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Costs and benefits of offshore grids

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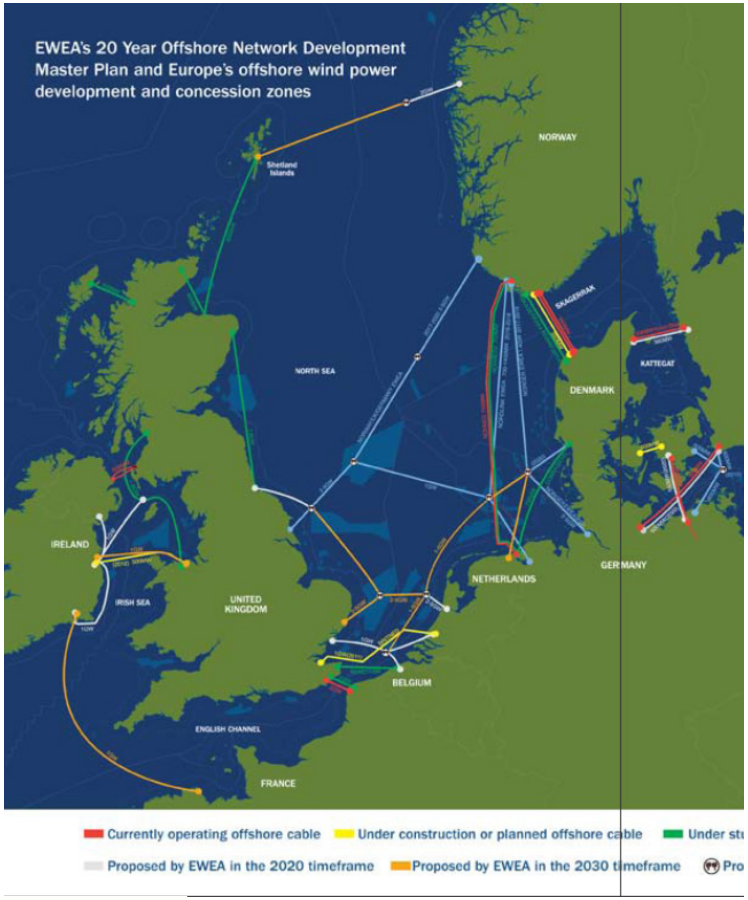

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Contents

- Why offshore grids?
- Challenges
- Offshore grid concepts
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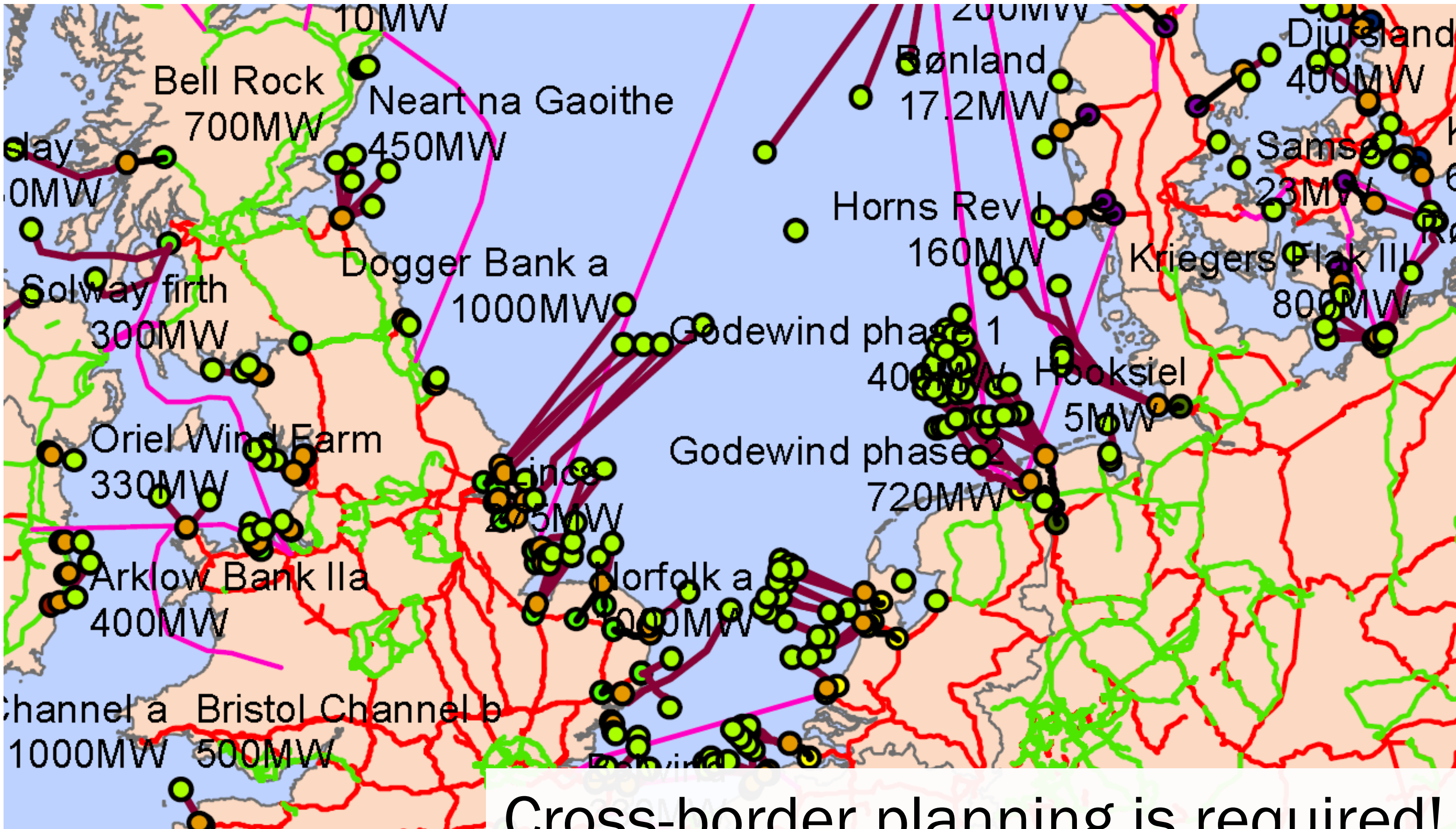
A scenario of 130 GW offshore wind power in 2030..



