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Hydrogen Tech World Conference 2023

THE DEVELOPMENT OF OFFSHORE HYDROGEN PRODUCTION TO ENABLE FURTHER GROWTH OF OFFSHORE WIND IN THE NETHERLANDS

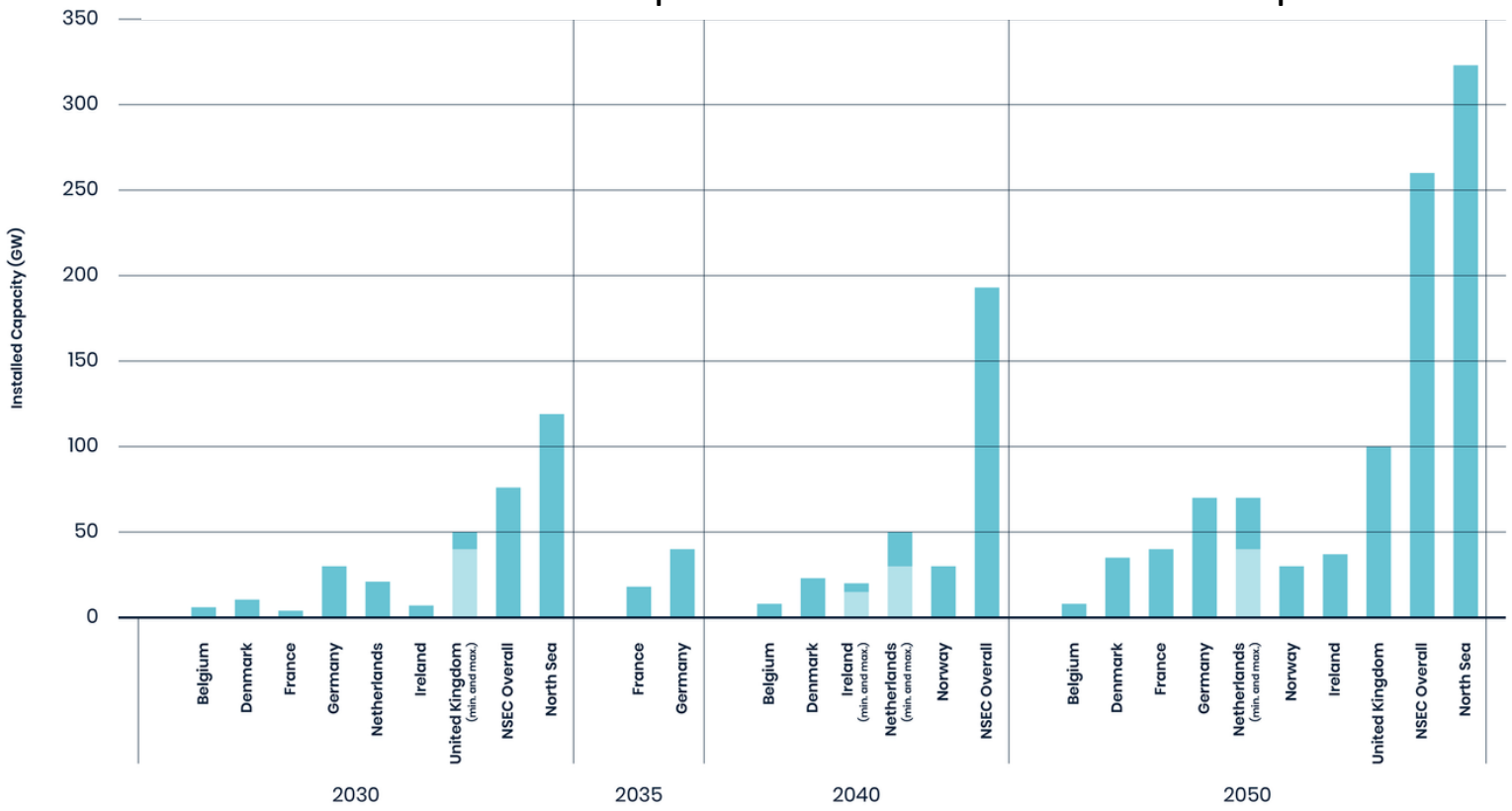
5 April 2023

RENE PETERS | TNO

Introduction

EXPANSION OF OFFSHORE WIND ENERGY IN EUROPE

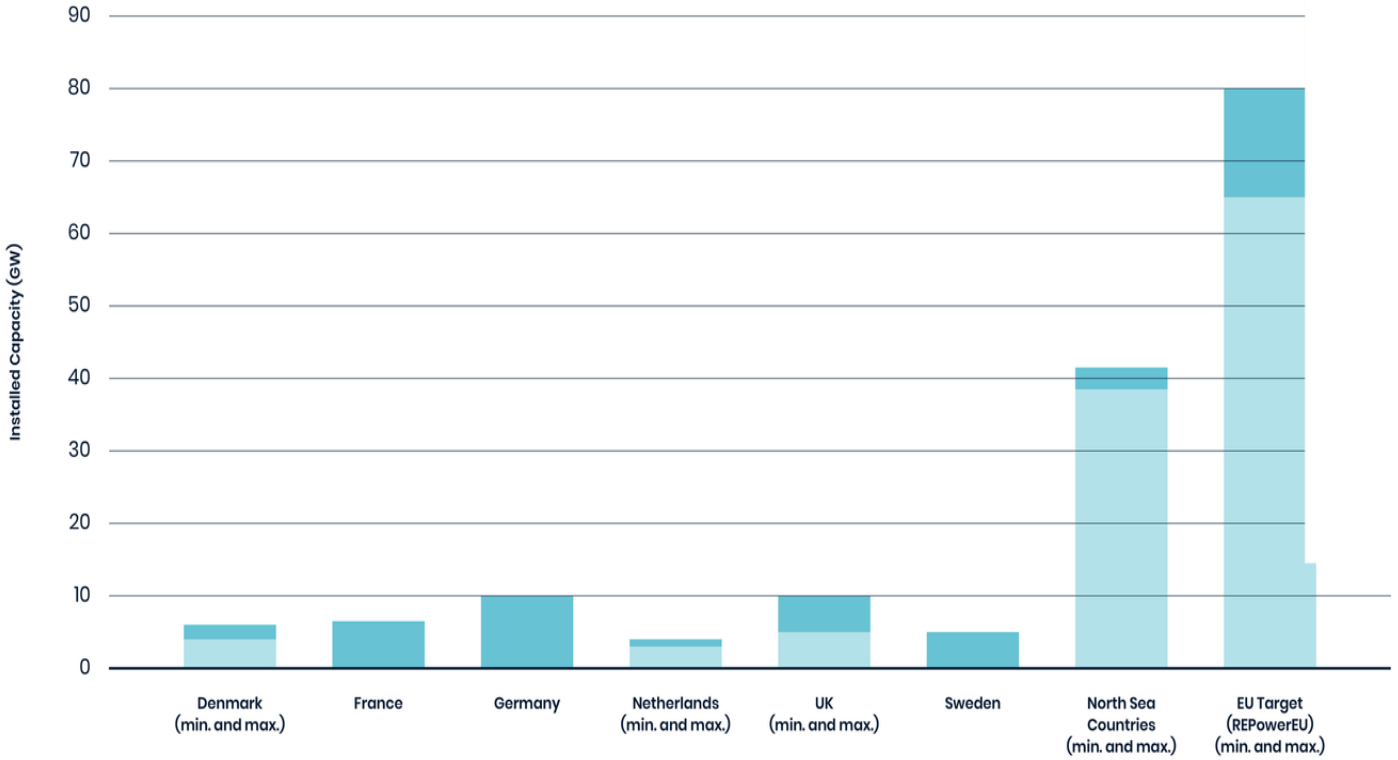
Predictions of installed capacities of offshore wind in Europe

