infrastructure and interconnector combined in one function.

ICRO DEVELOPMENT IS STEP-WISE AND MODULAR, LIMITING RISKS FOR STRANDED ASSETS

- Economies of scale from development of higher capacity solutions (150 to 525 KV)
- Development over period of several decades.
- Flexible, step-by-step development

- Allows integration of future offshore innovations in transmission assets, wind farm design, operations and maintenance
- Innovative concepts estimated to deliver ~ 30% cost reductions.



ADDITIONAL BENEFITS ARE ANTICIPATED THROUGH EXCHANGE BETWEEN ENERGY MARKETS

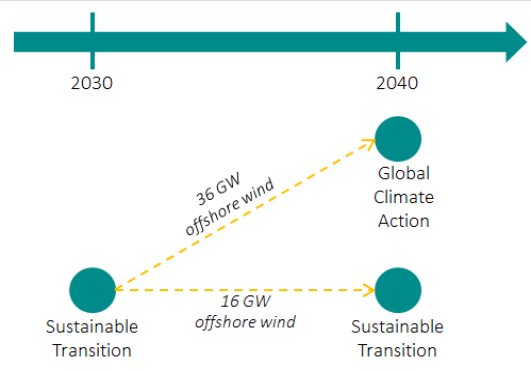
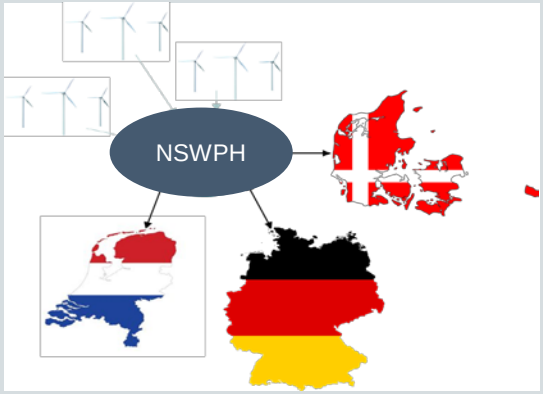


Illustration of the TYNDP18 scenarios applied in a pre-feasibility study conducted by the consortium

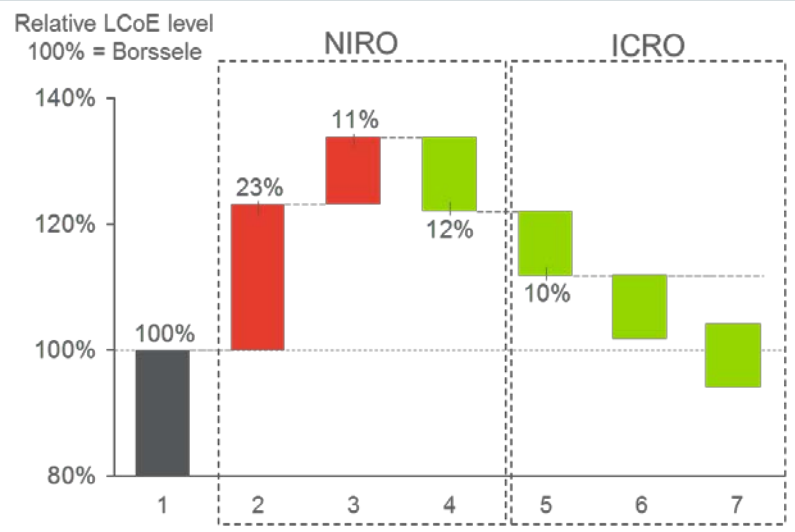
Pre-feasibility study assessing energy system indicators and socio-economic trade benefits excluding CAPEX costs for interconnectors

- Based on TYNDP 2018 scenarios
- RES production increases.
- **Socio-economic benefits of approximately 300 M€/year (ST2040) and 900 M€/year (GCA2040) in 2040**

NSWPH is modelled as 3 price areas with a copper plate between them and wind capacity connected to their respective ('national') price area



ICRO CAN REDUCE THE LCOE



LCoE cost components for a far offshore location (on/near Dogger Bank) compared to the Borssele area

1. Borssele baseline
2. Increased distance to shore, increased water depth and the requirement for DC infrastructure
3. Increased wake losses in a larger capacity offshore wind zone
4. Increased yield from better wind resource
5. Decreased cost – hub and spoke concept
6. Decreased cost - increased supply chain effectiveness resulting from coordinated roll-out with long term commitments and advantages of scale
7. Decreased cost - additional trade benefits from interconnection

ONSHORE GRID INTEGRATION SOLUTIONS

- **Increase near coast demand**
  - Electrification industry
  - Power to Heat (P2H)
- **DC connections directly to load centers**
- **Power to Gas (P2G) and storage**
- **Interconnection other countries**
- **Expansion of onshore grid**