Cross-border planning is required!

Source: A. Woyte, 3E/OffshoreGrid

Drivers for Offshore Transmission

OffshoreGrid

COMPETITION & MARKET

- Prices differences push for more commercial interconnectors
- Improve competition on EU energy market and support trade

INTEGRATION OF RENEWABLES

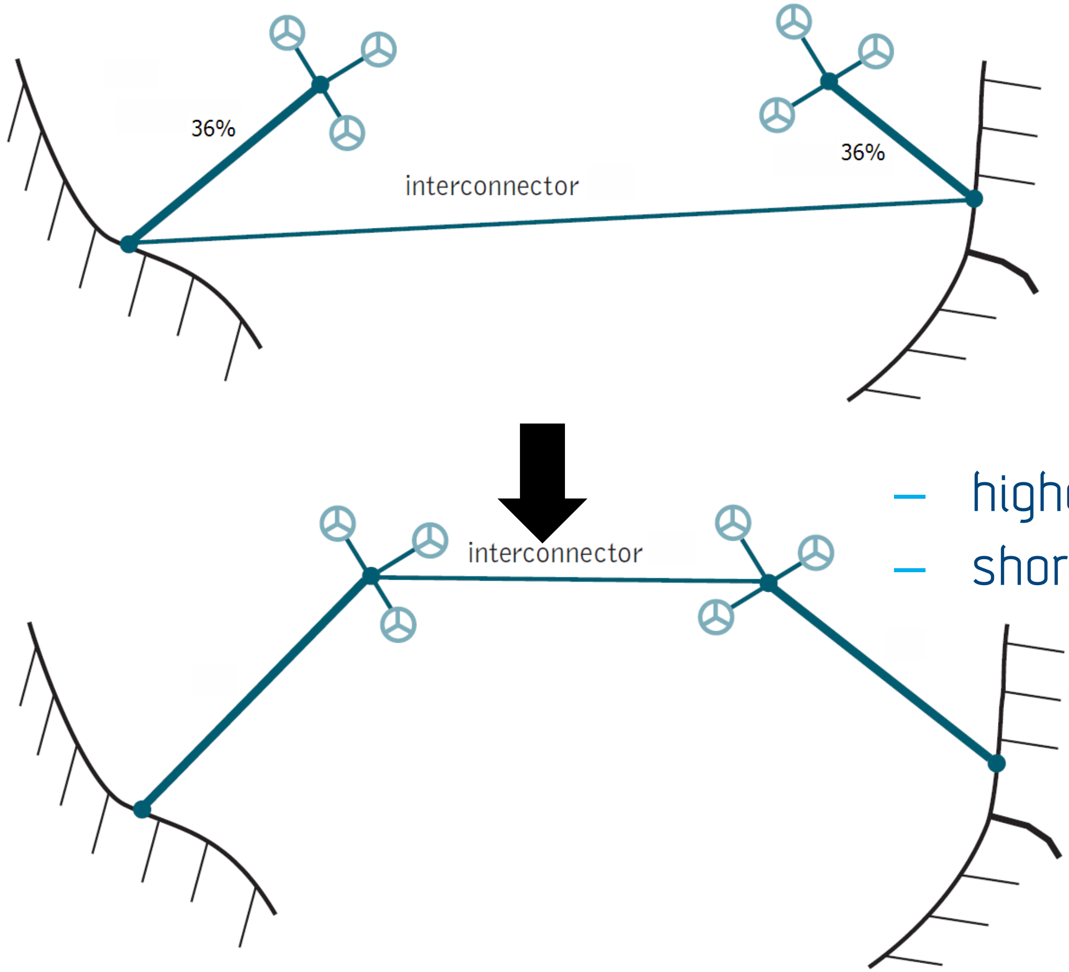
- Spatial smoothing of wind power
- Introduction of flexibility: e.g. reservoir hydropower in Norway

