Copenhagen Infrastructure Partners

Offshore energy hubs as enablers of large-scale cost-efficient hydrogen production

5th European Hydrogen & P2X Conference 2024

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Europe's journey Net Zero transition - an integrated energy system

Four drivers leading EU's green transition setting an ambitious political direction, but practical implementation delays transition

Drivers

Race to Net Zero: Climate Change

Energy independence

Renewable Energy Cost Competitiveness

Growth & jobs of the green transition

Political Ambitions

Global Policy Objectives	**Paris Accord** *(2015)*
European Policy Objectives	**Esbjerg Declaration** *(May 2022)*
	Marienborg Declaration *(August 2022)*
	EU Green Industrial Plan *(Feb 2023)*
	Ostend Declaration *(April 2023)*
Global Industry Competition	**Inflation Reduction Act** *(July 2022)*

Delayed implementation

Complexities

Is it possible to reach Net Zero by 2050?

What are the effects on consumer prices?

How can stability in the energy mix be maintained?

What is the role of offshore wind power?

Where can green hydrogen be sourced?

CIP view on Europe's 2050 power and hydrogen markets

A model-based approach developed with insight from industry leaders

Joint modelling effort to understand Europe's[2] pathways to net zero by 2050

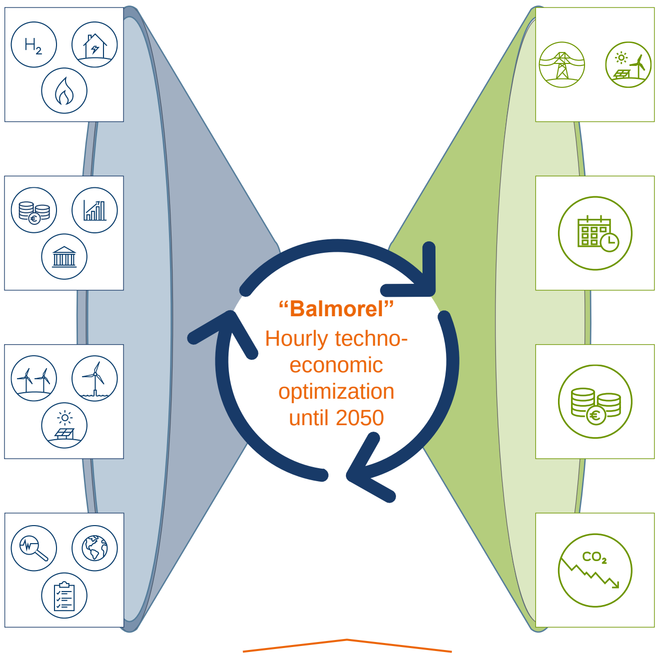
Model inputs[1]

Demand:
Power, heat and hydrogen demand

Economic:
Fuel and CO_2 prices, cost of capital

Technology:
capacity factor, efficiency, meteorology

System constraints:
reserve capacity, max renewables build-out p.a.



Model outputs[1]

Optimal capacity additions per power tech. / transmission line

Optimal generation dispatch and power flows

Electricity and hydrogen supply cost

CO_2 emissions

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An integrated European energy system

Notes: 1) Not exhaustive; **2)** The model covers EU 27 countries and UK.

Europe's energy transition requires massive offshore wind expansion

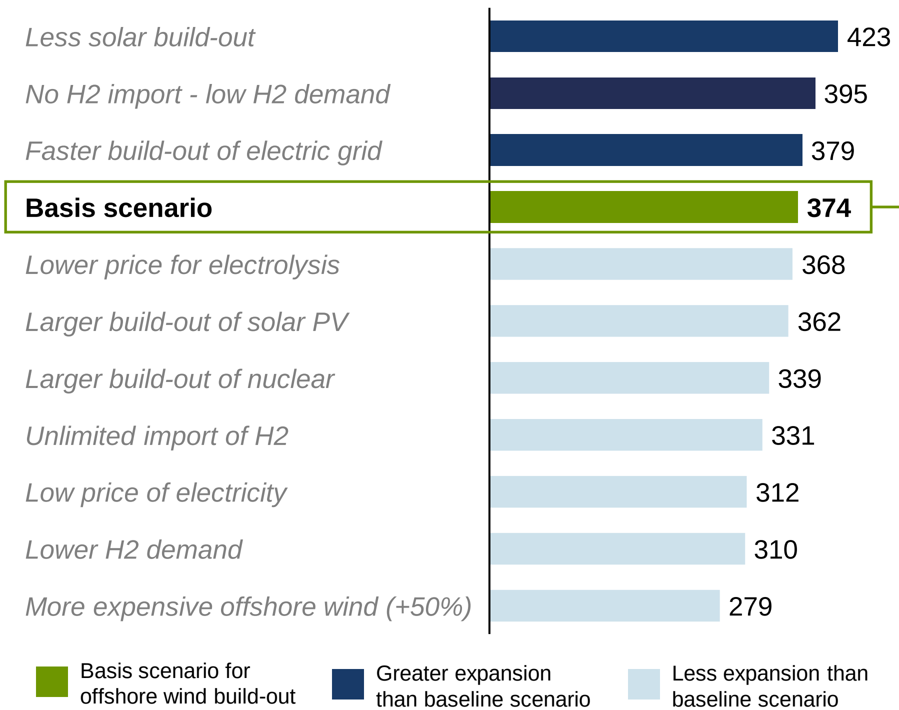
Assuming a green transition of Europe in 2050, Balmorel-model shows the optimal expansion of energy production in Europe

