Towards a fully integrated North Sea Offshore Grid

- An economic analysis of a Power Link Island / OWP hub

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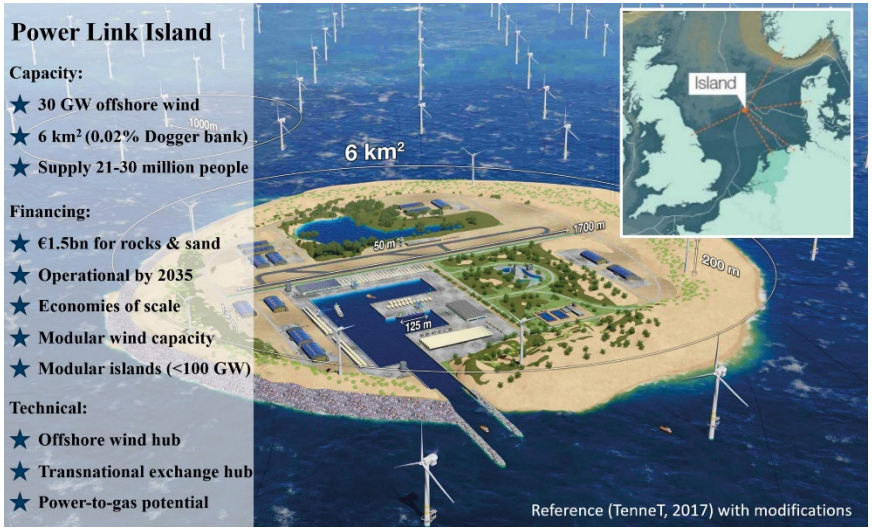
Keywords: North Sea Offshore Grid, Grid Typologies, Market Integration, Optimization, TEP, GEP

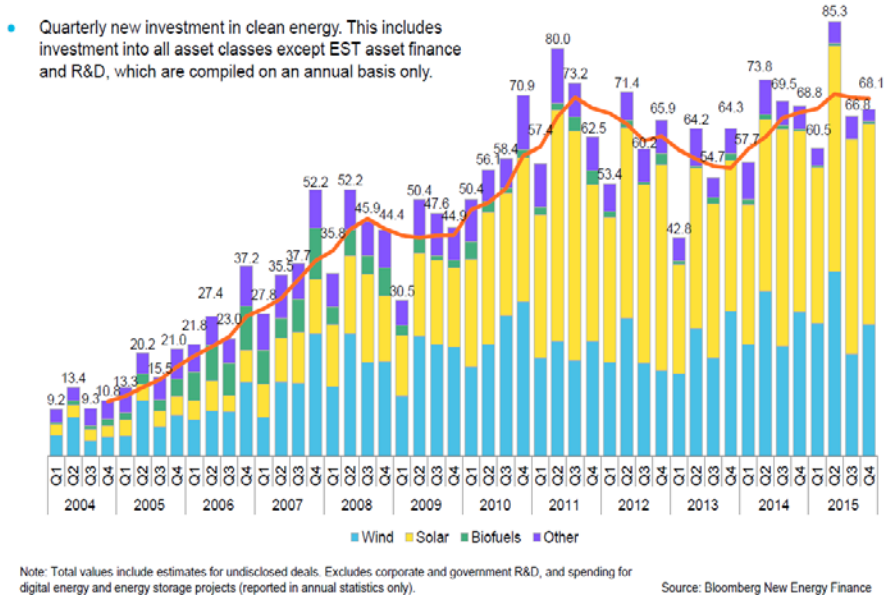
Outline for the talk

1. **Main drivers for multinational TEP**
   - More renewables -> need for flexibility
2. **Motivation: Different grid topologies**
   - Radial // Meshed // Artificial Island (!)
3. **Added value of an artificial island**
   - “Power Link Island” versus radial solutions
4. **Conclusions and work in progress**

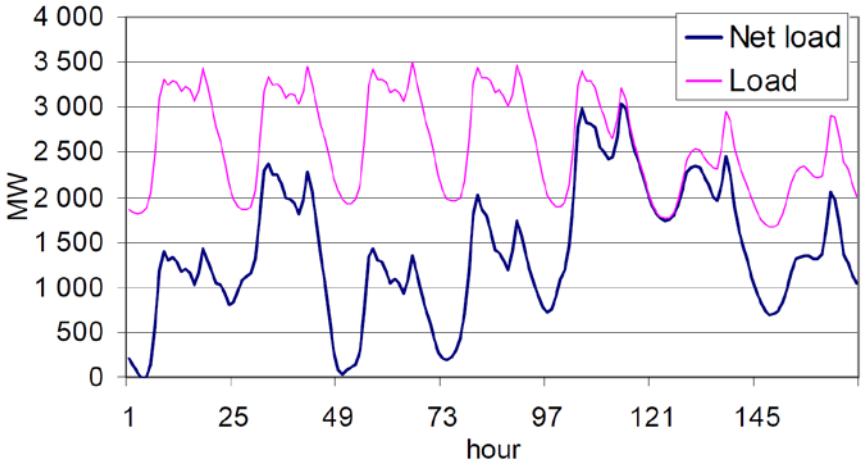


As we know: More renewables comes into the system

Quarterly Investments by Assets (ex. R&D)



