BALMOREL
Energy system model

Offshore wind build-out in the North sea and the Baltic sea

Nina Dupont
Ea Energy Analyses

BALMOREL
Energy system model

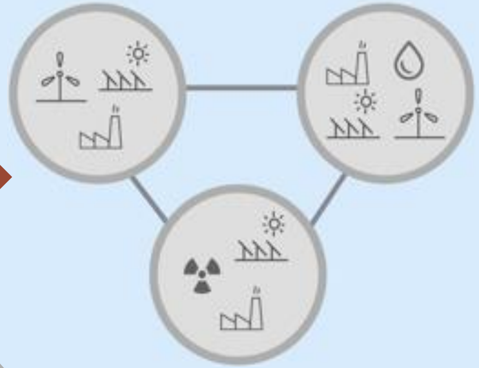
- Power system modelling tool
  - Least-cost optimization
  - Bottom-up
  - Open source
  - Transparent

Model inputs

Model inputs include
- Demand prognoses
- Fuel prices
- Policy constraints
- Existing and committed generation capacity
- Existing and committed transmission capacity
- Investment catalogue for generation capacity
- Investment catalogue for transmission capacity

The model is designed to work with multiple scenarios, e.g. with more or less renewable energy or with variations of parameters such as electricity demand, fuel prices, CO2 prices etc.

Least-cost dispatch

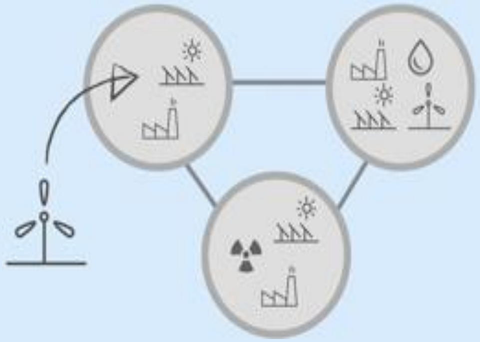


Each generator is represented with capacity (MW), fuel, efficiency and costs (operating costs and start/stop costs).

The model finds the optimal dispatch of each generator – given the available transmission capacity between areas. The optimal dispatch represents the lowest total costs for the entire model area.

Simultaneous optimization

Least-cost investments



The model considers future investments technologies and potential locations. Refurbishments or shutdown of existing capacity can be part of the investment options.

Local and global limitations of resources and different geographical conditions are considered. The least cost investment is made while fulfilling requirements about CO2, renewable energy, firm capacity and policies.

STUDY ON BALTIC OFFSHORE WIND ENERGY COOPERATION UNDER BEMIP

Finished June 2019

A study for the BEMIP working group under the European Commission

THEMA CONSULTING GROUP

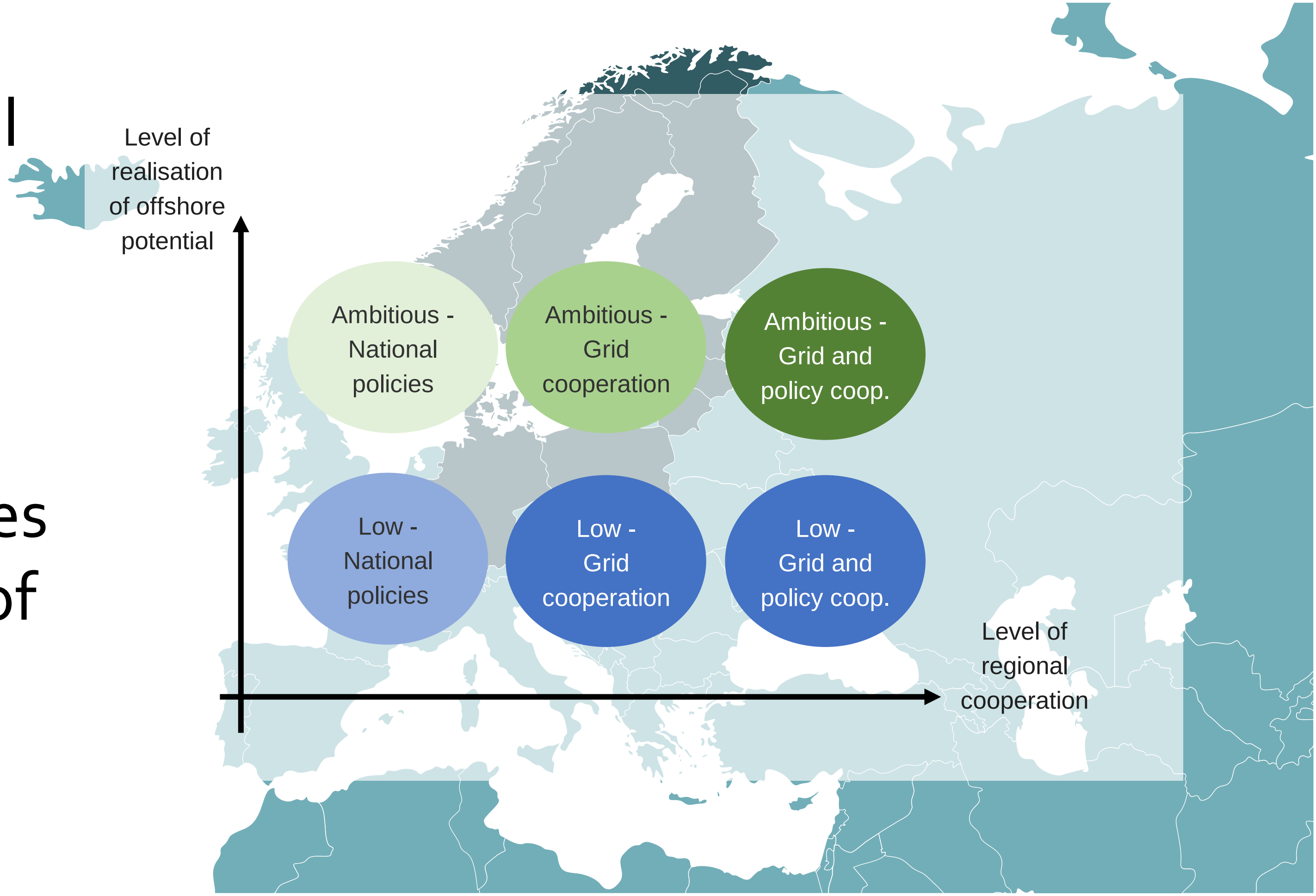
Ea Energy Analyses

COWI

Study objective and setup

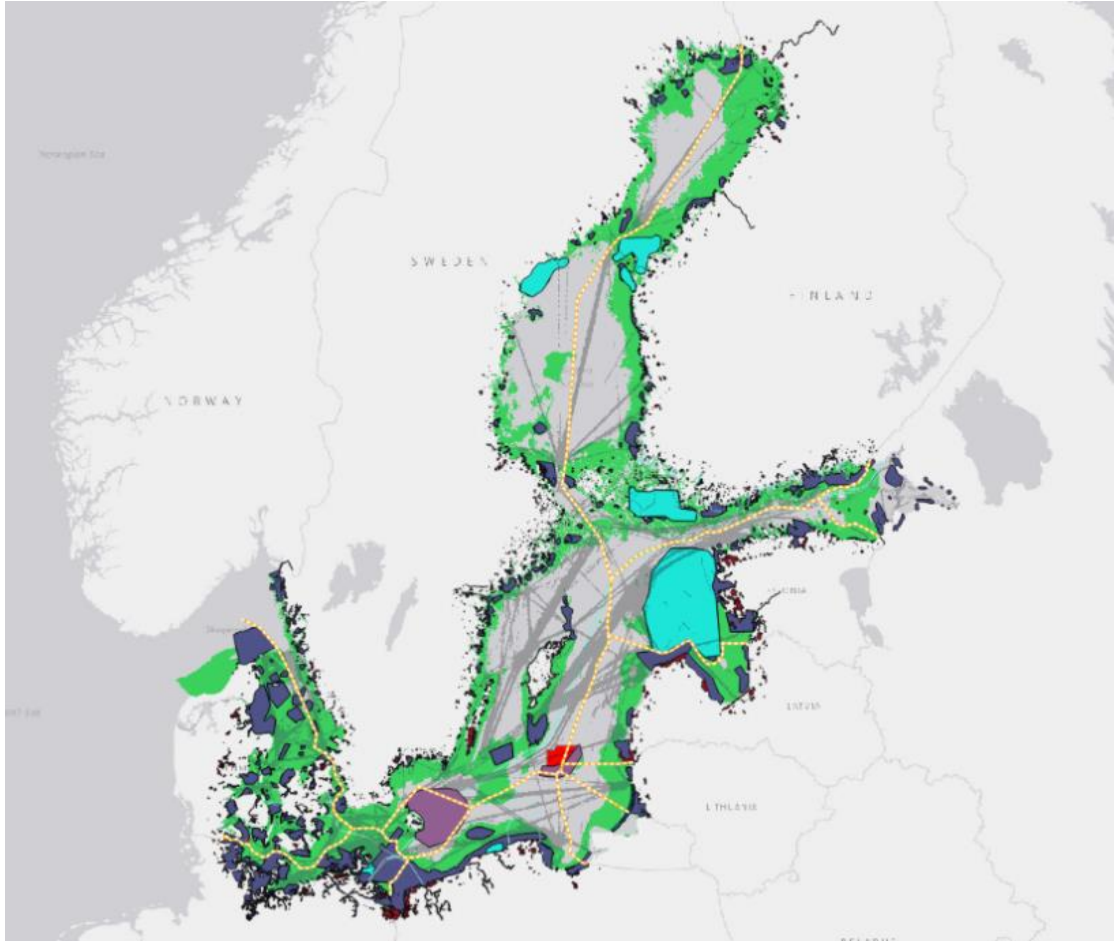
- Assess offshore wind potential and identify locations in the Baltic Sea Region

- Opportunities for and obstacles to coordinated development of offshore wind in the BSR

