North Sea Offshore Networks; Enabling Offshore Wind and Balancing Power
London 6-8 June 2011

Designing offshore grid layouts and analysing their power market impact

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NOWITECH in brief

- **Objective:**
  Pre-competitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis on deep sea (+30 m).

- **Work packages:**
  1. **Numerical design tools (including wind and hydrodynamics)**
  2. **Energy conversion system**
     (new materials for lightweight blades & generators)
  3. **Novel substructures (bottom-fixed and floaters)**
  4. **Grid connection and system integration**
  5. **Operation and maintenance**
  6. **Concept validation, experiments and demonstration**

- **Total budget (2009-2017):**
  +NOK 320 millions including 25 PhD/post docs

R&D partners

SINTEF

NTNU – Trondheim
Norwegian University of
Science and Technology

IFE
Institute for Energy Technology

Associate R&D partners

Risø DTU
National Laboratory
for Sustainable Energy
DTU

Fraunhofer
IWES

University of
Strathclyde
Glasgow

Massachusetts
Institute of
Technology

NREL

TU Delft

Industry partners

Vestas

Vestavind OFFSHORE

NTE

Statkraft

Lyse

FUGRO FUGRO OCEANOR

GE

Statoil

DONG energy

EDF

Statnett

DEVOLD AMT Advanced Multiaxial Technology

SmartMotor Energy Efficient Technology

AkerSolutions™

DNV

Associate industry partners

NORWEA Norsk vindkraftforening

EnergiNorge

Navitas Network

NVE

Norwegian Centres of Expertise NCE Instrumentation

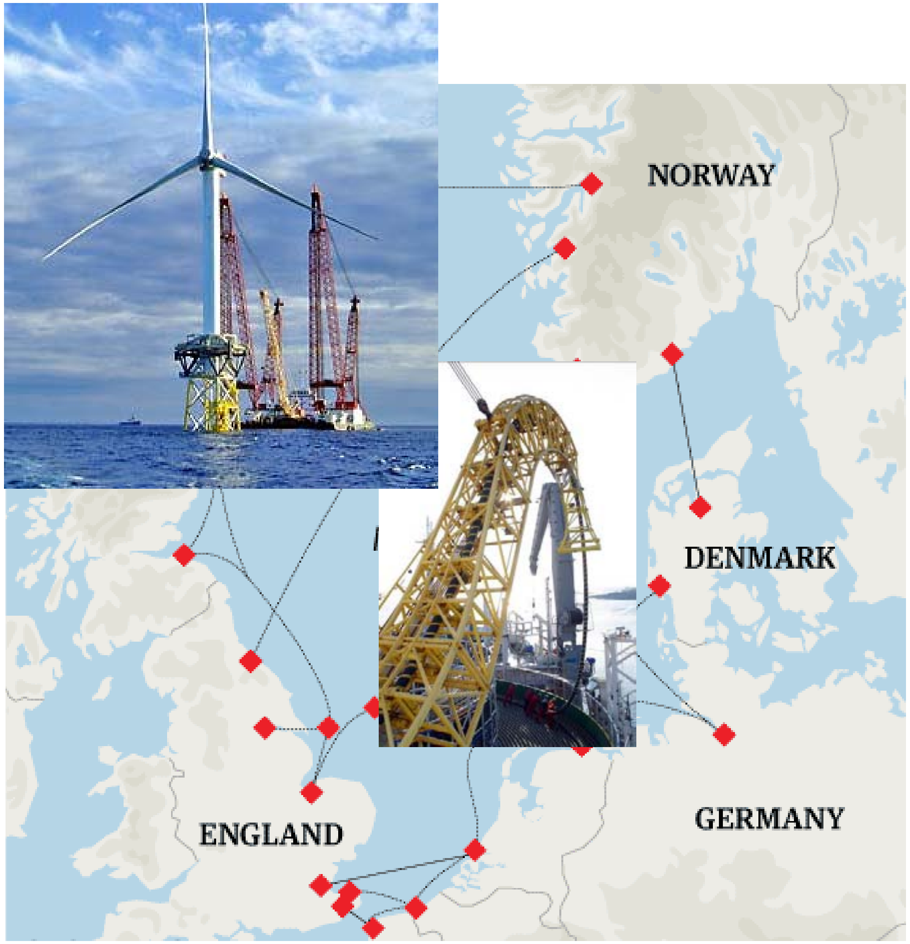
enova

INNOVATION NORWAY

NOWITECH Work Package 4:
Grid connection and system integration

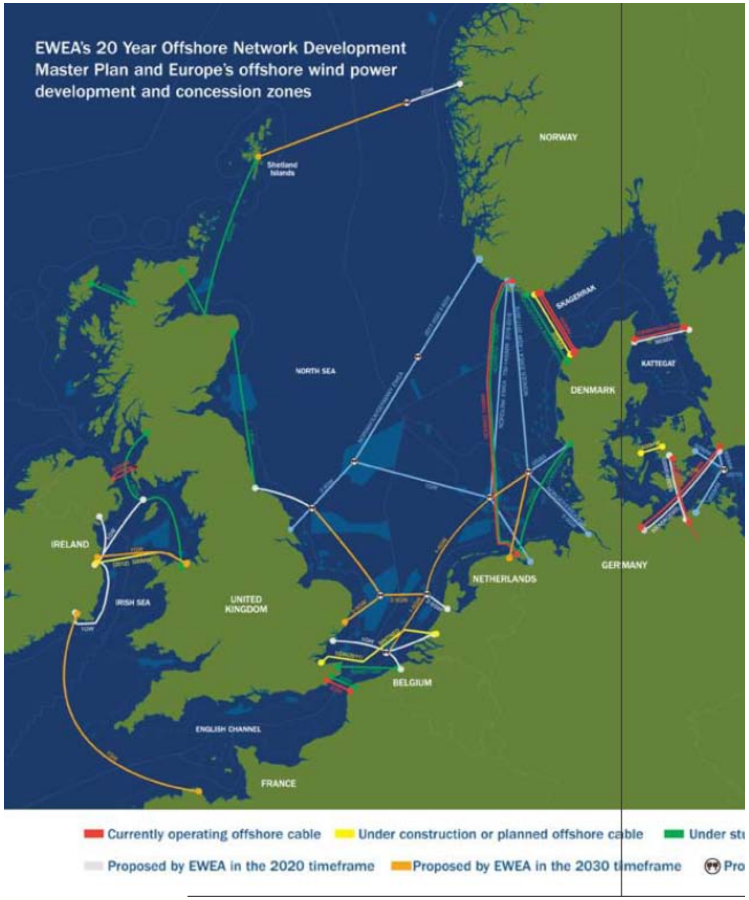
Objective:

To develop technical and market based solutions for cost effective grid connection and system integration of offshore wind farms.



Three main tasks:

- Internal electrical infrastructure for offshore wind farms
- Grid connection and control
- Market integration and system operation