SECURITY OF SUPPLY & TRANSMISSION ADEQUACY

- Improve connection around North Sea
- Bypass onshore electricity transmission bottlenecks

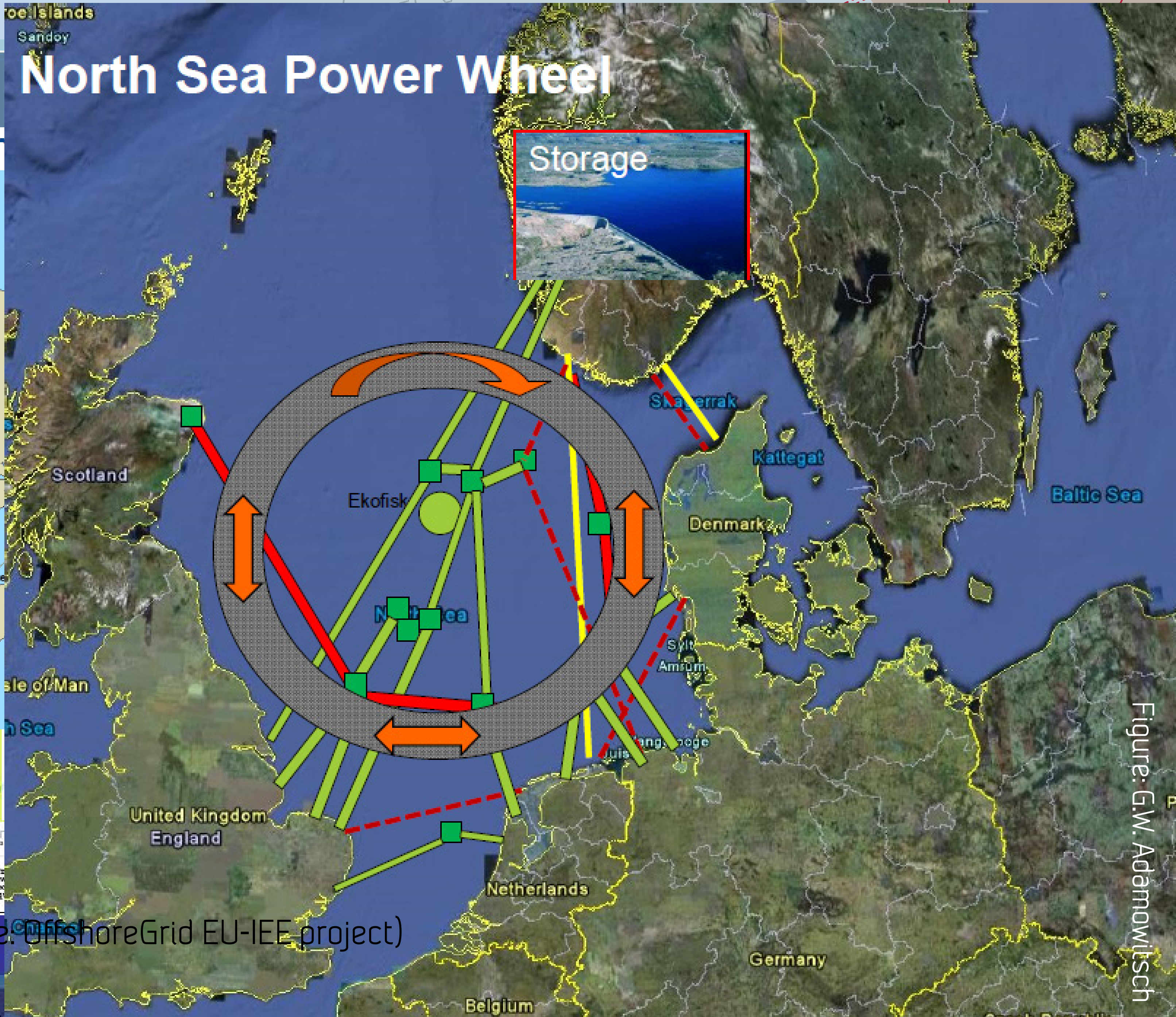
Source: A. Woyte, 3E/OffshoreGrid

Offshore Network : Potential win-win situation



- higher utilisation of assets
- shorter cable distance

Source: A. Woyte, 3E/OffshoreGrid



(Source: OffshoreGrid EU-IEE project)