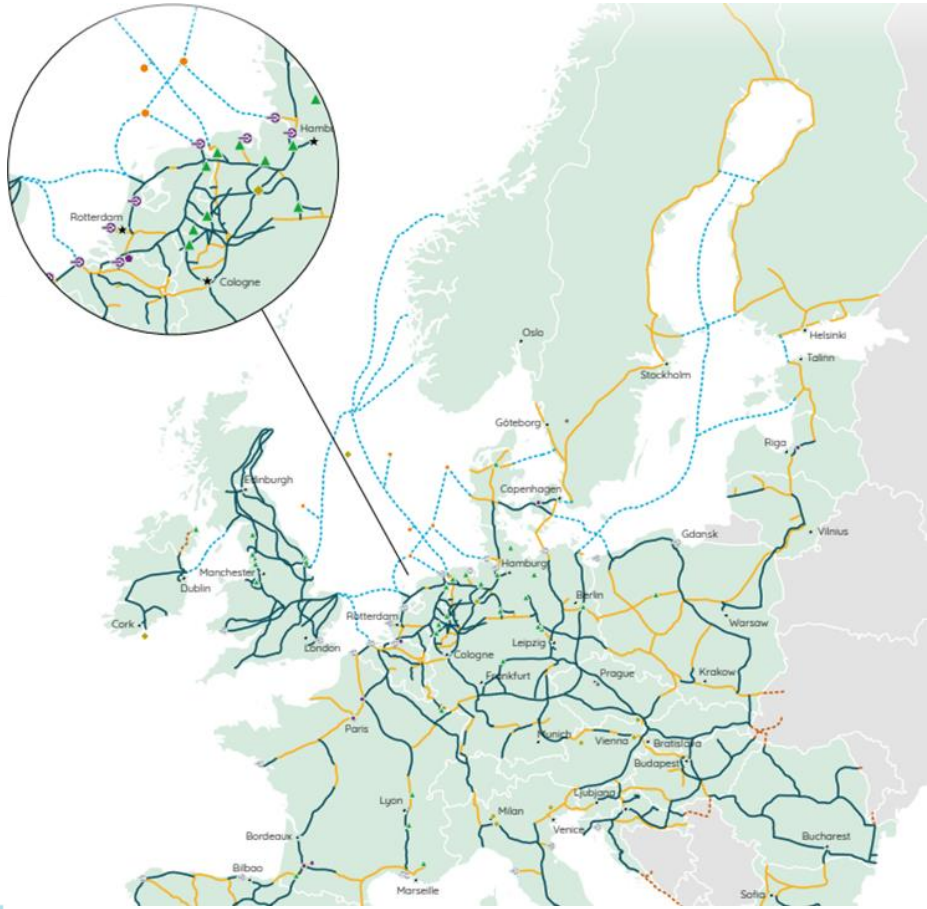


Introduction

GREEN HYDROGEN AMBITIONS EU

Predicted installed capacity for hydrogen production for 2030





CO2 emission reduction options for industry in NL

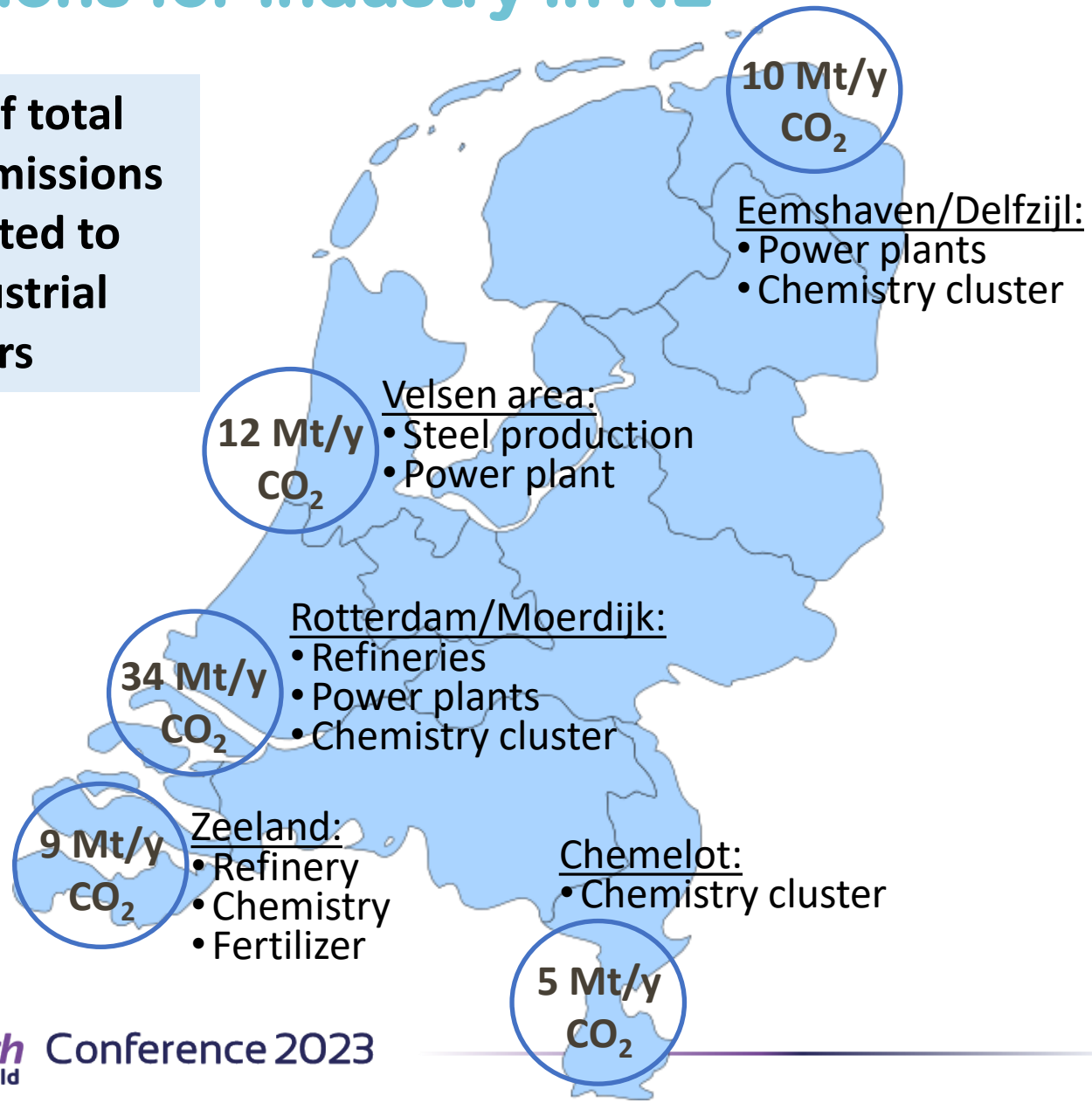
Main options for CO2 reduction:

- CCUS
- **Blue/Green H2**
- **Electrification**

All involve North Sea assets:

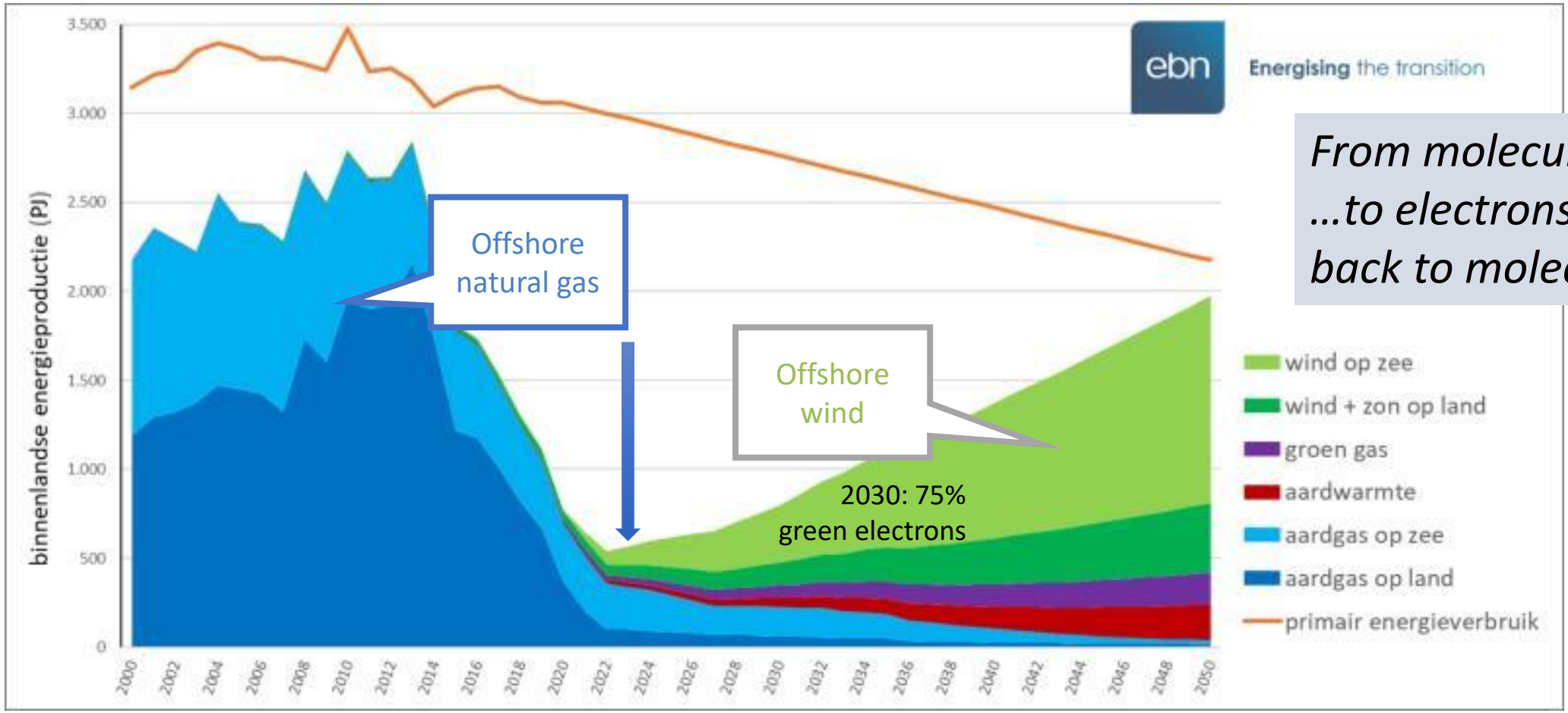
- Depleted gas fields for CO2 storage
- Pipelines for CO2/H2 transport
- Wind turbines to supply green power
- Platforms for offshore H2 production