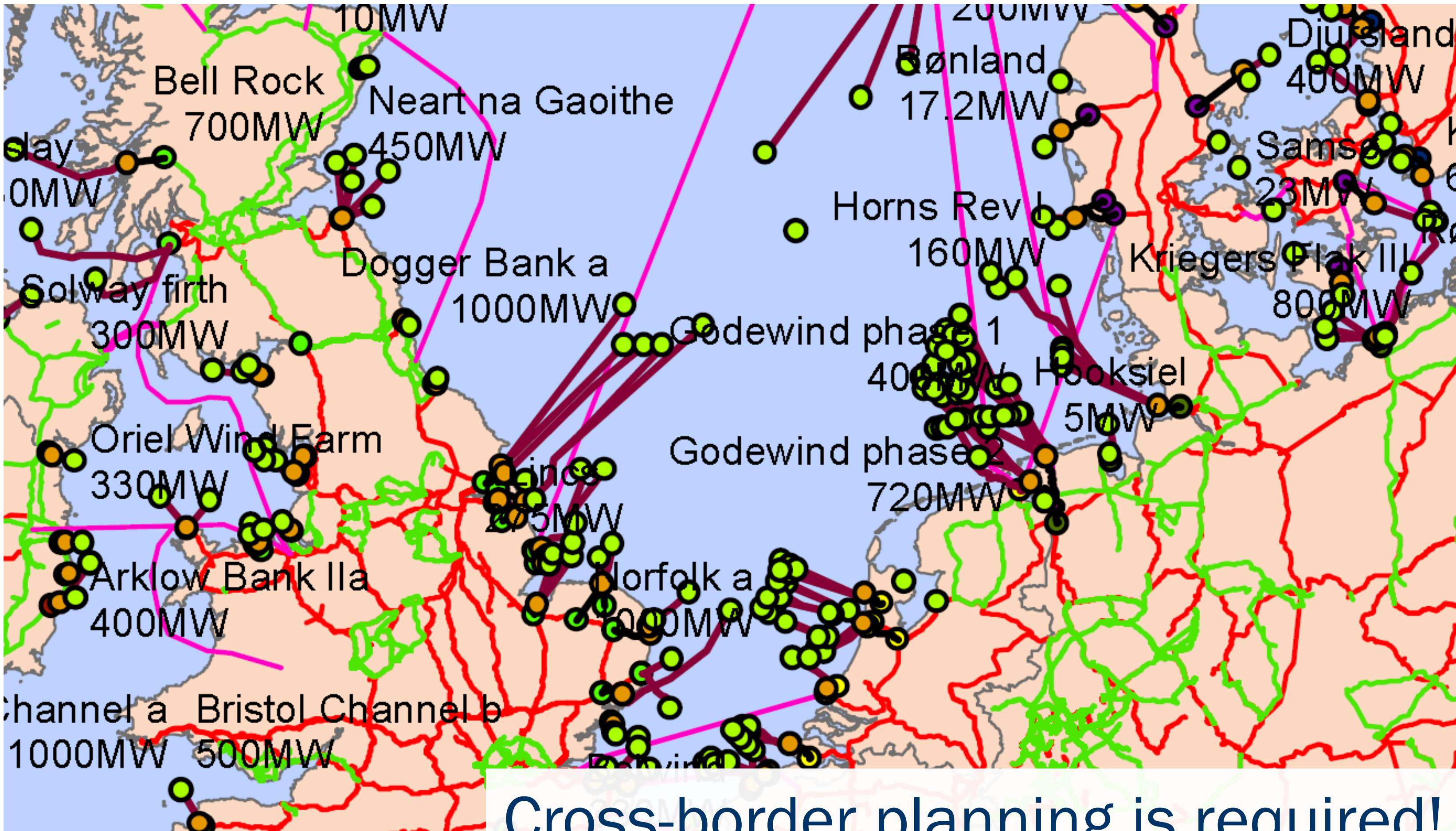


EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

Contents of presentation

- Why offshore grids?
- Offshore grid concepts
- An optimization approach
- Power market simulations

A scenario of 130 GW offshore wind power in 2030..



Cross-border planning is required!