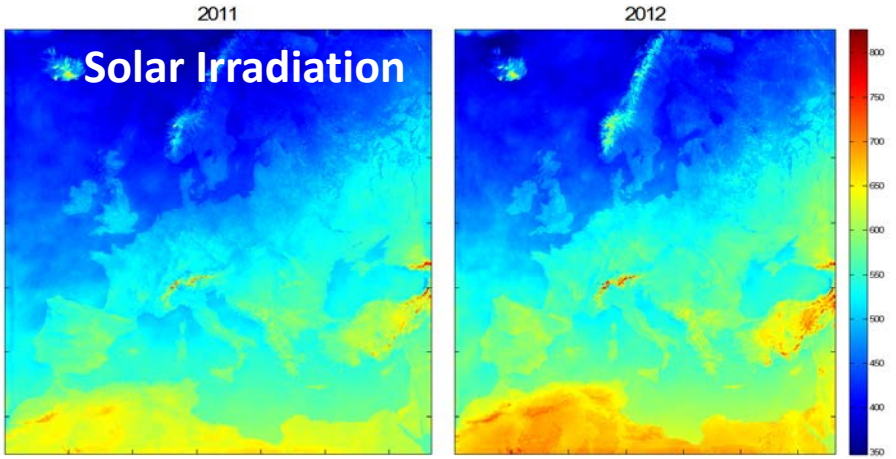
..causes a more volatile net-load

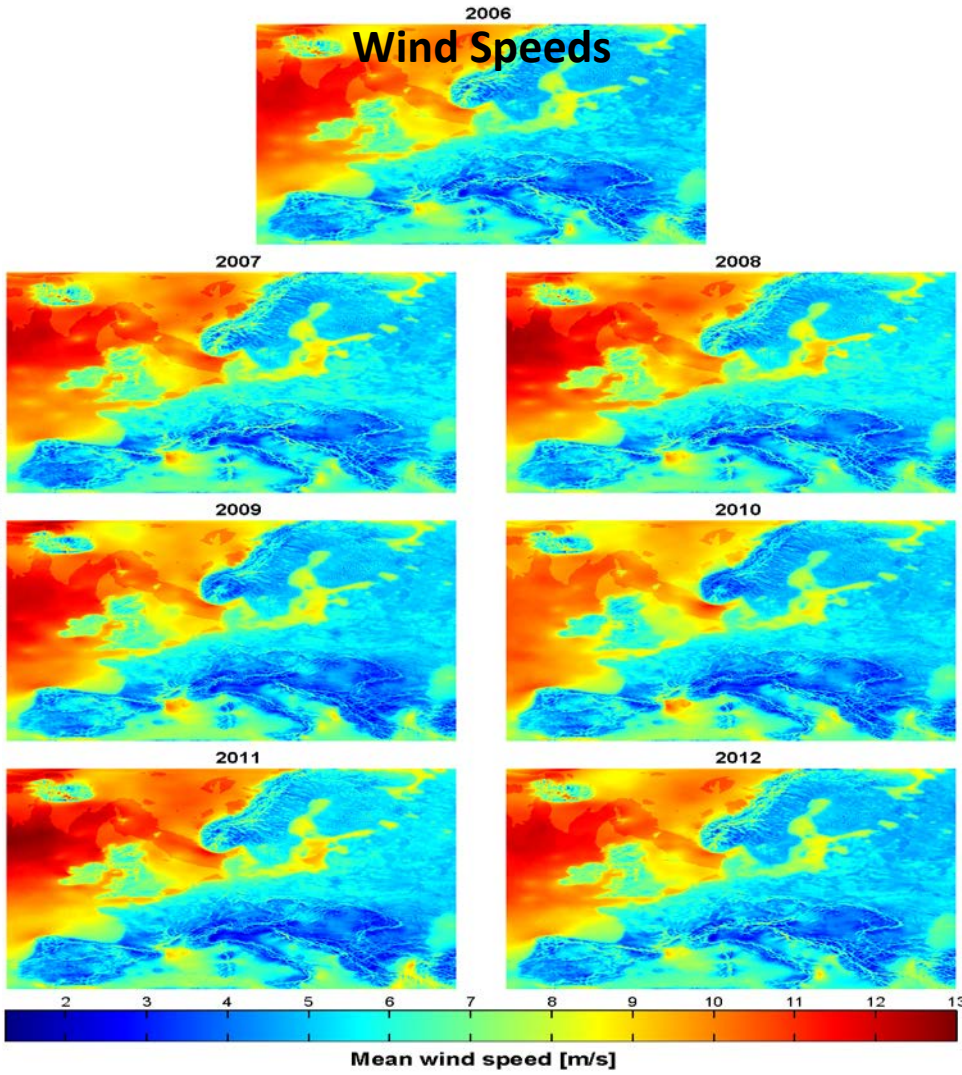


Ref: NREL, Holttinen (VTT)

Reference:
Bloomberg New Energy Finance // NREL Holttinen (VTT)

…and the renewable resources are geographically spread

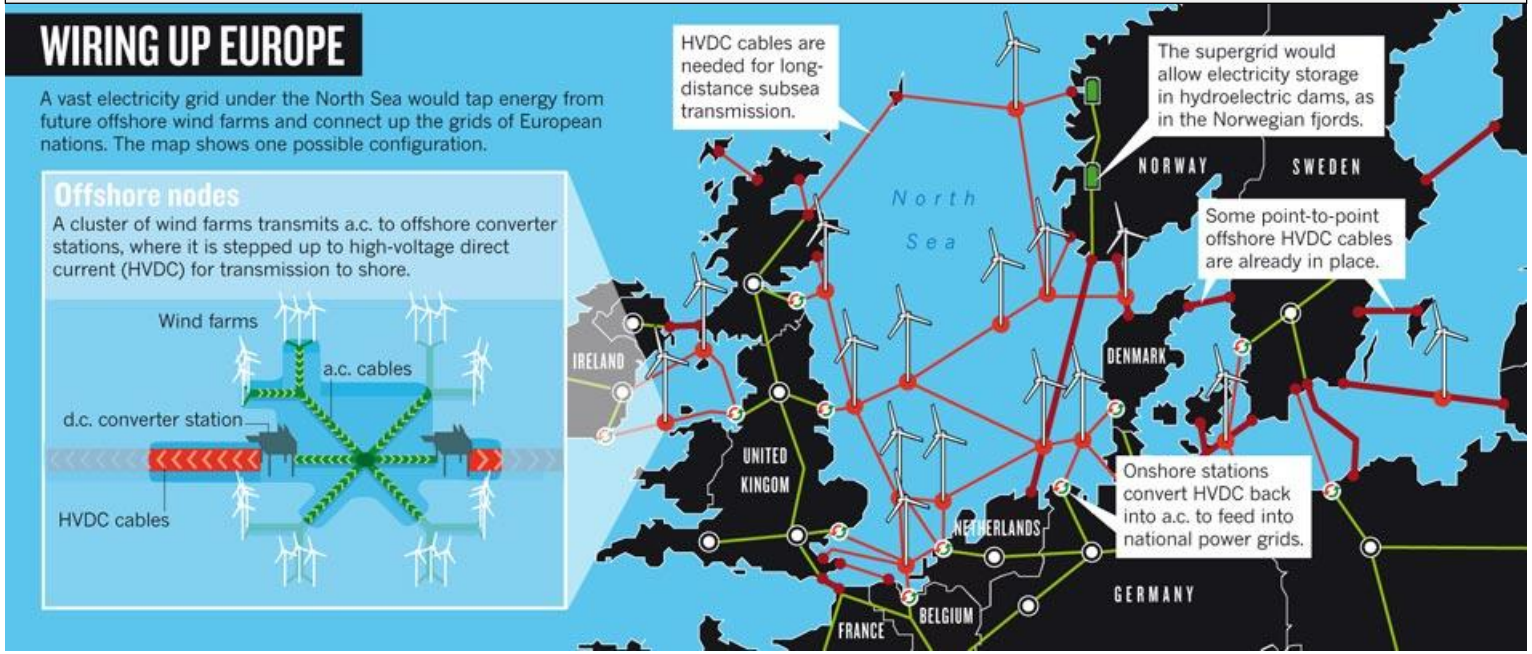




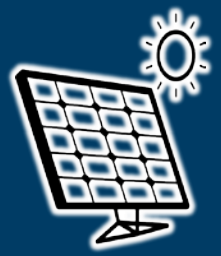
Reference:
Tobias Aigner PhD Thesis, NTNU

More RES yields a demand for infrastructure and flexibility

Increasing demand for spatial and temporal flexibility ➡ North Seas Offshore Grid (NSOG)



Reference:
www.nature.com



Power Link Island

Artificial island for transnational power exchange and distribution of offshore wind resources

Each PLI can include 30 GW offshore wind

Power Link Island

Capacity:

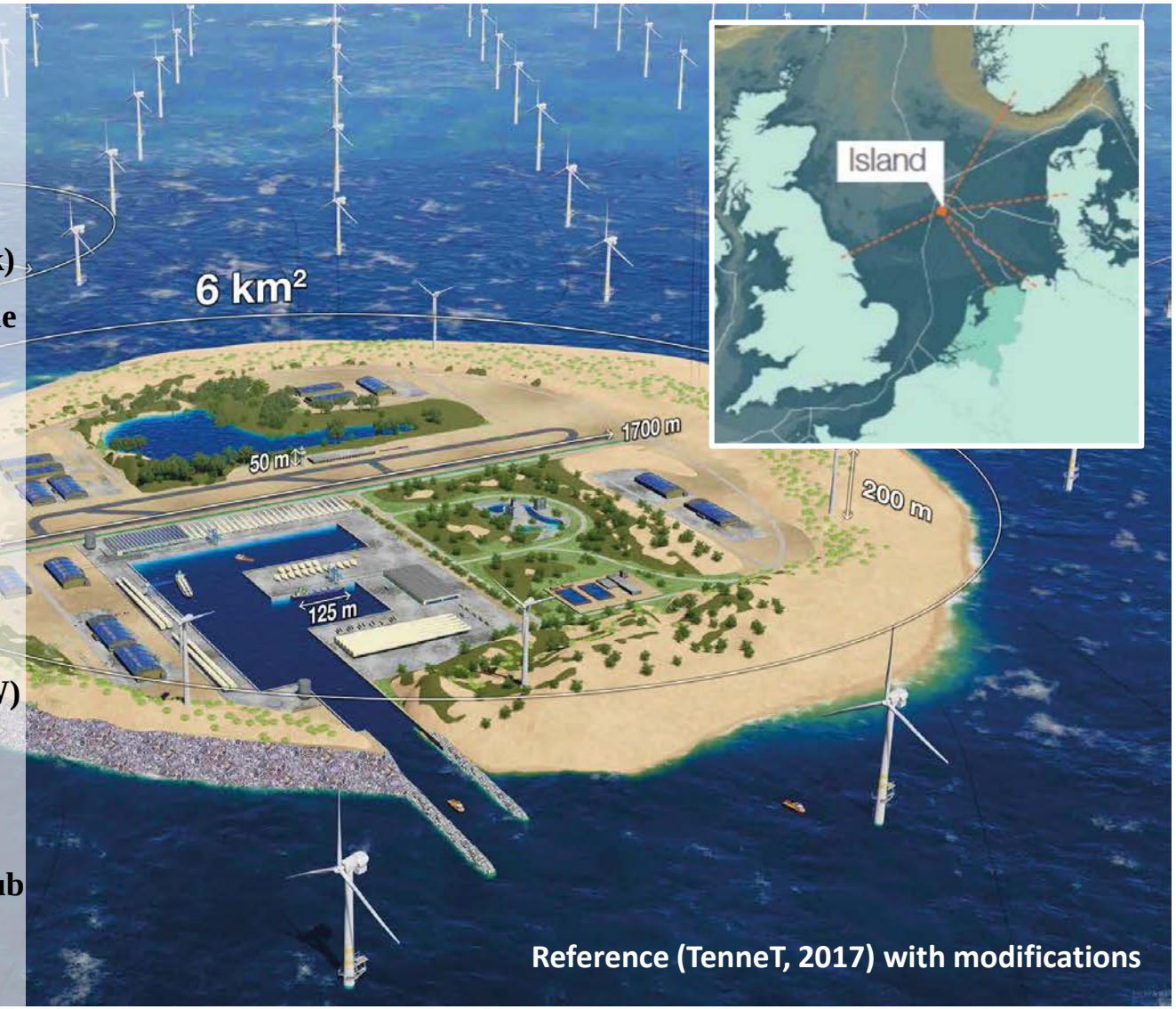
- 30 GW offshore wind
- 6 km² (0.02% Dogger bank)
- Supply 21-30 million people

Financing:

- €1.5bn for rocks & sand
- Operational by 2035
- Economies of scale
- Modular wind capacity
- Modular islands (<100 GW)

Technical:

- Offshore wind hub
- Transnational exchange hub
- Power-to-gas potential

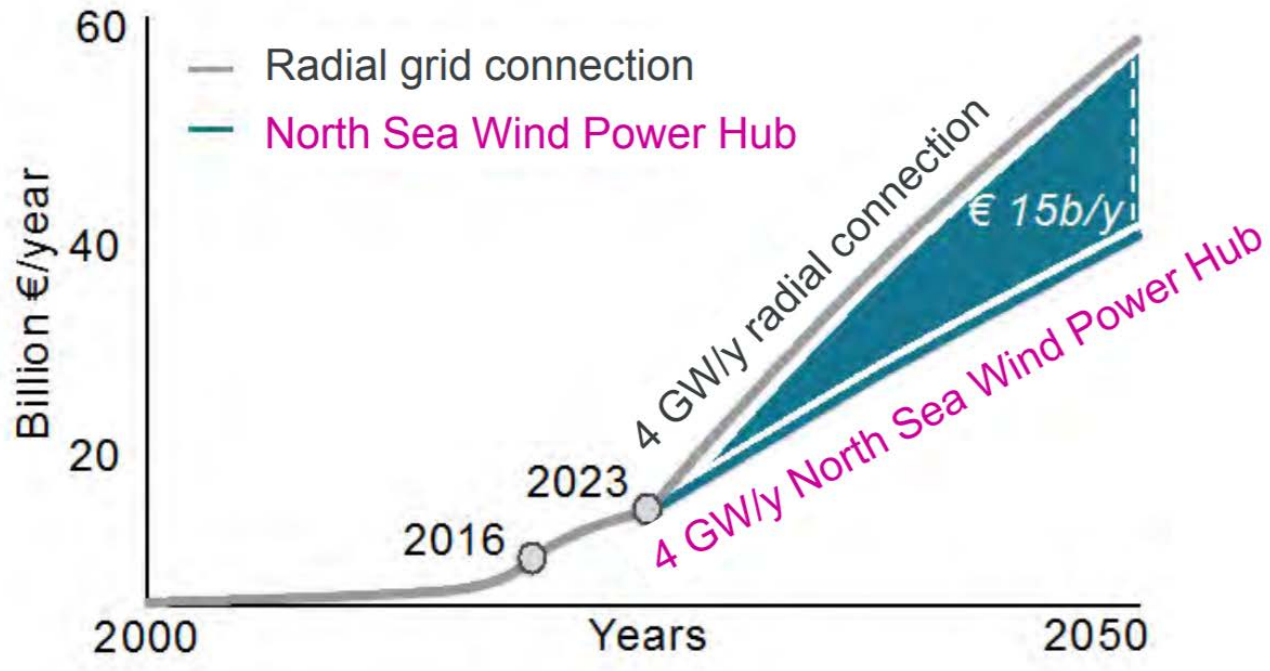


Reference (TenneT, 2017) with modifications

…with expected cost savings due to economies of scale

Development wind energy & offshore grid

Cost reductions by coordinated approach North Sea Wind Power Hub



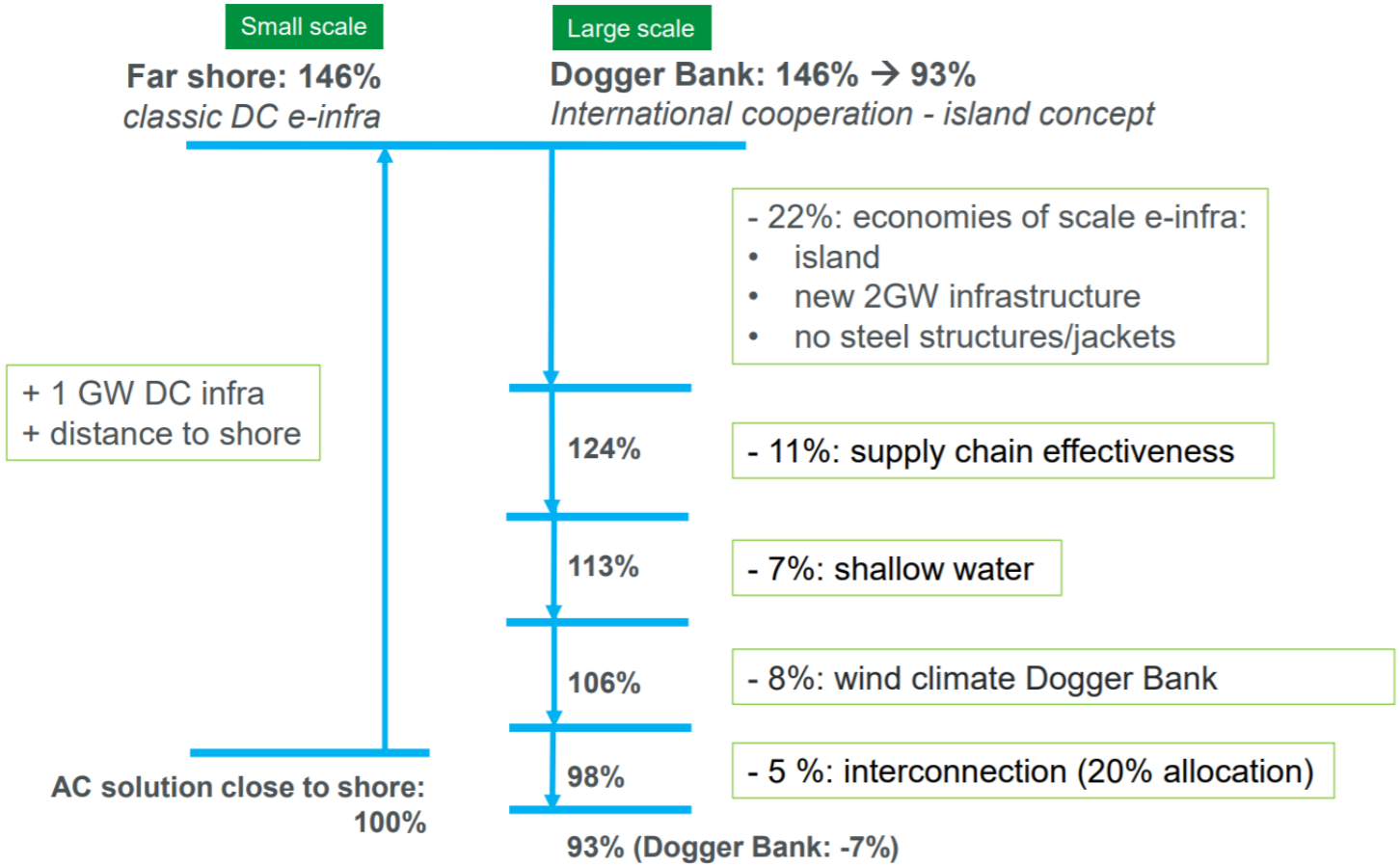
Source: Ecofys (commissioned by TenneT)

April-3-2017

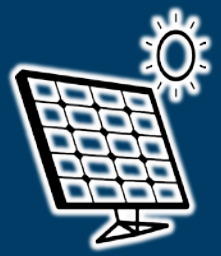
North Sea
Wind Power Hub

Reference:
TenneT

Cost reduction



Reference:
TenneT



Power Link VS radial

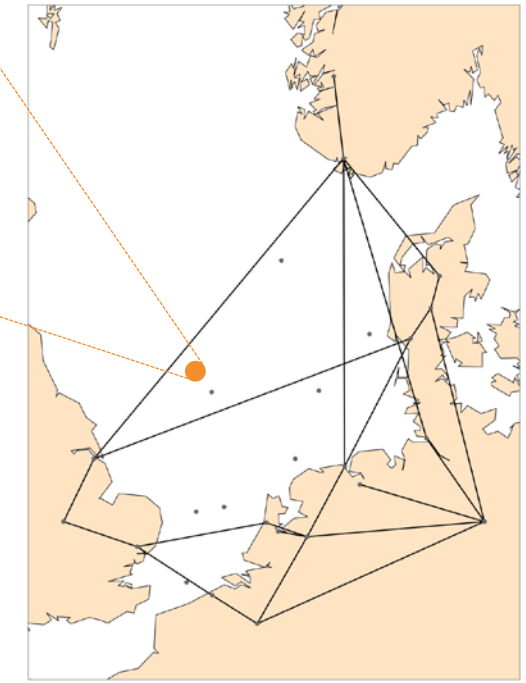
Assessing their performance with an optimization model for both investments and operation.

North Sea Offshore Grid 2030 Case study (ENTSO-E Vision 4)

Base case including OWP grid integration costs

- Grid
  - 2030 planned infrastructure
  - Domestic grid restrictions (~5 to 15 GW)
- Supply and demand
  - ENTSO-E Vision 4 (“Green Revolution”)
  - 65 GW OWP (Peak demand is 150 GW)
- Power flow modelling
  - Transport model due to HVDC connections
- Representation of hourly variability
  - Time series based on given geo coordinates
    - https://www.renewables.ninja/
  - Hydropower represented with hourly price series (water value)
    - Seasonal characteristics
  - Hourly load
    - ENTSO-E
- Goal
  - Include OWP to the lowest possible costs
    1. Radial solutions
    2. Power Link Island