Figure: G.W. Adamowitsch

Offshore grid challenges

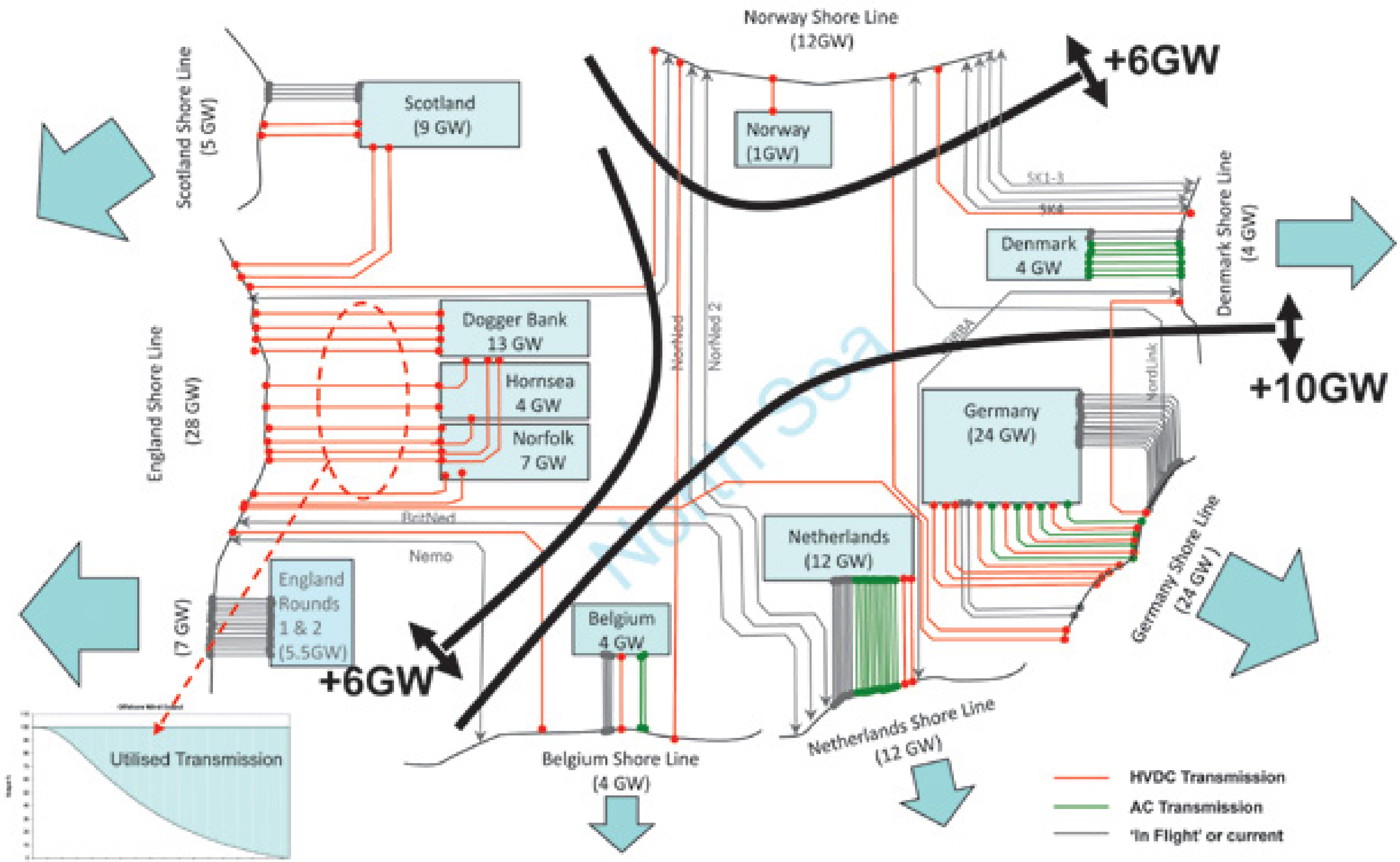
A grid solution that is cost effective for the society must be attractive for the developers!