Source: A. Woyte, 3E/OffshoreGrid

Building interconnections

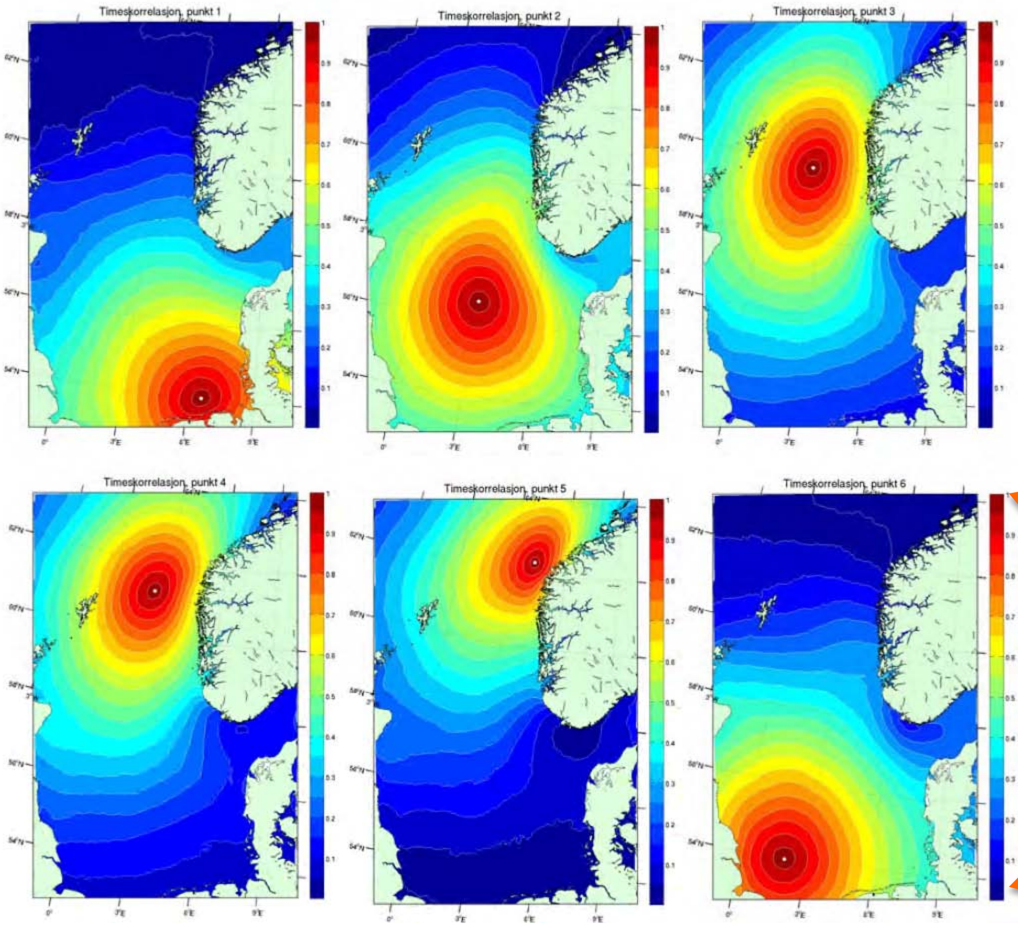


Figure shows correlation for hourly wind velocity in the North Sea.

Source: Kjeller Vindteknikk

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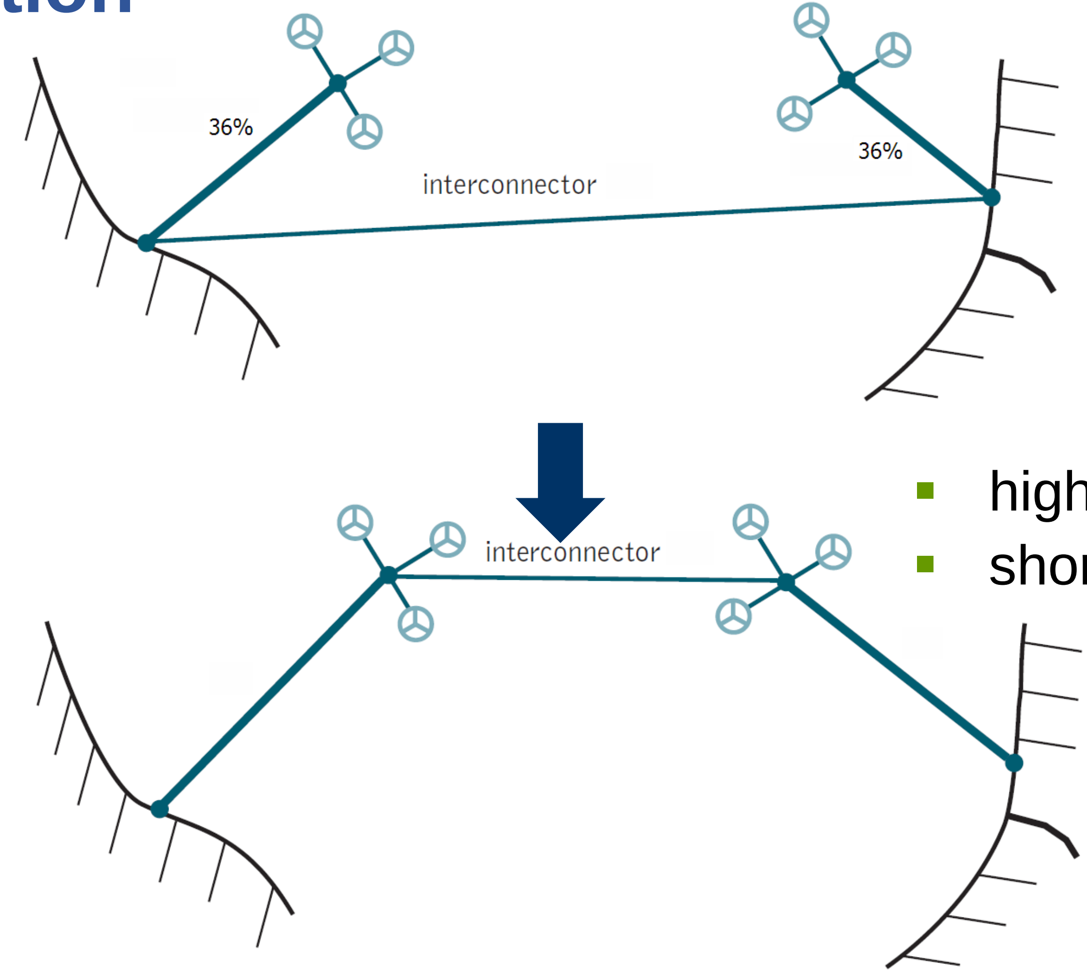
Correlation coefficient