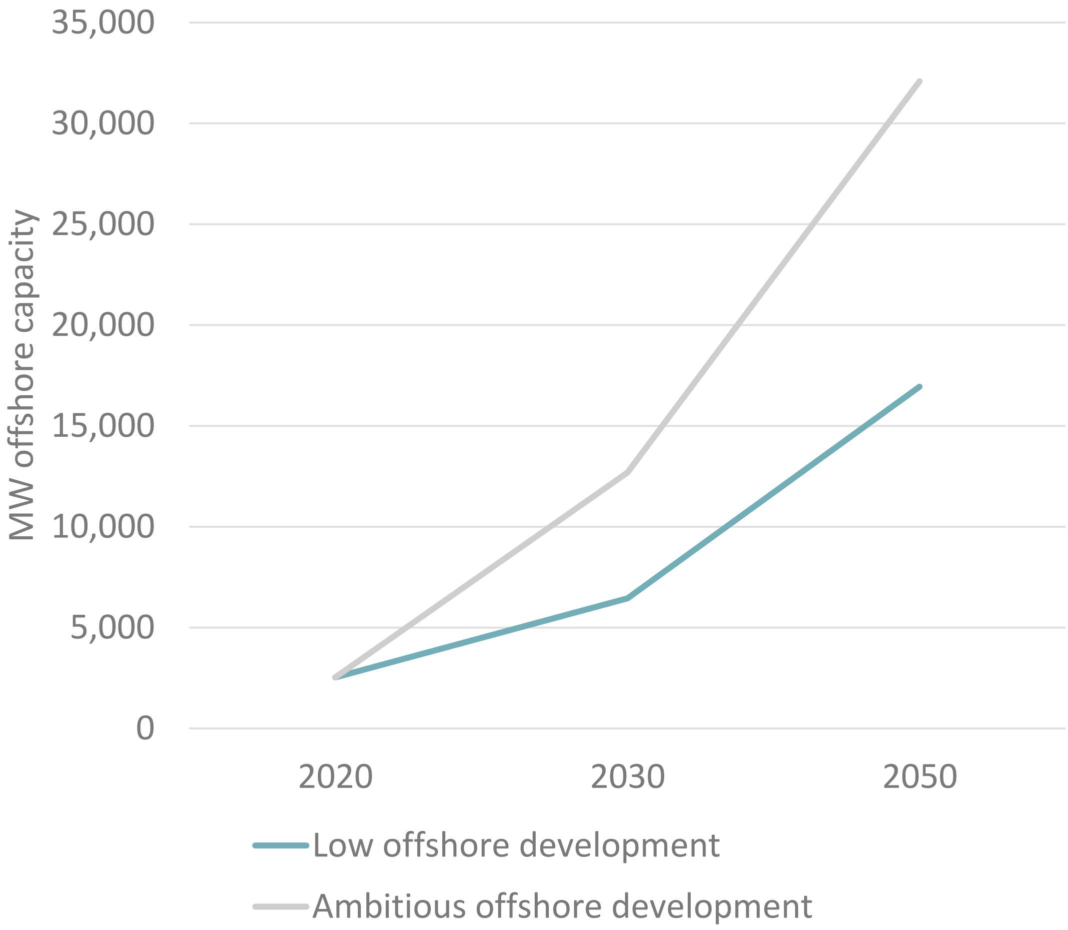


Physical potential

COWI GIS-based analysis

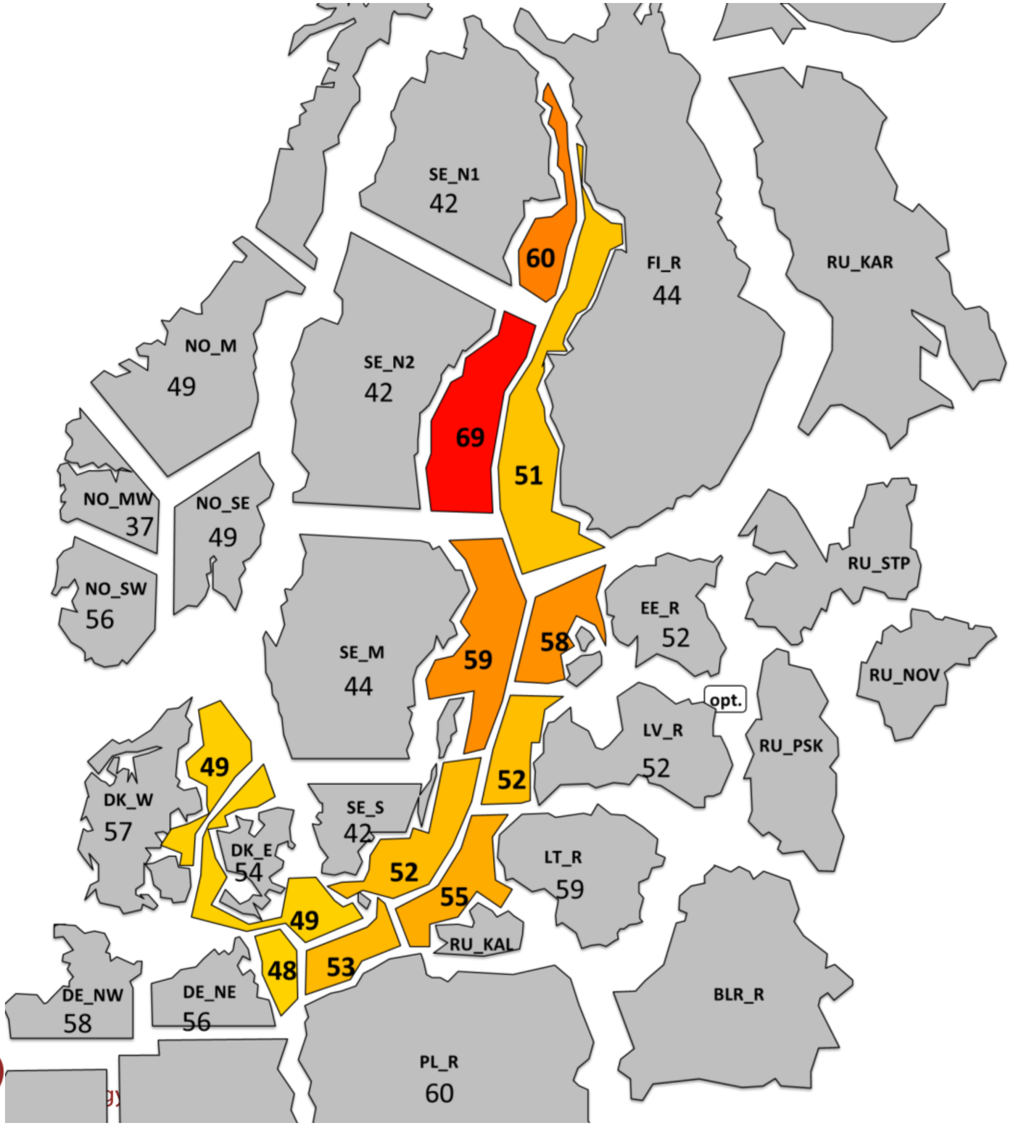


Scenarios for Baltic offshore

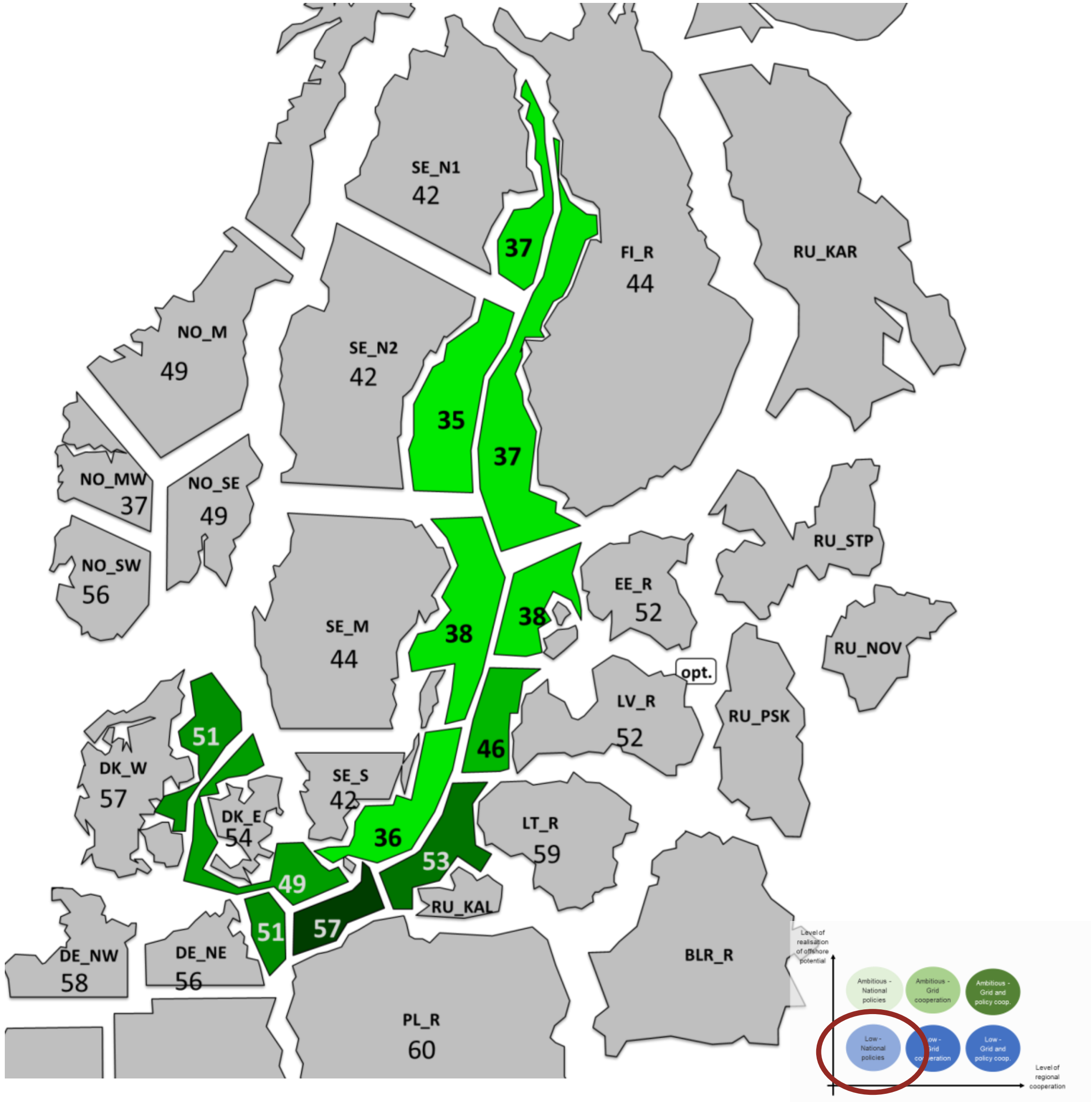


Model assessment

Baltic offshore LCOE 2030



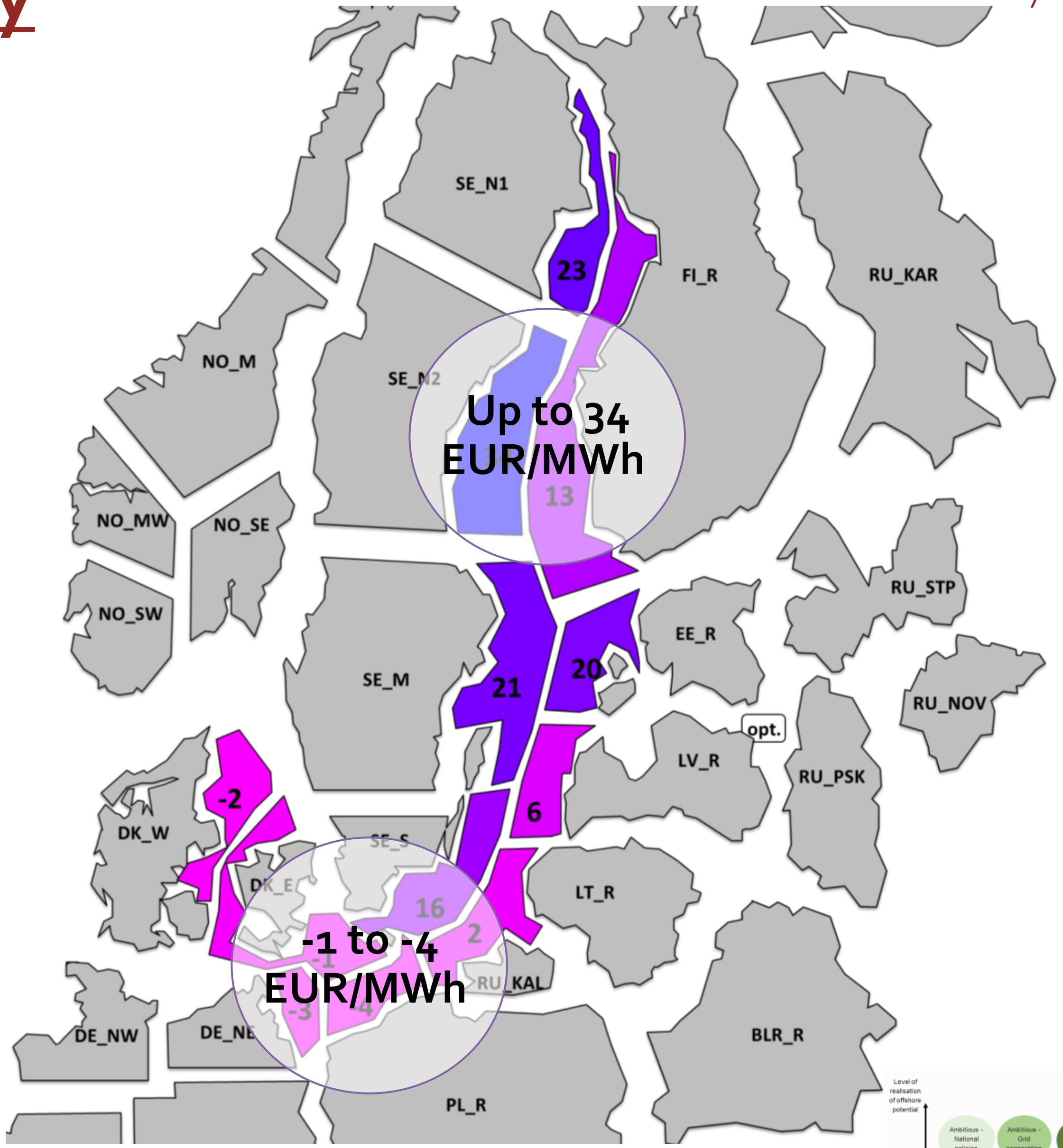
Baltic offshore market value 2030

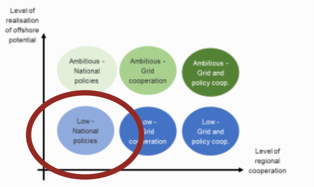


Estimated costs and returns vary

Baltic offshore cost efficiency

- Baltic offshore can reach grid parity
- Differences in cost and market value across the region
- Good alternative RE potential in Northern region -> lower market value
- Higher demand and less good RE potential in Southern region -> higher market value