Modelling by EA Energy Analysis shows a need for massive offshore wind deployment under a wide range of sensitivities...

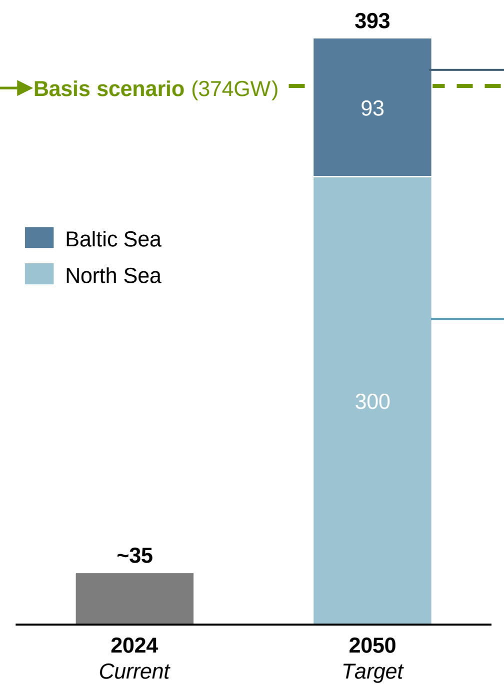
... which aligns with international targets of ~390GW offshore wind in the Baltic and North Sea by 2050

Ea Energy Analyses

Sensitivity | Offshore wind in Europe (GW)



Offshore wind (GW)



Aug 2022

Marienborg declaration
("Baltic Sea Summit")
✓ **93 GW before 2050**

Apr 2023

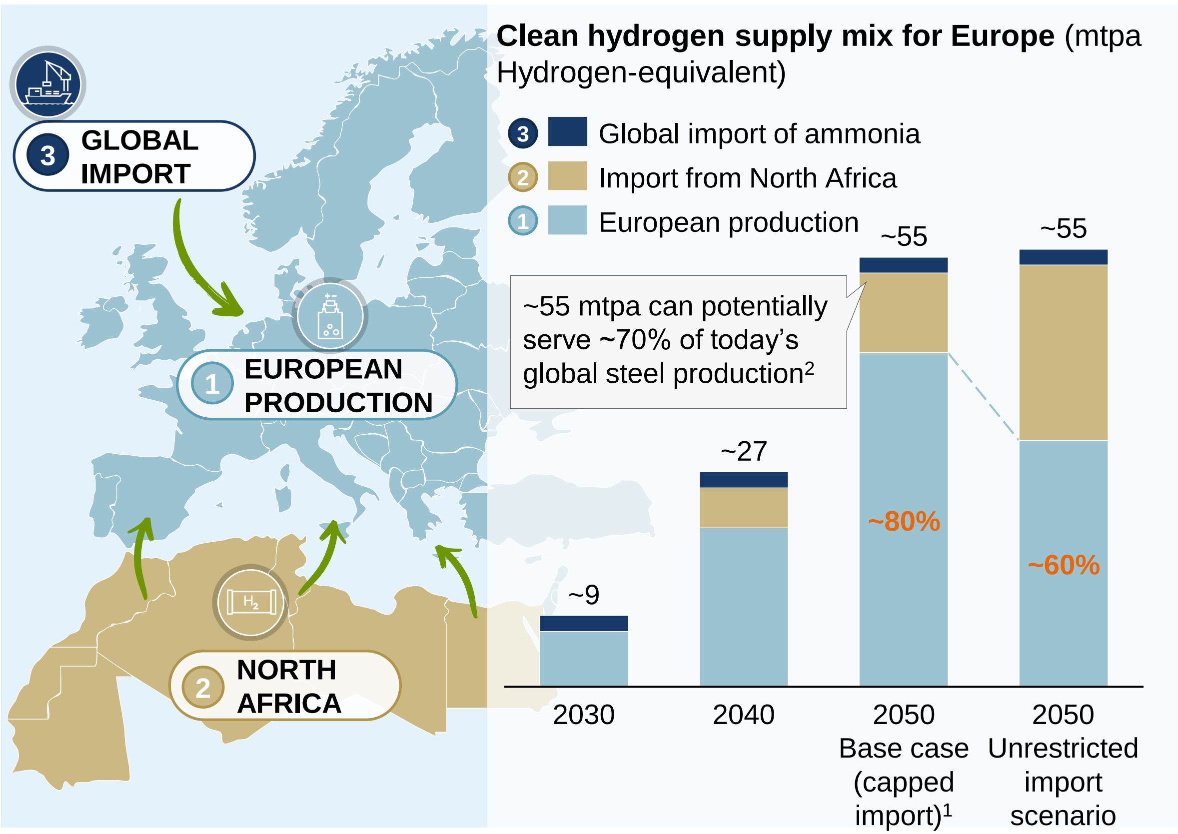
Ostende declaration
("North Sea Summit II")
✓ **300 GW before 2050**