Offshore Network : Potential win-win situation

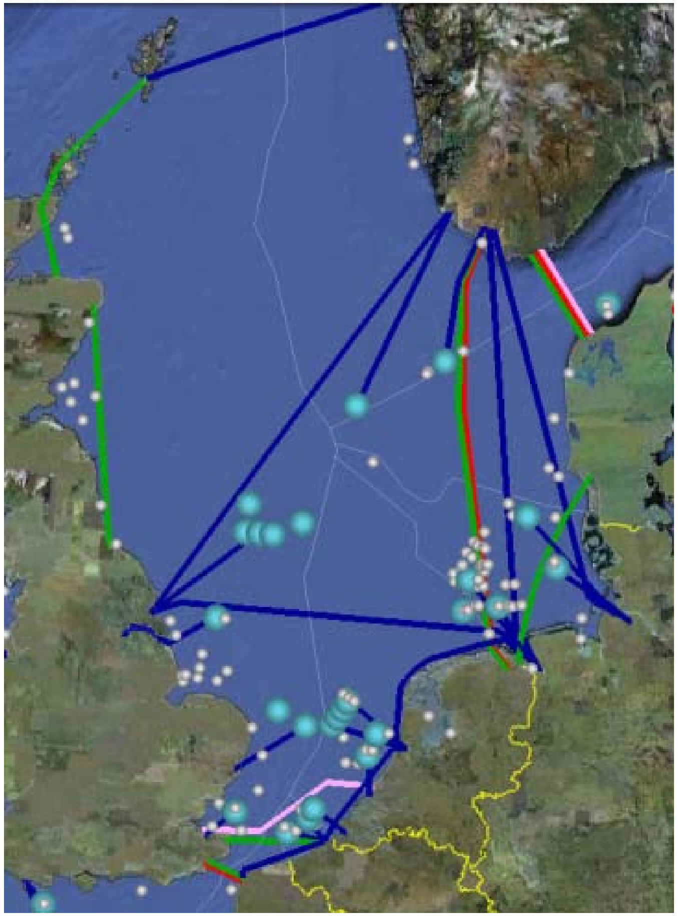


- higher utilisation of assets
- shorter cable distance

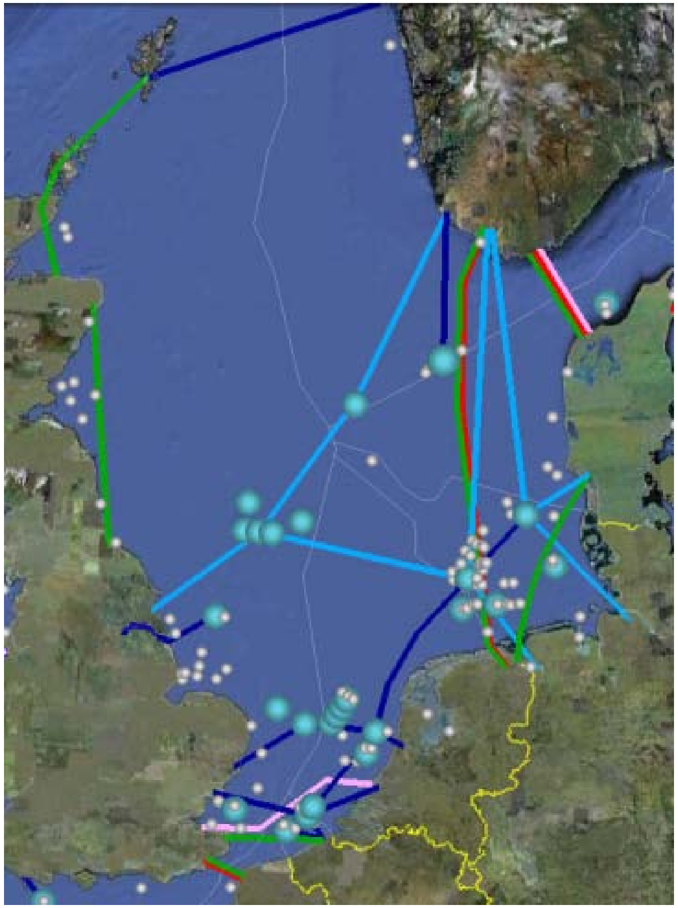