Base case

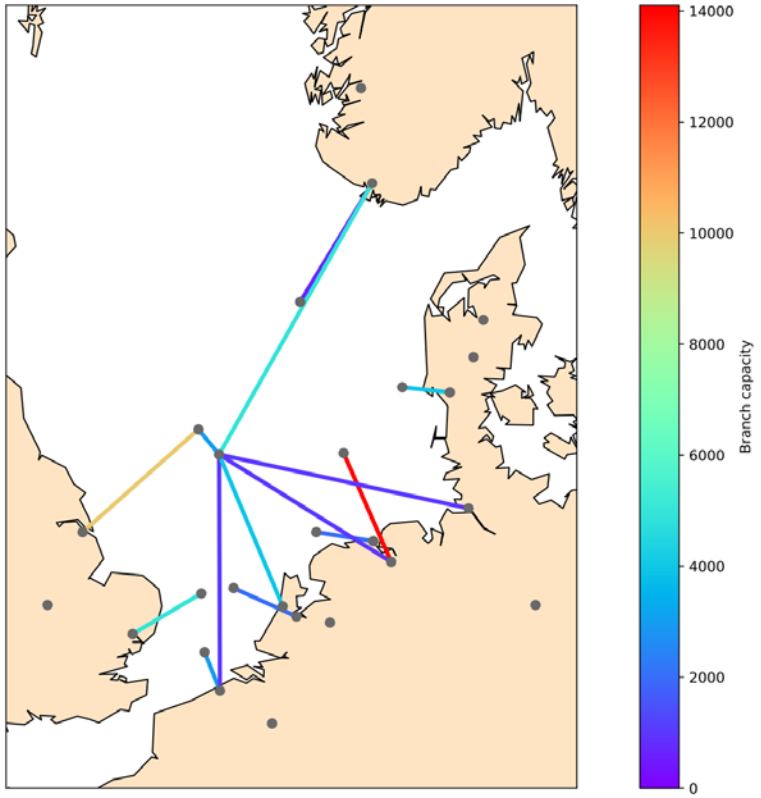


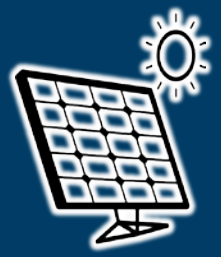
Value of having the possibility to invest in PLI

- Radial base case
  - PLI as a hub
  - No OWP capacity at the PLI

Total operation costs of the system (30 yrs)

- Radial: € 629 B
- PLI: € 610 B
- Cost savings: € 19





Value of connecting offshore wind to the island

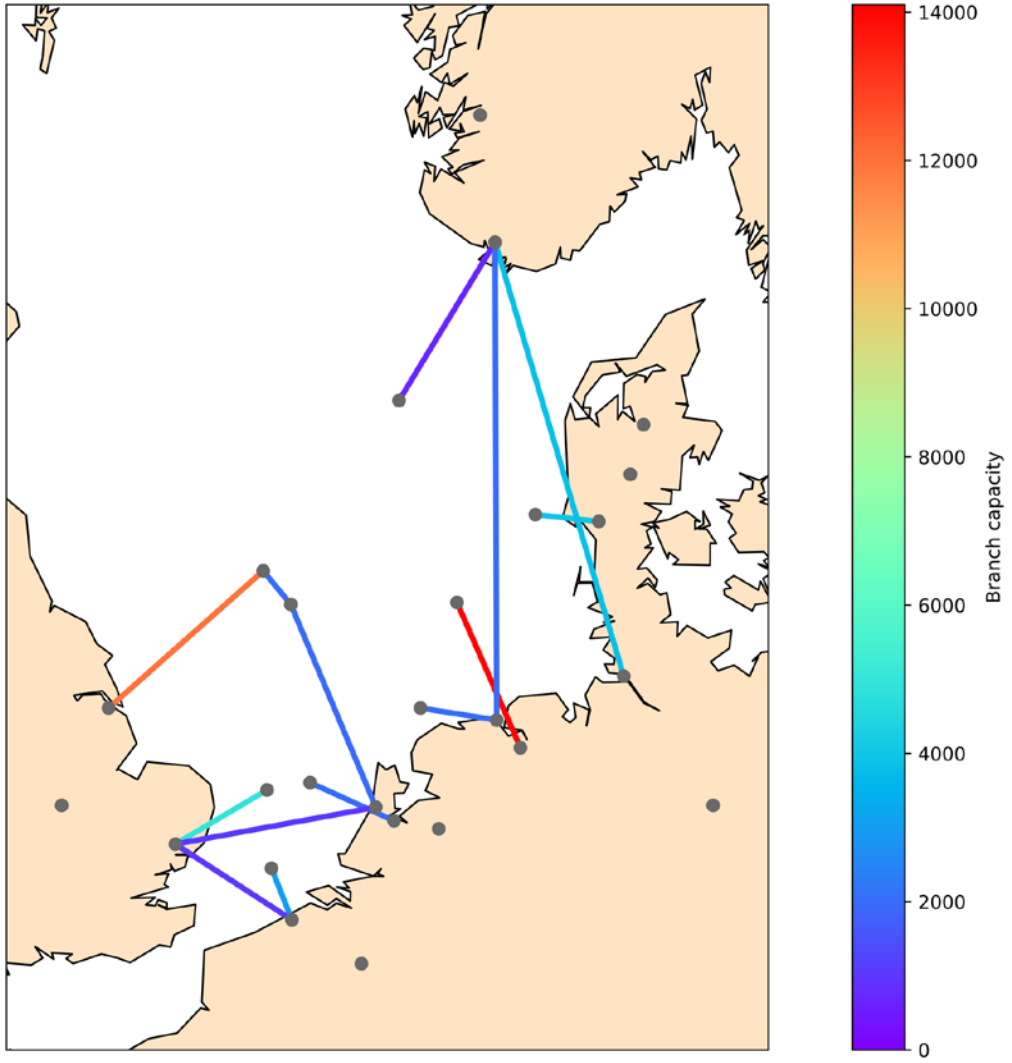
What is the cost savings from adding OWP to PLI including the option to expand interconnectors even more than planned capacities?

PLI without offshore wind allocated to it

- Radial expansion base case
  - No OWP at PLI
  - Allow interconnector expansion