- Sharing of costs and benefits between TSOs
  - Construction costs, losses, congestion rent, operation costs
- Support for wind power is different around the North Sea
- Different legalisation for
  - Permissions, system operation, grid codes, system operation
- Market integration and balancing of wind power

Joint "North Sea TSO"
Harmonized support schemes for wind power

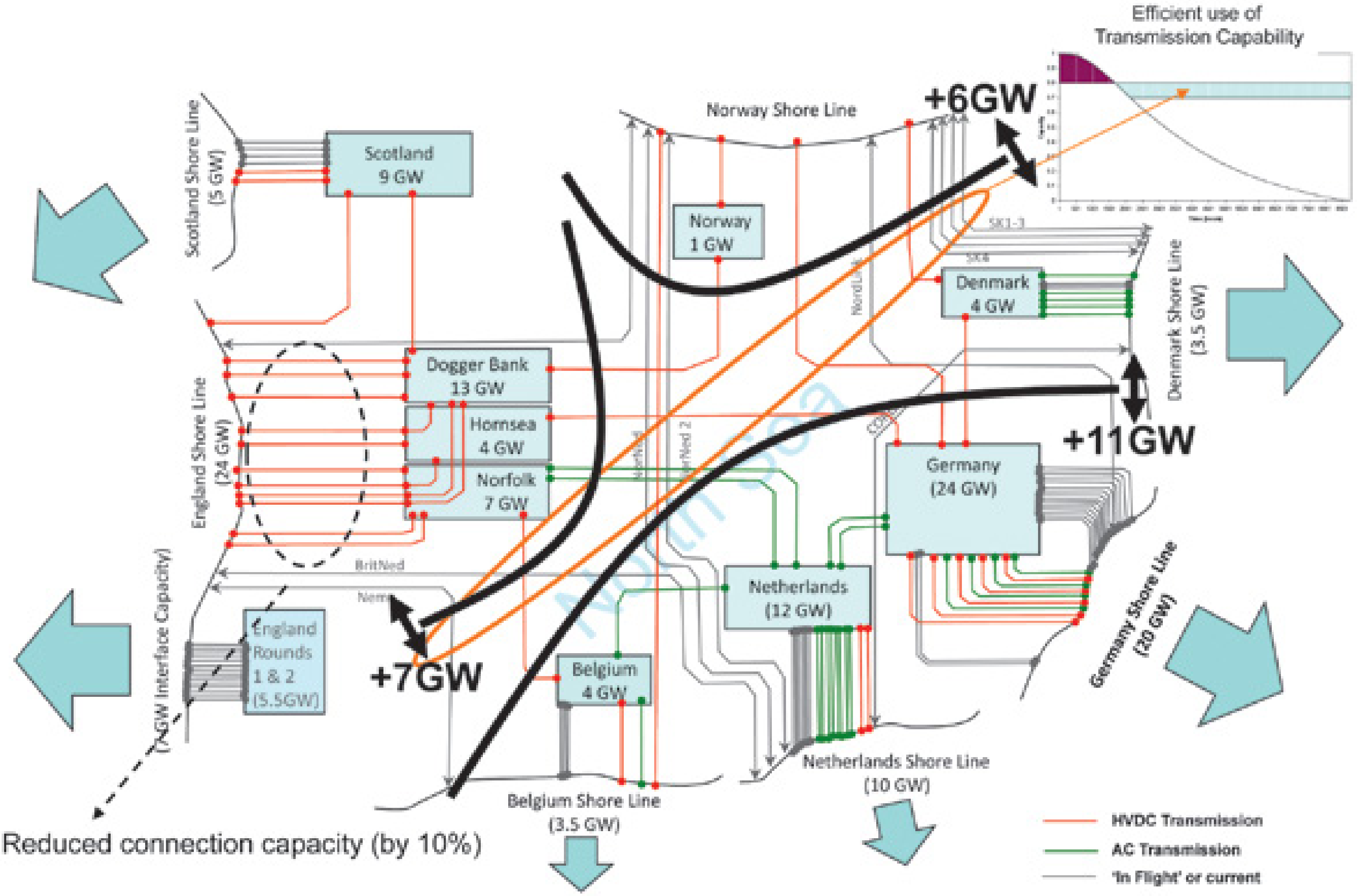
Sources:
•An analysis of Offshore Grid connection at Kriegers Flak in the Baltic Sea By Energinet.dk Svenska Kraftnät Vattenfall Europe Transmission
•Pentalateral Energy Forum : Working plan proposal on offshore electricity infrastructure