System costs

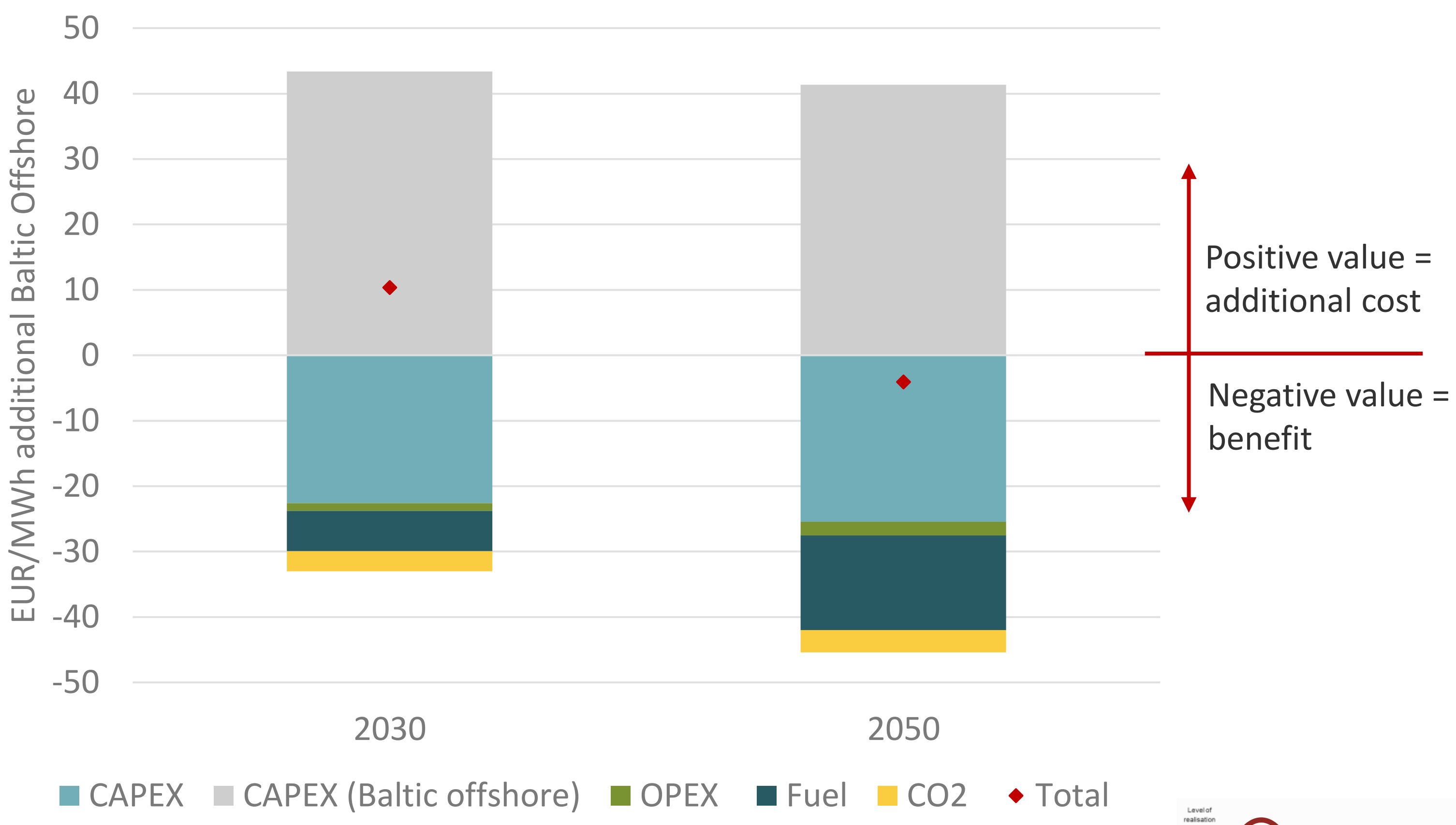
What are the total cost of supplying the system demand?

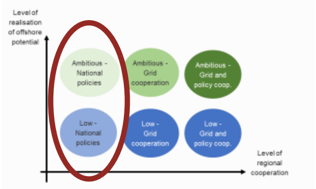
$$C_{tot} = C_{CAPEX} + C_{OPEX} + C_{FUEL} + C_{GHG}$$

Effects of higher wind deployment

- Higher CAPEX for Baltic offshore
- Reduced cost for other generation (CAPEX, OPEX, FUEL, CO_2)
- Until 2030, the ambitious scenario shows higher total system cost
- After 2030, ambitious development could be beneficial

Differences between ambitious and low scenario





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System costs

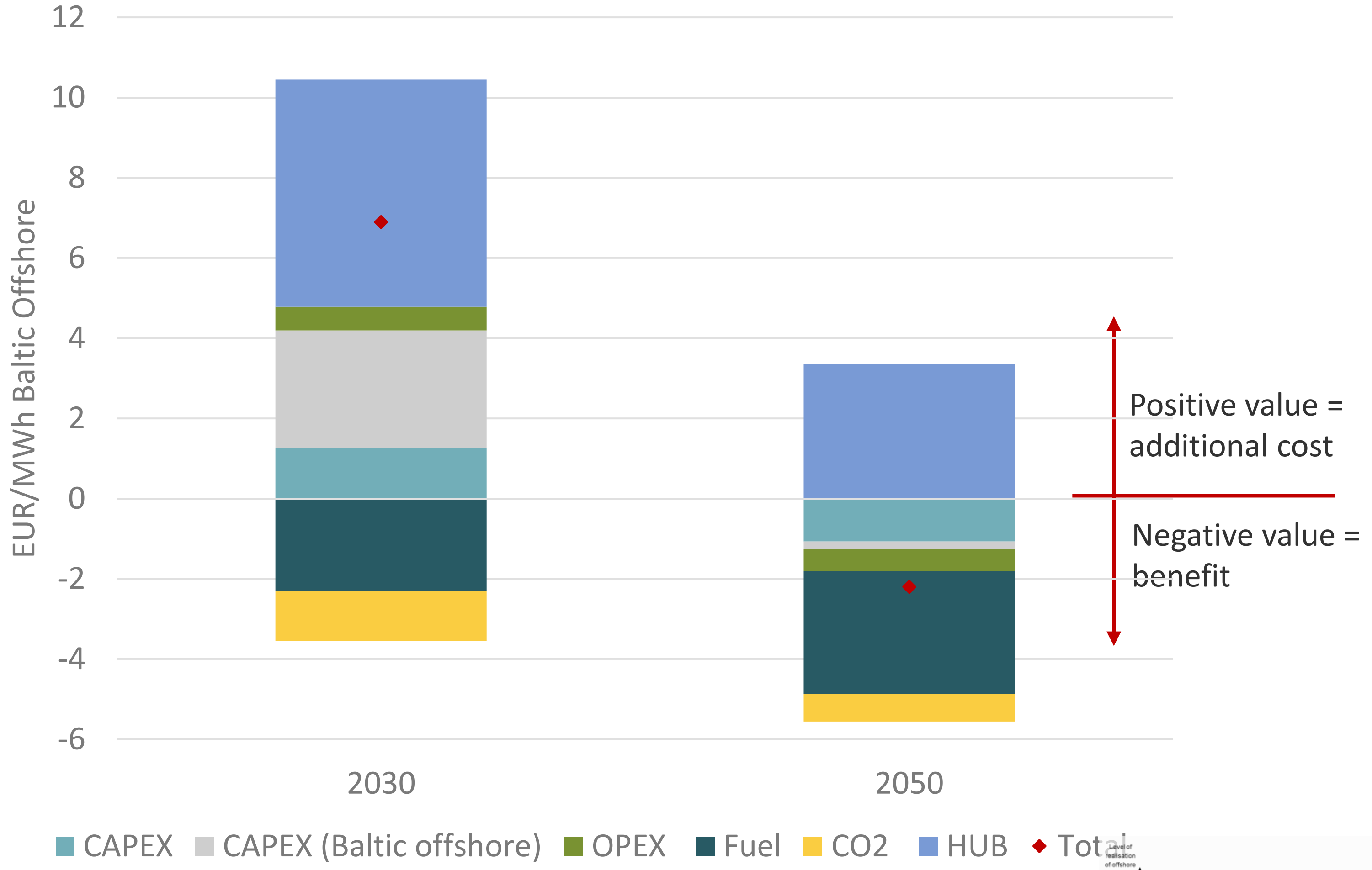
What are the total cost of supplying the system demand?

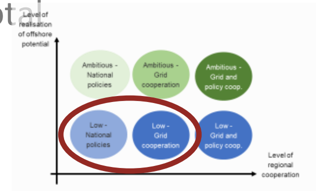
$$C_{tot} = C_{CAPEX} + C_{OPEX} + C_{FUEL} + C_{GHG}$$

Effects of grid cooperation

- Better integration of on- and offshore wind -> Reduced fuel and emissions costs
- Higher cost for Baltic offshore deployed at HUBS (some wind farms in deeper waters)
- By 2050, some 'deep' water sites are used anyway, and using advanced connections can therefore be a benefit.

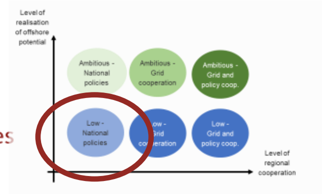
Differences between grid cooperation and national policies



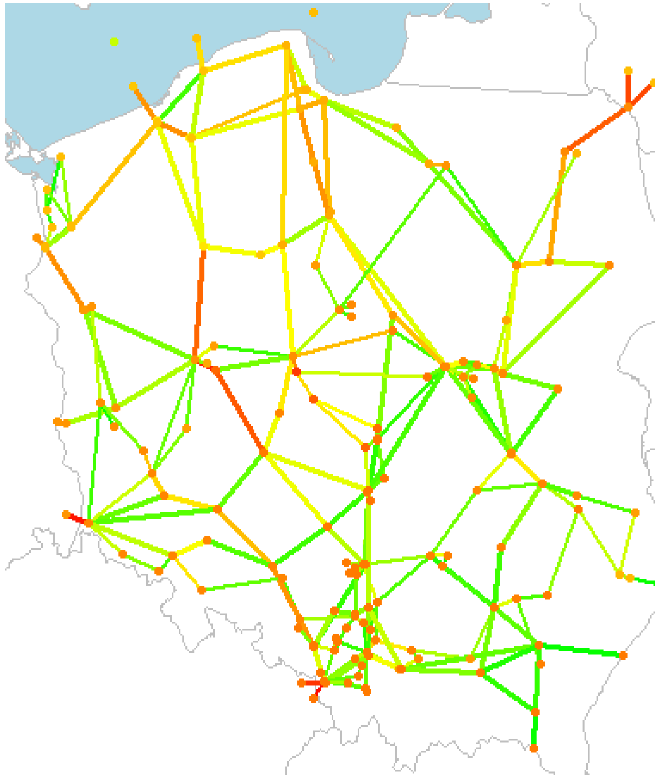


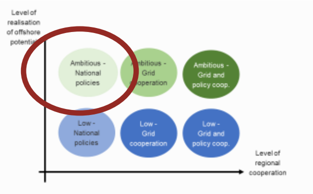
Detailed grid model assessment (THEMA)

