IEE OffshoreGrid

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The IEE Project OffshoreGrid

- Project DNA
- Objectives
- Structure of the models used
- Cost- and Power market model
- Final design approach
- Conclusions

Photos: C-Power

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PROJECT DNA

- Techno-economic study
- Cost-benefit analysis of different design options
- First in-depth analysis of how to build a cost-efficient grid in the North and Baltic Seas
- Budget 1.4 M€, 75% funded by EC
- Coordinator 3E, 8 partners, consultancy & applied research

Objectives

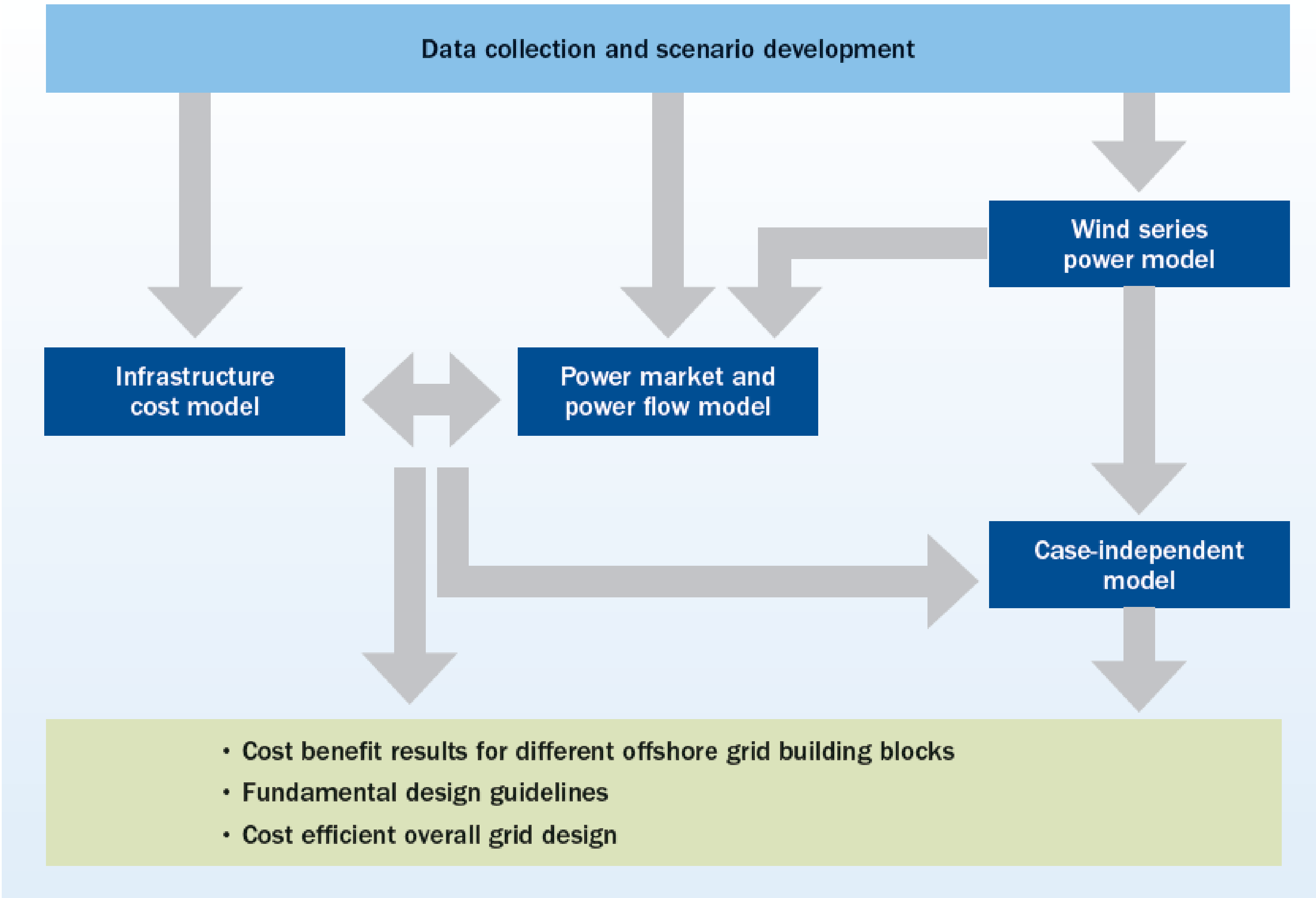
GENERAL OBJECTIVES

- Recommendations on grid topology and capacity choices
- Guideline for investment decision & project execution
- Trigger a coordinated approach for the Mediterranean ring

SPECIFIC OBJECTIVES

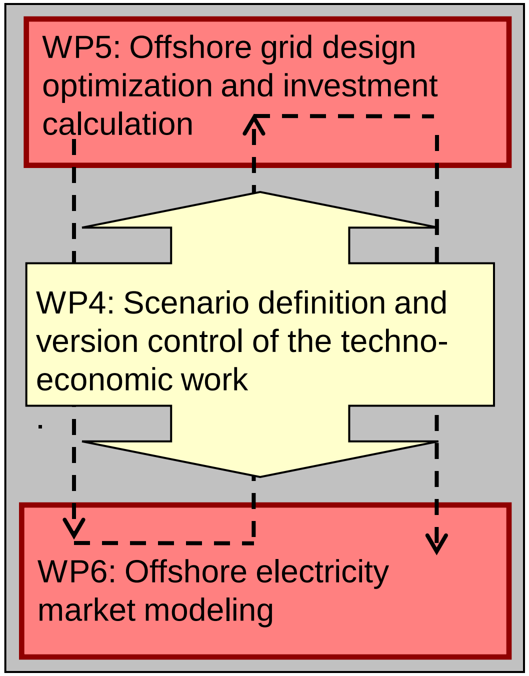
- A selection of blueprints for an offshore grid
- Business figures for investments and return
- Insight in interaction of design drivers and techno-economic parameters
- Representative wind power time series
- Feedback from & acceptance by stakeholders