ENTSO-E 2030 scenario. Pre-study on direct connections



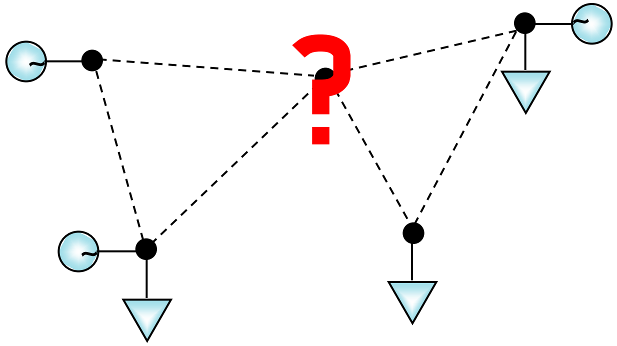
Source: www.entsoe.eu

ENTSO-E 2030 scenario. Pre-study on integrated approach



Source: www.entsoe.eu

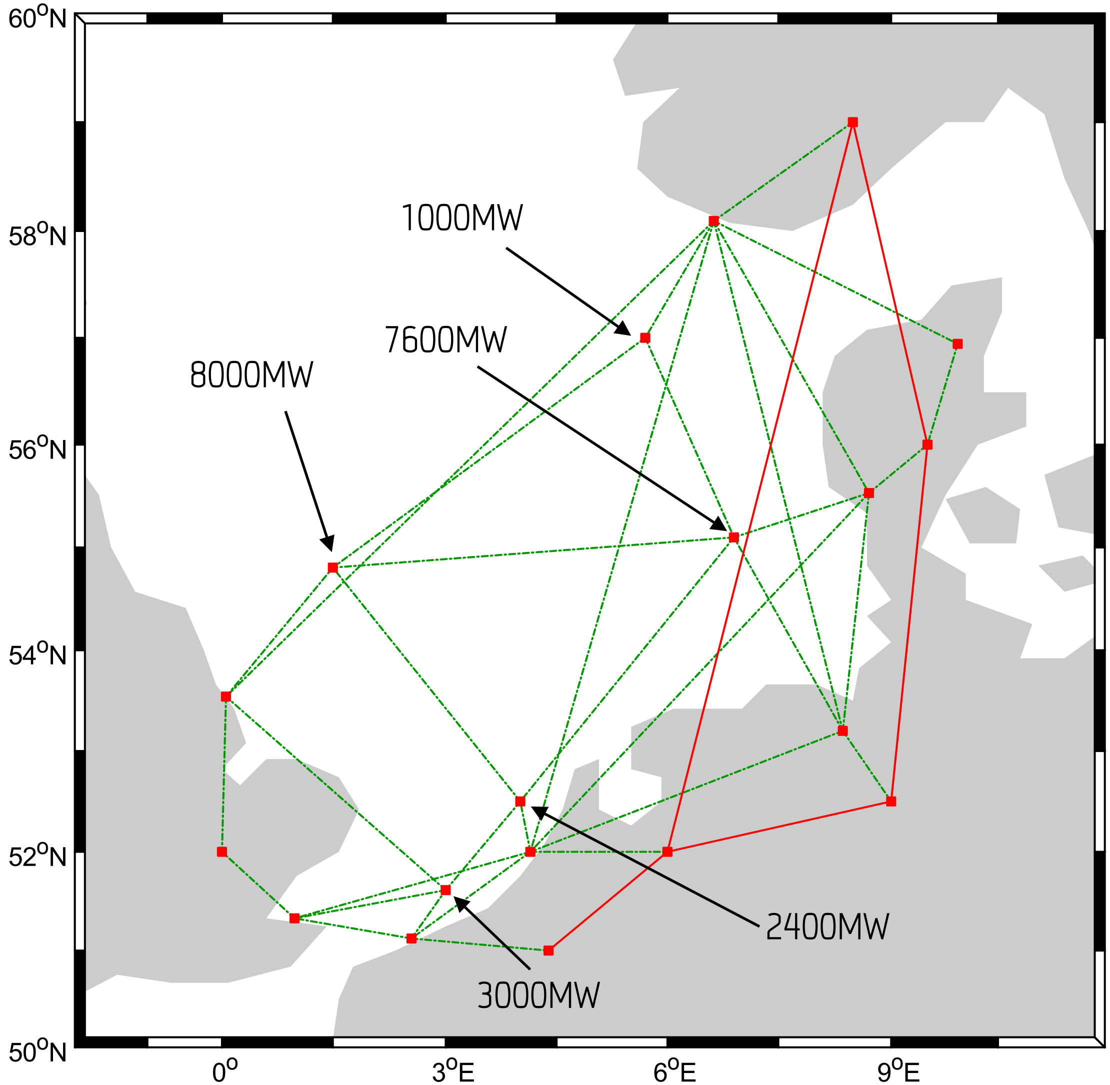
General problem description



- How to connect nodes with transmission lines to achieve optimal social benefit?