40% of total CO_2 emissions is related to 5 industrial clusters



North Sea energy program http://www.north-sea-energy.eu/atlas.html

Energy Production NL in Transition from Gas to Wind



From molecules CH4 …to electrons…. and back to molecules H2

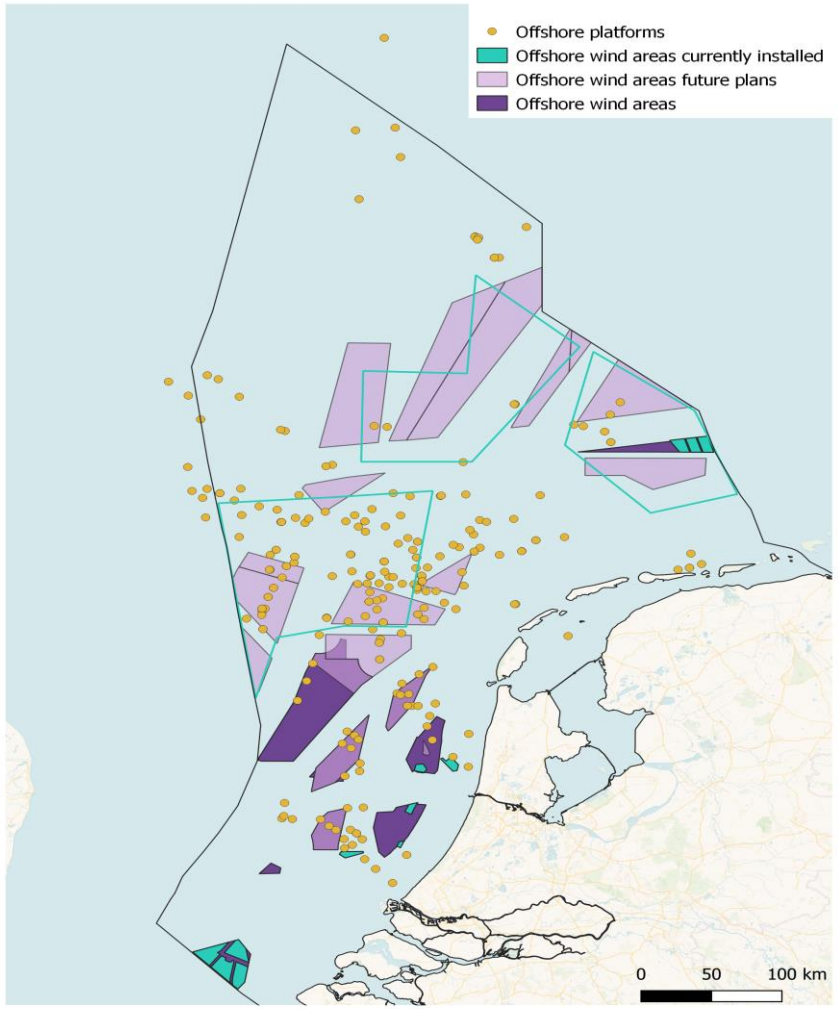
Offshore wind in the Netherlands
Vast potential and pivotal to reach Paris targets.

- 2023: 4.5 GW installed (under construction)
- 2030: 21 GW installed (all electric)
- 2040: 50 GW installed (incl. hydrogen)
- 2050: 70 GW total capacity

Planned wind farms

Existing platforms

- First pilots for offshore H2 production in NL:
- 2023: 1 MW – PosHYdon
- 2025: 2,5 MW – CrossWind HKN
- ?: 50-100 MW – ambition announced by Ministry EZK
- 2031: 500 MW – target announced by Ministry EZK (TNvd



GREEN HYDROGEN PROJECT PIPELINE IN THE NL

PLANS COUNT UP TO 9 GW, BUT NO FID YET

			t/m 2025	2026-2030	
ELYgator	Air Liquide	Terneuzen	200		
HyNetherlands	ENGIE	Eemshaven	100	1750	
Djewels-1	Nobian	Delfzijl	20		
Djewels-2	Nobian	Delfzijl		40	
H2ermes	Nobian-Tata	Velsen		100	
H2-fifty	Nobian-BP	Maasvlakte		250	
SeaH2land	Ørsted	Vlissingen	500	500	
Eemshydrogen	RWE	Eemshaven	50		
GZI Next	Shell/Gasunie	Emmen	10		
Hydrogen Holland I	Shell	Maasvlakte	200		← FID
NortH2	Shell en partners	Eemshaven		4000	
H2ero	TotalEnergies-Lukoil	Vlissingen	150		
Hydrogen to Maasvlakte	Uniper	Maasvlakte	100	400	
Eemshaven-West	Vattenfall	Eemshaven	10	90	
CurtHyl	Vattenfall	Maasvlakte	10	90	
Hy4Am - P2F Hemweg	Vattenfall	Hemweg	10	90	
VoltH2	VoltH2	Vlissingen	25	75	
VoltH2	VoltH2	Terneuzen	25	50	
Haddock	Yara-Ørsted	Sluiskil	100		
			1510	7435	

- All projects up to 2025 counts for 1,5 GW
- Between 2026-2030 another 7,4 GW
- **Total 8,9 GW in 2030** ← And growing

- **Hydrogen production**
- 9 GW will produce: 87 PJ H2/a = 720 kton/a
- 57,8 kWh and 4,664 FLH
- 14,5 GW offshore wind needed (assuming 1:1,5)

- + H2 import?

First wind – H2 project: H2RES (DK) 2 MW (2021)

Source: TNO (2022), Impact Fit for 55 voorstel voor herziening RED op de vraag naar groene waterstof in Nederland (link)

