North Sea Grid Infrastructure 2030-2050: *The Electrical Perspective*

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North Sea Grid Infrastructure: The Electrical Perspective

- North Sea Grid developments - The story so far
- (Political) ambitions 2030-2050
- The future: Towards a meshed offshore grid with energy hubs
- Challenges in the development path
- How to get there?

North Sea Grid Developments – The Story so far

North Sea Grid Developments over the years
A bit of TenneT history

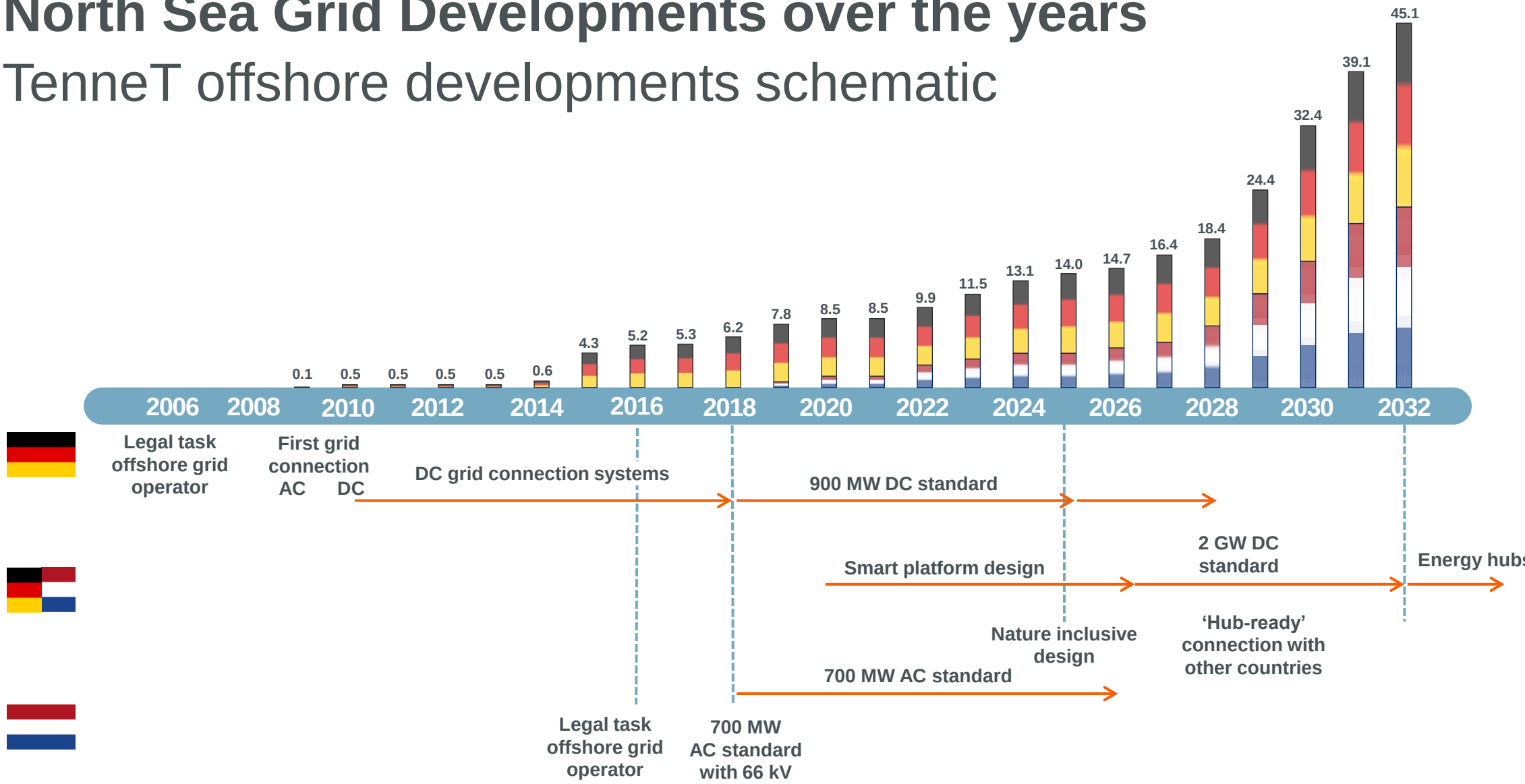
2009: First Offshore grid connections

2018: Standardisation of grid connection concepts to **700 MW AC** and **900 MW DC**