Problem:	Connect off-shore wind farms to the on-shore grid and build interconnectors between countries
Objective:	Maximize social economic benefit
Exogenous variables:	Capacity and location of offshore wind power clusters, possible land connection points, statistical description of wind and power prices, onshore grid equivalent, cost scenarios for grid infrastructure.
Unknowns:	Where to build cables and with what power rating
Problem type:	This is a mixed integer problem which can be solved with a branch and bound algorithm

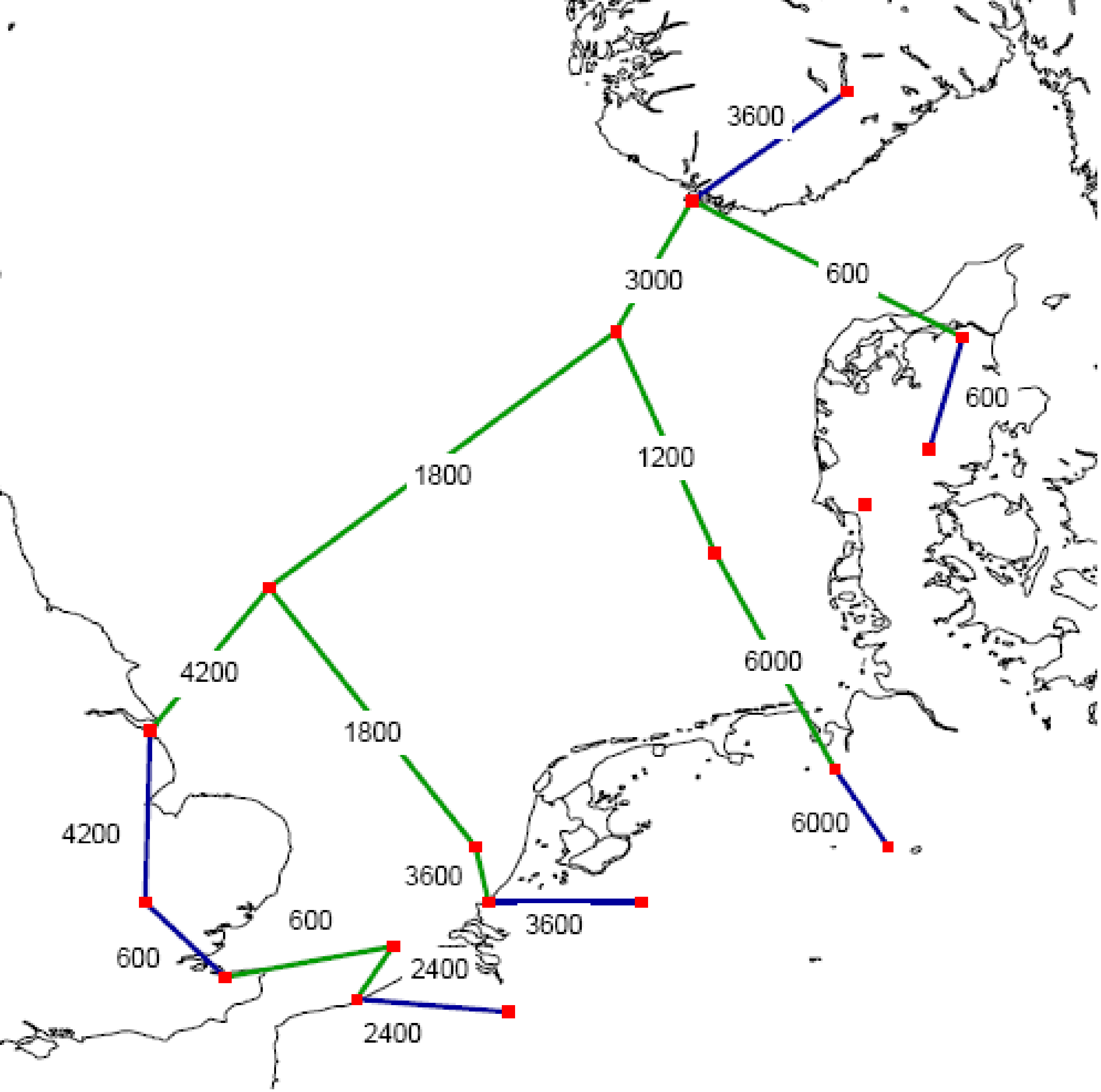
All considered interconnectors



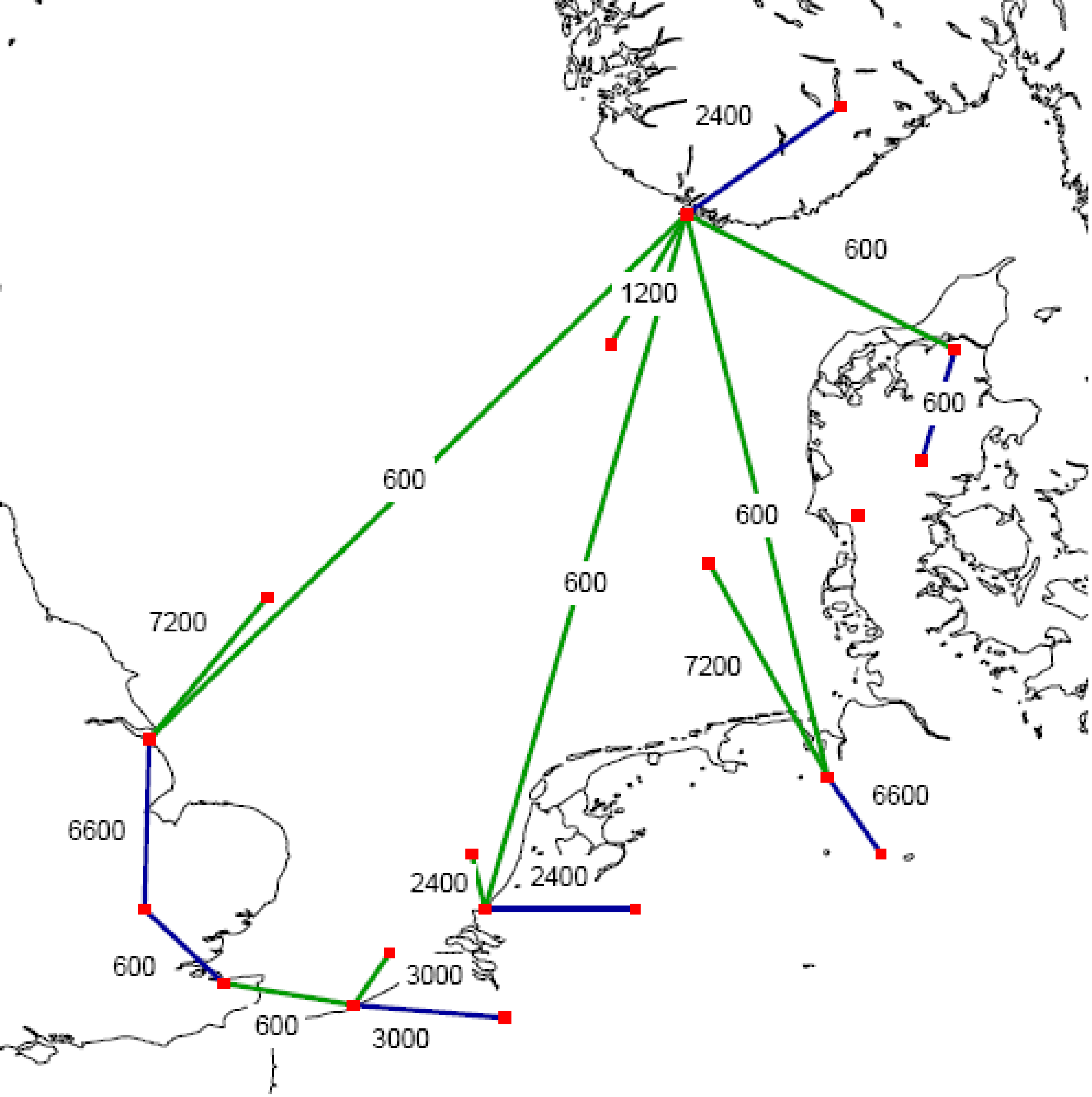
- 33 considered projects
  - Leads to 1e25 possible configurations
  - Impossible to enumerate
- Onshore wind and other offshore wind, TradeWind "2030 medium wind" scenario
  - Norway: 4980MW
  - Denmark: 7291MW
  - Germany: 46606 MW
  - Netherlands: 13246MW
  - Belgium: 2026MW
  - UK: 35312MW

See Trötscher, Korpås: Wind Energy, Wiley (2011)

An example of an optimized grid...



See Trötscher, Korpås: Wind Energy, Wiley (2011)



Locked to radial connections only...

- Investement in grid infrastructure approx. 27 billion. €
  - Depending on cost scenario
- Savings by allowing a meshed grid: approx. 2 billion €
- Better reliability for wind farms with a meshed grid
- Meshed grid is more complex to operate
- Uncertain costs of t-offs/circuit breakers

See Trötscher, Korpås: Wind Energy, Wiley (2011)

First conclusions: Offshore grid optimization

- Meshed grids give better economic benefit for the EU as a whole than do radial connections
  - Steps should be taken to reduce regulatory barriers
  - Pre-study indicates potential of savings of around 9-13% of investment cost
- Meshed grid have a higher utilization rate than do radial wind farm connections (~70% vs ~45%)
- Cost of VSC HVDC T-offs/circuit breakers as opposed to distance to shore will influence optimal grid structure
  - Higher costs short distance → radial + bilateral interconnectors
  - Lower costs long distance → meshed grid
- Meshed grids also…
  - … Improves reliability of grid connection for wind farms
  - … Makes it viable to connect wind farms further offshore