Base case

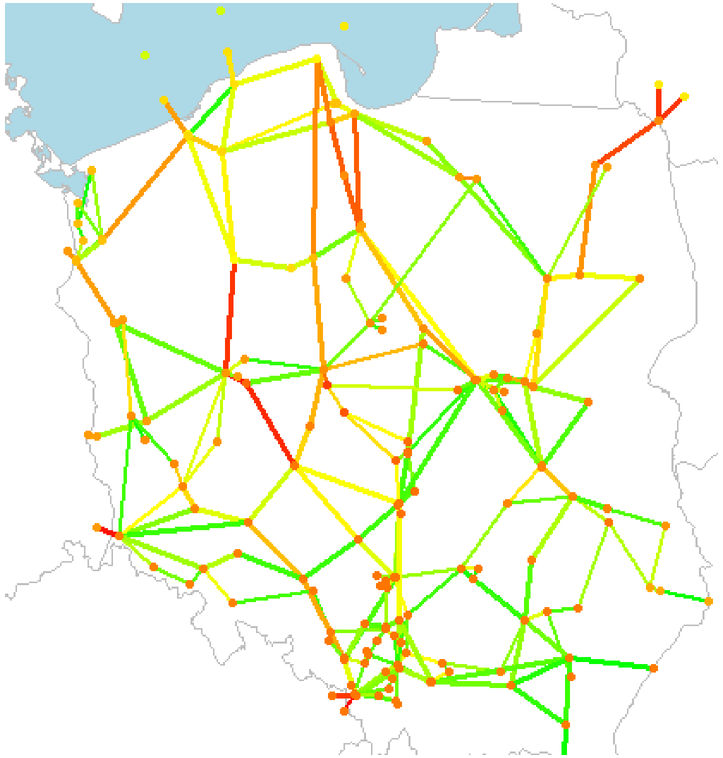


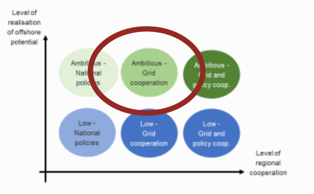
Ambitious, simple connection





Ambitious, advanced connection





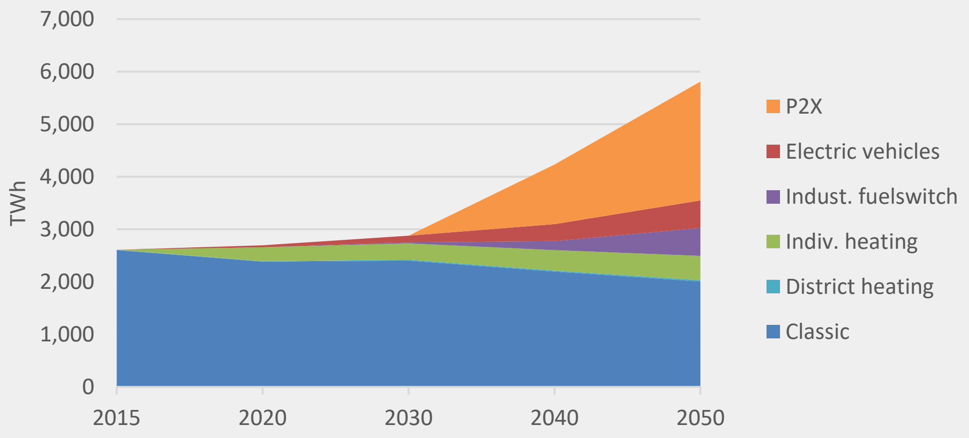
Offshore wind and infrastructure in Europe

Ørsted

Ea Energy Analyses

European Commission's 2050 Long-Term Strategy - 1.5TECH scenario

Power consumption development

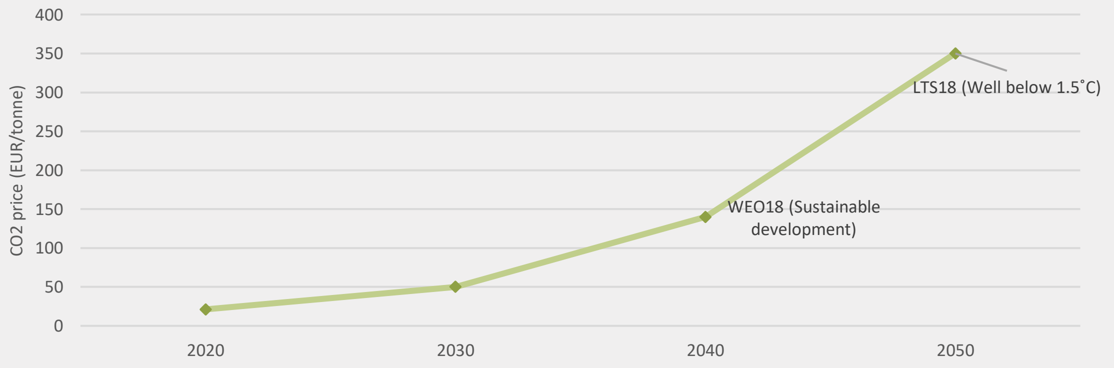


Power demand from 1.5 TECH scenario

- Decreasing classic demand
- Increasing EVs/Industrial fuel switch
- Huge increase in P2X
  - Hydrogen
  - E-solids
  - E-gas

CO_2 price (well below 1.5˚C) from EU commissions: 350 EUR/tonne used in 2050

Power demand Nordics and North-West Europe



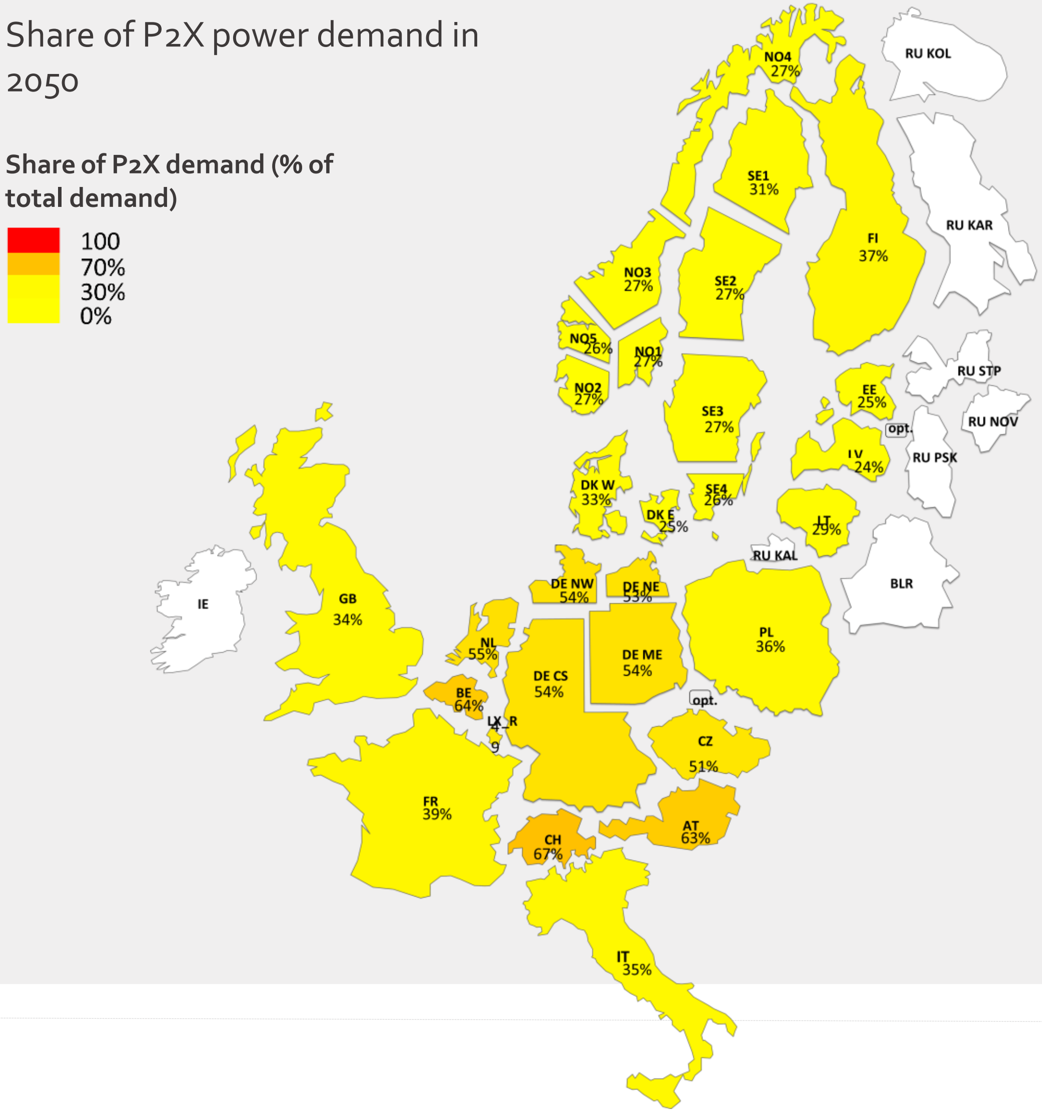
P2X demand allocation

P2X constitutes about **42% of total power demand in the modelled area in 2050.**

P2X demand is allocated across the European regions in the modelled area according to their **current energy demand for transport and industrial uses**.

The model can **move the supply of P2X** to another region (with lower electricity prices) or in time **at a cost of 30 EUR/MWh e-fuel**.

Share of P2X power demand in 2050



Offshore wind resource and potential

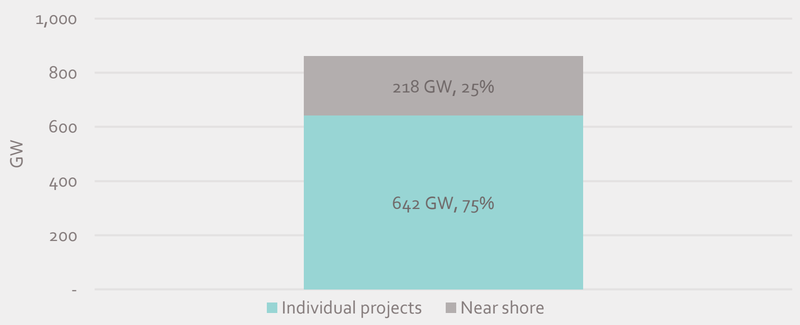
Offshore wind potential is modelled based on the 4C offshore wind database[I], offshore potentials from the BEMIP[II] project and the ENSPRESSO offshore wind energy potentials (low restriction scenario)[III].

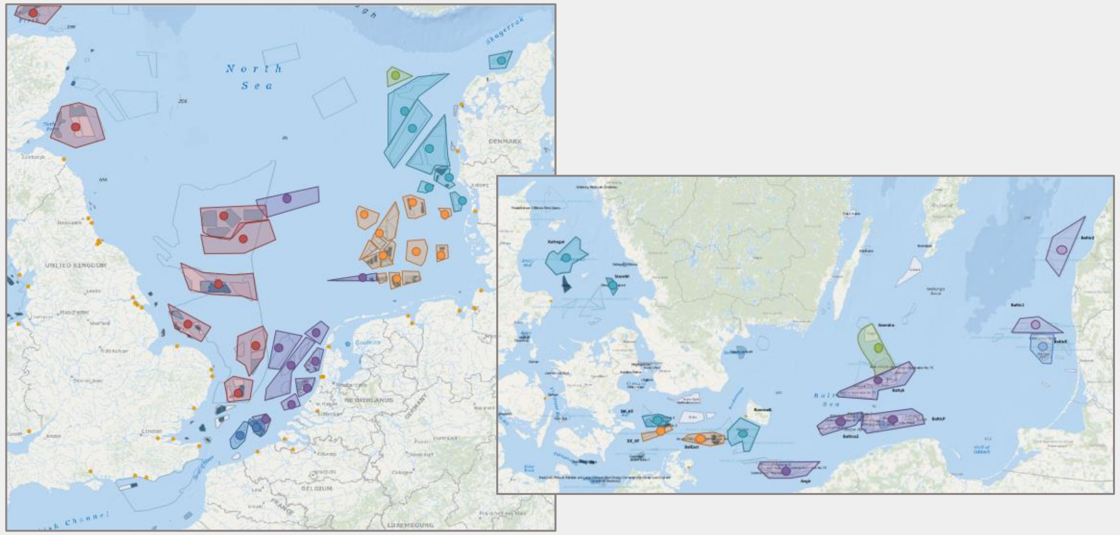
All offshore wind projects in the modelled area are included at sea depth <60m, totalling at 860 GW. Two representations are used:

- **Aggregated near-shore areas:** Smaller near-shore projects (<22 km) are modelled in an aggregated manner and are always directly connected to the country which owns the waters and therefore do not have any part in the hubs. The potential is set to 10% of the estimates in the ENSPRESSO database for areas less than 22 km from shore = 218 GW in total.
- **Individual projects:** Projects further out in sea are modelled as distinct offshore potentials with respective offshore connection point. The detailed site conditions are based on the 4C offshore wind database and the BEMIP project, scaled by country to match the total ENSPRESSO potentials for areas further out than 22 km = 642 GW in total.

Wind speed time series for each of the areas are based on MERRA-2 re-analysis data for 2014.