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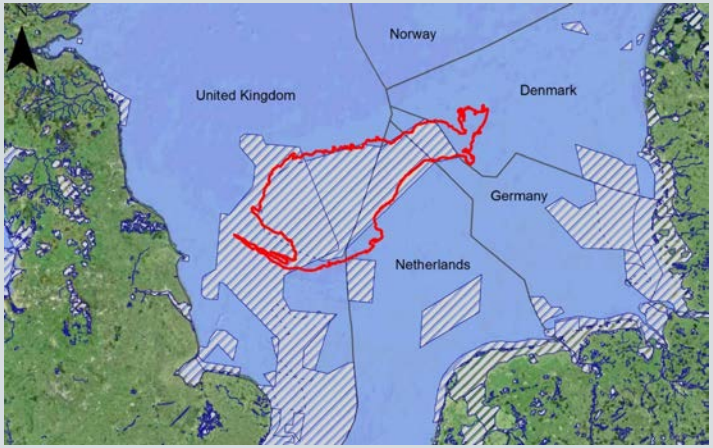
INTERNATIONAL NGO CONSULTATION

Joint fact finding process

DOGGER BANK: MOSTLY NATURA 2000-AREA

Basis for designation:

- Seabed H1110 subtype Dogger Bank
  - UK: 12,331 km2 (SAC/SCI)
  - NL: 4,715 km² (SAC)
  - G: 1,699 km² (SCI)
- Harbor porpoise (NL, G)
- Grey seal (NL)
- Common seal (NL, G)



The Danish part of Dogger Bank is not designated as a Natura 2000-area

Also other species protected under the EU Habitat and Bird Directive have taken into account

NGO JOINT FACT-FINDING PROCESS

Building the knowledge on ecological challenges and possibilities

- Early involvement of NGO's
- Building on knowledge of quick scans Netherlands and Denmark
- Co-designing of the Joint fact finding process
- Study program with clear research question and division of tasks
- Complementary to existing platforms

NGO JOINT FACT-FINDING PROCESS

Building the knowledge on ecological challenges and possibilities

• Deutsche Umwelthilfe e.V.	Germany
• Bundesamt für Naturschutz	Germany
• Royal Society for the Protection of Birds	UK
• The Wildlife Trusts	UK
• Birdlife	UK
• Federal Agency for Nature Conservation	UK
• WWF	Netherlands
• Greenpeace	Netherlands
• Natuur en Milieu	Netherlands
• Stichting De Noordzee	Netherlands
• Rijkswaterstaat	Netherlands
• Wageningen University & Research	Netherlands
• Natuurmonumenten	Netherlands
• Vogelbescherming	Netherlands
• North Sea Advisory Council	EU
• Renewables Grid Initiative	EU

TenneT | Energinet | Gasunie

STUDIES DONE SO FAR

Studies and assessments performed until now

- A preliminary desktop study with a quick scan of the geology and ecology DK and parts of GER
- Quick scan of ecological impacts Dogger Bank (NL and general)
- Gap analysis ecological monitoring