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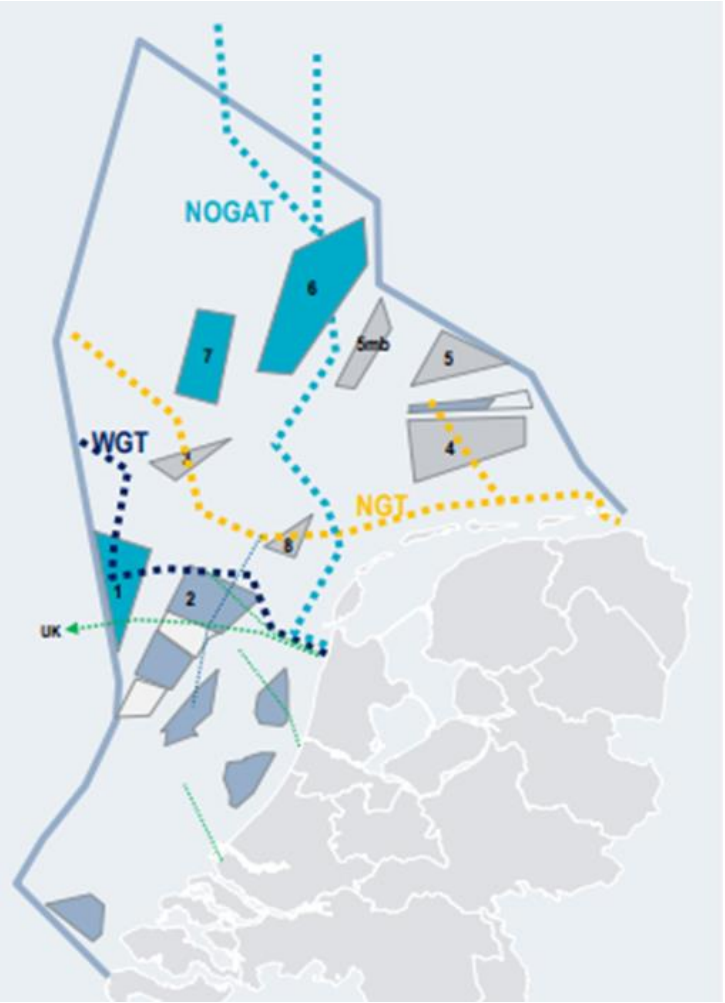
Why offshore hydrogen production?

- Future wind parks are developed further offshore (> 100 km)
- Energy transport via electricity from HVAC > HVDC (525 kV) costly
- Landing capacity of power cables increasingly more complex
- Absorption capacity of onshore electricity grid is limited
- Grid balancing with increasing intermittent production increasingly challenging
- Offshore pipelines become available for reuse for H2 from 2030 onwards
- Cost saving in offshore H2 production and transport significant when:
  - Distance > 100 km or when HVDC is required
  - Scale > 2 GW, as capacity of trunk lines well beyond 10 GW
- Benefits: pipelines are cheaper, faster to implement, have lower ecological impact and are more reliable than HVDC cables

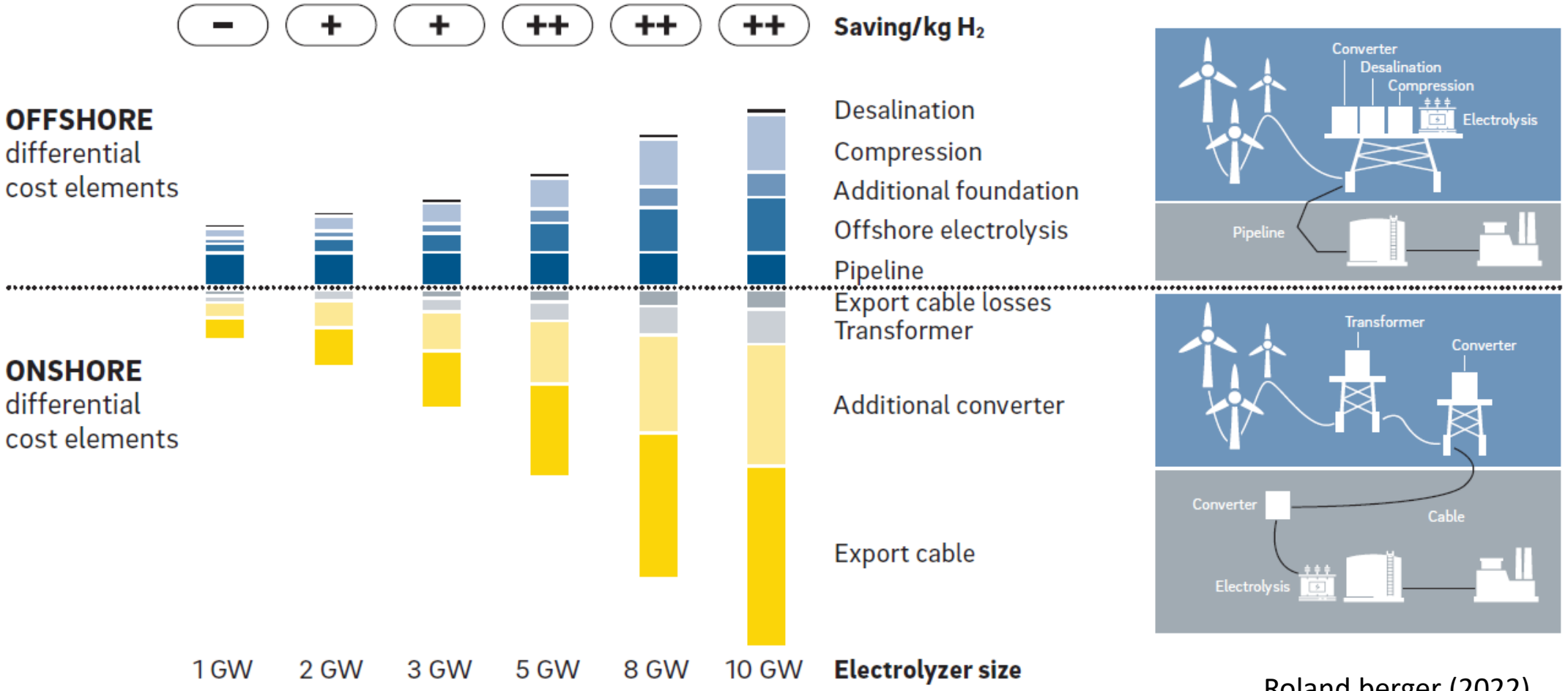
•Ref: www.north-sea-energy.eu, NSE(2020), Roland Berger (2021), AFRY (2022)



Cost comparison on- and offshore hydrogen

At larger scale, offshore hydrogen electrolysis is cheaper than onshore hydrogen electrolysis