Structure of the Models Used



Cost Model Objectives

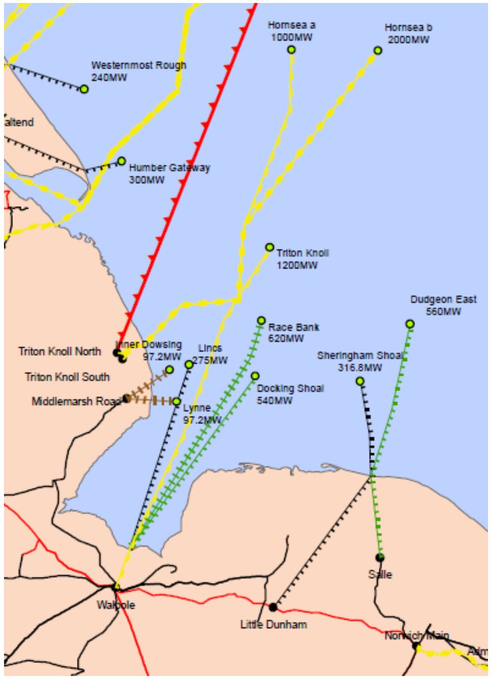
- To provide the technical design for an integrated offshore transmission network allowing:
  - connection of offshore wind and marine renewables
  - interconnection between the countries of the Baltic and North Seas for the purposes of arbitrage where justified.
- To provide a cost estimate for such a network or networks
  - Applied to all network designs
- Runs in parallel with Power Market Model



Cost Model: Costs of Offshore Infrastructure

TECHNICAL DESIGN MODEL INPUTS

- Offshore generation (GIS) locations, technologies, timing & capacities for each scenario
- Onshore connection points (GIS co-ordinates – Windspeed project)
- Network security criteria
- Subsea geology and topology
- Cost data and expected technological evolution (based on discussions with manufacturers)



COST MODEL OUTPUT

- Technical design
- Cable routes and capacities
- Investment costs

Power market model

- SINTEF's Power Market Simulation Tool (PSST) – Flow-based power market simulator
  - compute technical and economical parameters for different scenario cases
  - **generation cost, energy prices, price differences**, *load duration, offshore grid utilisation*, etc.
- Hour-by-hour optimal power flow – minimises generation cost (socio-economic optimum)

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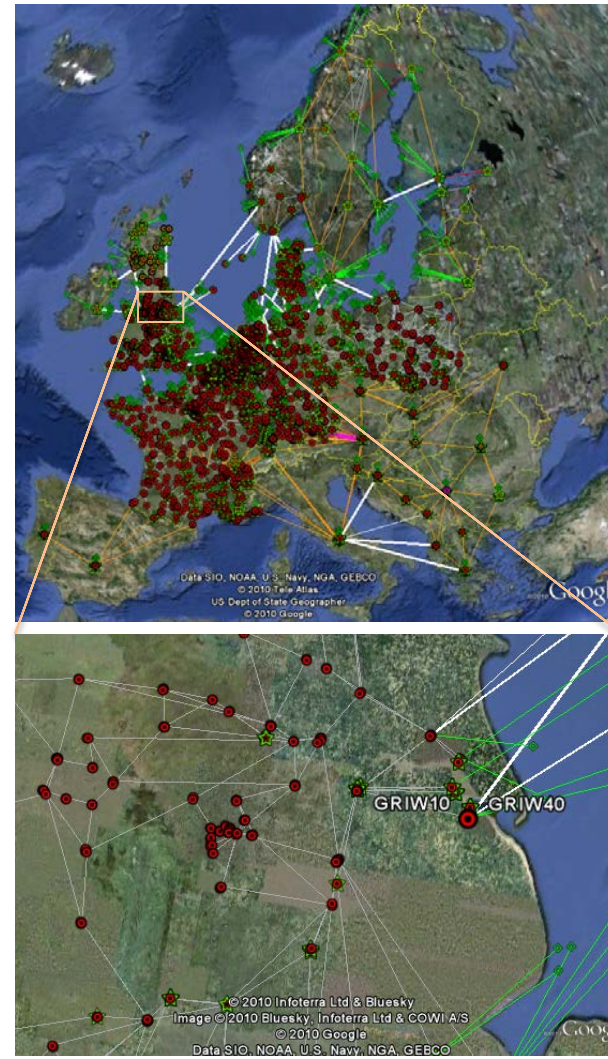
Simulation model

- Data
  - UCTE Study Model (winter 2008) + British (public data) + Nordic and Eastern Europe
    - 4836 buses, 1494 generators, 8484 branches
    - Approximately 2 hours to run the market model
- 2010, 2020, 2030
  - up-scaled demand and generation capacities



Key Assumptions

- Uniform up-scaling of demand and generation within each country
- Grid upgrades
  - Unlimited capacity on branches within each country (except between zones in Germany and in the Nordic region)
  - According to ENTSO-E Offshore TYNDP
- Grid connection point of many generators only approximate (including onshore wind)
- Not included in simulations:
  - Power losses
  - Start-up costs / ramp rate limitation
  - Reserve capacity
  - Forecast errors (demand, wind)

Scenarios

- Electricity load → PRIMES, ENTSO-E
- Electricity generation → Platts, ENTSO-E, average efficiency
- Wind power → EWEA scenarios, mesoscale model
- Grid development → UCTE study model, partly relieved internal constraints
- Onshore connection points → WindSpeed, national data
- Technological development → Manufacturers
- Economical data (infr. costs, fuel costs, CO2…) → Manufacturers, → IEA, EC, (Inter)national reports

Approaches

- Two highly efficient grid designs were identified: The **Direct Design** and the **Split Design**. The grid designed was evolved step-wise.

- **Approach for the Direct Design**
- Step 1 The construction of direct interconnectors taking the large price difference between countries as guidance.
- Step 2 Beneficial tee-in solutions or the interconnection of countries via hub-to-hub connections were identified. (Step 2 was only started when step 1 could not identify anymore beneficial direct interconnectors)
- Step 3 Beneficial meshed connections were identified. (Step 3 was only started when neither step 1 nor step 2 could identify beneficial connection solutions)

- **Approach for the Split Design:**
- Similar as in the Direct Design, but in step 1 direct interconnectors where replaced with split wind farm connections where beneficial.

What Countries Should be Connected?

