Future North Sea Infrastructure

Enabling the change, one of the EnergyNL2050 puzzle pieces!

Alan Croes
Corporate Asset Owner
The European energy transition

Ambitious goals

- EU ambition: 80-95% CO$_2$ reduction in 2050 compared with 1990 levels
- Large volumes of RES needed,
- Suppose 100% RES, what does that mean?:
  - 2000 GW of sun PV required to cover 50% of the electricity demand (TU Delft)
  - 600 GW offshore & onshore wind power required to cover 50% of the electricity demand (EWEA)
- Cooperation North Sea States is essential to reach the European energy goals
- European States should agree upon targets/goals
TenneT

- Europe’s first cross-border grid operator for electricity
- 22,000 km high-voltage lines
- 41 million end-users, ~3000 employees
- HQ Arnhem (NL), Bayreuth (GER)
- 99,99% security of supply
- EUR 15.4 bn assets
- EUR 22 bn investments: 8-10 bn offshore (NL + GER, 10 years)
## TenneT offshore by 2023

### Germany
- Fifteen grid connections for offshore wind farms
- Twelve DC connections, three AC connections
- 5,000 MW at present
- 9,832 MW by 2023 (7,132 MW by 2019)
- NordLink: 1,400 MW (2020)

### Netherlands
- Five grid connections for offshore wind farms
- Only AC connections
- 3,500 MW by 2023
- NorNed (2008): 700 MW
- BritNed (2010): 1,000 MW
- COBRA cable (2019): 700 MW

By 2023 TenneT will have realized 17.1 GW of offshore connection capacity (13.3 GW for offshore wind energy, 3.8 GW for interconnection): 13,000 km cable.
### TenneT offshore Germany

#### Operational

<table>
<thead>
<tr>
<th>Project</th>
<th>Capacity (MW)</th>
<th>Commissioning</th>
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<tbody>
<tr>
<td>alpha ventus</td>
<td>62</td>
<td>2009</td>
</tr>
<tr>
<td>BorWin1</td>
<td>400</td>
<td>2010</td>
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<tr>
<td>BorWin2</td>
<td>800</td>
<td>2015</td>
</tr>
<tr>
<td>DolWin1</td>
<td>800</td>
<td>2015</td>
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<tr>
<td>HelWin2</td>
<td>690</td>
<td>2015</td>
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<tr>
<td>Riffla</td>
<td>113</td>
<td>2014</td>
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<td>SylWin1</td>
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#### Under construction

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<tr>
<td>DolWin2</td>
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<td>2016</td>
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<tr>
<td>DolWin3</td>
<td>900</td>
<td>2018</td>
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<td>2016</td>
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#### Total

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<th>Project</th>
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<th>Commissioning</th>
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<tr>
<td>Total</td>
<td>7,132</td>
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#### Planned

<table>
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<th>Project</th>
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<td>DolWin6</td>
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<td>2023</td>
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<tr>
<td>DolWin5</td>
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<tr>
<td>BorWin5</td>
<td>900</td>
<td>2025</td>
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</table>
TenneT offshore Netherlands

- Five wind areas of 700 MW
- Lowest possible LCOE
- Planning of the ‘Energy Agreement’
- Future proof
- Minimal habitat disturbance
- Innovative

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity</th>
<th>Area</th>
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<tbody>
<tr>
<td>2016</td>
<td>700 MW</td>
<td>Borssele</td>
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<tr>
<td>2016</td>
<td>700 MW</td>
<td>Borssele</td>
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<tr>
<td>2017</td>
<td>700 MW</td>
<td>Hollandse Kust (zuid)</td>
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<td>2018</td>
<td>700 MW</td>
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<tr>
<td>2019</td>
<td>700 MW</td>
<td>Hollandse Kust (noord)</td>
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TenneT subsea interconnectors

- Price conversion: high-low price areas
- Security of supply
- Social welfare
- Market coupling
- Efficient use and exchange of renewable energy production

<table>
<thead>
<tr>
<th>Year</th>
<th>Interconnector</th>
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<tbody>
<tr>
<td>2008</td>
<td>NorNed</td>
</tr>
<tr>
<td>2011</td>
<td>BritNed</td>
</tr>
<tr>
<td>2019</td>
<td>COBRAcable</td>
</tr>
<tr>
<td>2020</td>
<td>NordLink</td>
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</table>
- TenneT (25%), KfW (25%), Statnett (50%)
- First direct connection between German and Norwegian electricity markets
- 623-km-long HVDC cable link, capacity of 1,400 MW, ready by 2020
- Connecting Norwegian hydropower to German wind and solar energy; natural storage of wind energy
TenneT (50%), Energinet.dk (50%)
First direct connection between the Dutch and Danish electricity markets
325-km-long HVDC cable link, capacity of 700 MW, operational ready by 2019
Multi terminal ready: prepared to connect wind farms
Connecting Danish wind power to Dutch/European wind and solar energy
Security of supply
Our view

➢ Sun will be the winner
➢ But, also wind needed
   ➢ Wind energy on land
   ➢ Wind energy near shore
   ➢ Wind energy far shore
   • Construction (expensive)
   • Maintenance (expensive)
   • Infrastructure (expensive)

Challenge
➢ How to get cost level down?
Why is offshore wind needed?