2022: Further scaling up transmission capacity towards **2GW** grid connections

North Sea Grid Developments over the years

TenneT offshore developments schematic



North Sea Grid Developments over the
TenneT Offshore grid connections in overview

In operation

2009	Alphaventus (DE)	62 MW
2010	BorWin1 (DE)	400 MW
2014	Riffgat (DE)	113 MW
2015	BorWin2 (DE)	800 MW
	DolWin1 (DE)	800 MW
	SylWin1 (DE)	864 MW
	HelWin1 (DE)	576 MW
	HelWin2 (DE)	690 MW
2016	DolWin2 (DE)	916 MW
2017	Nordergründe (DE)	111 MW
2018	DolWin3 (DE)	900 MW
2019	BorWin3 (DE)	900 MW
	Borssele Alpha (NL)	700 MW
2020	Borssele Beta (NL)	700 MW
2022	Hollandse Kust (zuid) Alpha (NL)	700 MW
	Hollandse Kust (zuid) Beta (NL)	700 MW
2022	**16 grid connections**	**9,932 MW**

Future

2023	DolWin6 (DE)	900 MW
	Hollandse Kust (noord) (NL)	700 MW
2024	Hollandse Kust (west) Alpha (NL)	700 MW
2025	DolWin5 (DE)	900 MW
	BorWin5 (DE)	900 MW
2026	BorWin6 (DE)	980 MW
	Hollandse Kust (west) Beta (NL)	700 MW
2028	IJmuiden Ver Beta (NL)	2,000 MW
2029	BalWin3 (DE)	2,000 MW
	BalWin4 (DE)	2,000 MW
	IJmuiden Ver Alpha (NL)	2,000 MW
	IJmuiden Ver Gamma (NL)	2,000 MW
2030	Ten noorden van de Wadden-eilanden (NL)	700 MW
	Nederwiek 1 (NL)	2,000 MW
	Nederwiek 2 (NL)	2,000 MW
	LanWin1 (DE)	2,000 MW
	LanWin2 (DE)	2,000 MW
2031	Doordewind 1 (NL)	2,000 MW
	Doordewind 2 (NL)	2,000 MW
	LanWin4 (DE)	2,000 MW
	LanWin5 (DE)	2,000 MW
	21 grid connections	**32,480 MW**

North Sea Grid Developments over the years

Overview 2 GW connections

TenneT´s 2 GW connections
(as at November 2022)

offshore projects
- route
- route to be determined
- search area onshore converter

In The Netherlands		Year of commissioning
1	IJmuiden Ver Beta	2028
2	IJmuiden Ver Alpha	2029
3	IJmuiden Ver Gamma	2029
4	Nederwiek 1	2030
5	Nederwiek 2	2030
6	Nederwiek 3	2031
7	Doordewind 1	2031
8	Doordewind 2	2031

In Germany

9	NOR-9-2 (BalWin3)	2029
10	NOR-9-3 (BalWin4)	2029
11	NOR-12-1 (LanWin1)	2030
12	NOR-12-2 (LanWin2)	2030
13	NOR-11-2 (LanWin4)	2031
14	NOR-13-1 (LanWin5)	2031

offshore wind farms (OWF)
- in operation
- under construction
- planned
- potential OWF areas

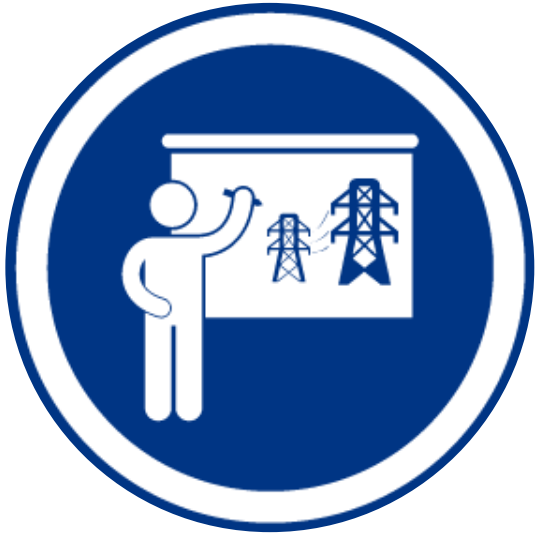
- converter station
- exclusive economic area
- federal state border