Source: Analyses from EA Energianalyses (2023)

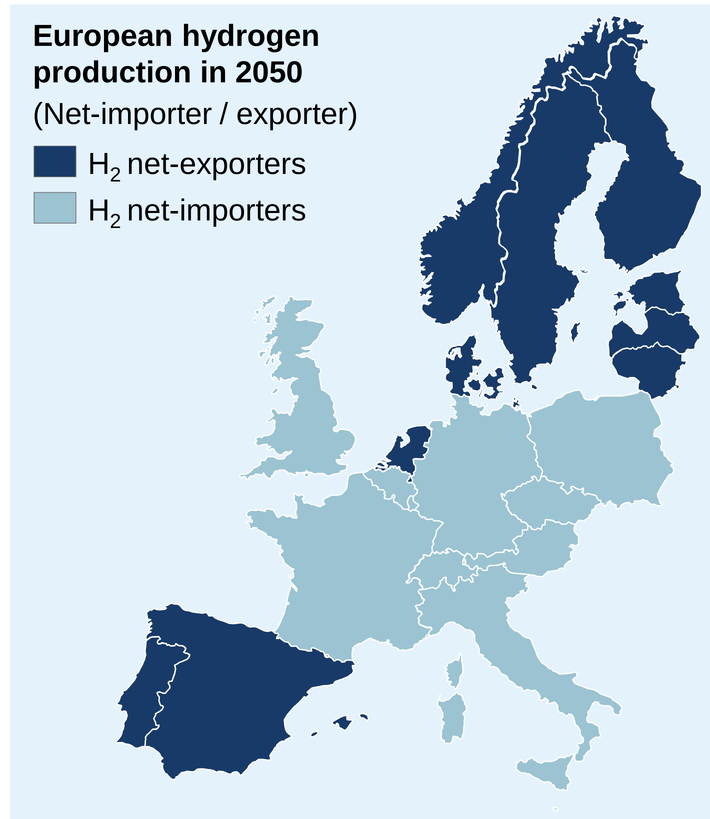
Notes: **1**) On behalf of CIP, EA Energy Analyses has modeled the expansion of offshore wind in the North Sea and the Baltic Sea. The analysis is based on Balmorel modeling of the European energy system, which models the optimal economic dispatch- and capacity expansion for the energy system across Europe.

European production to account for majority of Europe's hydrogen supply

European-based hydrogen production to account for ~60-80% of total supply in 2050, despite cost-competitive imports from North Africa



Renewable-abundant countries to lead European hydrogen production



Notes: 1) European import hydrogen at competitive prices from North Africa expected to be capped by political motives such as energy dependency or industry policies – in this case capped at 10 mtpa hydrogen from 2040 forward; **2)** Calculation based on 'Decarbonising primary steel production: Techno-economic assessment of a hydrogen based green steel production plant in Norway' (Bhaskar et al., 2022).