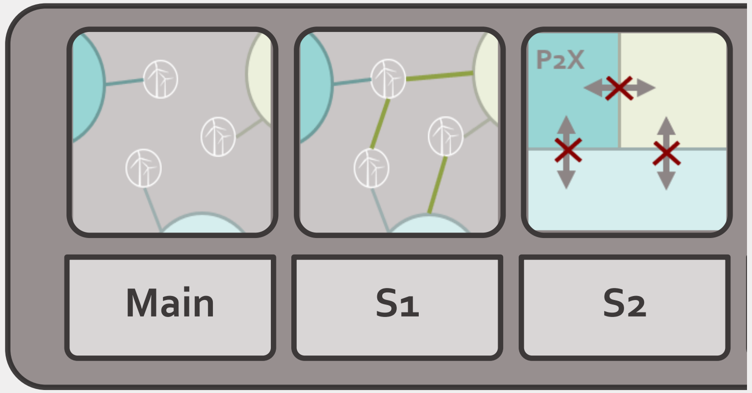
Offshore wind potential in modelled area





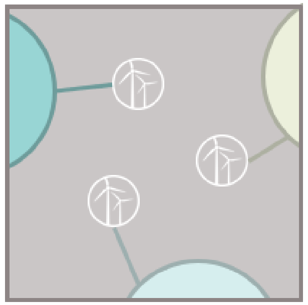
[I] https://www.4coffshore.com/offshorewind/
[II] https://ec.europa.eu/energy/en/topics/infrastructure/high-level-groups/baltic-energy-market-interconnection-plan
[III] https://data.jrc.ec.europa.eu/collection/id-00138

Scenario set-up



S1 Multi-linked hubs: Sensitivity on the impact of a meshed offshore grid: The optimization of the offshore grid can utilize multi-linked hubs, meaning that offshore wind farms can be connected to more than 1 country or to each other

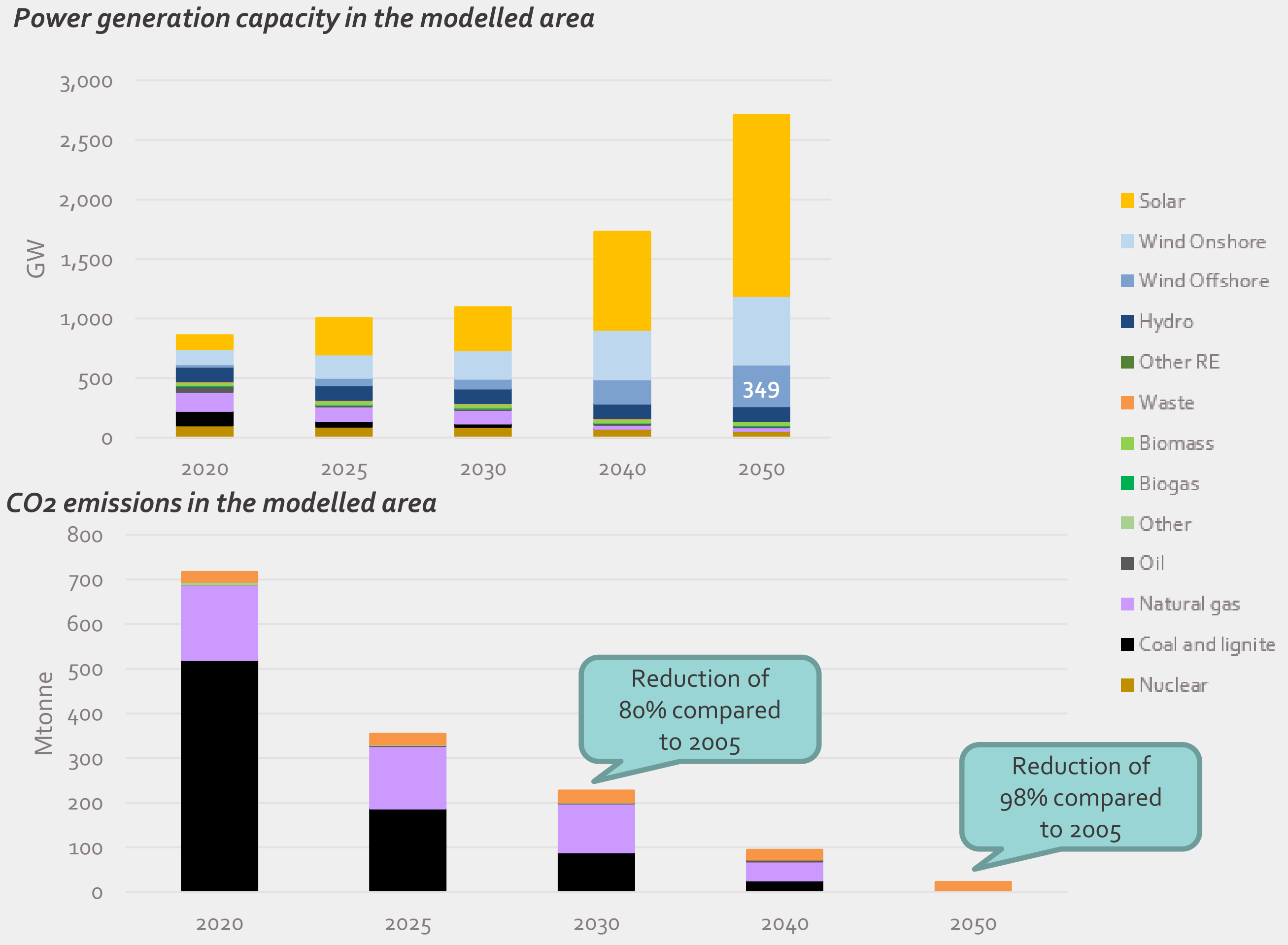
S2 No P2X redistribution: Sensitivity on the importance of co-optimizing power system development and P2X production: The production of e-fuels is assumed to be located in the same region as the demand for these fuels.



MAIN SCENARIO

Model results

Model simulations show an offshore deployment comparable to 1.5TECH scenario by the EC



Offshore wind capacity (2050)

- 1.5TECH: 451 GW
  - For the entire EU
- Scaled: 385 GW
  - Scaled with demand to model area
- Main scenario: 349 GW

CO_2 emissions (2050)

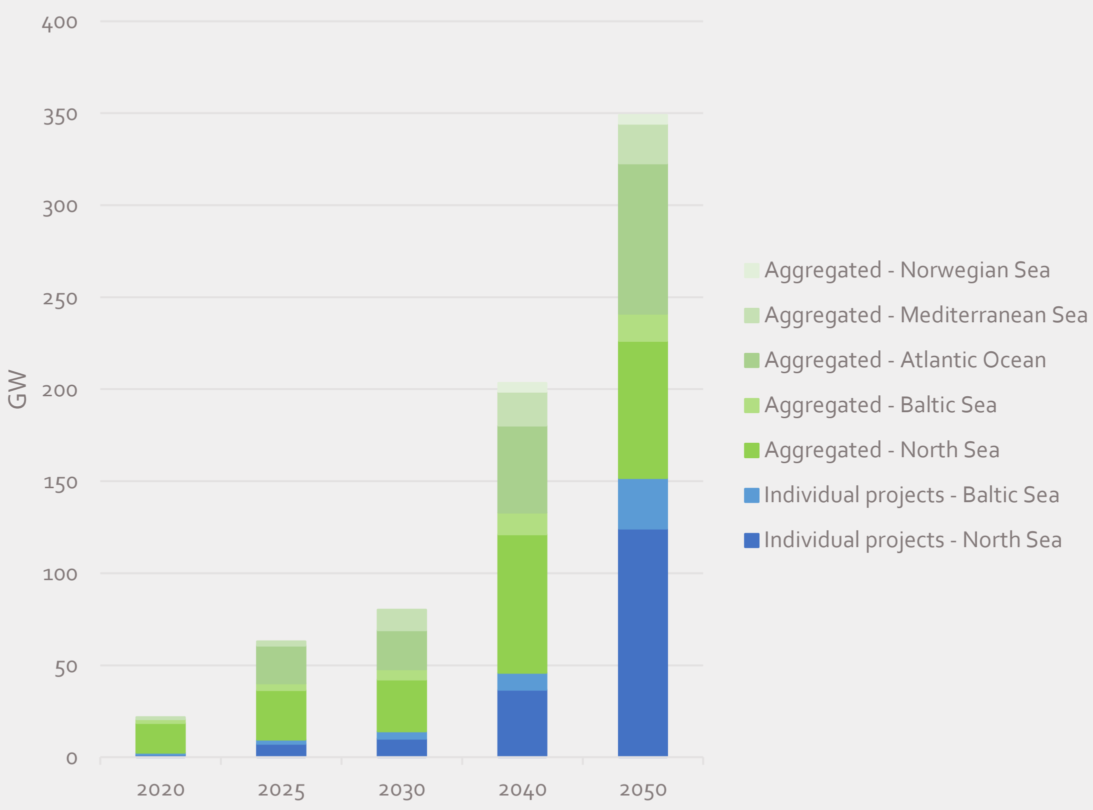
98% reduction compared to 2005

- Only waste-incineration-related emissions left**

* Onshore/offshore split based on assumptions for respective full load hours
**Reduction of emission of waste-inceration requires waste-management strategies, that have not been analysed in this project.

Offshore wind capacity build-out

Offshore wind power capacity in 2050 by sea and representation type

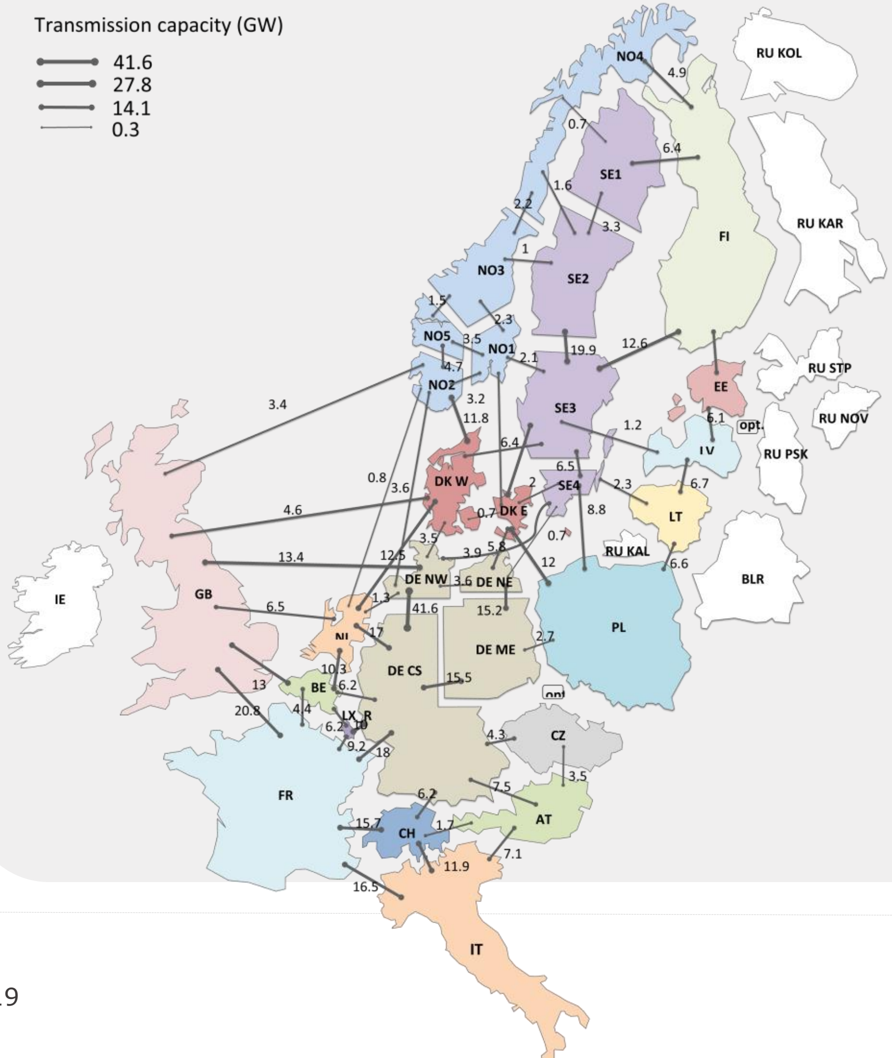


Most of the offshore wind capacity (57%) is found in the North Sea with about 200 GW by 2050 .

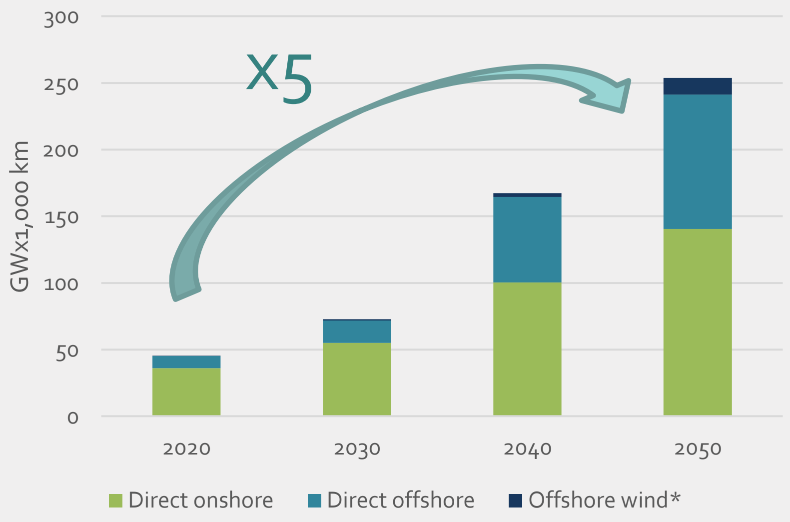
The Baltic Sea capacity is 42 GW.