- Methodology
  - Take existing market model with:
    - Hubs (129GW Generation Offshore)
    - All interconnectors as per ENTSO-E TYNDP
  - Analyse price differences from Market Model
  - Assess where trade interconnectors would be profitable (Lifetime Revenue > Capital cost)
  - Run in Market Model and Assess Net benefit
  - Add / remove links as required through iterations

What to compare? – Net Benefit

Costs ⟷ Compare ⟷ Benefits

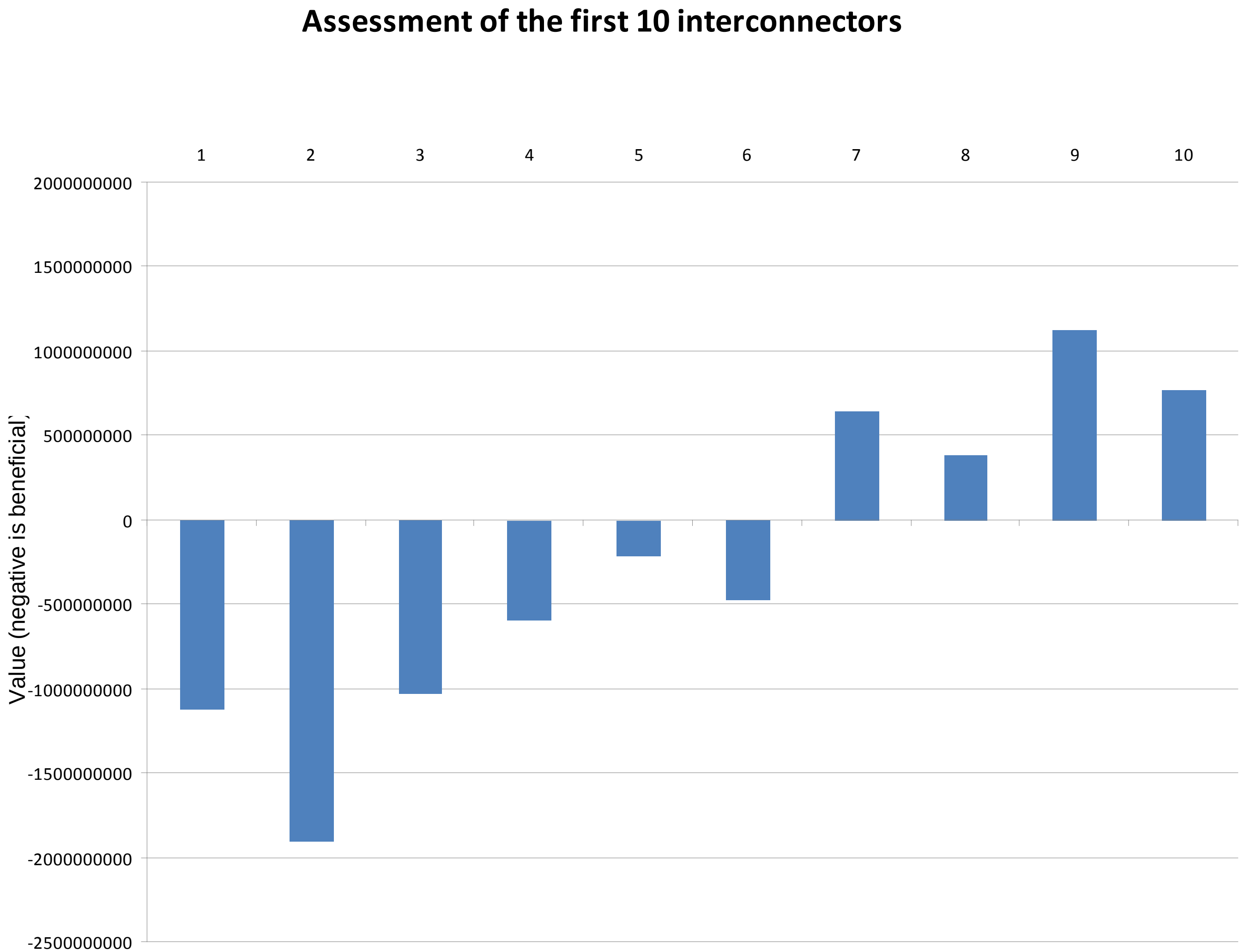
Infrastructure costs:
- Offhore substation
- Onshore substation
- Subsea cables AC or DC

Lower system generation costs due to better interconnection = More connection capacity allows to generate where it is cheapest.

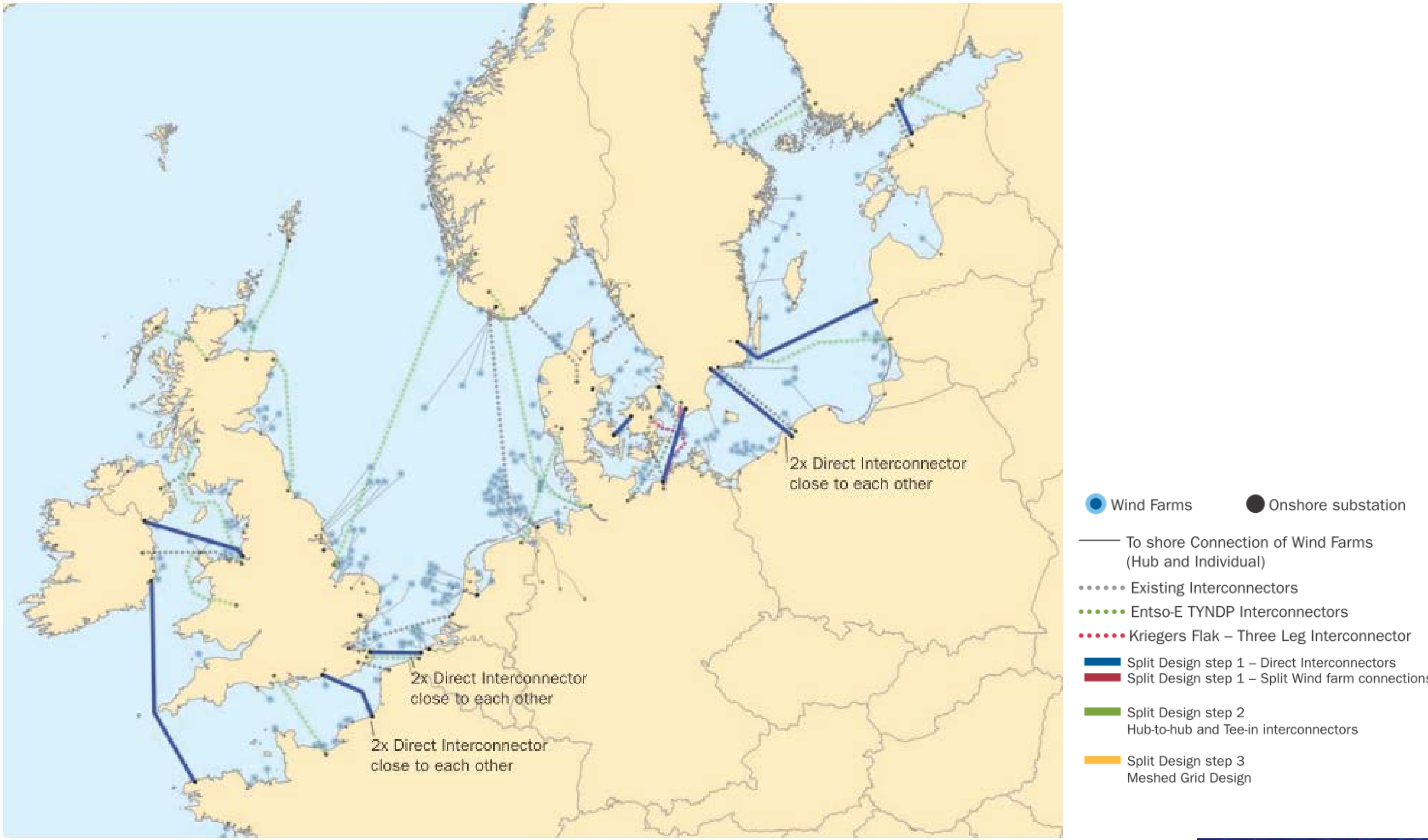
Result of infrastructure cost model.