Offshore wind buildout crucial for EU hydrogen supply

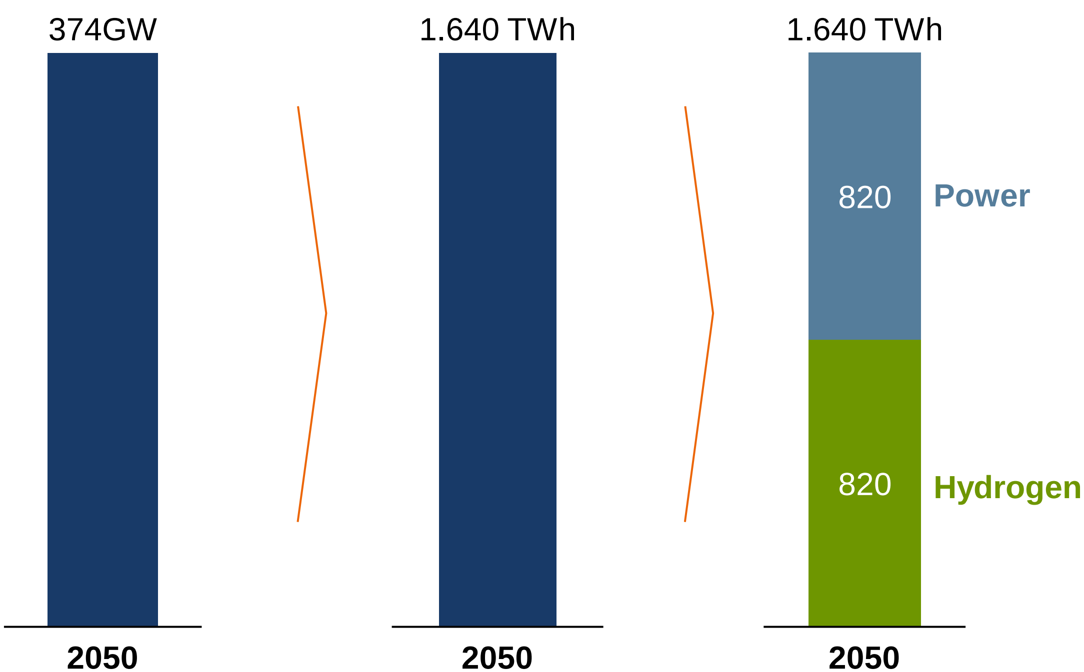
Offshore wind has an important role in reaching net zero providing large amounts of energy to both power and hydrogen grids

Role of offshore wind

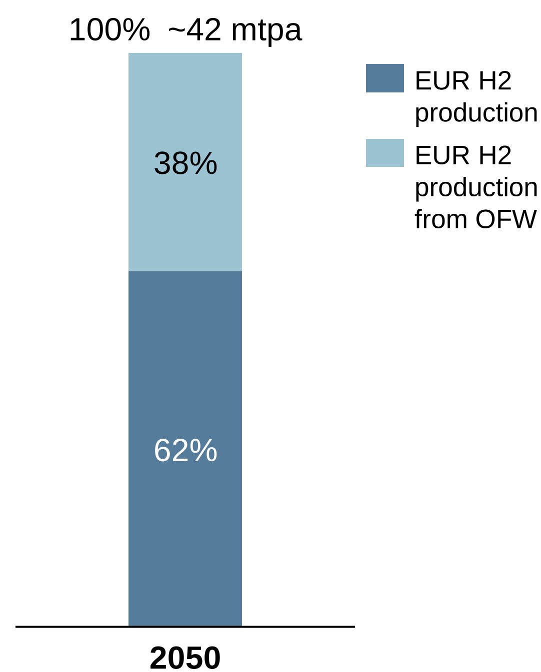
Reaching European climate goals by 2050 expected to require very large amounts of offshore wind

Offshore wind buildout will result in around 1,460 TWh of energy generation

50% of the wind energy generation will be used as power and 50% as hydrogen



38% of European hydrogen production is expected to come from offshore wind in 2050