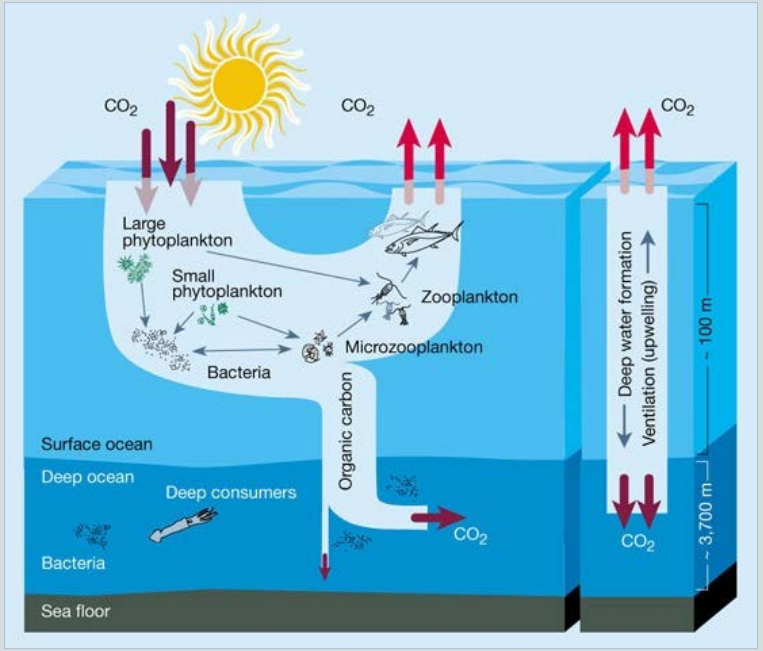
FIRST INSIGHTS QUICK SCAN

Ecological value	Conclusion
Sea mammals	• Mitigation measures are needed to prevent significant impact of under water noise • No significant impact of the operational phase of offshore wind areas is expected • Possible attraction due to higher food abundance
Birds	• A significant impact of large scale Offshore Wind on several bird species cannot be ruled out at this moment, more research is needed for several bird species
Fish	• When impact of under water noise will be mitigated, the impact is mainly positive
Habitat & Benthos	• No significant impact on habitat H1110 is expected, but the decline in habitat area could be a problem for permitting • Introduction of hard substrate is positive for biodiversity and biomass
Rare species	• Significant impacts are not expected from offshore wind development • Due to decreased fishing and vessel activity and increased food availability, a large wind farm could be attractive to sharks and rays
Water column	• Turbidity in construction phase, primary production may decrease/change • Impact on the food chain

KNOWLEDGE GAPS – POWER HUB ISLAND

Specific for Dogger Bank

- Impact of sediment plume on primary production and benthos
- Disturbance by light: birds can be attracted
- Role as breeding and resting area for birds:
- Role of island as hub for invasive species:
- Use new knowledge to include Building with nature in design



KNOWLEDGE GAPS – WIND TURBINES

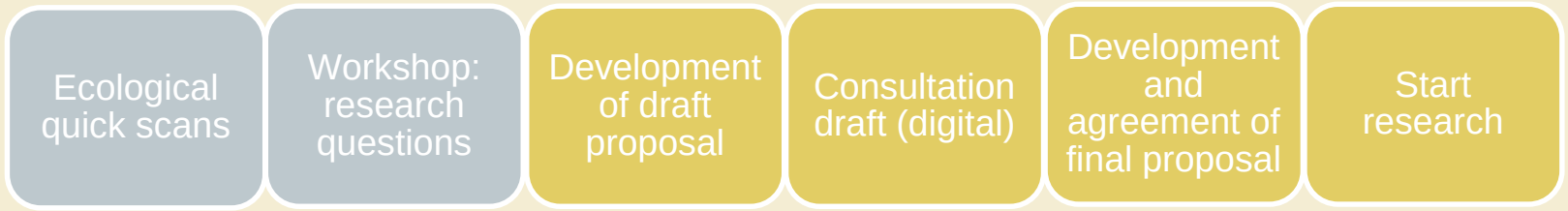
Specific for Dogger Bank

- Seasonal and spatial distribution of seabirds
- Timing and spatial magnitude of migration of migratory birds
- Abundance of bats at sea and their behavior in windfarms
- Stepping stones for invasive species or coherent network
- Use new knowledge to include Building with nature in design

REACTIONS JOINT FACT-FINDING

- *To get legitimacy for this project, you have to be extremely transparent about the assumptions*
- *Other measures are relevant too, such as energy saving*
- *You have to look into alternatives*
- *We have to be careful not to see the North Sea as the easy option to avoid public critique*
- *Integral spatial planning is necessary*
- *Although the concept might create a positive contribution to birds, what problem are you exactly solving?*

WHAT IS NEXT



- **Stakeholder panel: advisory platform**
- **Consortium: responsible for the research (scoping) and data**