Total operation cost of the system over 30 years

- €597 B



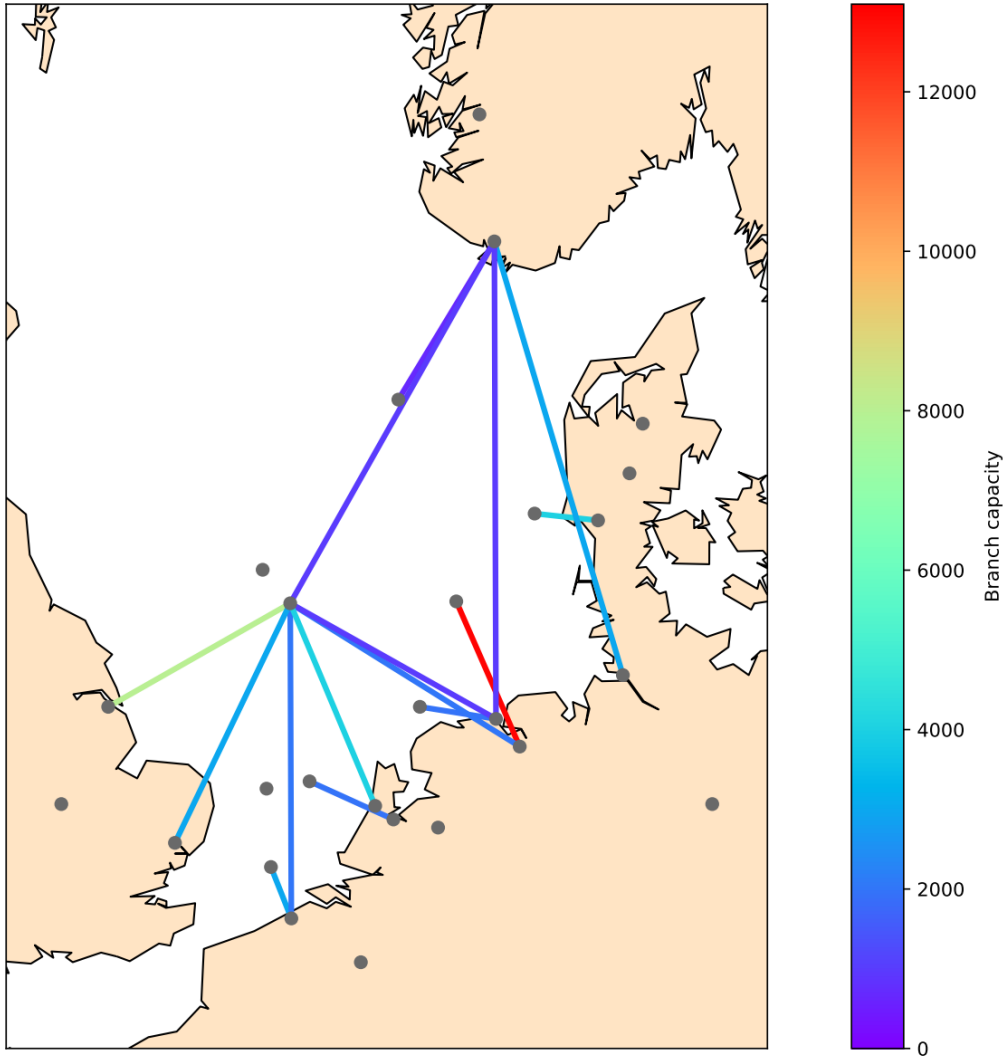
PLI with 30 GW allocated to it

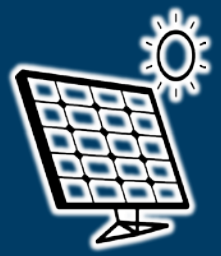
- Compared to radial exp base case
  - Allow interconnector expansion
  - 30 GW at PLI (Reallocating from GB)

Total operation costs of the system

- Without PLI: €597 B
- With PLI: €589 B

- Cost savings = €8 B





Including generation expansion

Assuming planned interconnectors for 2030. What are the cost savings allowing for PLI when trying to anticipate changes in the generation mix? ENSTO-E V4 exogenous plus additional Generation Expansion Planning (GEP).

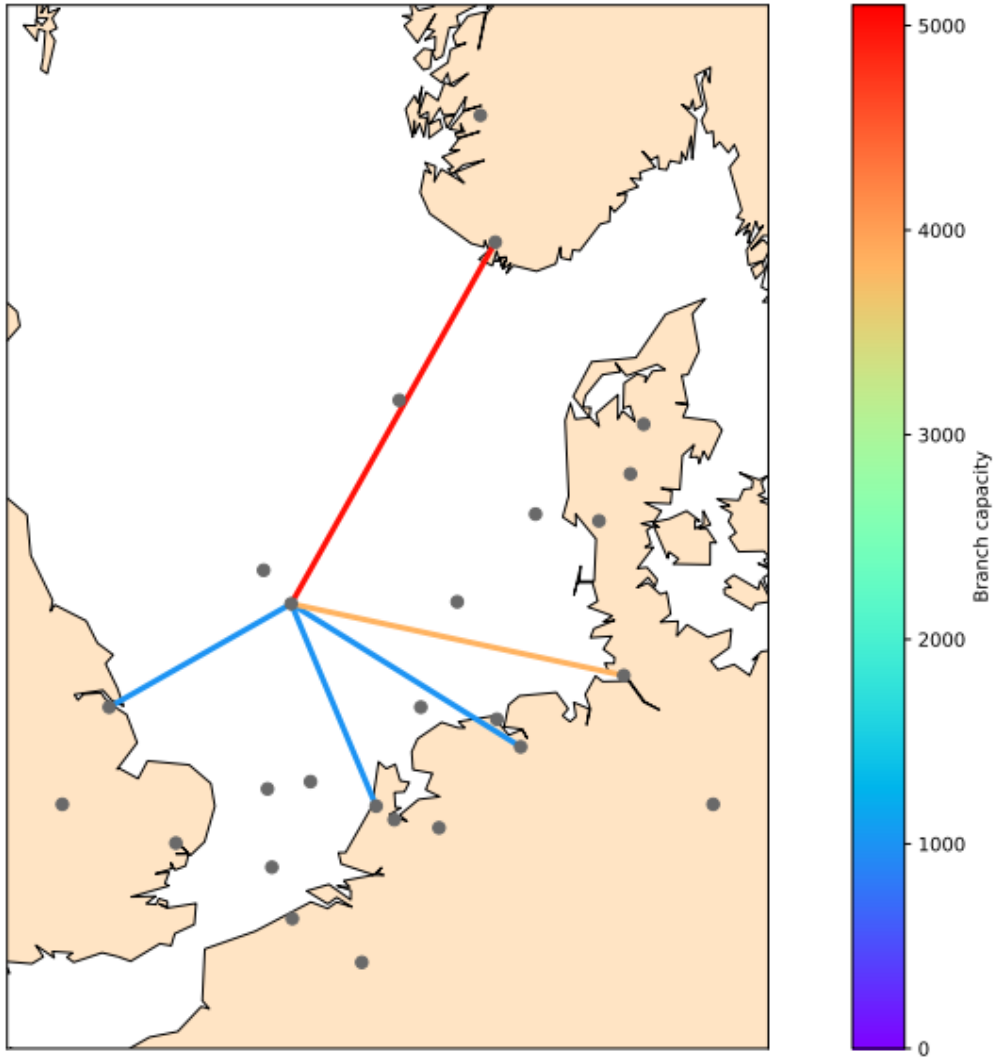
PLI with GEP base case as reference

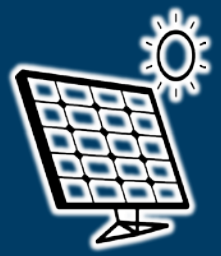
- Radial base
  - OWP already integrated for free
  - GEP (except for hydro or nuclear)
  - TEP for a PLI
    - No additional interconnectors

Total operation costs of the system:

- € 507 B
- € 496 B
- Cost savings €11 B

- … significant cost savings also when accounting for GEP (i.e. a stable GTEP equilibrium before PLI TEP)