Transmission expansion results

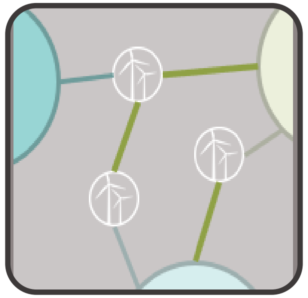
Transmission capacity in the modelled area (2050)



Between 2020 and 2050, total transmission capacity expressed in GWx1,000km grows five-fold. An increasingly large share of the total transmission consist of direct offshore connections.



* Offshore wind includes all connections to offshore windfarms which are not "near-shore"

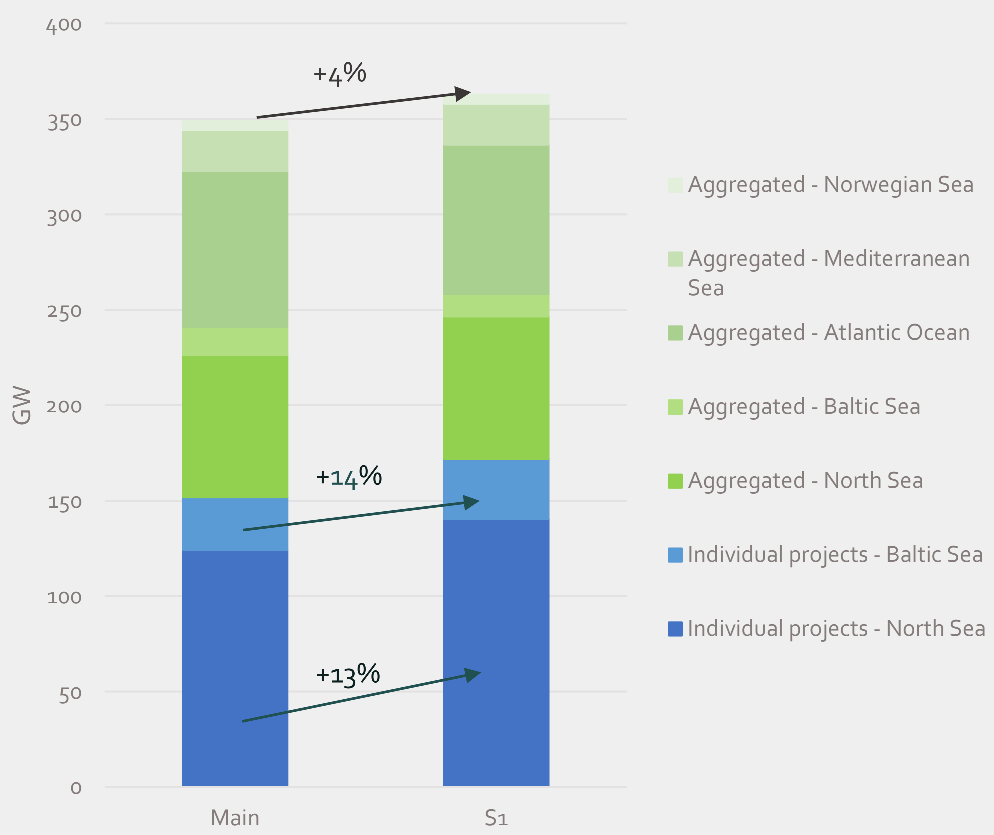


SENSITIVITY ANALYSIS

Multi-linked hubs

Offshore wind capacity build-out

Offshore wind power capacity in 2050 by sea and representation type



Total offshore build-out increases with 4% compared to the *Main* scenario, due to meshed offshore transmission.

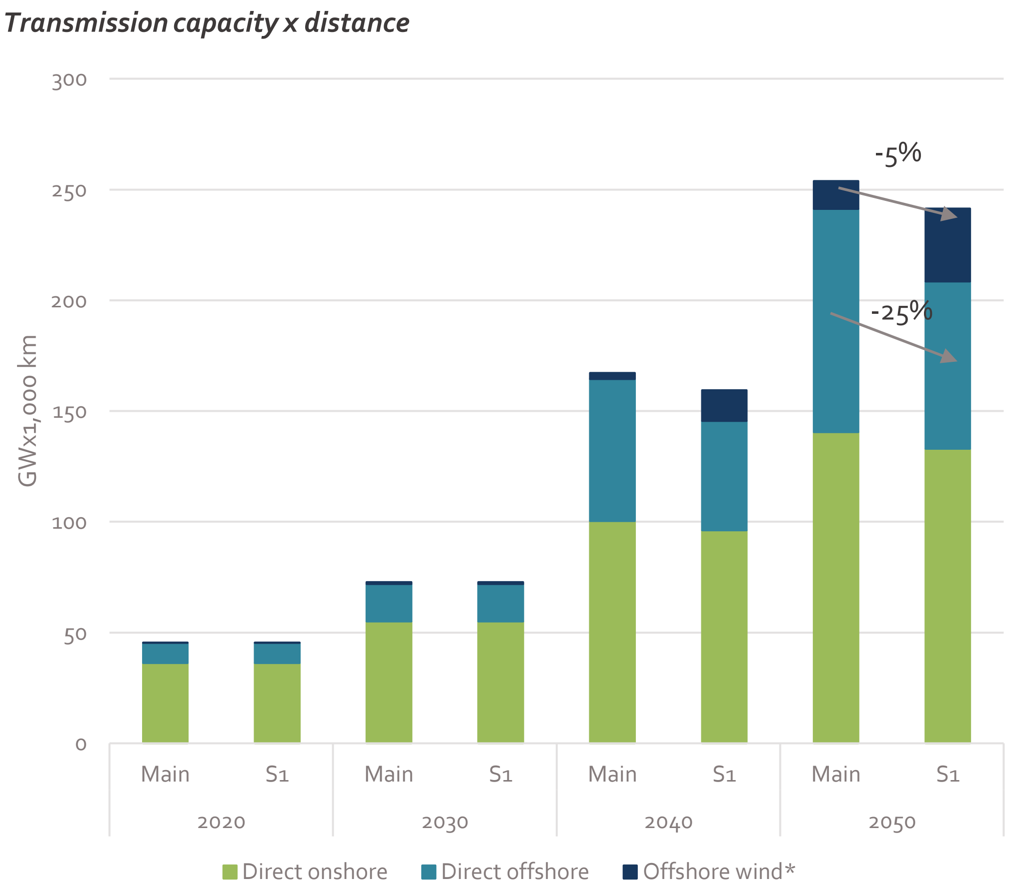
The increase of offshore capacity by sea is:

- North Sea: +8%
- Baltic Sea: +3%

The offshore wind capacity increase at hubs (modelled as individual projects) is 13%, by sea:

- North Sea: +13%
- Baltic Sea: +14%

Meshed offshore transmission can reduce the need for direct transmission connections between zones



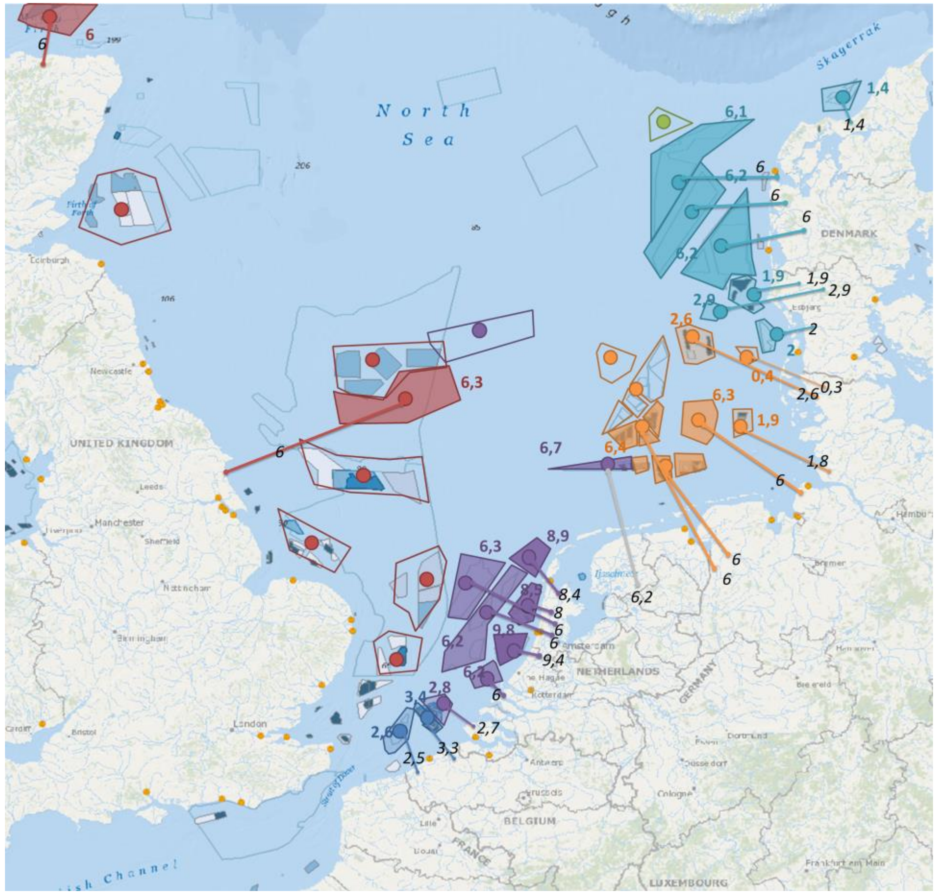
* Offshore wind includes all connections to offshore windfarms which are not "near-shore". In the S1 Multi-linked hubs sensitivity, this category includes all shore-to-wind site and wind site-to-wind site connections

Direct offshore transmission (transmission capacity connecting two countries across open sea) can be reduced by 25% when allowing for meshed offshore transmission. This is about 25 GWx1,000km.

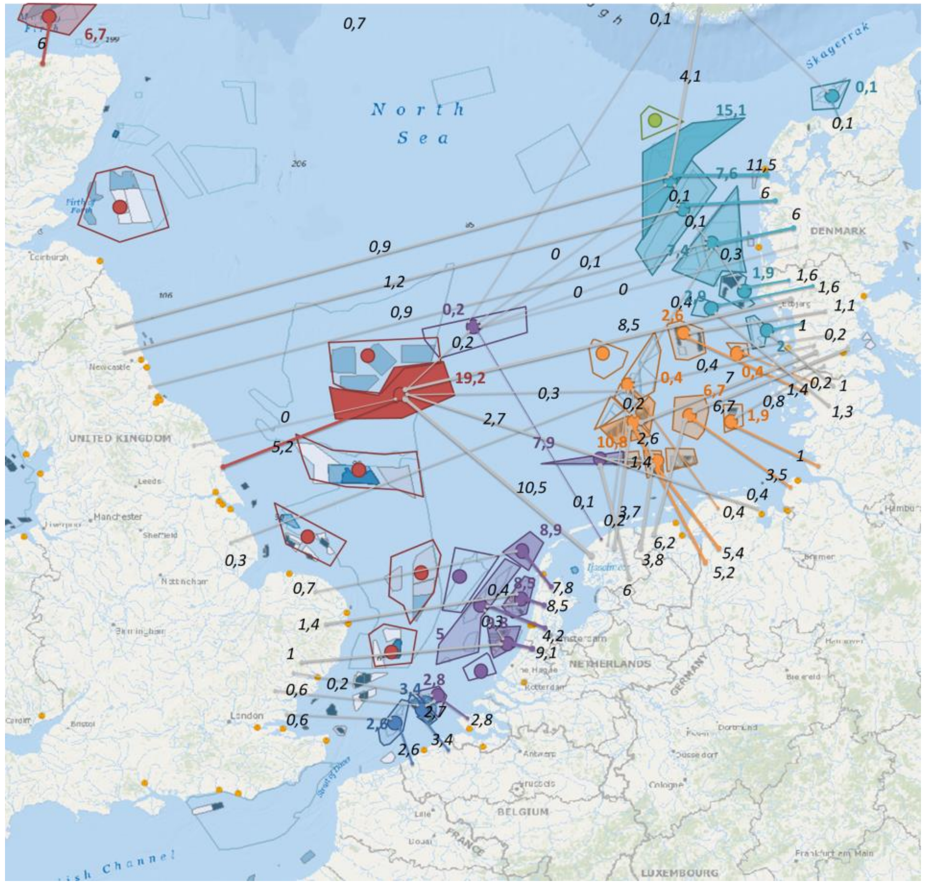
Despite an increase in hub connected transmission capacity (country to wind site or wind site to wind site) **the total infrastructure size reduces by 5%.**