Results of European Power Market and Grid Flow Model

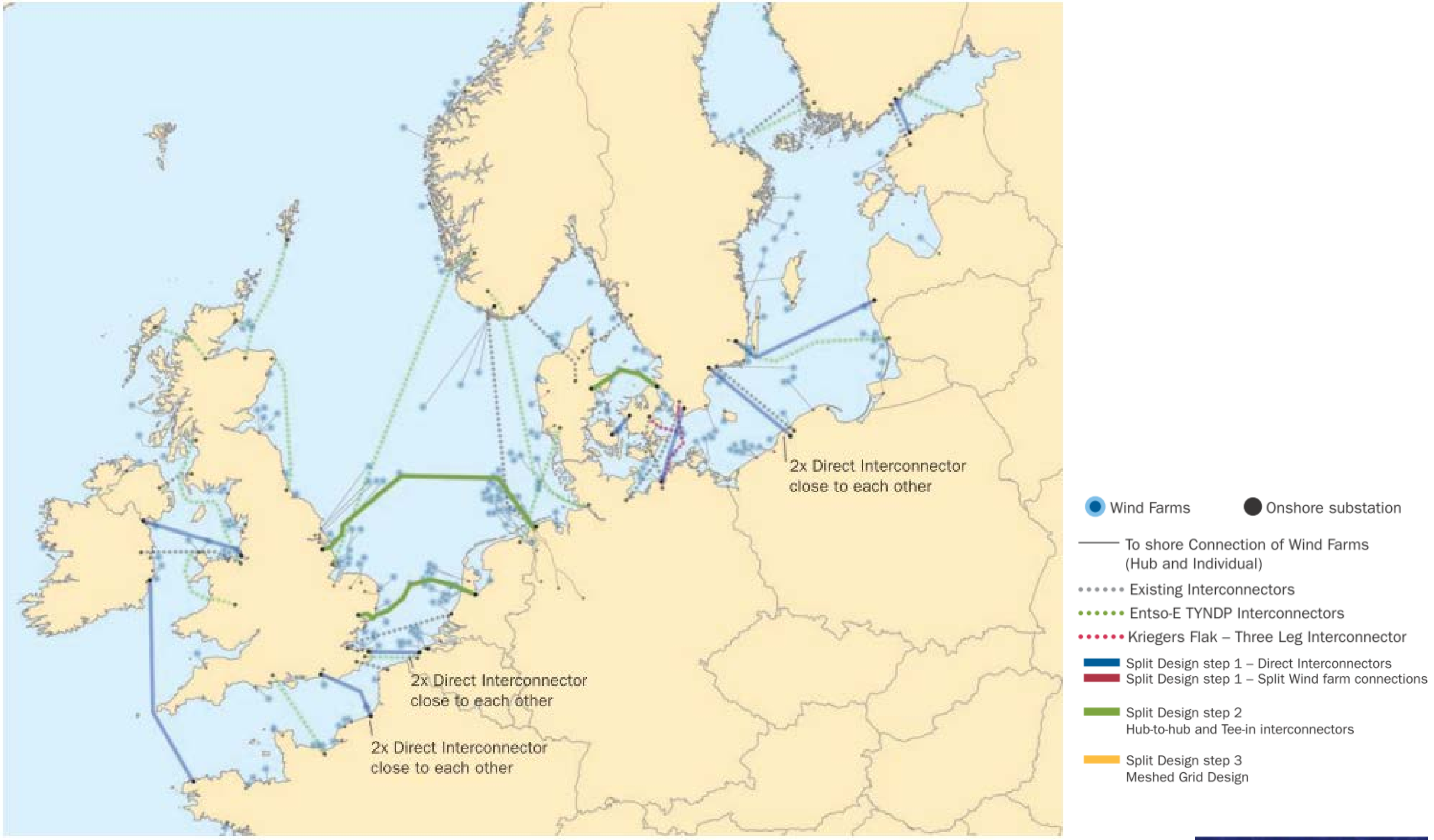
Assess Net Benefit



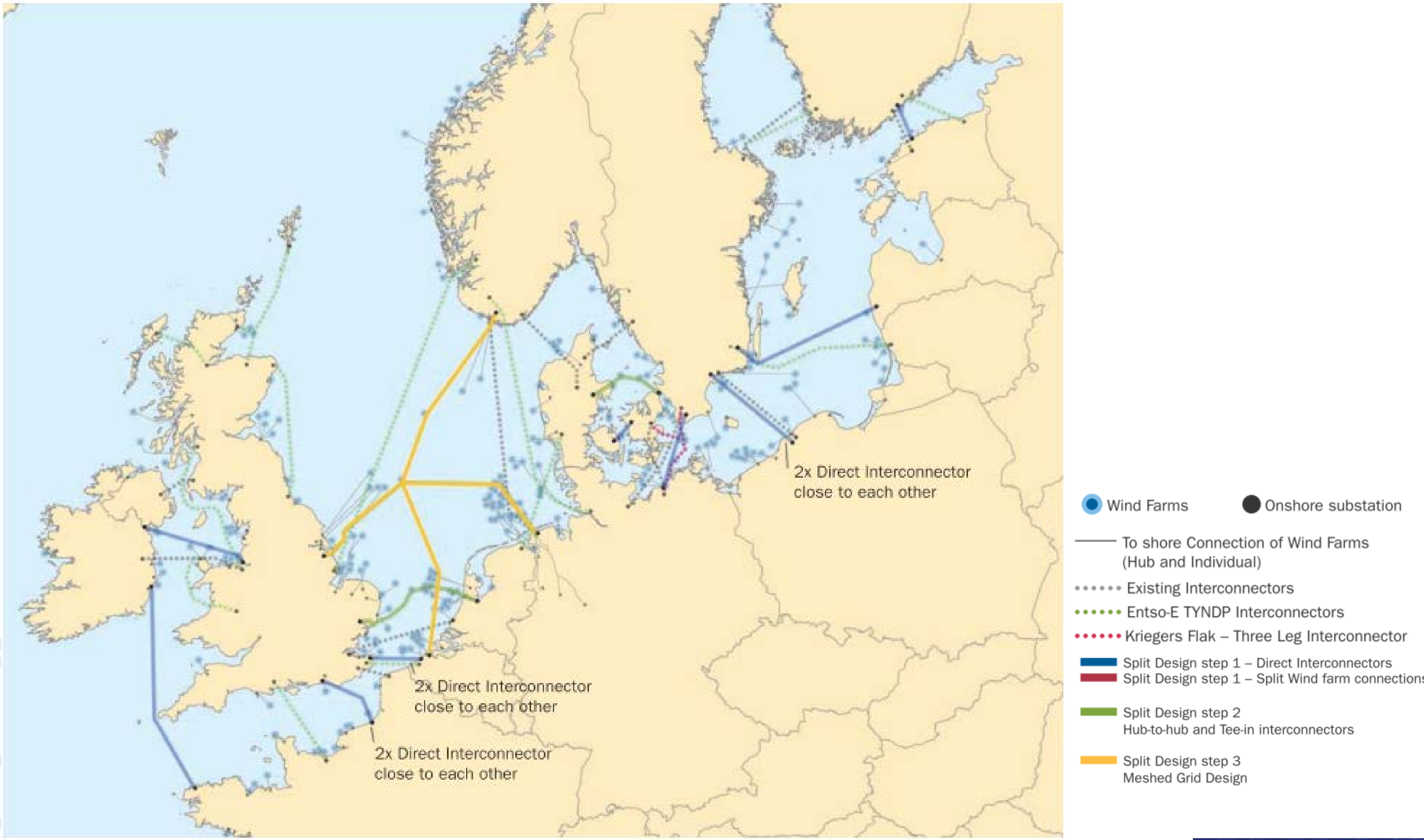
Direct Design Step 1



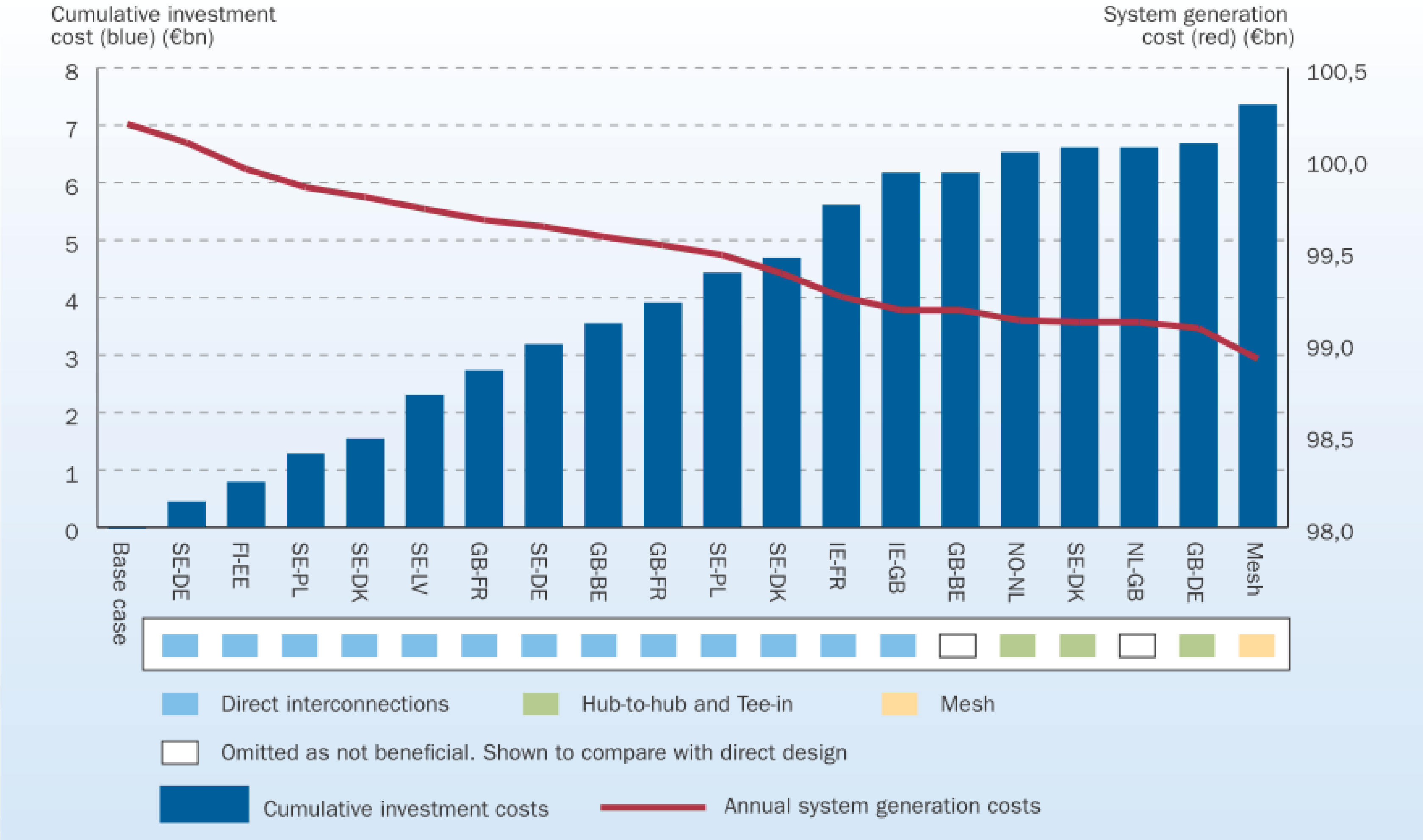
Direct Design Step 2



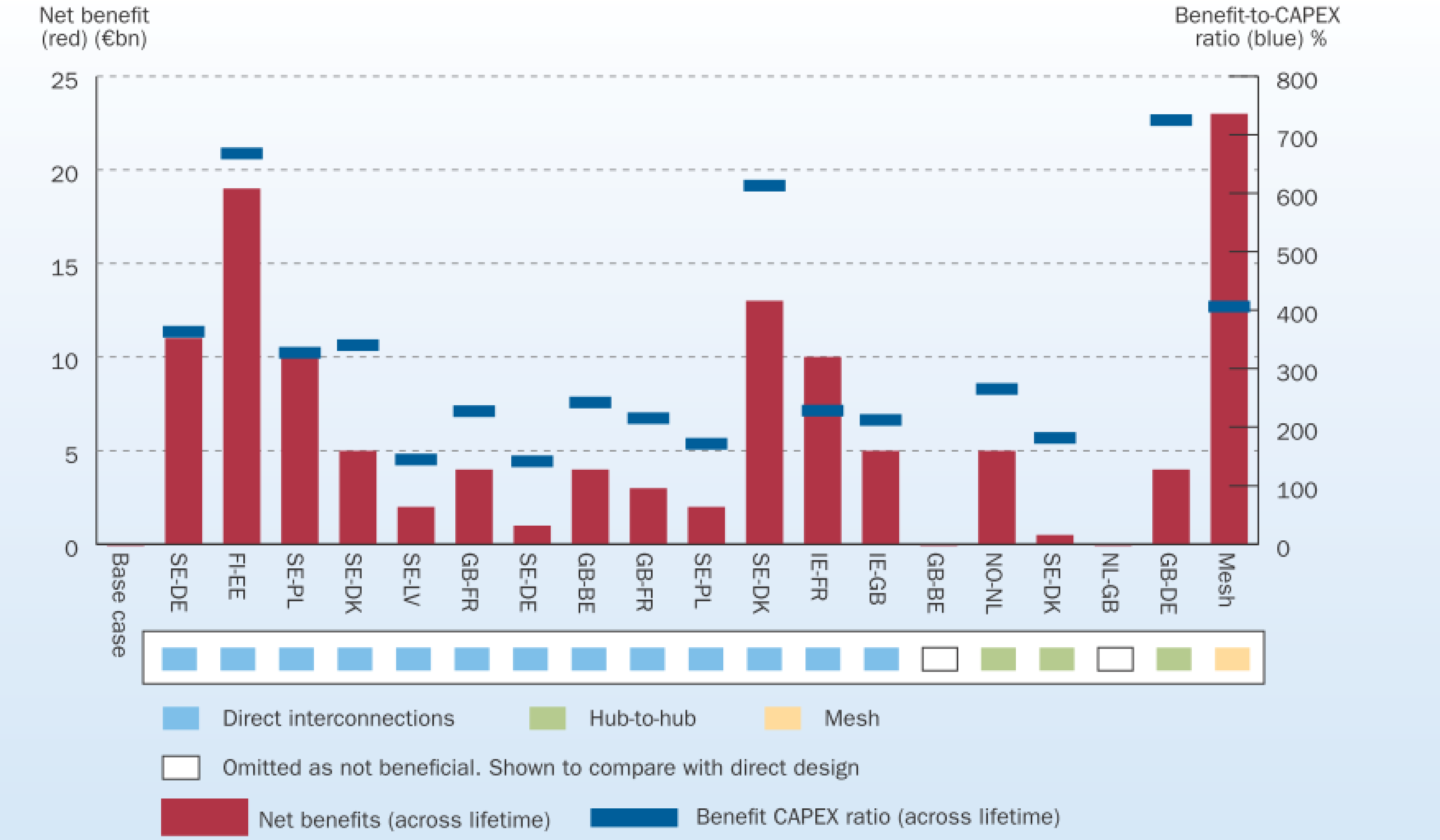