(Political) Ambitions 2030-2050

(Political) Ambitions 2030-2050

TenneT: Actively shaping the energy transition

EU climate targets:
a fully climate neutral Europe by 2050



Offshore wind will play a **crucial role** in this energy transition

The North Sea as the **powerhouse** with international projects

(Political) Ambitions 2030-2050
North Sea Energy Cooperation (NSEC)

The North Seas Energy Cooperation (NSEC) was established in **2016**

Goal: facilitating the cost-effective deployment of offshore renewable energy, in particular wind, and promoting interconnection between the countries in the region

10 member countries and European Commission:
- Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden, UK
- UK rejoined in December 2022 (after Brexit)
- European Commission

Irish presidency 2022
- signing new political agreement establishing offshore targets for NSEC countries:

- **260 GW** of offshore wind energy by **2050,**
- intermediate targets of at least 76 GW by 2030 and
- 193 GW by 2040.

(Political) Ambitions 2030-2050
Esbjerg Cooperation

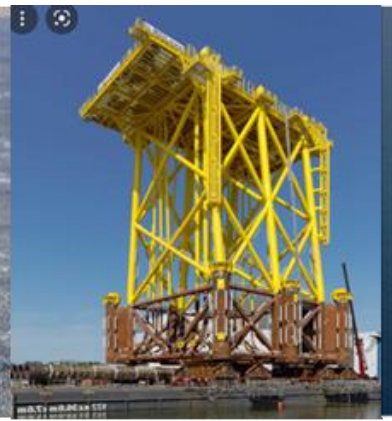
- *Esbjerg* statement (18 May 2022) → **65 GW** offshore wind tot 2030, **150 GW** in 2050
- *Esbjerg* TSOs (frontrunners): 50Hertz (DE), Amprion (DE), Elia (BE), Energinet (DK), Gasunie (NL/DE), TenneT (NL/DE)
- *Esbjerg* as accelerator → making offshore meshed grid concrete, defining first projects
- Implementation of goals of the Esbjerg Declaration are **"Chefsache".**
- The group consists of the **frontrunners** of the energy transition with Belgium, Denmark, the Netherlands and Germany
- The size of the group is large enough to **make a difference**, but small enough to drive the **development of a common vision for the North Sea concretely and fast**

(Political) Ambitions 2030-2050
Netherlands

- Ambition **50 GW** by 2040, **70 GW** by 2050 (current target around 2030 21.5 GW).
- Focus on electrons *and* offshore hydrogen conversion
- Roll out offshore wind from 2030 onwards via **Hub-based** approach
- Focus on **large-scale energy hubs** to connect different wind areas in an integrated approach (electrons & molecules) including interconnection of hubs with other energy hubs (international focus)
- **Synergies** with other offshore energy sources also taken into account (such as solar/storage etc.)
- Starting already with **first demonstration/ pilot projects**.

- Ambitions to land in **Energy Infrastructure Plan North Sea 2030-2050.**






The future: Towards a Meshed Offshore Grid with Energy Hubs

Towards a meshed offshore grid with energy hubs
Vision on the future offshore grid >2030