Complementary cycles reduce seasonal storage

Sun PV and wind energy are complementary during the year

mix 1kWh sun with 2kWh wind
Tender results OWF

Different years, location and scope does not explain all the differences.
Realism or optimism in cost reduction

LCoE of coal, gas and offshore wind (€/MWh)

- **Coal**: Increase in LCoE is driven by fewer full load hours and increased CO₂ prices.
- **Gas**:
- **Offshore wind**: 40% to 46% LCoE reduction

Source: Fraunhofer ISE (CO₂ price of €35/tonne in 2030 used), PwC and DNV GL analysis

TKI Wind op Zee analyse uit Okt-15

Ecofys analyse ’17 obv TenneT aansluitingen in GE en NL

Tendercap 124 €/MWh

55 €/MWh
North Sea infrastructure

Three main functions
• Connection of countries: price convergence
• Transmission of offshore wind energy
• Enhance system security and stability by allowing the exchange of power

No consumption at sea

Impact of failures differs
• Cost of onshore failure 200 x cost of electricity not delivered
• Cost of offshore failure 1 x cost of electricity not delivered
Solution: the Wind Connector

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

Country A

<table>
<thead>
<tr>
<th>~40%</th>
<th>100%</th>
<th>~40%</th>
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</thead>
</table>

Country B

Country A

<table>
<thead>
<tr>
<th>~100%</th>
<th>100%</th>
<th>~100%</th>
</tr>
</thead>
</table>

Country B
Solution: hub and spoke concept

Hub and spoke delivers

Scale
A large scale European roll-out for offshore wind delivers a significant contribution to cost reduction.

Location
When far shore becomes necessary, shallow waters with great wind conditions contribute to cost reduction.

Wind connector
The wind connector combines large scale wind farms with powerful interconnectors for higher system efficiency.

Hub function/ island
By connecting the interconnectors on the island, a hub can be build that facilitates optimal energy transmission and a further European Market integration.
Solution: location

When far shore becomes necessary to realize the required scale

Shallow waters
Water depth has a significant impact on the development for offshore wind. A development in shallow waters contributes significantly to cost reduction.

Wind conditions
Wind conditions get better further at sea, which partially compensates the increase in cost for distance.

Central location
For a European coordinated roll-out, a central location is important.
Combining wind with interconnectors
The modular island: facts & figures

- Possibly three islands: 6 km² each, 200 mln m³ sand
- €1.5 bn (rock and sand only, no infra/facilities)
- Possible connections to existing pipeline infrastructure
- Facilitates approx. 30 GW of wind farms per island
- 15 Converter stations (2 GW each) on the island
- Total: 70 GW, 7,000 turbines (10 MW)
- On the Dogger Bank: 11,400 km²
- Hard substrate: 4.4 km² (0.02% of total Dogger Bank surface)
## Solution: scale

### Far shore: 135%
- **classic DC e-infra**

### Small scale
- AC solution closer to shore: 100%
- + 1 GW DC infra + distance to shore

### Large scale
- Far shore
  - International cooperation - island concept

### Far shore
- 120%
- 110%
- 100%
- 95%
- 90%

### 15%: economies of scale e-infra:
- island
- new 2GW infrastructure
- no steel structures/jackets

### 10%: strong, stable wind

### 10%: shallow water

### 5%: Volume → Economies of scale wind industry (20% increase)

### 5%: interconnection (20% allocation)
The modular island

Feasibility given a step wise approach & stakeholder views
Step 1

Explore & develop ‘near shore’ wind

- Individual projects by North Sea countries
- Relatively short term goals
- NL: 3.500 MW (additional) in 2023
- TenneT offshore grid developer & operator
- Separate interconnectors
- Onshore wind
Step 2

IJmuiden Ver

- Develop grid concept for IJmuiden Ver
- Development of currently appointed areas (Boven de Wadden and Hollandse Kust) possible with standardized TenneT 700 MW concept)
- First tender 2020
- In operation from approx. 2024
Step 3

Connect to infra UK

- Connect IJmuiden Ver to UK energy area (e.g. East Anglia)
- Investigate island solutions
- Cooperation with UK
- Connect to existing oil and gas infrastructure
- Approx. 2025 – 2030
- Timing possibly simultaneously to step 2
Step 4

Large scale, far shore

- Facilitates required economies of scale
- Optimal wind conditions
- Shallow waters
- Central position North Sea countries
- Interconnection hub: Wind Connectors
- Development up to 2050
Ecological quick scan flora & fauna

In close consultation with environmental organisations

- Dogger Bank = Natura2000 area
- Additionally: the impact on other species using the Dogger Bank area
- First exploratory study of environmental impacts show:
  - Bio diversity: introduction of hard substrate marks a change to the area, however a limited change increasing biodiversity and biomass
  - Fish and sea mammals: mitigation measures or innovations limiting under water noise during construction are necessary, during operation mainly positive impact of offshore wind expected
  - Birds: impact depends on the way birds use the area, more research is needed for several bird species.
What’s next?

- Current autonomous offshore developments by the North Sea countries are important to meet national targets and reach necessary cost reduction.
- Invite the North Sea countries to discuss and further develop this vision to work towards a coordinated approach.
- Explore possibilities IJmuiden Ver (interconnection, small island, conversion, combination with existing infrastructure).
- Explore possibilities East Anglia with British TSO.
- Invite research community and industry to come with novel ideas.
Future North Sea Infrastructure

Thank you for your attention
TenneT is a leading European electricity transmission system operator (TSO) with its main activities in the Netherlands and Germany. With approximately 22,000 kilometres of high-voltage connections we ensure a secure supply of electricity to 41 million end-users.

Taking power further