INDICATIVE



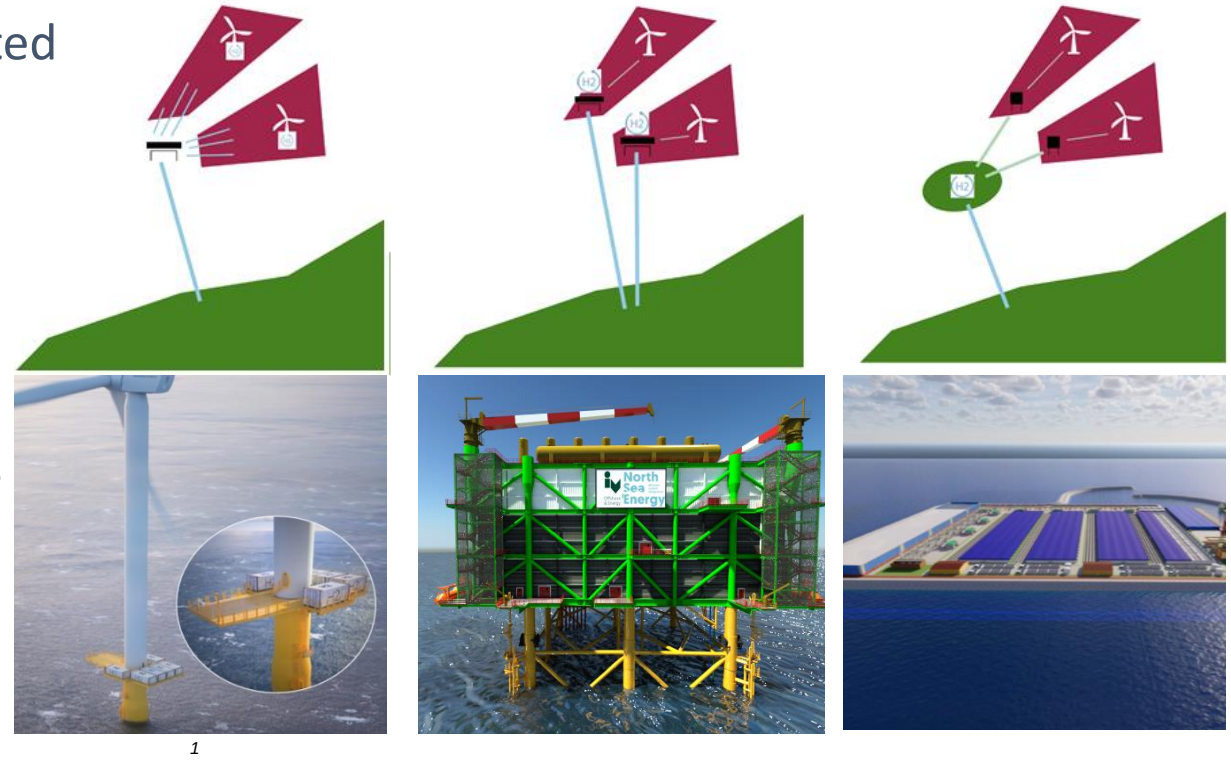
Roland berger (2022)

Conclusion:

OFFSHORE HYDROGEN PRODUCTION IS A PREREQUISITE FOR FURTHER GROWTH

- Intermittent wind power
  - Absorption capacity of the onshore grid is limited
- Flexibility needed
  - Large scale energy storage required
- Spatial constraints landing offshore wind
  - Transport capacity H2 >> capacity HVDC cables
- System cost benefits
  - In particular transport and storage costs

3 POTENTIAL CONCEPTS



1

a) Electrolysis at the turbine, scale 15 – 20 MW

b) Electrolysis on wind farm level, scale 300 – 500 MW

c) Electrolysis on energy island, scale Multi GW

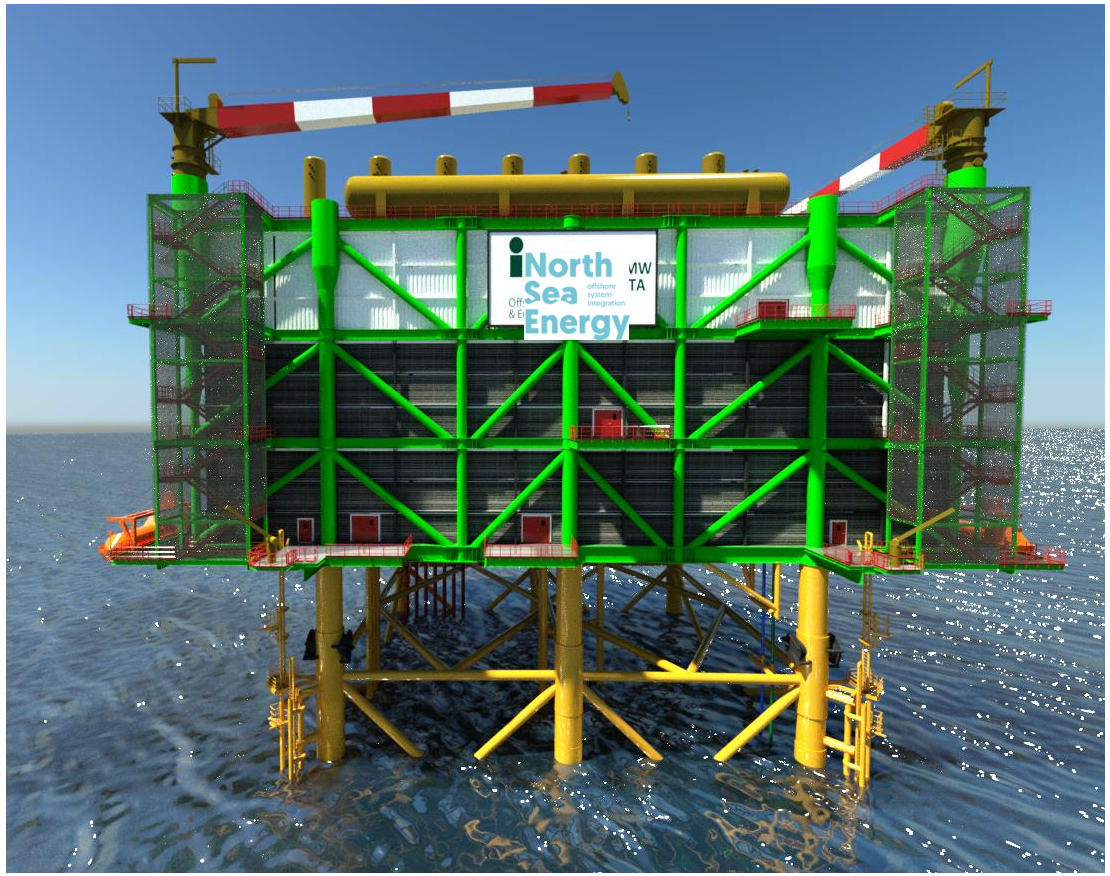
Worlds first offshore hydrogen project that brings green hydrogen to shore