- An interconnected DC overlay grid, linking multiple offshore wind farms from different countries, and connecting with onshore DC grids, will form the **backbone of the North Sea powerhouse**.
- The meshing of the DC grid at sea and on land, the interconnection of multiple offshore wind farms from different countries, and the integration of hydrogen electrolysis, will mean **lower costs** for customers, **better utilisation of the electricity supply**, and **a more robust system**.
- To realise this vision, offshore DC hubs will **Collect, Connect and/or Convert** offshore wind energy.
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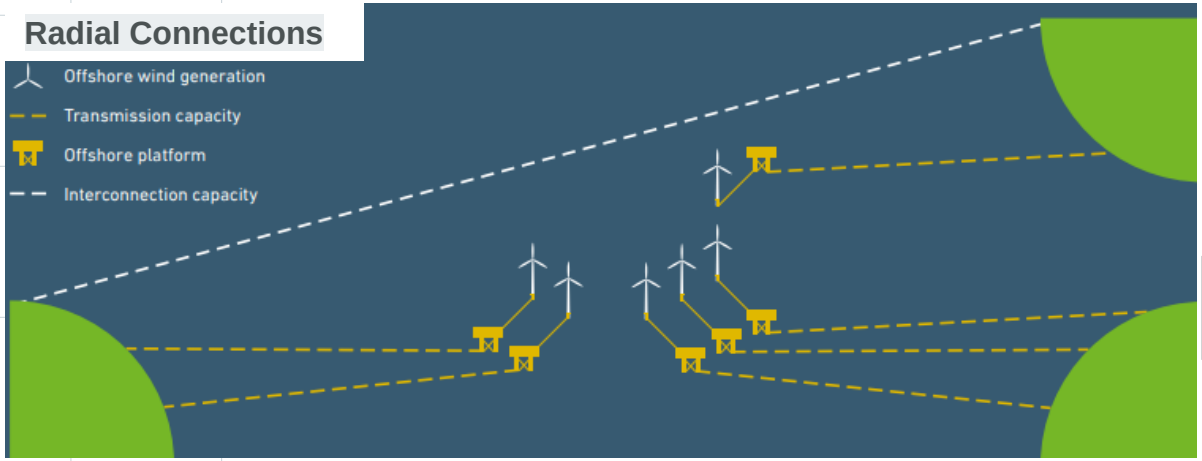
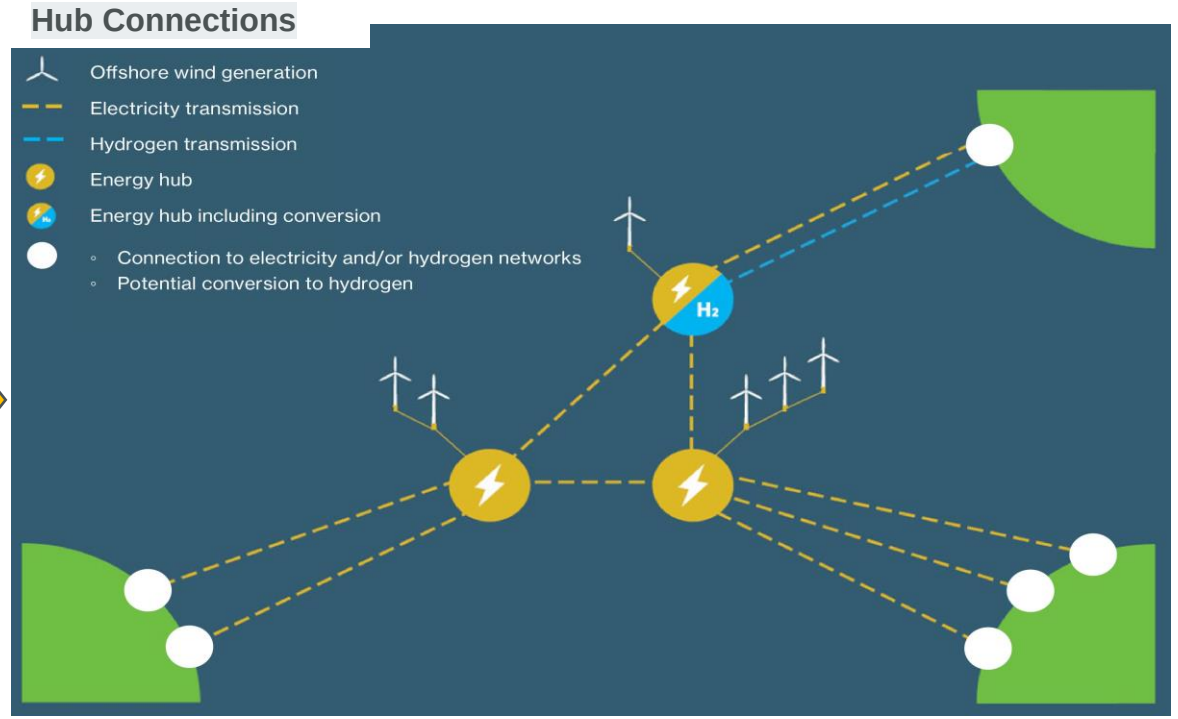
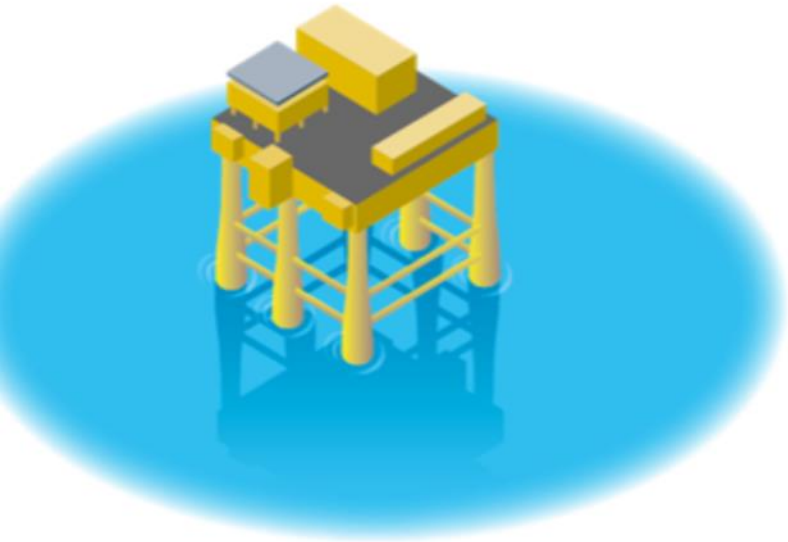
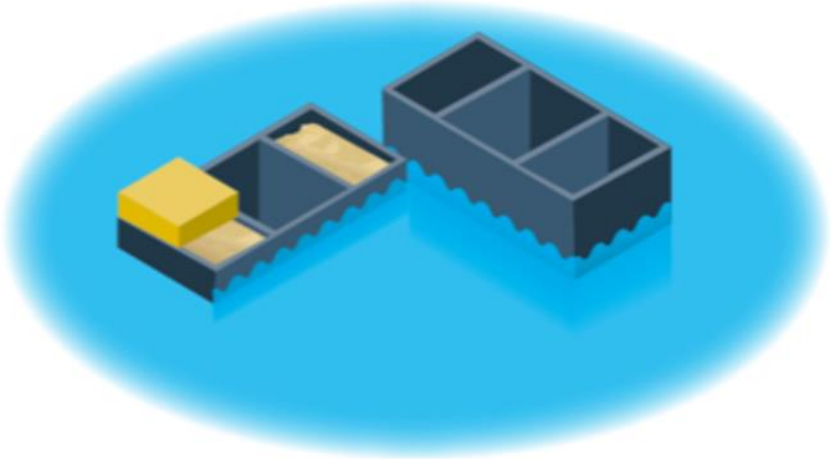
Towards a meshed offshore grid with energy hubs
From radial connections to hubs