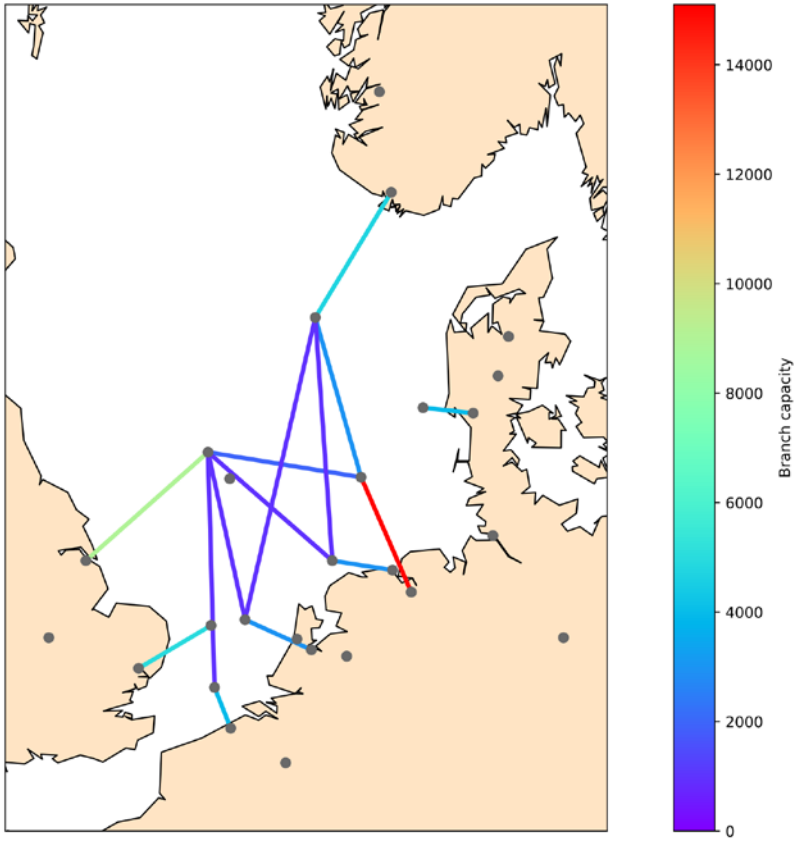
Meshed solutions

Some meshed alternatives to include offshore wind power

Base case incl costs for connecting OWP (meshed)

- Meshed base case (without interconnector expansion)

- Radial: €629 B
- Radial + PLI: €610 B
- Meshed: €611 B

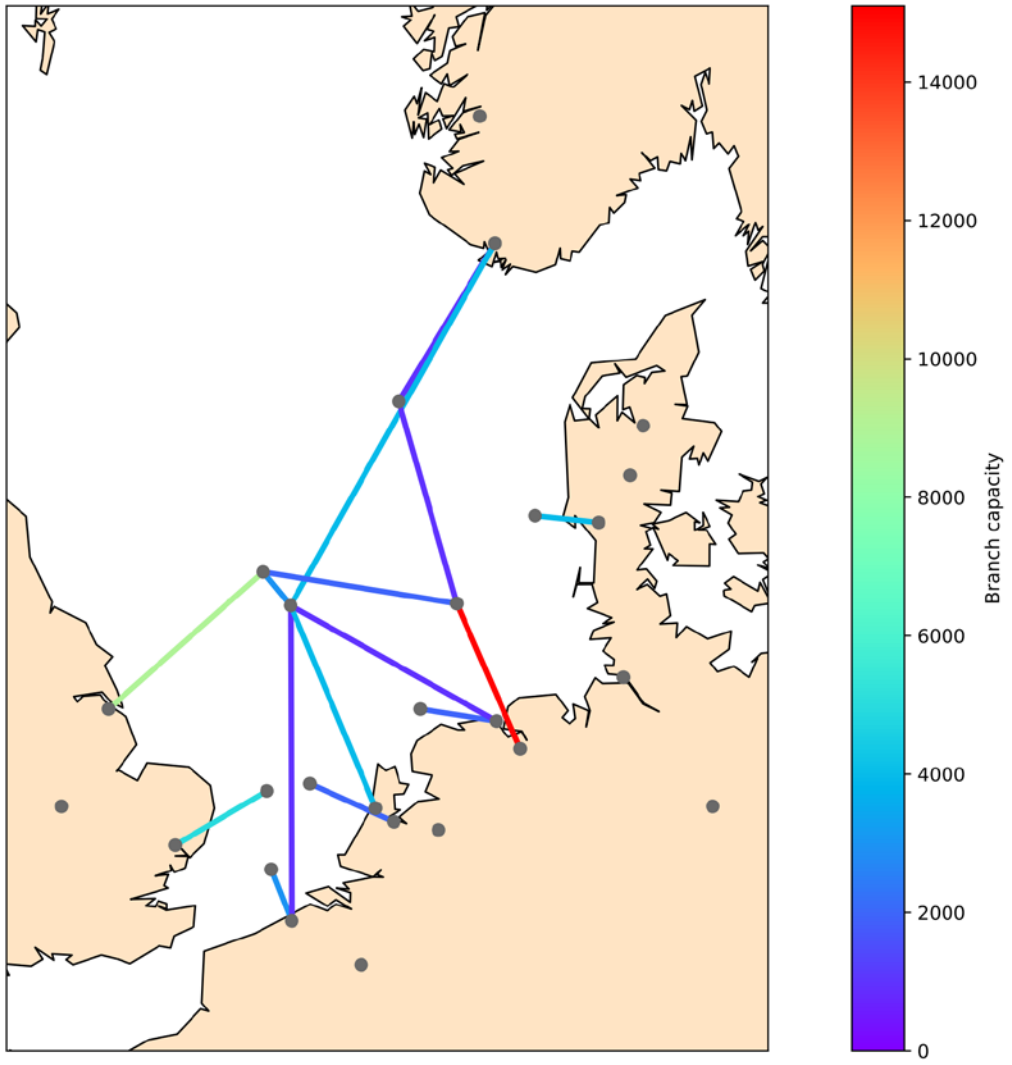


Base incl costs for including OWP (meshed) + PLI (as hub)

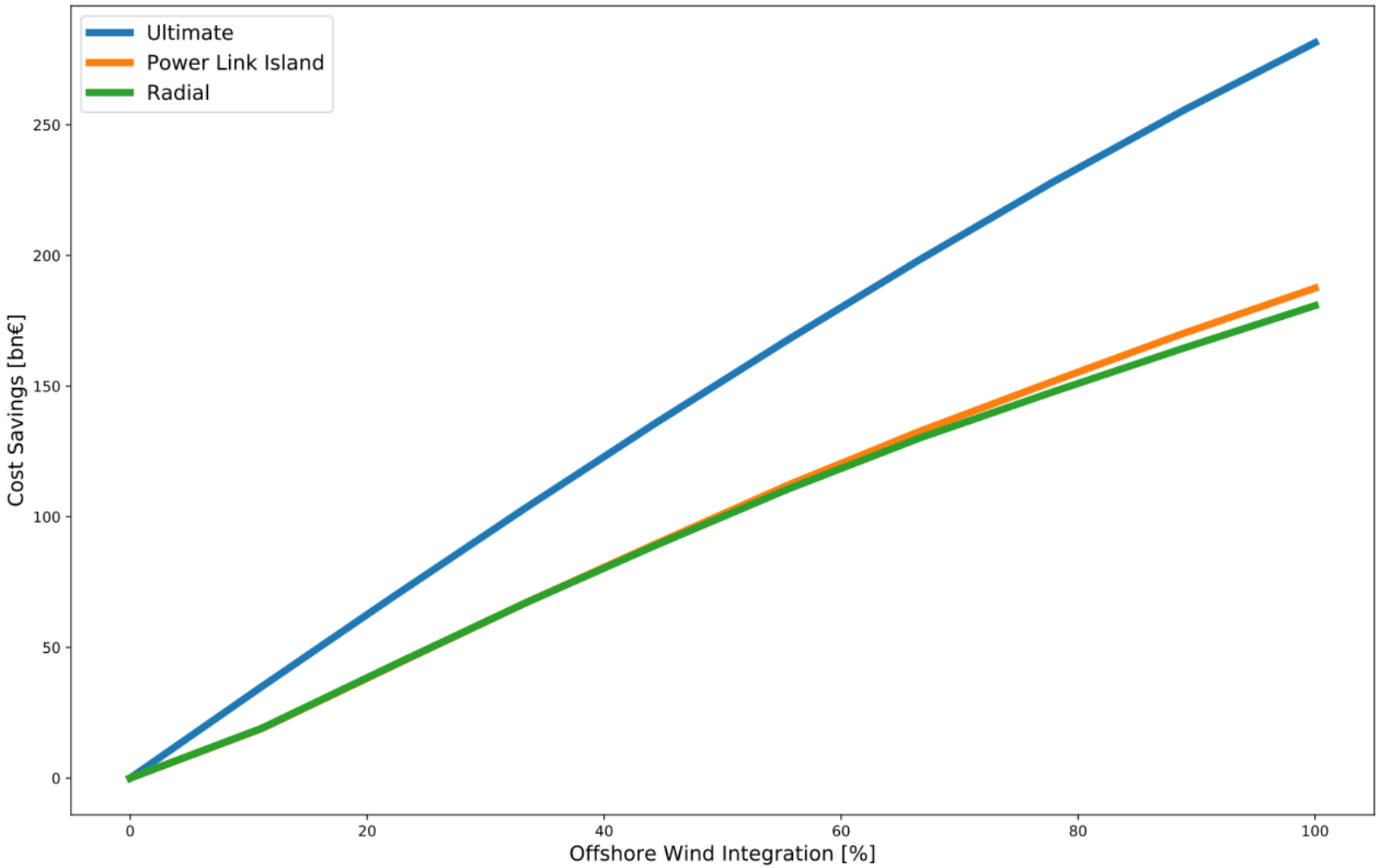
- Meshed base case
  - PLI as a hub (no wind allocated)
  - No additional interconnectors