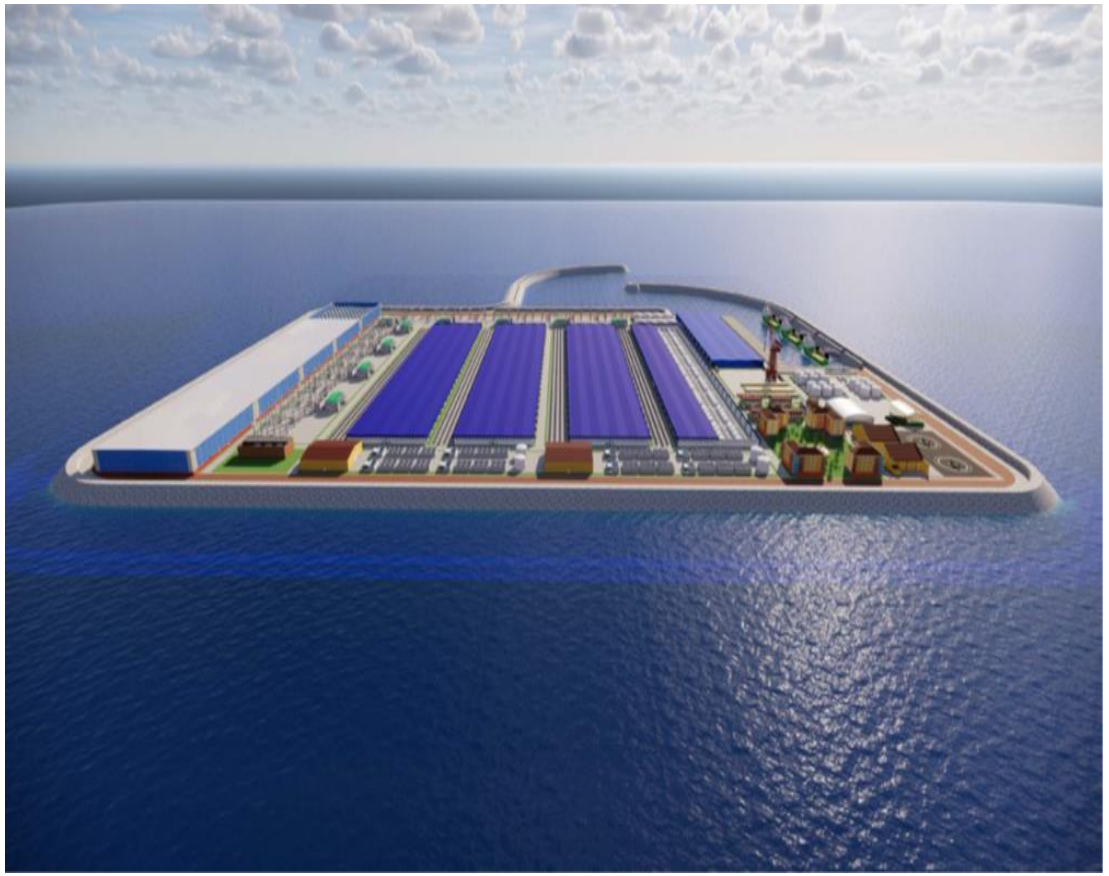
JUST DO IT.

POSHYDON

Upscaling of offshore H2 production

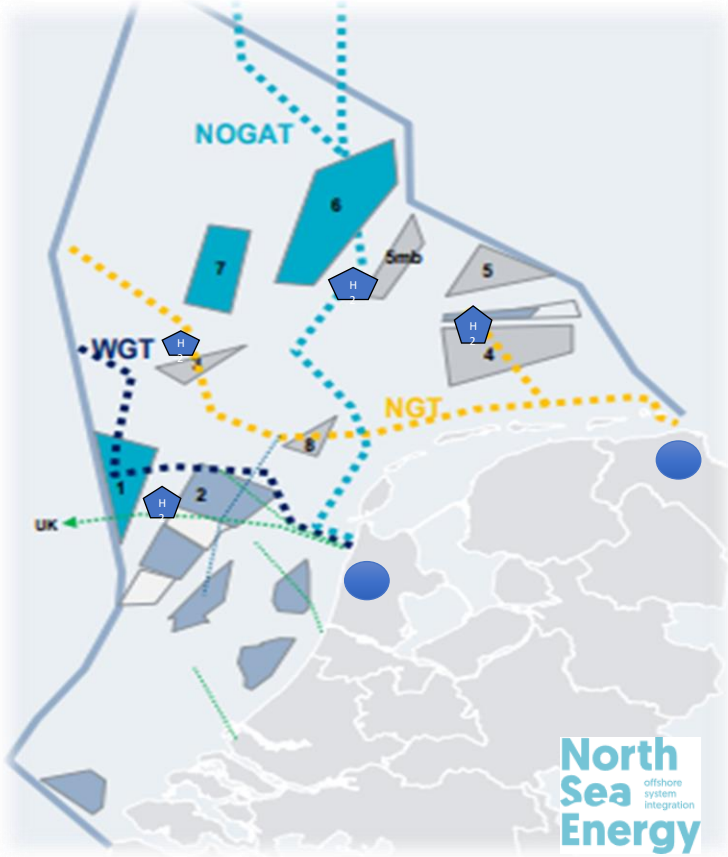
- Far offshore wind developments in combination with green hydrogen production to GW scale
- Platform or island solutions (> 100 km offshore and > 2 GW capacity)
- Policy ambition NL: Demo 500 MW offshore hydrogen production in 2031