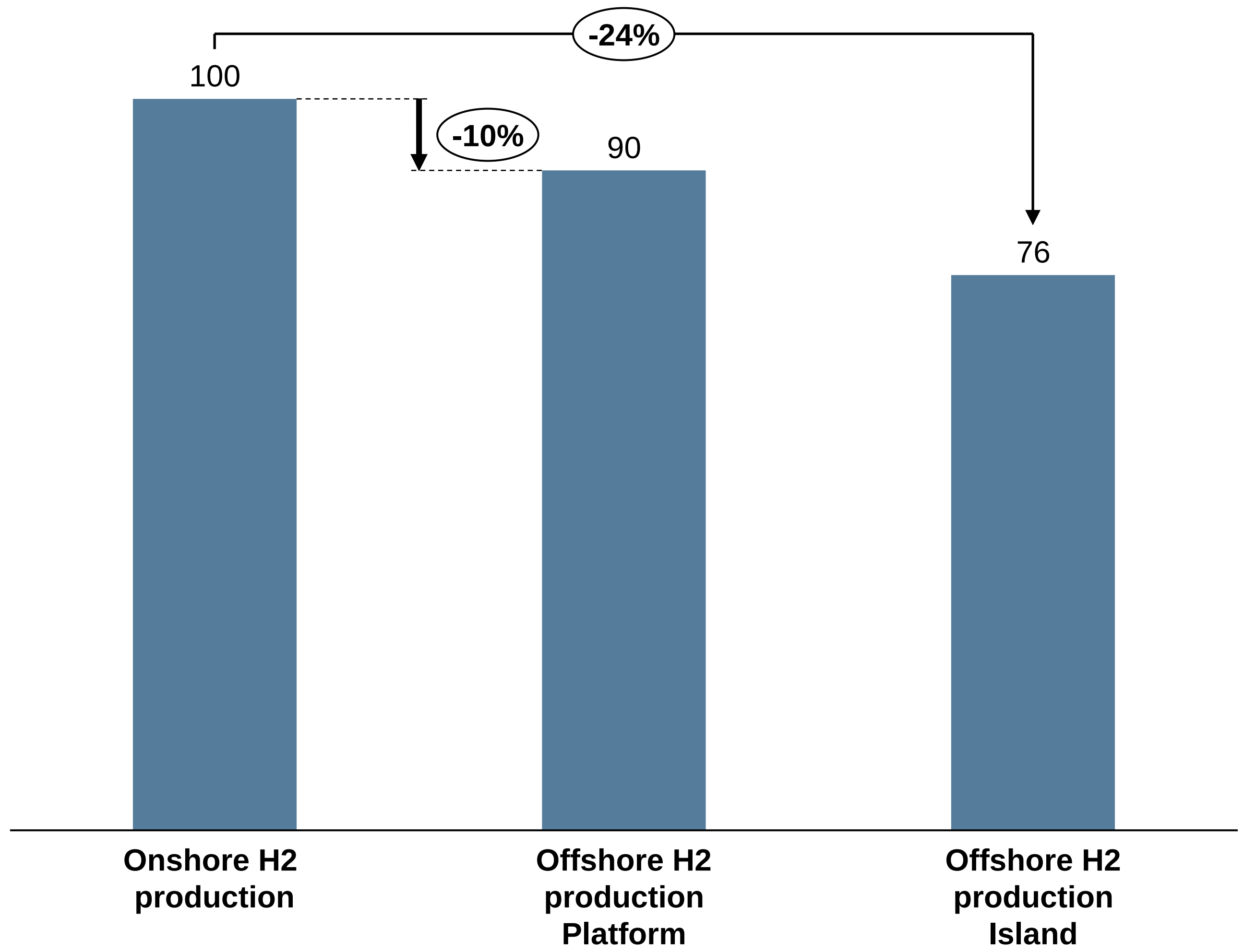


Source: EA Energianalyse

Offshore hydrogen production is key to enable European cost-competitive hydrogen

CIP and EU gas-TSO have performed a pre-feasibility study of offshore green hydrogen production

Indexed LCoH (EUR/ kg H2) for three scenarios



Comments

The analysis is based on:

- **Specific location** in German EEZ
- **Detailed layout** of
  - –Wind farm
  - –PtX plant
  - –HVDC transmission
  - –Hydrogen transmission

Savings driven by

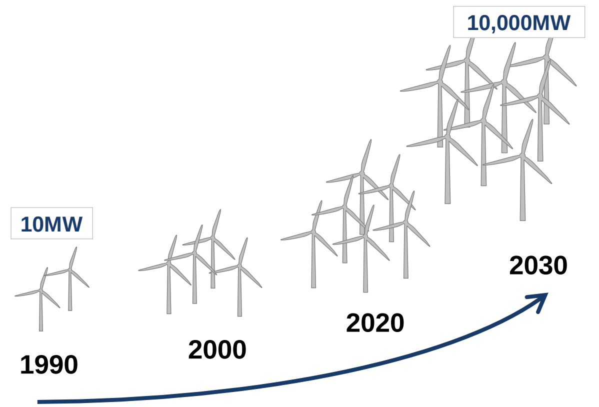
- Pipeline cheaper than cables and converter stations
- Lower power losses
- At scale artificial islands cheaper than platforms

Future offshore wind build out will require new approach to integrate the energy into the global energy systems