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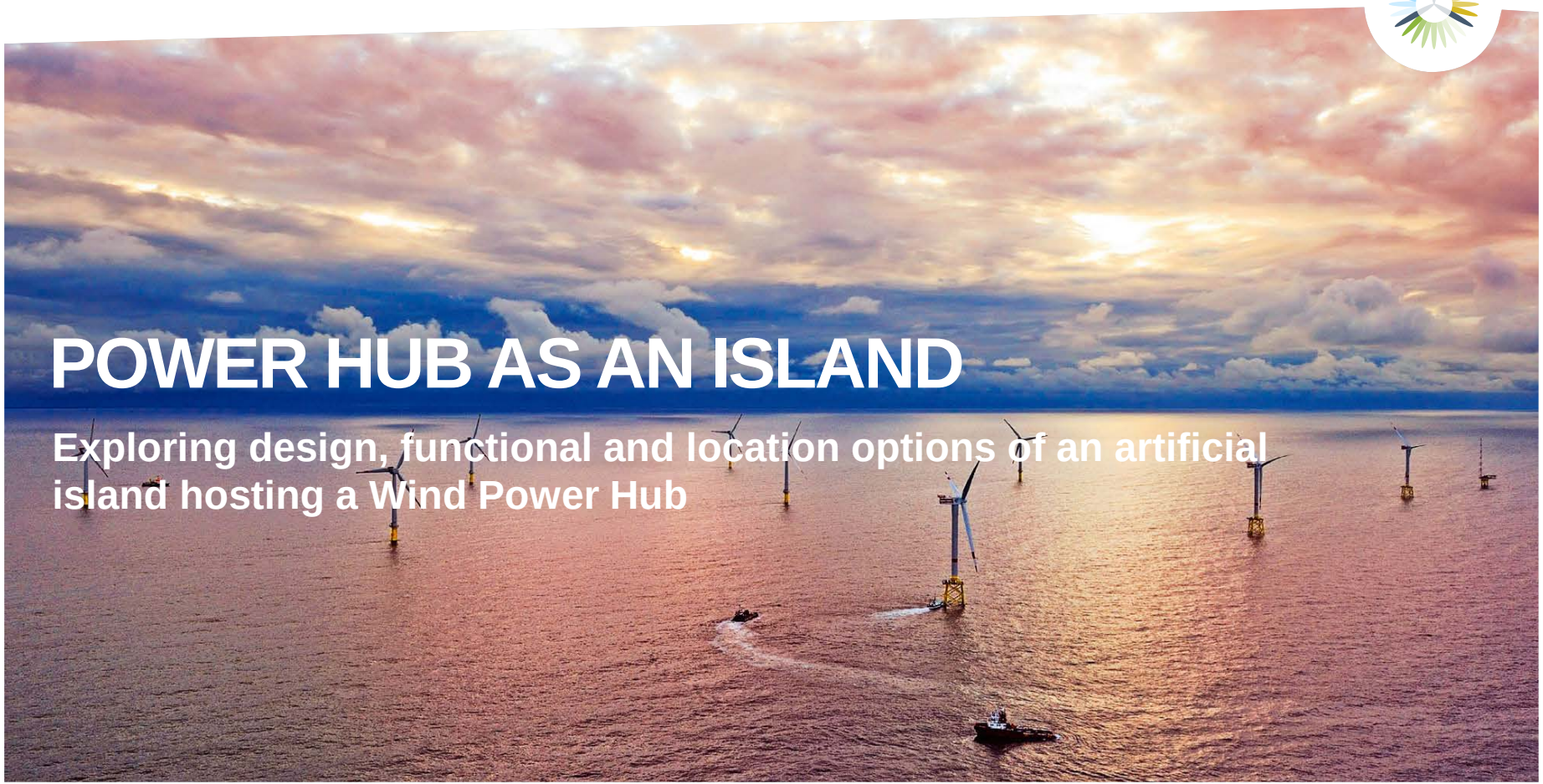


POWER HUB AS AN ISLAND

Exploring design, functional and location options of an artificial island hosting a Wind Power Hub

A POWER HUB AS AN ISLAND CAN REDUCE TOTAL SYSTEM COST

- Reduction of the total system cost is essential to facilitate large scale offshore wind.
- All options to further reduce cost - including an artificial island- should be considered
- An artificial island can perform different functions:
  - Supporting heavy electrical infrastructure components;
  - Providing a base for wind farm installation operation and O&M activities;
  - Supporting power conversion and storage technologies.
- The cost reduction potential of an island depends on a balance between functionality and needs.
- The potential cost reduction of creating an artificial island in the centre of large offshore wind capacity zones should be evaluated in detail.

TECHNICAL FEASIBILITY OF ISLANDS FAR OFFSHORE HAS BEEN DETERMINED FOR MULTIPLE LOCATIONS

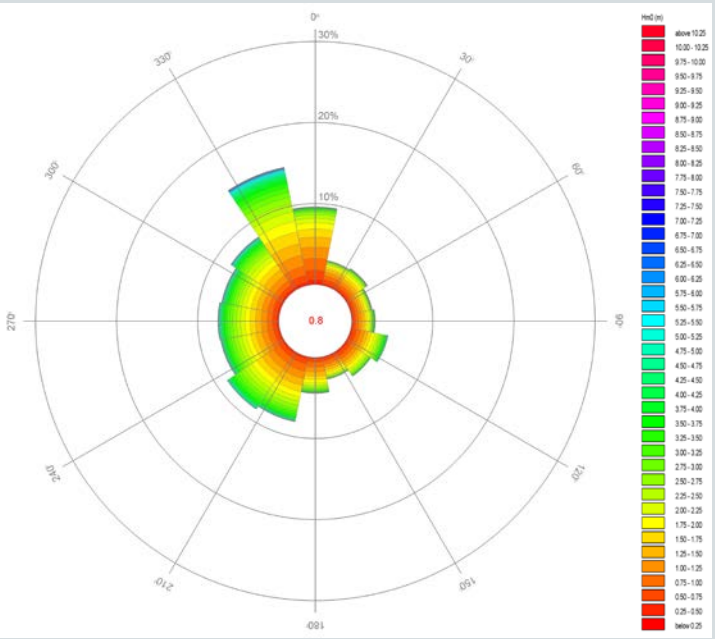
A detailed feasibility study was conducted for Dogger Bank:

- Wave and surge conditions
- Extreme wind conditions
- Geotechnical data on subsoil composition for design specification
- Various layouts evaluated