- Radial: €629 B
- Radial + PLI: 610 B
- Meshed: 611 B
- Meshed + PLI: €609 B

- Cost savings: € 2 B



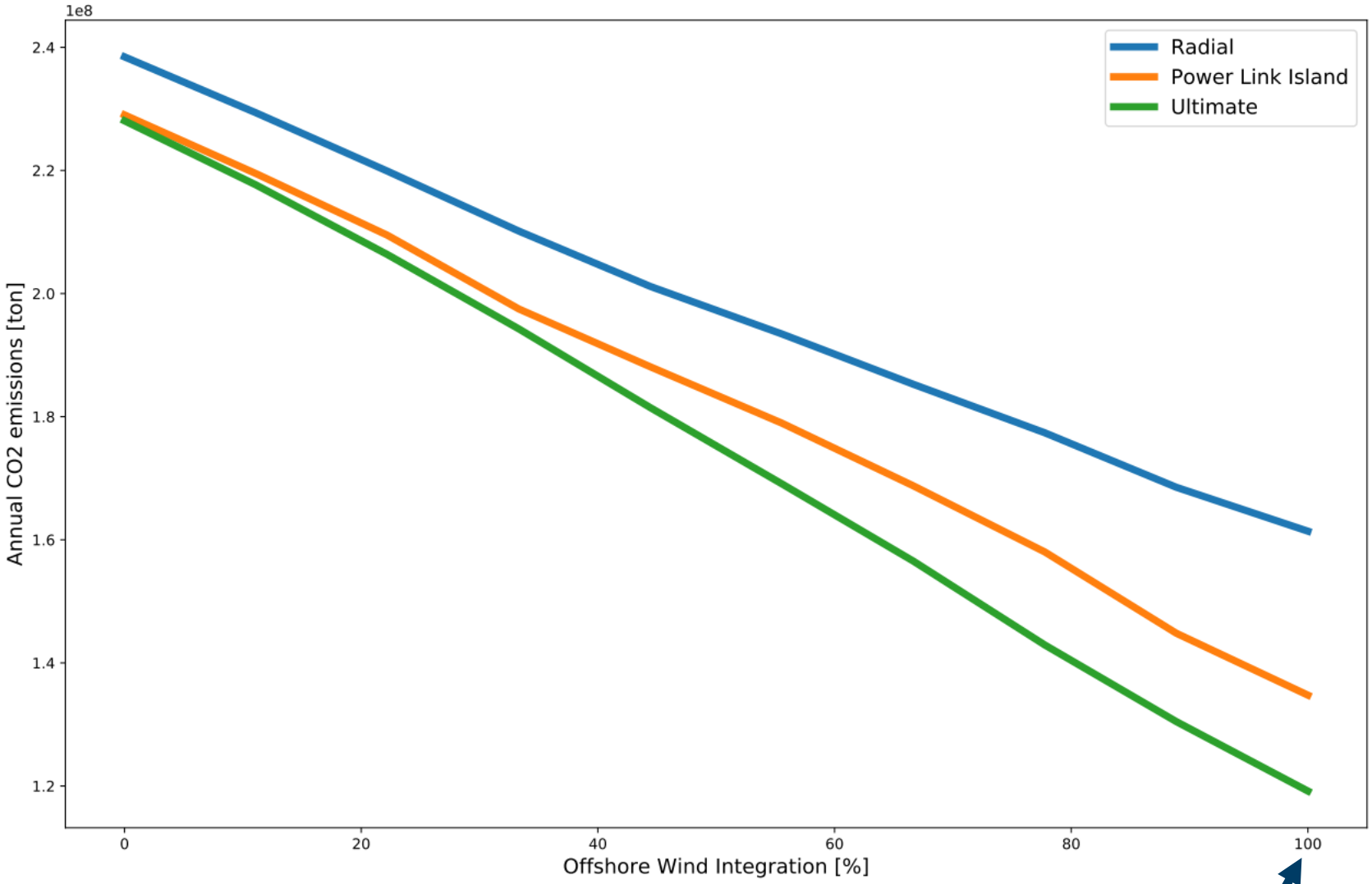
PLI shows increasing value when OWP capacity increases



ENTSO-E V4 (65 GW)

Ultimate = Unlimited (free) capacity at candidate corridors

…it has an even more clear impact on CO2 emissions



ENTSO-E V4 (65 GW)

Ultimate = Unlimited (free) capacity at candidate corridors

"PLI yields significant costs savings for an integrated NSOG"

Relevant findings from the optimization model:

*Different comparisons of radial- and **PLI integration of OWP capacity yields system cost savings up to €19 B over 30 years** depending on the degrees of freedom in the planning model.*

*When trying to anticipate the impact of generator expansion, the added value from the PLI is still significant (**~€11 B**).*

*Assuming other flexible grid integration alternatives, such as a meshed grid, the added value of a PLI is expected to be around **€ 2B**.*

Key takeaways so far:

*The PLI provides a more **cost-efficient OWP integration** than radial solutions, **reducing curtailment of wind** as well as increasing trade possibilities (**spatial flexibility** at a lower investment cost).*

*It is shown that **the relative value of a PLI increases when the level of offshore wind power capacity increases**.*

Limitations and future work:

***cost uncertainty** // Unit commitment // multi-sector // onshore grid representation // local flexibility*