Three main drivers for energy islands

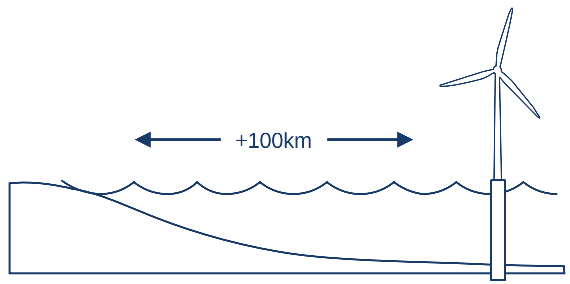
1

Offshore wind is rapidly developing towards larger and more integrated projects



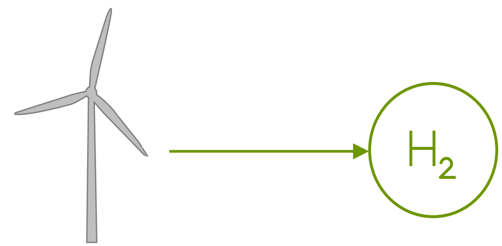
2

More than 70% of global offshore wind potential is located far from shore



3

Significant share of future offshore will be converted into hydrogen



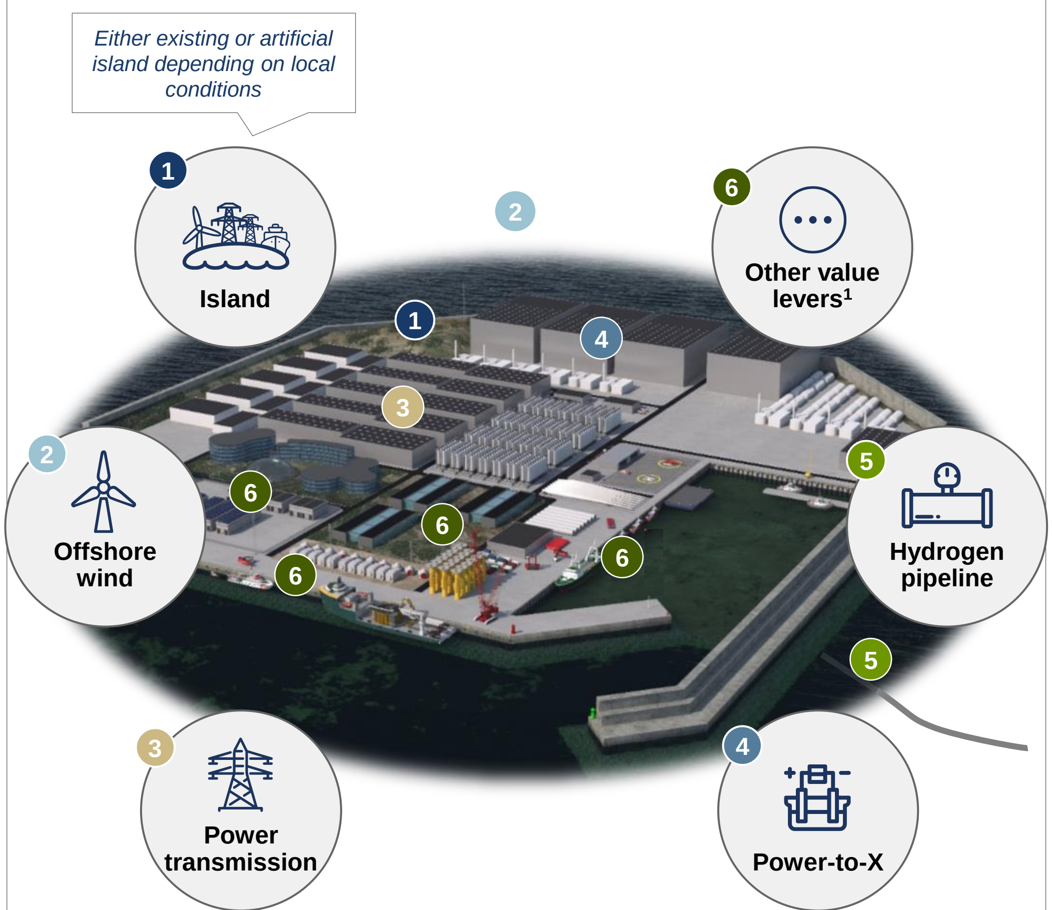
Traditional radial connections no longer fit for purpose - too costly, too slow, and do not enable system balancing synergies between power and hydrogen production → New approach needed

Details on following pages

Rationale for energy hubs

Energy hubs are expected to become corner stones in the development, deployment and integration of ultra large-scale offshore wind

Six building blocks for energy hubs



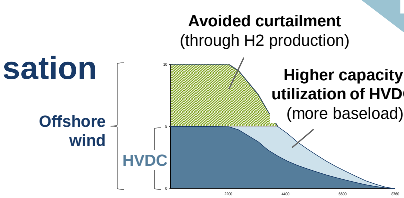
Value proposition

Hydrogen pipelines with significantly lower energy transport costs compared to HVDC
(~20% of HVDC cost)