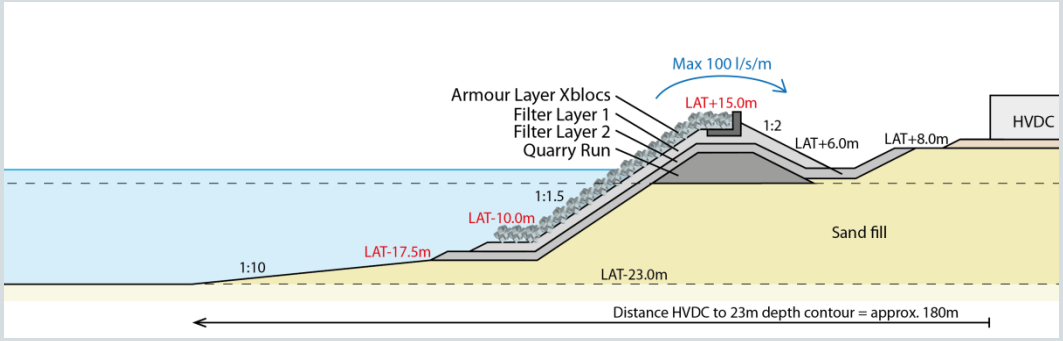
- Living quarters
- Runway: usability assessment under local wind conditions
- Cable landings and HVDC equipment
- Harbour
- Revetment and sea defense design

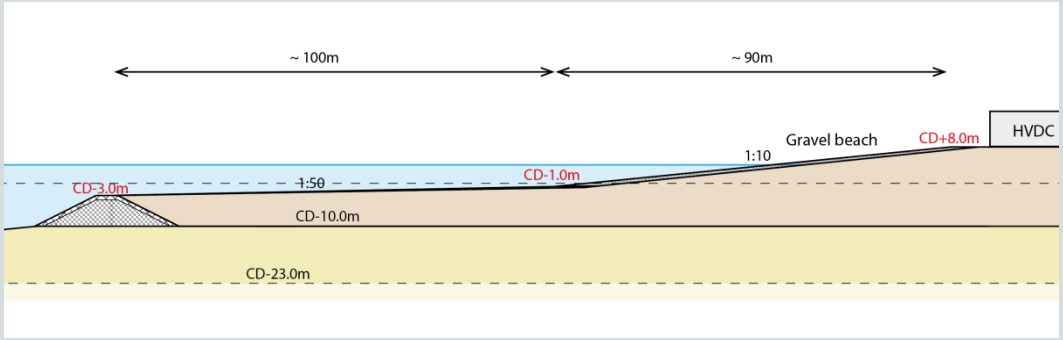
DEPTH AND WAVE CONDITIONS MAIN PARAMETER FOR ISLAND DESIGN

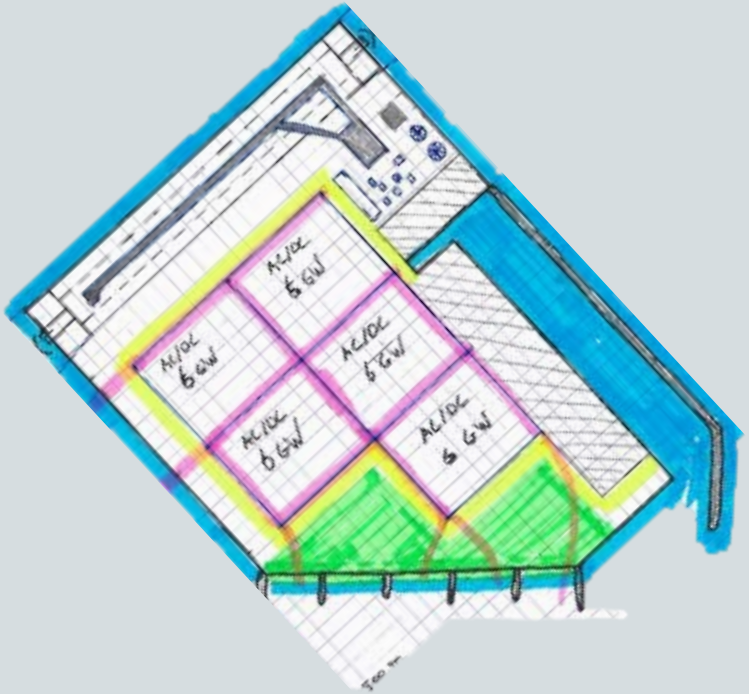
- Depth and significant wave heights drive design criteria and revetment choice
- Significant wave height is location and direction dependent
- Harsher conditions in Doggersbank than nearshore (Hs +30%)
- Waves determine design of island