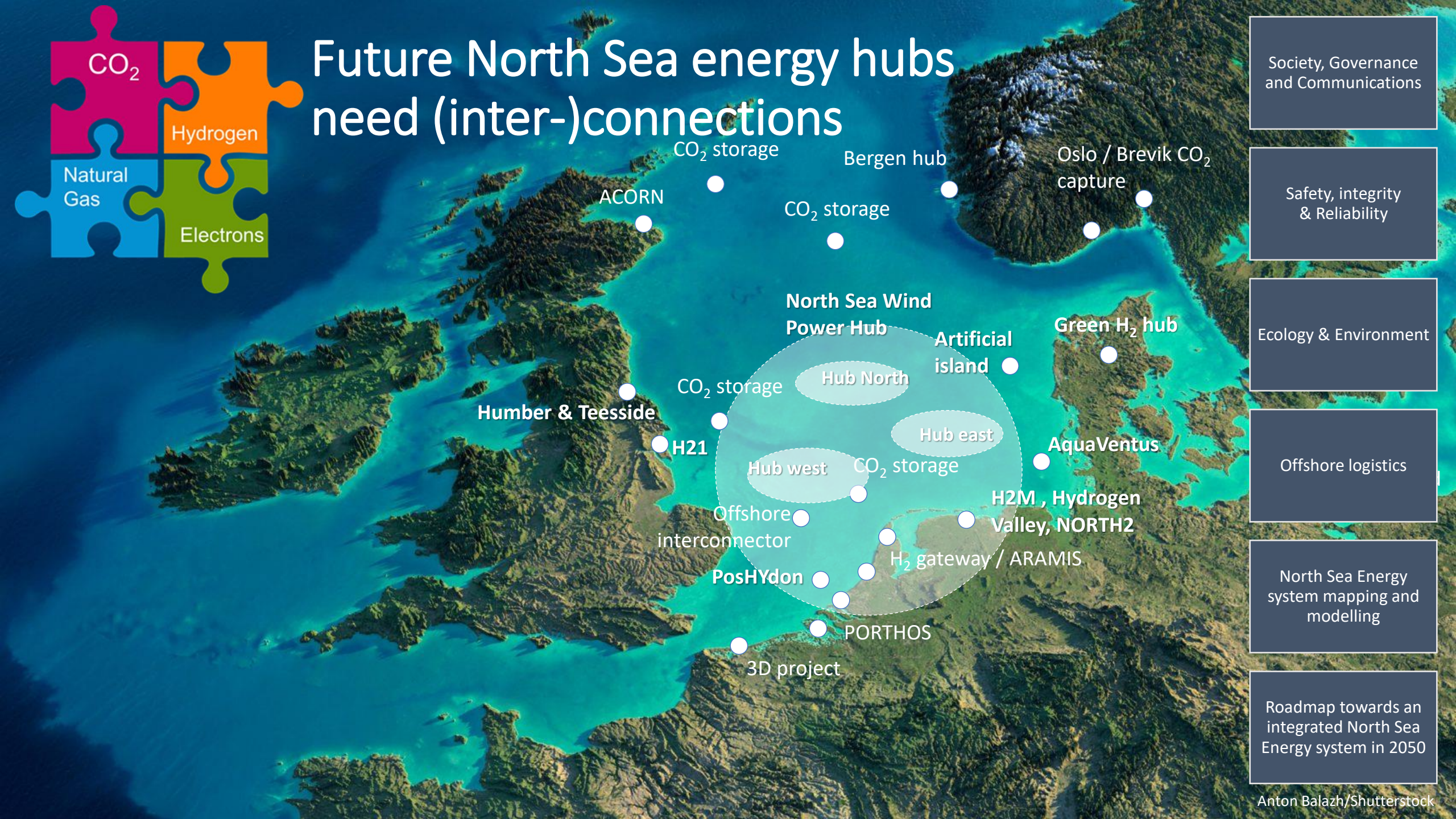


Hydrogen infrastructure development in the Netherlands

ONSHORE AND OFFSHORE H2 TRANSPORT DEVELOPMENT IN THE NETHERLANDS



- National Hydrogen Backbone development of Gasunie (2020). Receive 750 M€ funding, 1,5 B€ investment (2024 – 2028)
- Offshore Hydrogen production and transport by North Sea Energy (2022). Key locations Den Helder and Uithuizen


CO_2
Hydrogen
Natural Gas
Electrons
Future North Sea energy hubs need (inter-)connections
CO_2 storage
ACORN
Bergen hub
CO_2 storage
Oslo / Brevik CO_2 capture
North Sea Wind Power Hub
Artificial island
Green H_2 hub
Hub North
CO_2 storage
Humber & Teesside
H21
Hub east
AquaVentus
Hub west
CO_2 storage
H2M , Hydrogen Valley, NORTH2
Offshore interconnector
H_2 gateway / ARAMIS
PosHYdon
PORTHOS
3D project
Society, Governance and Communications
Safety, integrity & Reliability
Ecology & Environment
Offshore logistics
North Sea Energy system mapping and modelling
Roadmap towards an integrated North Sea Energy system in 2050
Anton Balazh/Shutterstock

Proposed way forward via NSEC collaboration

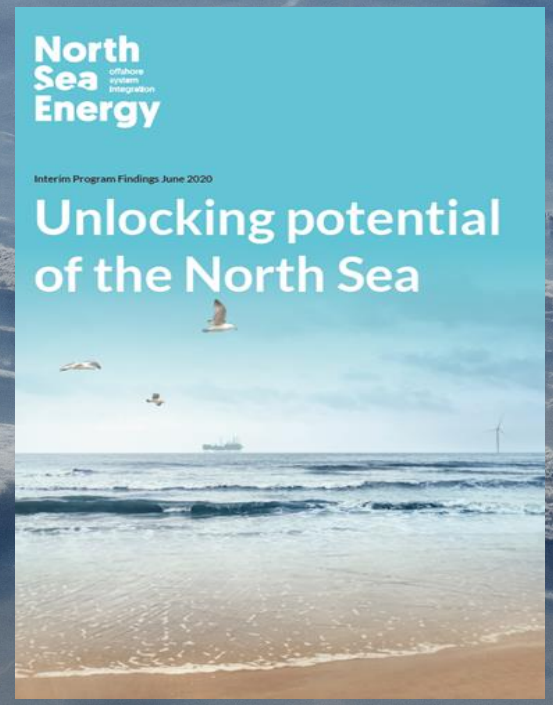
By collaborating between NSEC countries, reaching the offshore wind and H2 targets can be accelerated.

Topics for intensified collaboration:

1. Determine a common roadmap towards a multi-GW scale offshore hydrogen producing North Sea.
2. Identify methods to incentivize combinations of offshore wind and electrolysis
3. Define of a joint vision on offshore energy infrastructure
4. Setup common innovation programs and collaborative R&D
5. Alignment on European legislation, standards and policy, that also focusses on offshore production, transport and storage of hydrogen.

www.tno.nl/en/newsroom/insights/2023/02/north-sea-countries-unite-forces/

QUESTIONS?



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North Sea Energy offshore system integration

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