VS

B

Higher HVDC cable utilisation and lower curtailment of offshore wind



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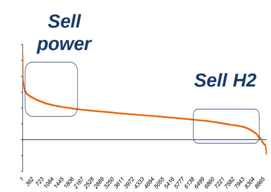
Synergies from combining power and H2 production
Producing power when power prices are high, and hydrogen when electricity prices are low



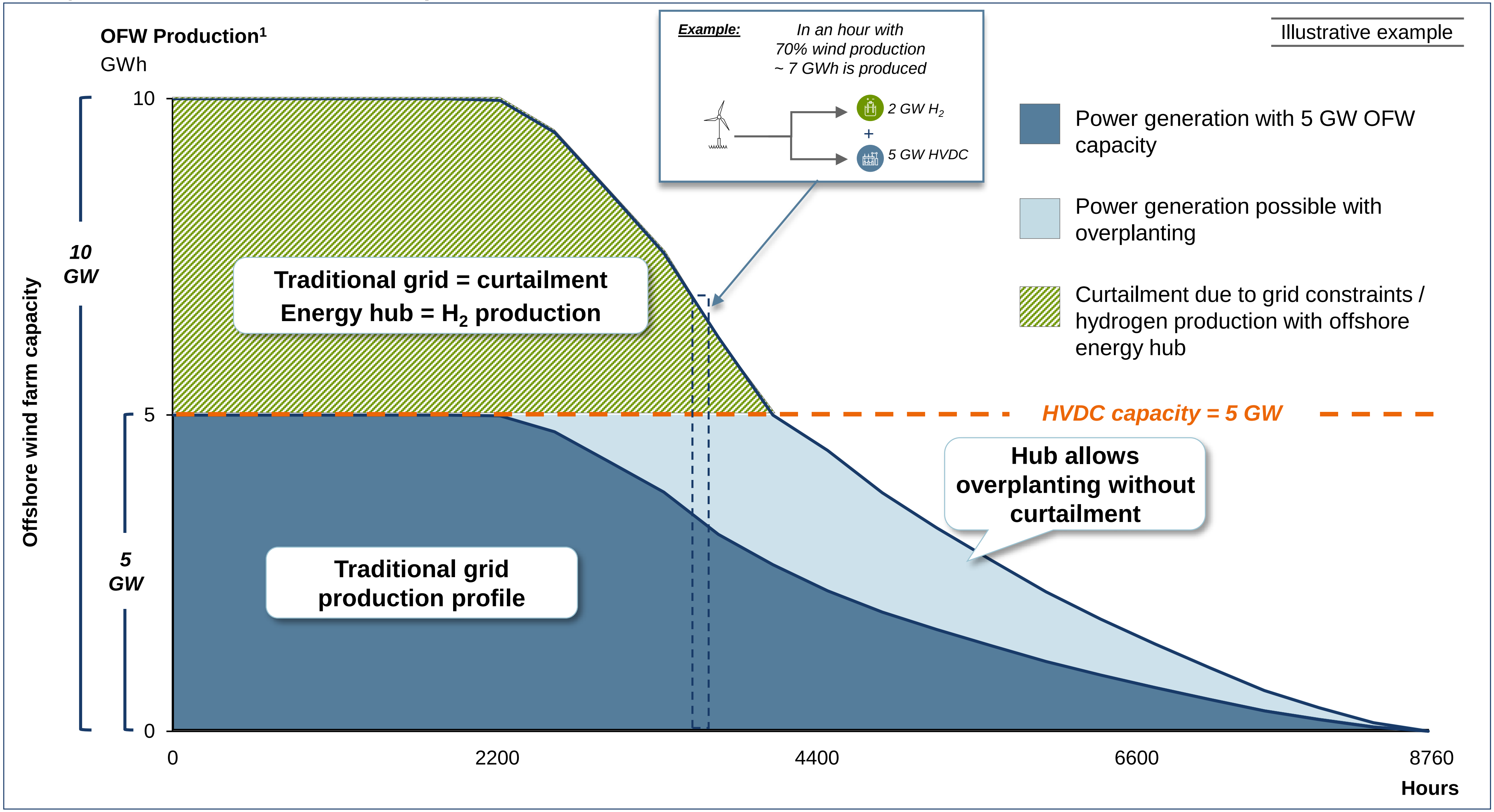
Local job creation and **economic growth**
Estimated +10,000 FTE during construction

Notes: 1) Potential value levers for the island include harbour for O&M and installation, defence, emergency response, storage, etc.