LAYOUT CONSIDERATIONS AND BREAKWATER DESIGN







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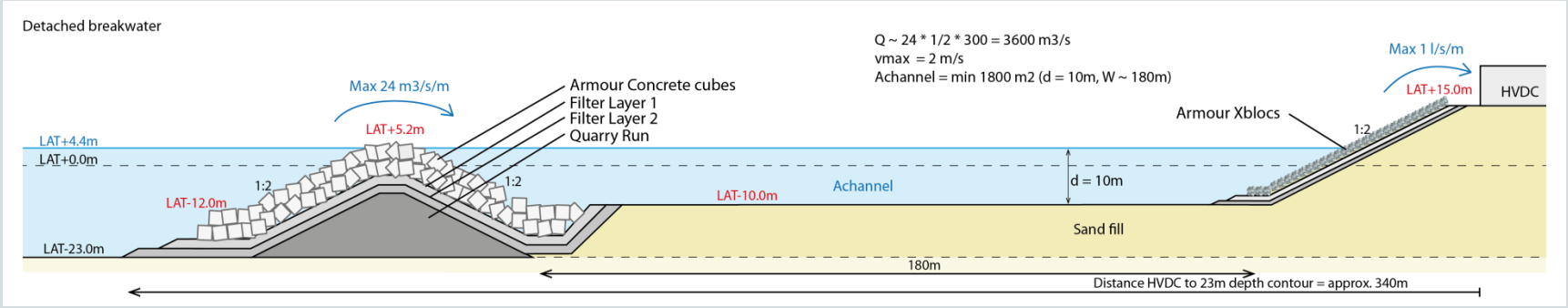

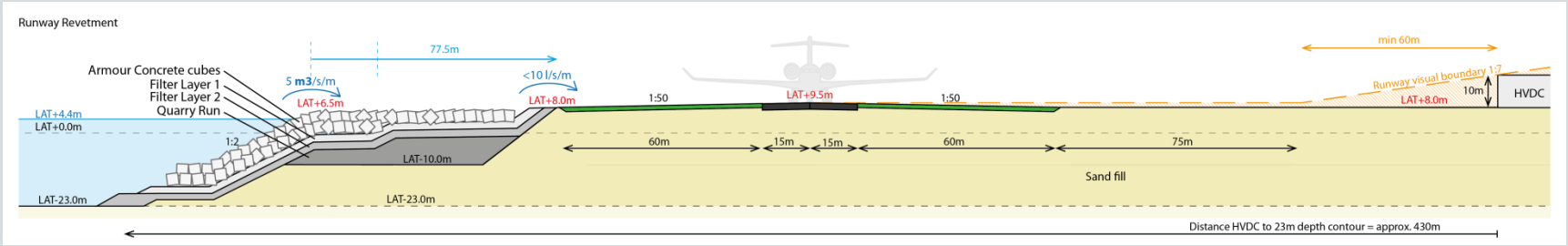

AIRSTRIP GIVES LOGISTIC ADVANTAGE HOWEVER IS DRIVER FOR ISLAND SIZE

- Availability depends on airstrip orientation, wind conditions, aircraft size
- Inclusion dependant upon industry feedback and analysis

POWER LINK ISLAND COULD FUNCTION AS LOGISTICS AND O&M BASE FOR OFFSHORE WIND FARMS

- Living quarters
- Pre-assembly area for wind turbines
- Long berth for CTV’s, SOV’s, installation vessels
- Harsh conditions far offshore require new innovative access methods

NATURE AREA COULD BE COMBINED WITH OFFSHORE CABLE LANDING

- The island could be used as nature area to compensate the ecologic impact
- Gravel beach could facilitate cable landing
- The large amount of cables and phasing of cable landings requires multiple locations for concentrated landing

AN ISLAND CAN FACILITATE POWER CONVERSION AND STORAGE TO SUPPORT GRID FLEXIBILITY OPTIONS

- Increased capacity of intermittent energy sources will require flexibility options and increased interconnection levels
- Artificial islands could play a role as it would provide the opportunity to create hydrogen from offshore wind energy on site.

COST REDUCTION ACHIEVED WITH A “LEAN ISLAND” DESIGN FOR E-INFRA ONLY

- A "lean island” provides cost efficient support for electrical infrastructure only
- A “lean island” can potentially reduce LCoE with approximately 10% compared to "business as usual" connection scenario

COMPARISON MAASVLAKTE 2 & NSWPH

	MV2	NSWPH
Context >	National	International
Purpose >	Container, distribution & industry	Power Hub, conversion & wind farm services
Area >	2000 / 1000 ha	500 ha (incl. 100 ha nature)
Max wave height >	8,5 m	12 m
Revetments >	3,5 km	ca 7 km
Sand coast >	7,5 km	Ca 1,5 km
Amount of Sand >	240 million m3	200 million m3
Construction period >	3 years	7 years

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What is next and how to get involved

End

POWER TO GAS

Creating a robust and cost effective offshore energy supply

SUBSTANTIAL OFFSHORE WIND CAPACITY POSES ENERGY SYSTEM DESIGN CHALLENGES

Strong growth of intermittent RE source in electricity generation, with up to 180 GW offshore wind in 2045 (translate COP21 scenario) poses challenges:

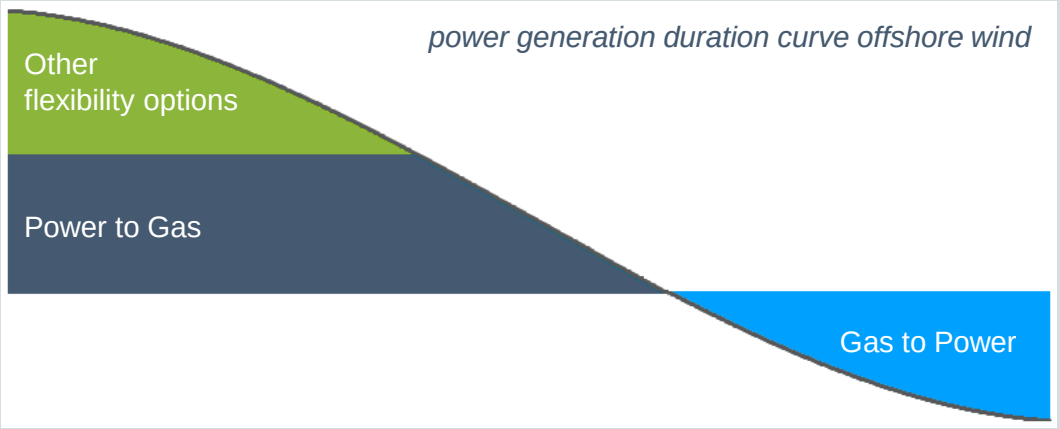
- **Avoid curtailment** with increasing amounts of variable renewable energy in the system
- Absorptive capacity of onshore electricity system to facilitate offshore wind and **prevent congestion**
- Reduction of dispatchable power will increase the **need for flexibility options** on all time scales, including weeks, months and years
- Flexibility provided by P2G may reduce the need for electrical interconnector capacity potentially **leading to investment cost savings**

P2G in combination with storage complements the electricity system

POWER TO GAS CAN PARTLY FACILITATE IN THE NEED FOR FLEXIBILITY AND STORAGE

Possible instruments:

- Interconnection
- Demand Side management
- Hydro storage
- Power-to-heat
- **Power-to-gas**
- Gas-to-Power



POWER TO GAS IS A VIABLE OPTION FOR THE FUTURE

- H2 is by experts considered to be the only flexibility/storage instrument for the electricity market for long durations (>days/weeks)
- Electrolysis is on a learning curve → The market will become mature e.g. the cost price will decrease by ≥ 50%
- H2 storage in caverns is an already existing option
  - In operation for many years in UK and US
  - Volume 1 cavern 1.000.000 m3 → 240.000 MWh (= 6.100 tons H2) ~ 24.000.000 Tesla power walls of 10 KWh

H2 MARKETS: MOBILITY AND INDUSTRY ARE PIVOTAL SECTORS THAT ARE HARD TO ELECTRIFY DIRECTLY

Mobility and Industry are challenged by achieving the CO2 neutral objectives - hydrogen can play a roll as molecules/energy carrier.

1. **Mobility, especially for long distance and/or heavy duty: cars, trucks, trains, boats, airplanes**
2. **Industry**
   - ✓ Feedstock for (petro)chemical industry in combination with carbons from biomass
   - ✓ High temperature heating (process heat, steel production)
3. **Possible future option for residential heating**

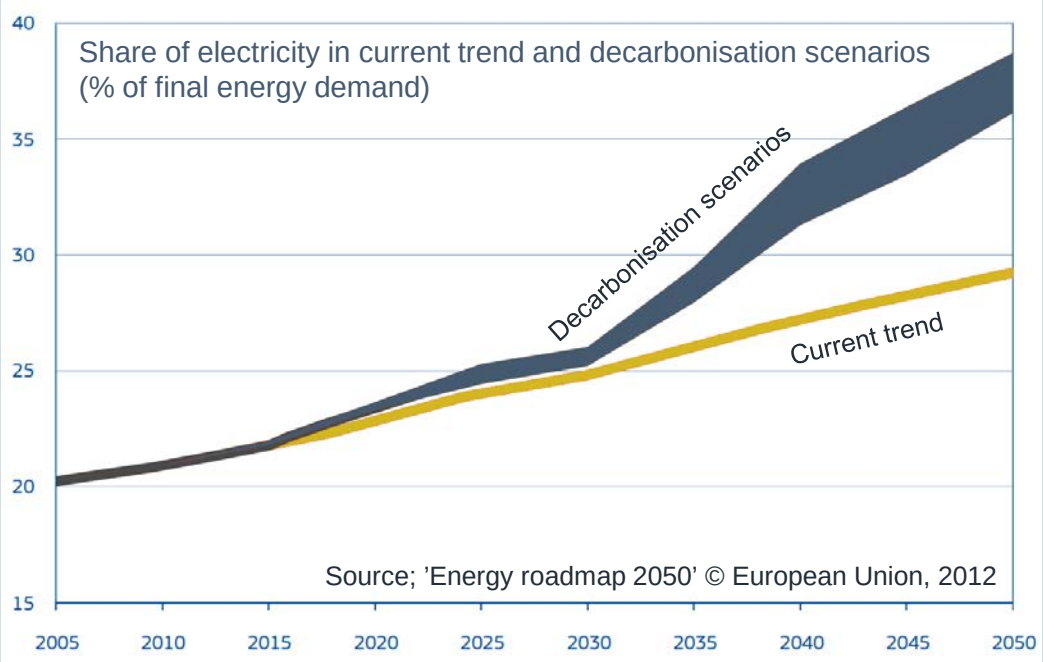
Government and other stakeholders increasingly support the H_2 option