Direct Design Step 3



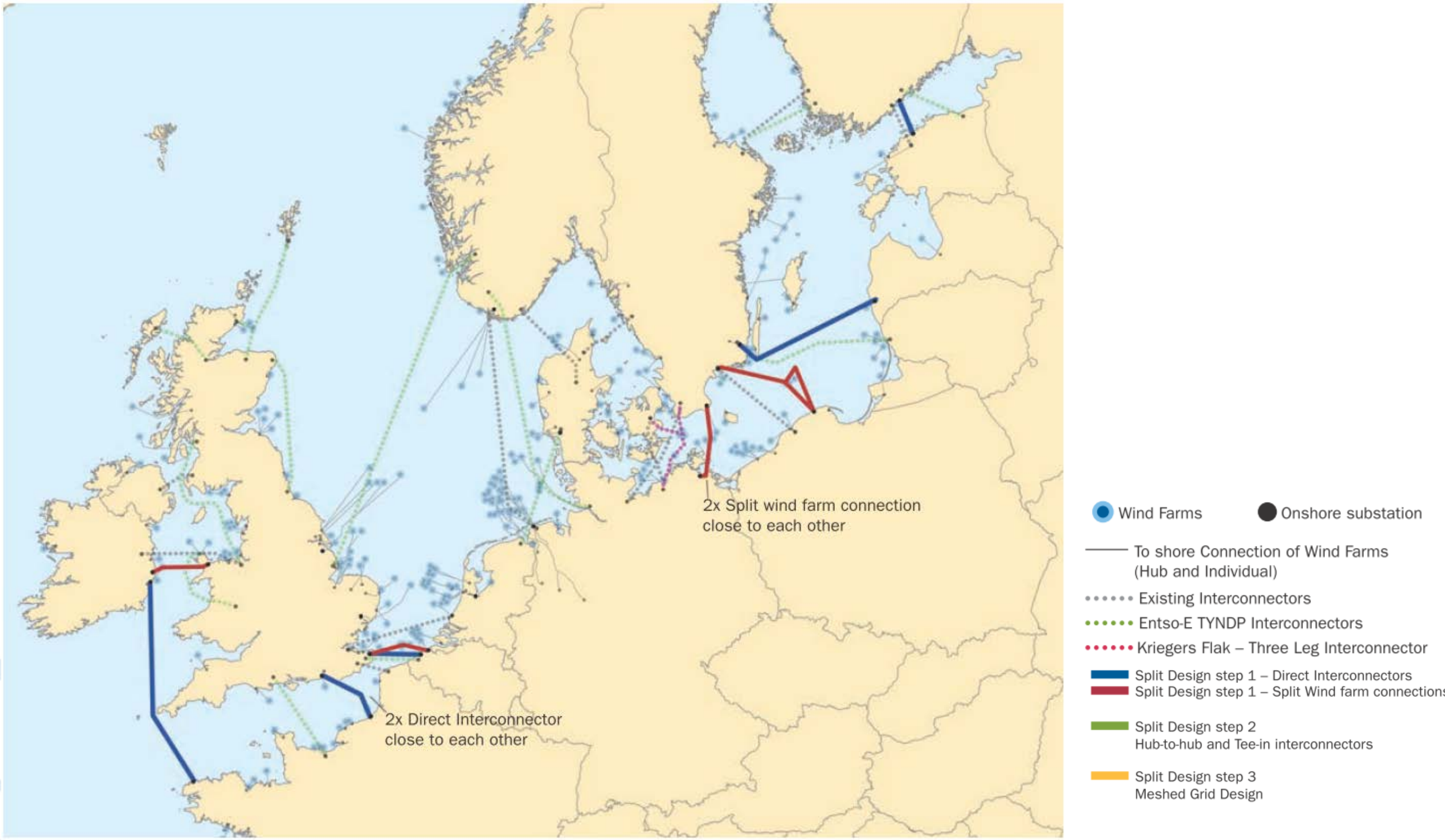
Direct Design Results



Direct Design Results



Split Design Step 1



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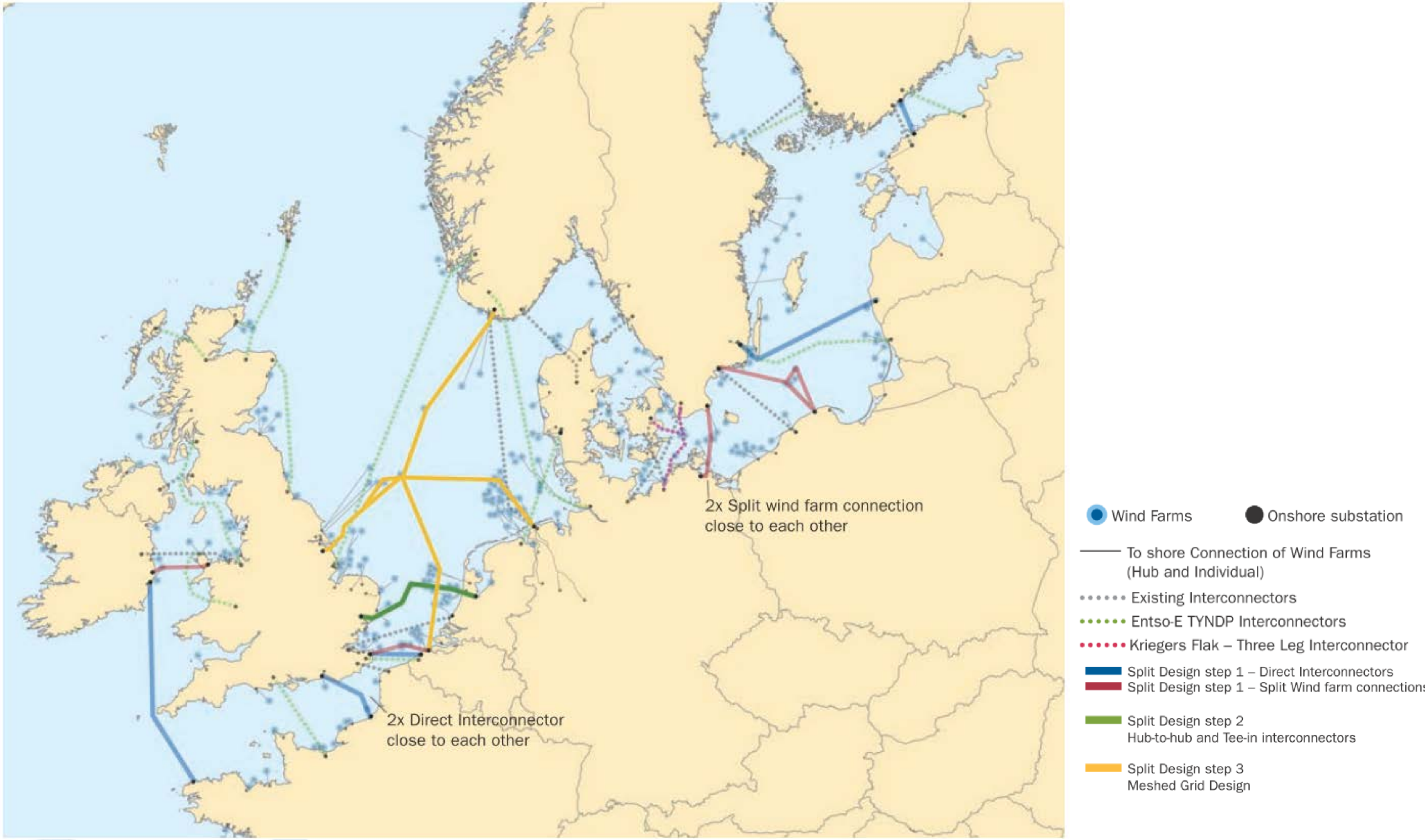
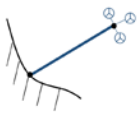
Split Design Step 2 & 3



Summary conclusions – Grid design options

HUBS



- Beneficial with large distance to shore and WFs close to each other.
- Hubs also beneficial for other reasons than cost (environment, logistics…)
- Even if delays or cancellations, hub solution can still be beneficial

T-CONNECTIONS

- Beneficial when:
  - Low price differences, WF far from shore, simple tee-joint instead of additional platform
  - Lowest prices in country of wind farm
  - Wind farm capacity either low or double the interconnector size
- Economics of split wind farm connections are in general even better.