North Sea 2050 – illustrative maps

Main



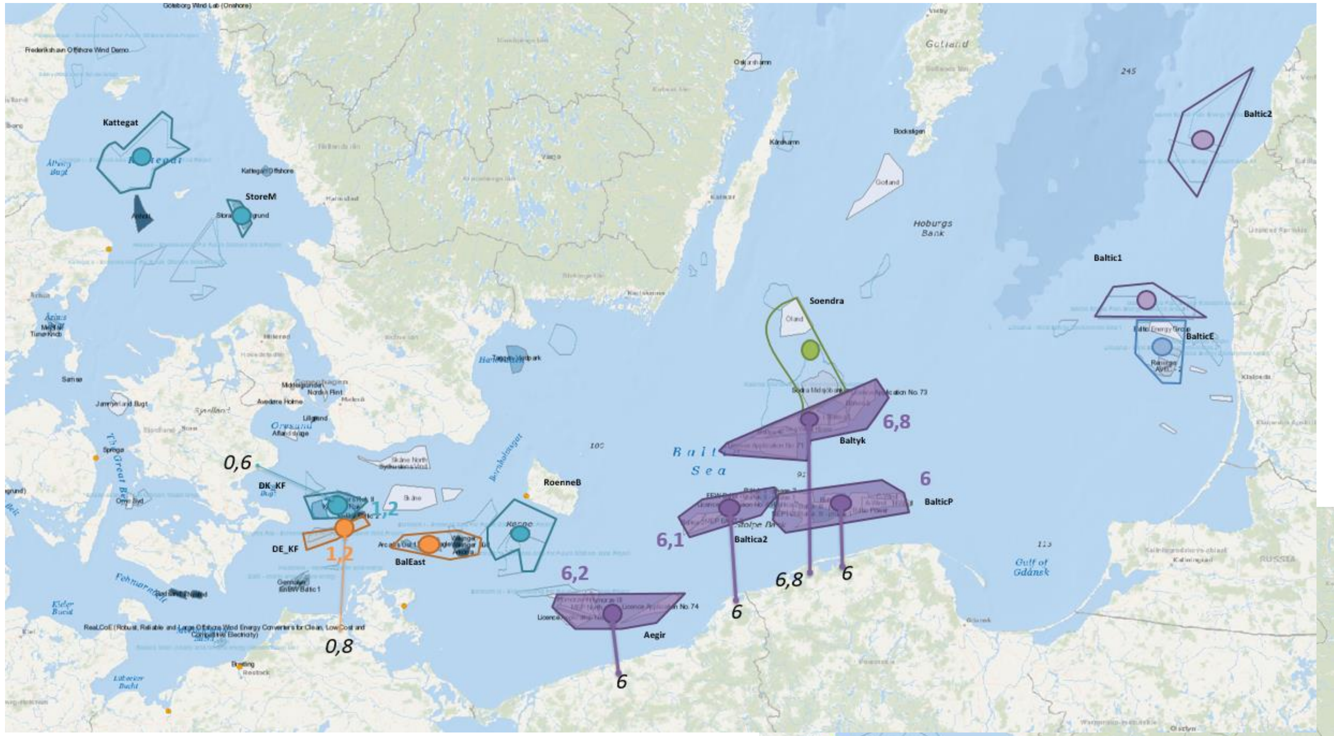
S1 Multi-linked hubs



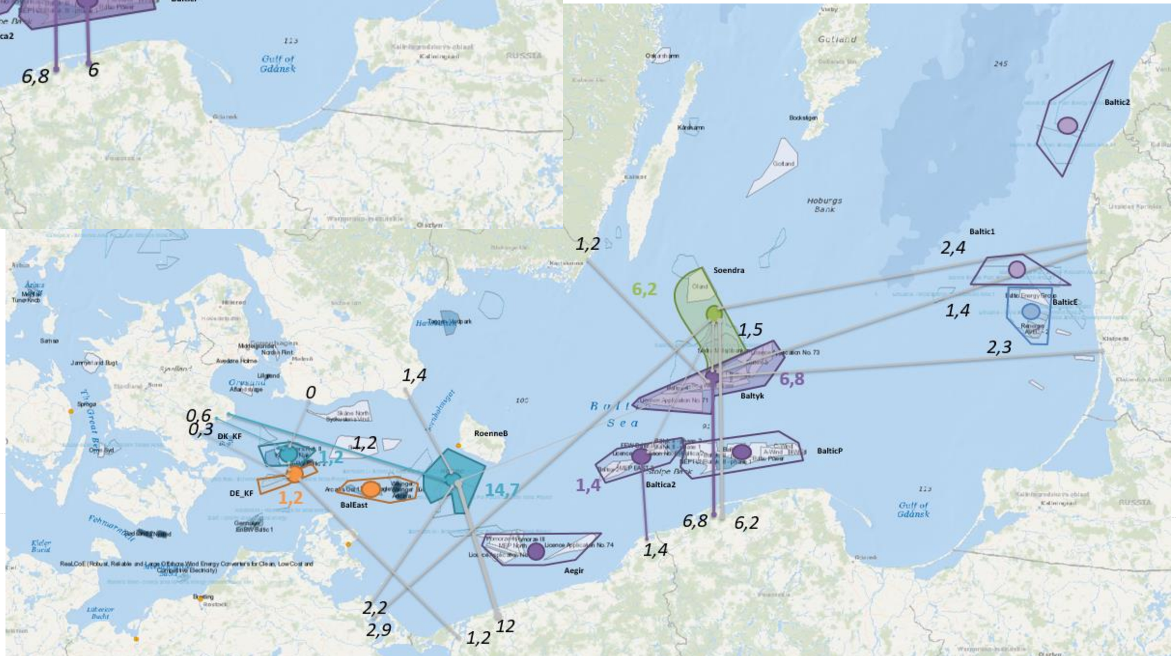
The maps are illustrative for the benefit of connecting hubs to more than one country and do not show actually expected transmission build-out. In reality, transmission cables and smaller hubs might be merged to form larger meshed offshore corridors

Baltic Sea 2050 – illustrative maps

Main



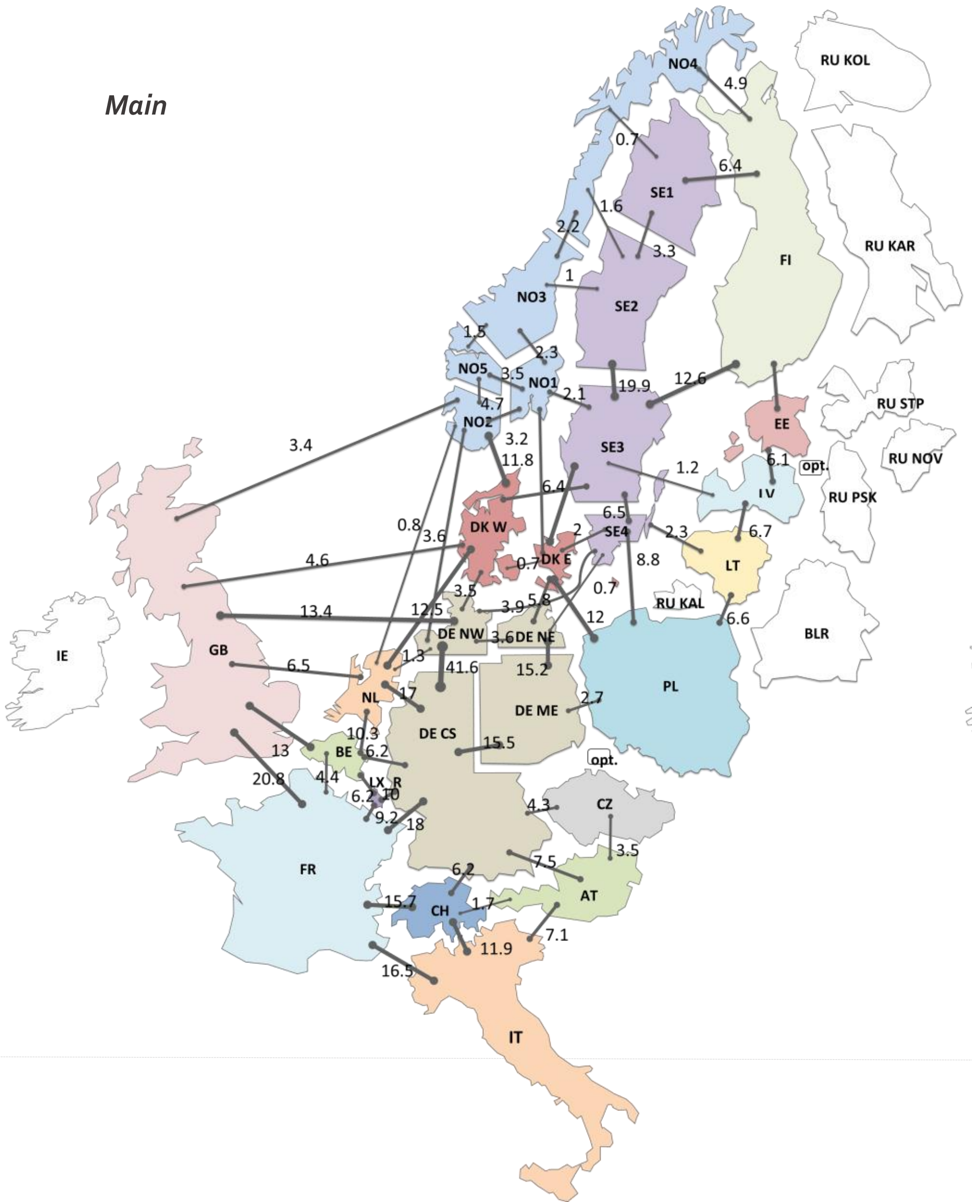
S1 Multi-linked hubs



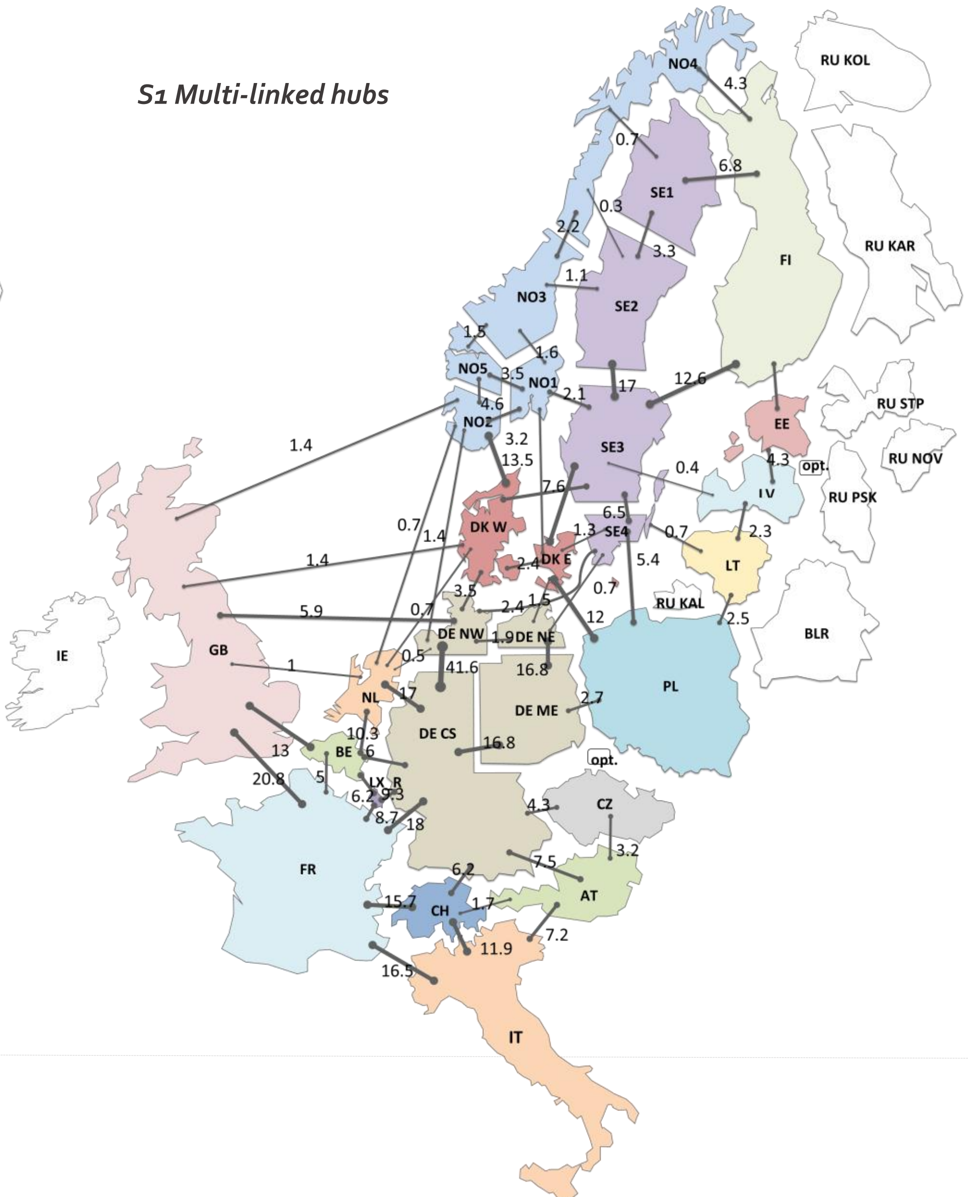
The maps are illustrative for the benefit of connecting hubs to more than one country and do not show actually expected transmission build-out. In reality, transmission cables and smaller hubs might be merged to form larger meshed offshore corridors.