LARGE SCALE OFFSHORE ENERGY PRODUCTION NEEDS A ROBUST TRANSMISSION SYSTEM

- Hydrogen transmission can play an important role in the Hub and Spoke concept.
- Assessment
  - Where P2G; on the island and/or on shore
  - Cables vs pipelines
  - New pipelines & existing pipelines
- Existing gas infrastructure (off - and onshore) has good opportunities to be re-used for H2 transport.
  - In 2018 Gasunie will refit an existing natural gas pipeline for hydrogen transport.

WE NEED HYDROGEN IN A DECARBONISED SOCIETY

1. Not everything can be electrified
2. We need a back-up during windless winter weeks (“Dunkelflaute”)
3. Currently, molecules are the backbone of the energy (and electricity) system. Something has to replace it.



SUGGESTIONS TO TAKE ON BOARD FOR 2018 STUDIES

- **Describe roll out of P2G related to roll out offshore wind up to 2050**
  - Hub and spoke concept
  - Possible congestion offshore / onshore
- **Model impact of imbalance of offshore power hub over time**
  - Load duration curve
- **Model solutions of imbalance over time (market based)**
  - Merit order of flexibility options
- **Model solutions of P2X within the hub and spoke system (structural)**
  - Cases: solutions on island, onshore solutions, re-use of existing oil&gas infra

➢ Gas themed studies in 2018 will be carried out by in the consortium.

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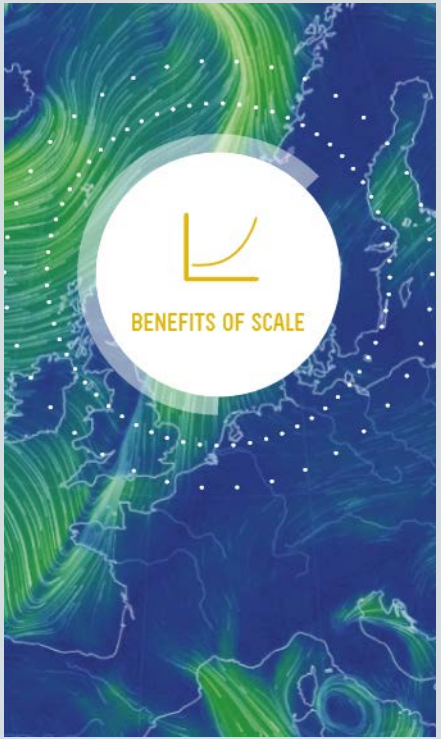
WHAT'S NEXT AND HOW TO GET INVOLVED

FURTHER CONSULTATION IN 2018

NSWPH consortium will approach stakeholders

- Input from the industry essential moving forward
- Outcome of this session basis for next step
- Next moment will be in 2018
- The process will be open and transparant

VISIT THE WEBSITE FOR INFORMATION



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- Description of the NSWPH
- Organisation
- Studies
- Environment
- News and events

Contact us at info@northseawindpowerhub.eu

North Sea Wind Power Hub

TenneT Netherlands, TenneT Germany, Energinet, Gasunie and Port of Rotterdam joined forces to develop a large scale European electricity system for offshore wind in the North Sea. The NSWPH consortium partners consider the project to be an important possible alternative path of an internationally coordinated roll-out towards accomplishing the green energy transition and achieving the Paris Agreement. By developing the North Sea Wind Power Hub project, the consortium endeavours to make the energy transition both feasible and affordable. Central to the vision is the construction of one or more hubs at a suitable location in the North Sea with interconnectors to bordering North Sea countries. The whole system may function as a hub for transport of wind energy, an interconnection hub to the connected countries, a working hub for offshore wind developers and a location for possible Power to Gas solutions.

POWERED BY ENERGINET TenneT Taking power further gasunie Port of Rotterdam