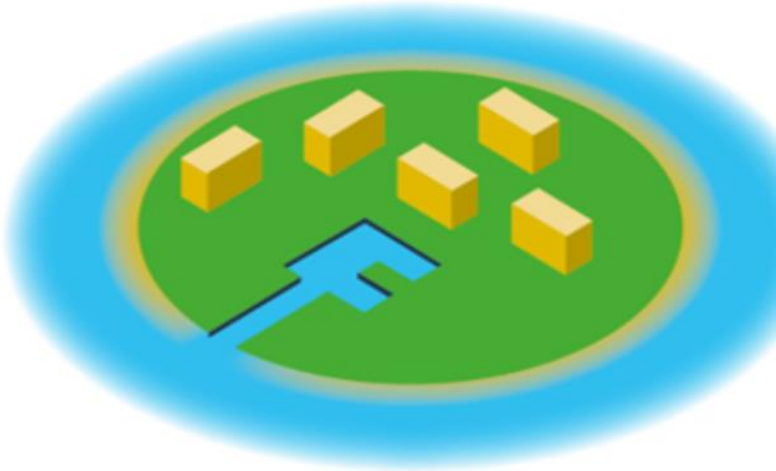




Towards a meshed offshore grid with energy hubs
Hub functions and lay outs







Collect

Connect

Convert

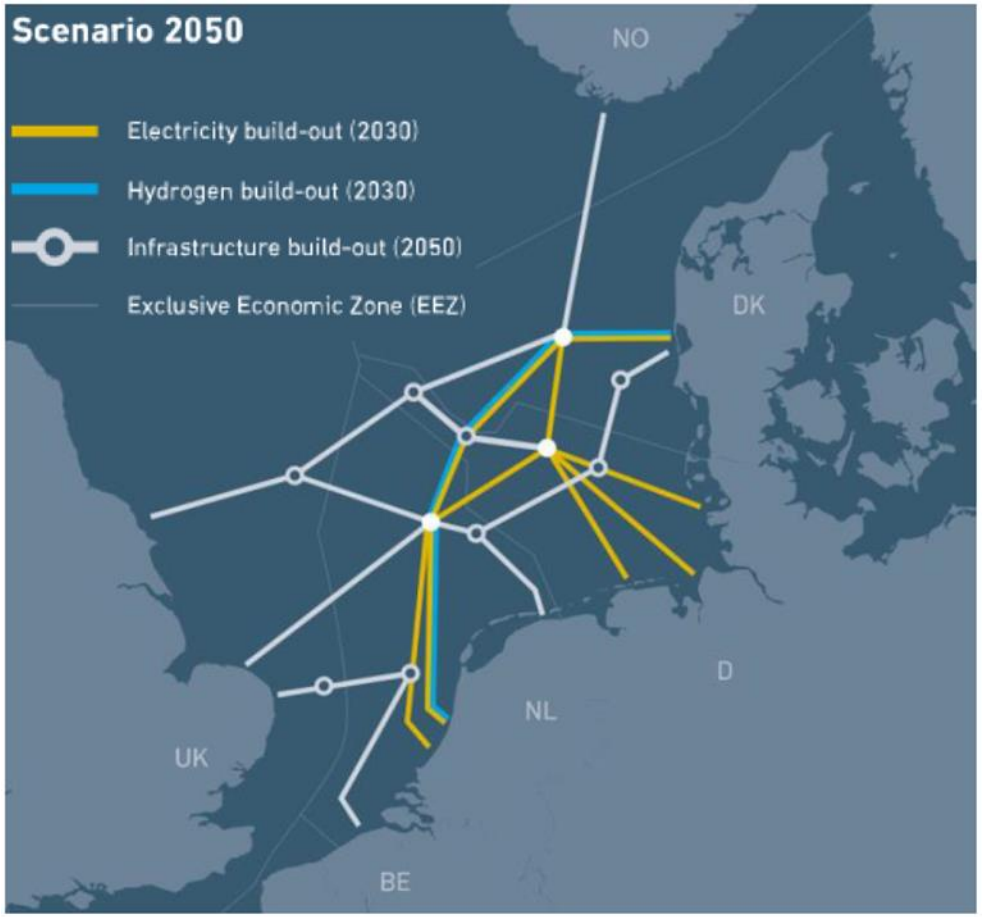
An energy hub is an offshore energy node that performs at least two of three functions:

- Collecting energy, e.g. from different wind area's
- Connecting offshore grids in different countries (hybrid interconnectors) and/or wind areas (interlink)
- Converting energy, e.g. between electricity and energy carriers such as hydrogen

Challenges in the development path

Challenges in the development path
New features in the future energy system

1. International approach
2. System integration between electrons and molecules
3. Robustness, flexibility and modularity required
4. Further development of standards and technology
5. Regulatory and market adaptations
6. Spatial & Permitting alignment



Working towards a European standardised approach

Challenges in the development path

New principles for design and operations for HVDC grids

Future HVDC systems mutually compatible and interoperable

- Capability of HVDC converters, switching stations, protection and control, etc. to work seamlessly together.

Fault Separations devices (HVDC breakers) to clear faults in the DC grid

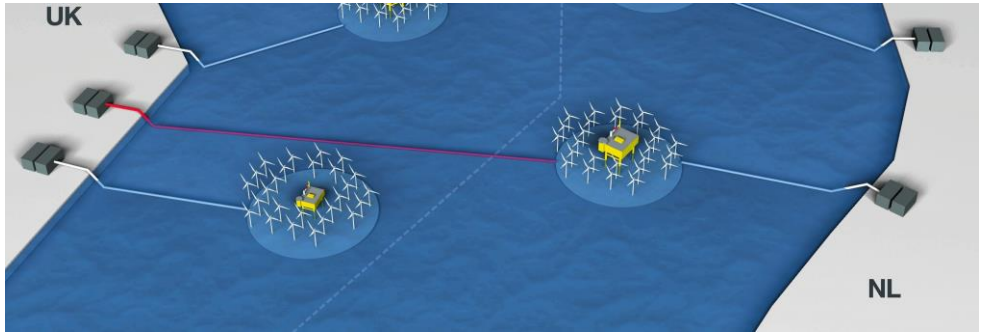
- DC is continuous current and can be compared by stopping a heavy train in milliseconds.