Hub-to-Hub Connections

- Beneficial when:
  - Low price differences, countries far from each other and WFs close
  - Wind farm connection capacity high compared to interconnection capacity
- Links to the country with most often highest prices should be largest

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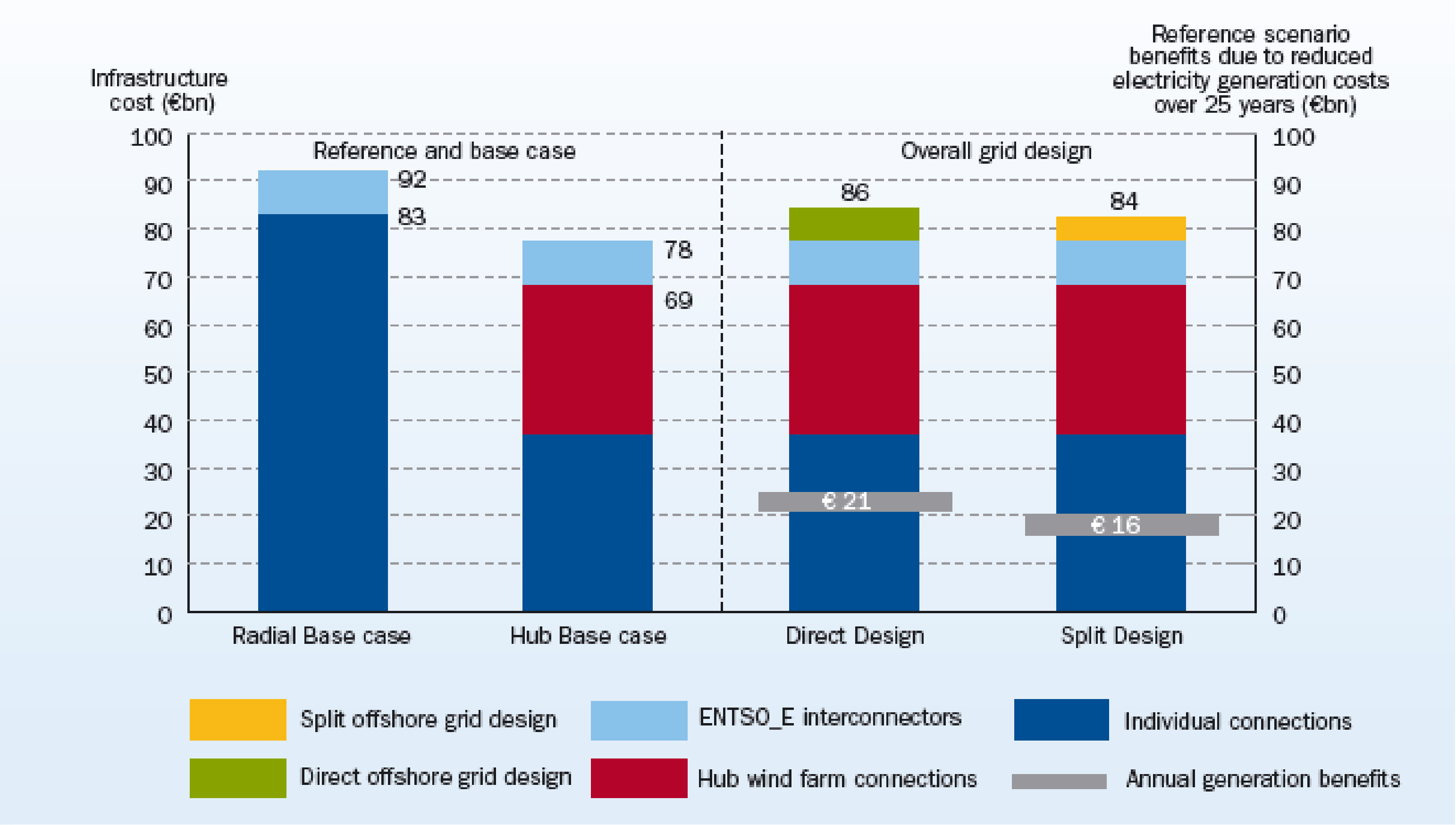
Main Results in a Nutshell – Total costs



- Hub connection saves €14 bn .
- Additional interconnections costs €5-8bn and bring benefits €bn 16-21
- The financial numbers speak clearly for an offshore grid.

Summary conclusions – Overall grid design

- Two offshore grid design methodologies were assessed
  - Direct design: builds on direct interconnectors, then integrated solutions and meshed links
  - Split design: builds interconnections by splitting wind farms, then integrated solutions and meshed links
- Where beneficial, split connections have proven to be more cost-effective then direct interconnections

> - An offshore grid will be built step by step. Every step influences both the future and the existing projects → To identify an efficient design is a highly complex problem
> - The two designs presented in this report bring useful understanding and conclusions that allow the grid development to be brought forward with modular steps in the best possible way.

Final conclusions

- The following key benefits of an interconnected offshore grid are supported by the OffshoreGrid findings:
  - Can be highly beneficial from an economic perspective
  - Contributes to reaching the 20-20-20 target
  - Will increase the security of supply
  - Is a step towards an integrated electricity market
  - Helps to smooth fluctuations and integrate RES
  - Further connects northern storage capacities to the power system

> The advantages of an offshore grid are clear.
>
> Now policy support as well as EU coordinated review of regulatory regimes is needed to implement innovative design solutions and create the beneficial offshore grid.