Allowing for optimization across power sales and hydrogen production

Hydrogen production on energy island can serve as a stabilising factor in the electricity grid

Hourly distribution of offshore wind production

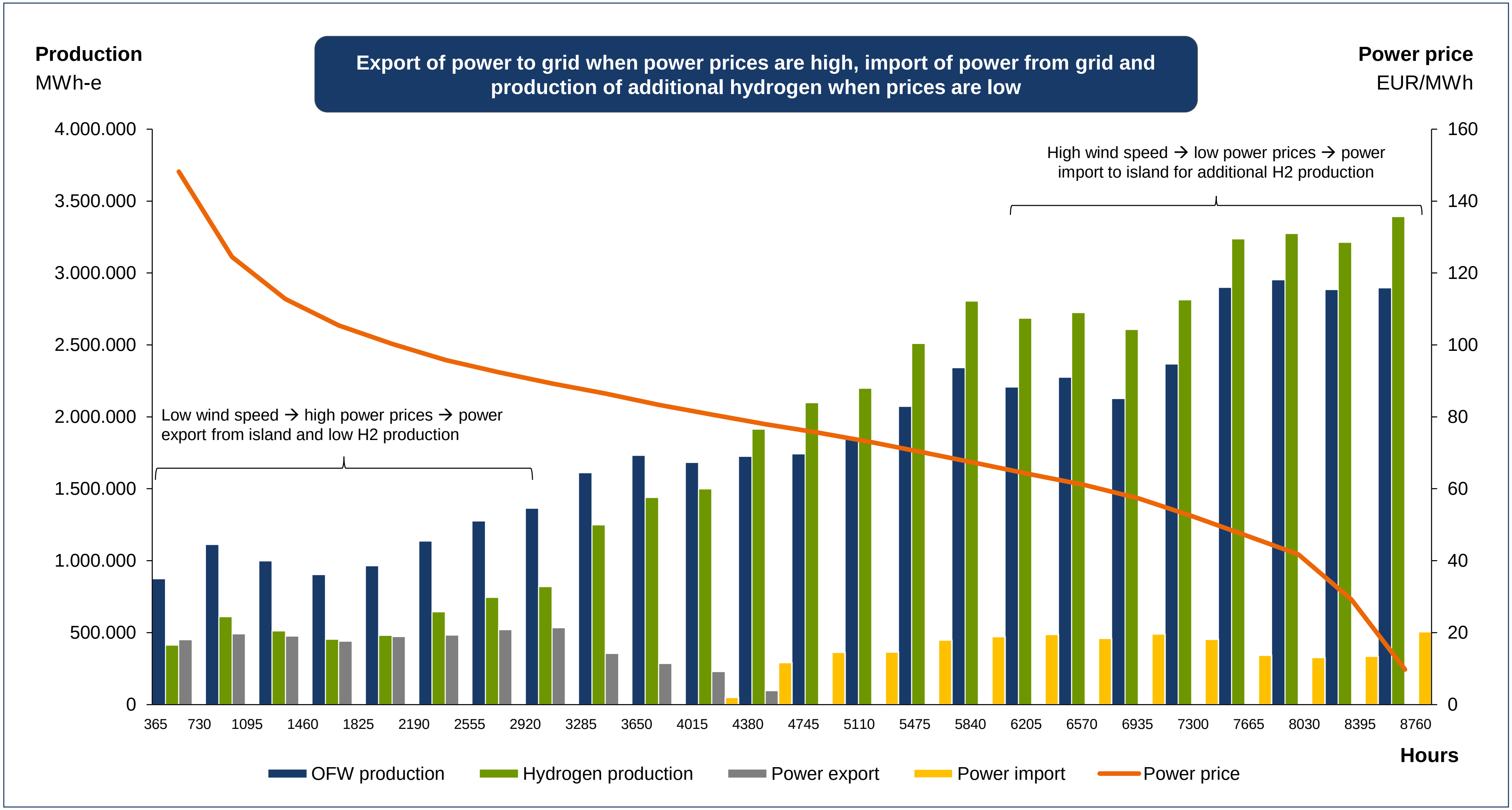


Notes: **1)** Production based on profile from European offshore windfarm

Allowing for optimization across power sales and hydrogen production

Export of power to grid when power prices are high, import of power from grid and production of additional hydrogen when prices are low

Illustrative price duration curve and production distribution in full year of operations



Take-aways for enabling largescale offshore hydrogen production in Europe

Build out of hydrogen infrastructure

Develop regulatory framework for offshore hydrogen transmission and production

Models for private capital into offshore hydrogen transmission and production