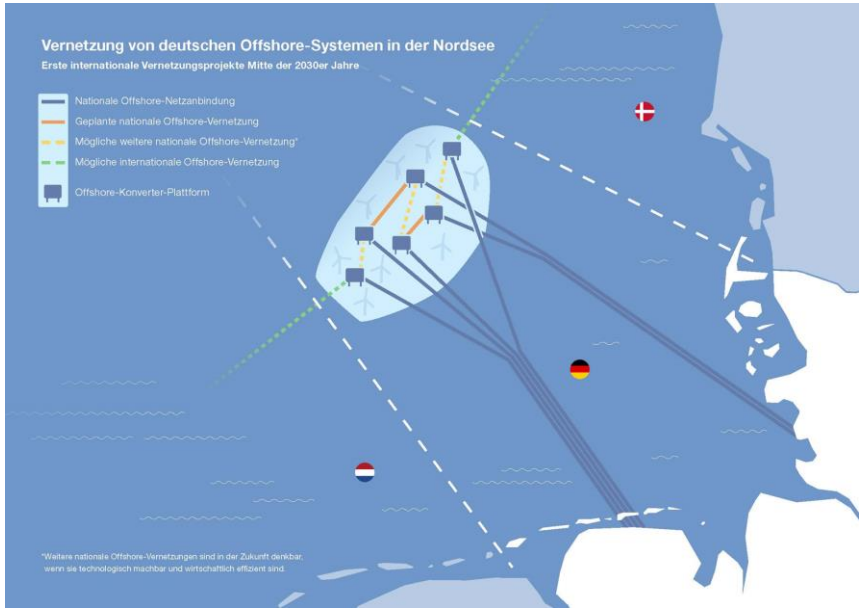
Stability of the HVDC grid is different then the AC grid

- HVDC grid response is much faster, “shorter” balancing stick, asks for different control principles.

How to get there?

How to get there?
Starting the first projects and learn!





First projects under exploration:

- Multi-purpose interconnector (Hybrid interconnector NL-UK)
- Hydrogen demonstration project NL
- German Offshore Interconnection cluster Hub-2-Hub connection NL-DK
- Prinses Elisabeth Island Belgium
- Danish Energy Islands
- ….

Rijksoverheid

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Windpark boven Groningen beoogd als 's werelds grootste waterstof op zee productie in 2031

Nieuwsbericht | 20-03-2023 | 12:10

In het windenergiegebied Ten noorden van de Waddeneilanden plant Nederland de eerste grootschalige waterstofproductie op zee. Het windpark is goed voor circa 500 Megawatt elektrolysecapaciteit en moet rond 2031 operationeel zijn. Het gebied is gekozen omdat hier al een windpark gepland stond voor de productie van elektriciteit, mogelijk een bestaande aardgasleiding hergebruikt kan worden voor het transport naar land én het goed aangesloten kan worden op het waterstofnetwerk op land.

How to get there?
Harvest from cooperation in an international setting

- International groups developing concepts
- TSO's bundling forces (e.g. Esbjerg group)
- High level of stakeholder engagement (market parties, NGOs, supply chain)
- Providing input to governmental plans
- Countries working together on governmental level, harmonizing regulatory frameworks

Lighting the way ahead together!

TenneT is a leading European grid operator. We are committed to providing a secure and reliable supply of electricity 24 hours a day, 365 days a year, while helping to drive the energy transition in our pursuit of a brighter energy future – more sustainable, reliable and affordable than ever before. In our role as the first cross-border Transmission System Operator (TSO) we design, build, maintain and operate 24,500 kilometres of high-voltage electricity grid in the Netherlands and large parts of Germany, and facilitate the European energy market through our 16 interconnectors to neighbouring countries. We are one of the largest investors in national and international onshore and offshore electricity grids, with a turnover of EUR 6.4 billion and a total asset value of EUR 32 billion. Every day our 6,600 employees take ownership, show courage and make and maintain connections to ensure that the supply and demand of electricity is balanced for over 42 million people.

Lighting the way ahead together

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