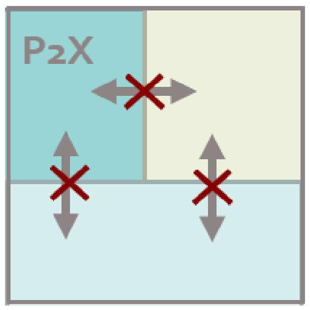
Direct transmission capacity between countries in 2050

Main



S1 Multi-linked hubs



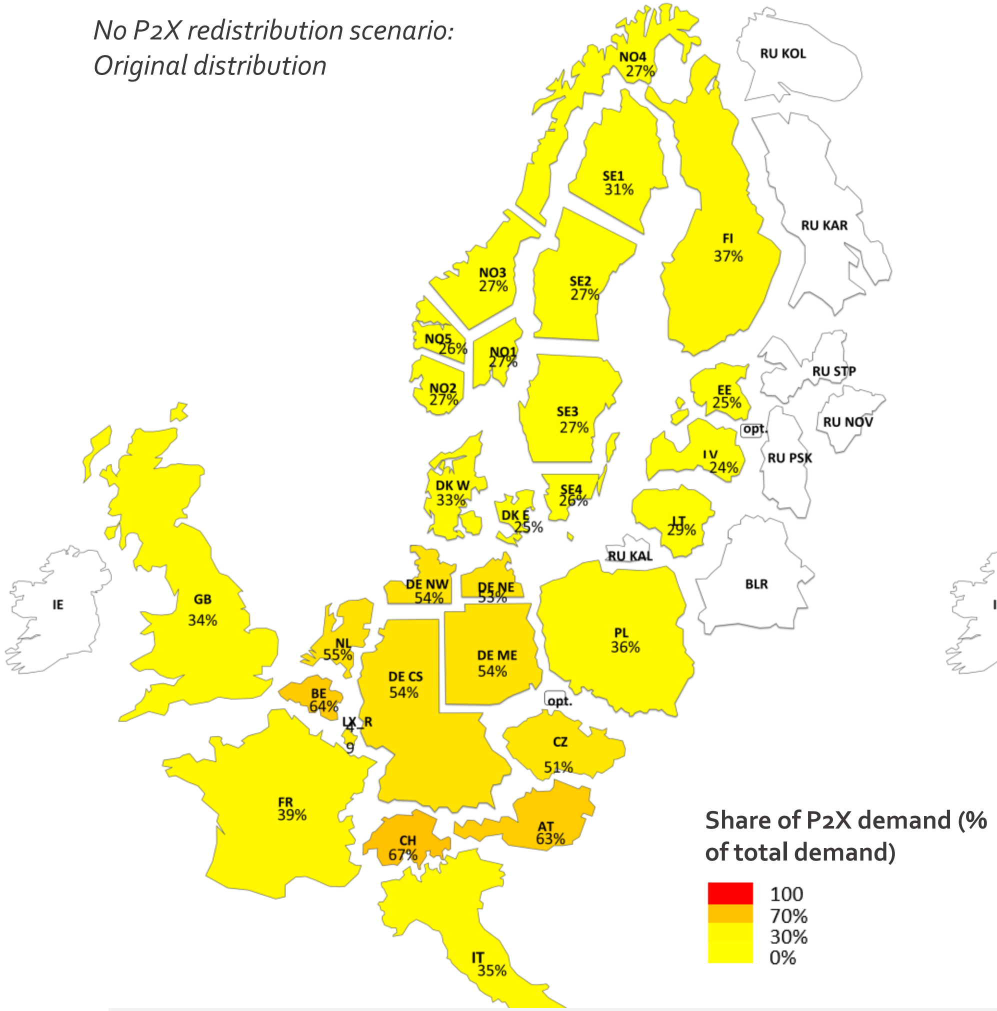


SENSITIVITY ANALYSIS

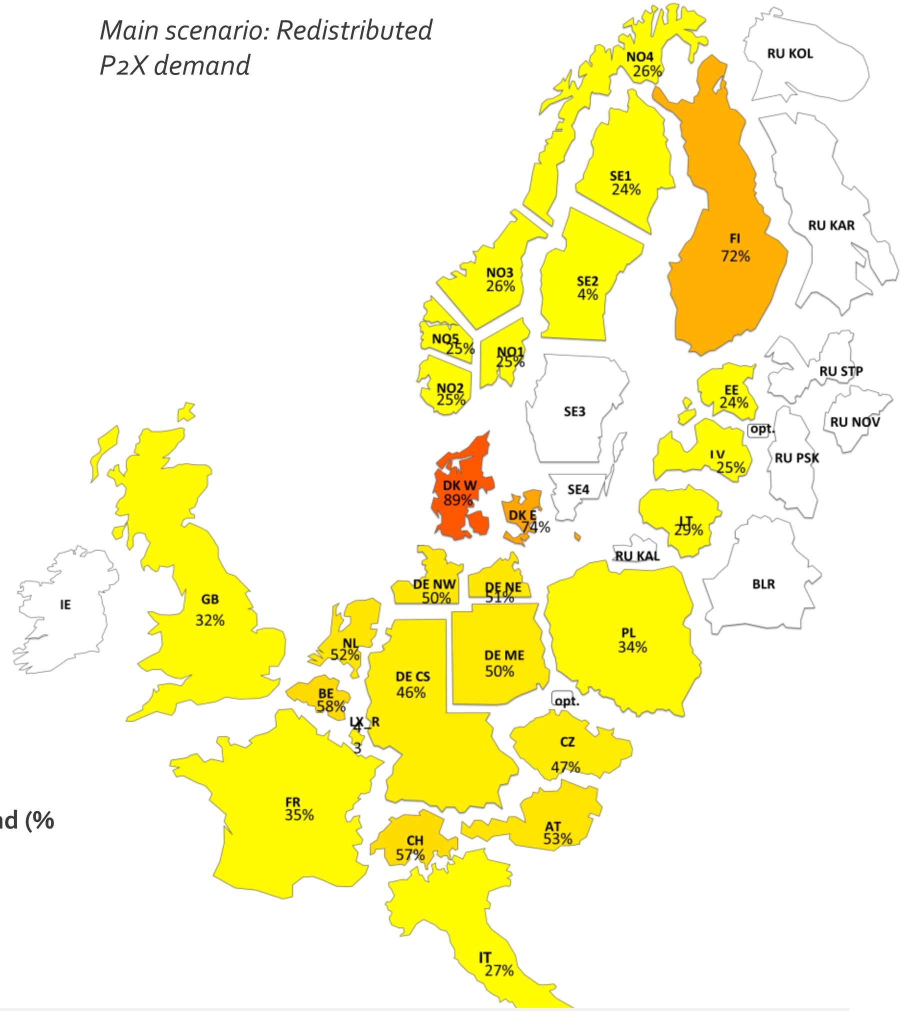
No P2X redistribution

P2X redistribution

No P2X redistribution scenario: Original distribution



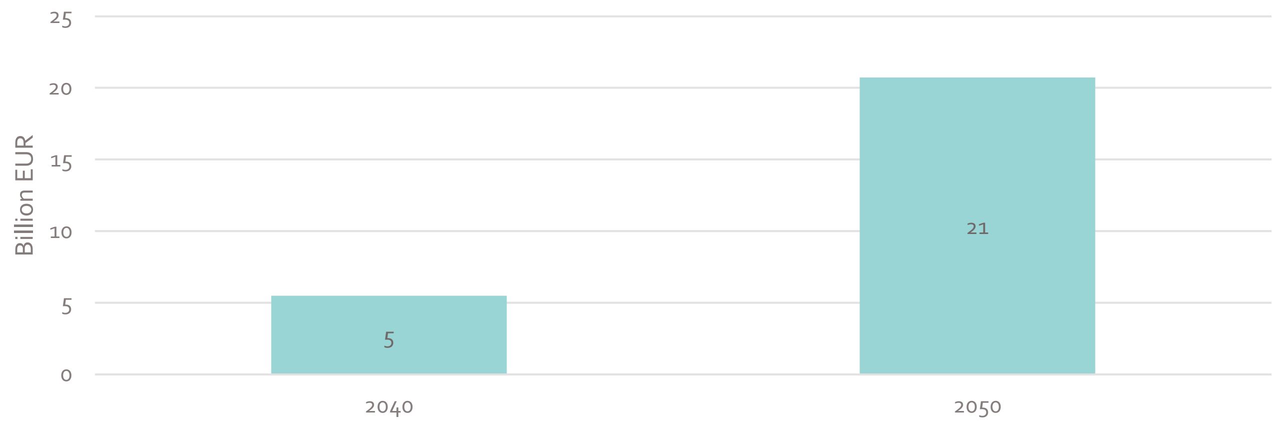
Main scenario: Redistributed P2X demand



Optimized allocation of P2X production, shows that Denmark and Finland could become major e-fuel production countries. Power prices in these countries are low due to high shares of wind generation (offshore in Denmark, onshore in Finland).

There is a potential synergy between offshore wind and P2X generation

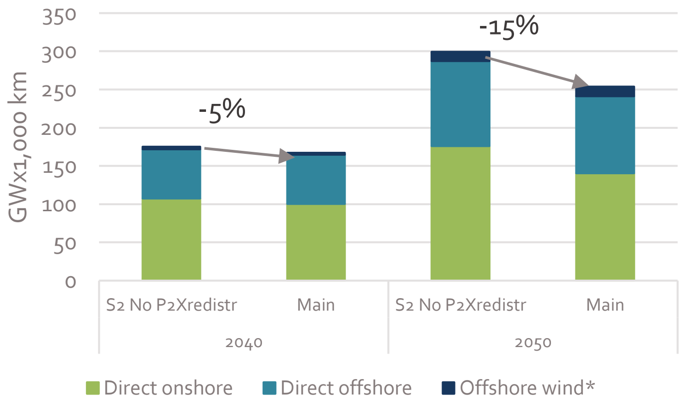
Combined system cost savings* by enabling P2X demand redistribution

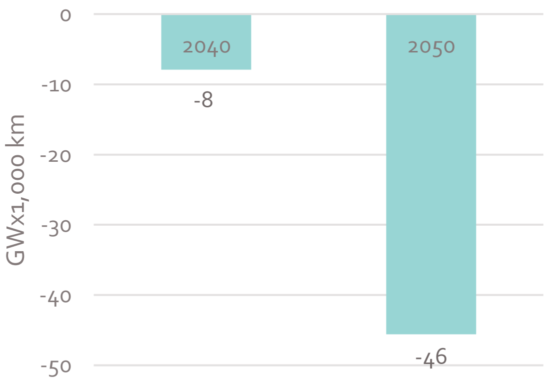


Comparing *Main* to *S2 No P2X redistribution*, shows that by 2050, 21 billion EUR/year can be saved in the modelled area by enabling redistribution of P2X production. This saving accounts for the cost of redistributing P2X.

By 2050, the total transmission capacity is decreased by 46 GWx1,000 km, corresponding to 15% by allowing P2X redistribution in the *Main* scenario compared to the sensitivity without the redistribution option

Combined descrease in transmission capacity x distrance





* The decrease in total system costs by enabling P2X demand redistribution: Costs include capital costs, O&M and fuel costs as well as P2X redistribution costs, CO2 externality costs

Links

- **Bemip-study (Thema, Ea and COWI 2019)** https://www.ea-energianalyse.dk/da/publikationer/study-on-baltic-offshore-wind-energy-cooperation-under-bemip/

- **Offshore wind and infrastructure in Europe (Ea 2020)** https://www.ea-energianalyse.dk/en/cases/offshore-wind-and-infrastructure/

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Thank you!

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2030 2050
2 Transmission line capacity (GW)
Offshore potential
Hub 4
Hub 3
Hub 2
Hub 1
NO1
SE3
SE4
DK1
DK2
DE
PL
LT
LV
EE
0.75
1.0
0.5
1.5
3.5