Source: A. Woyte, 3E/OffshoreGrid

Example Scenarios from the OffshoreGrid project

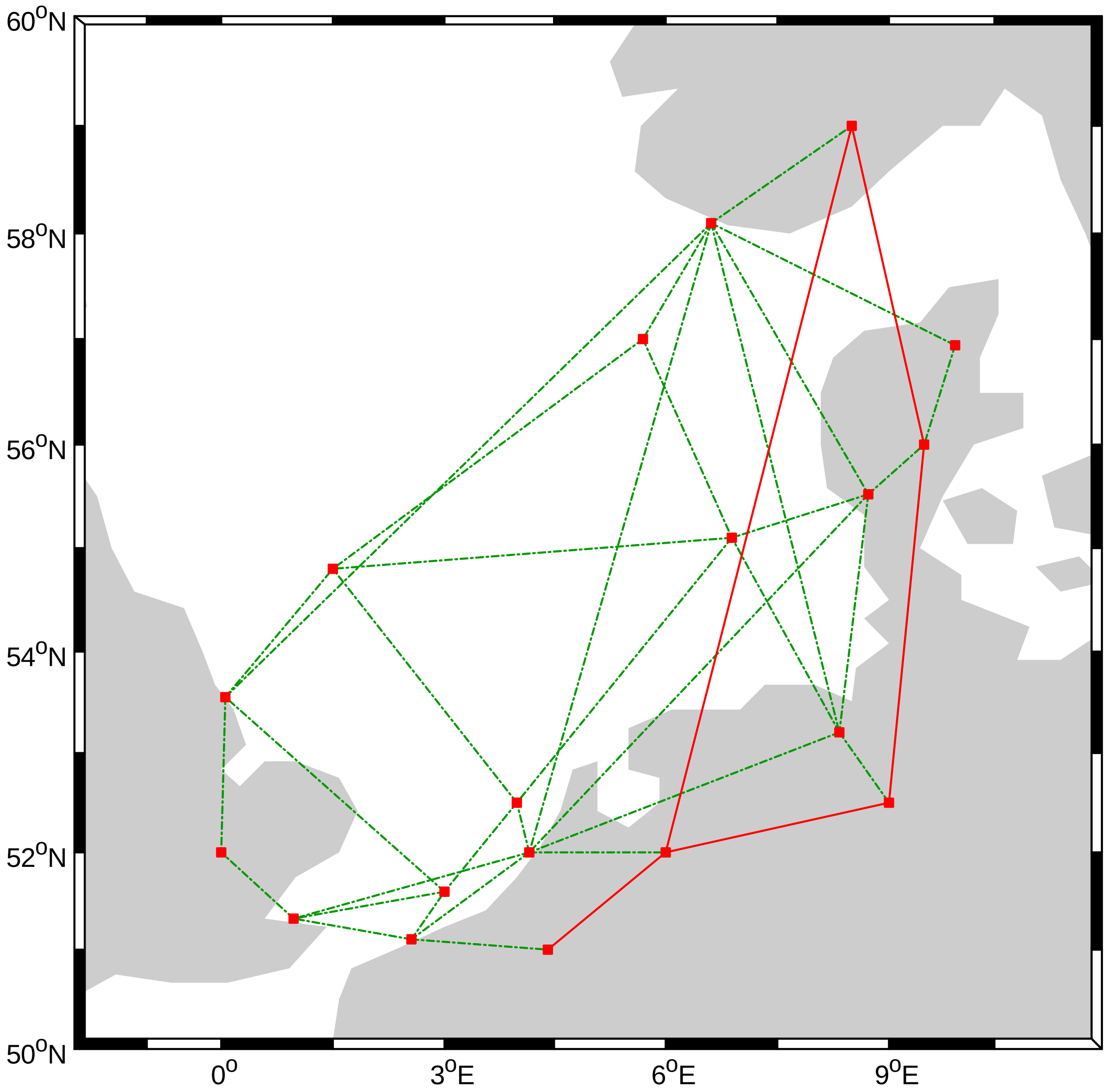
“Trade-driven approach”



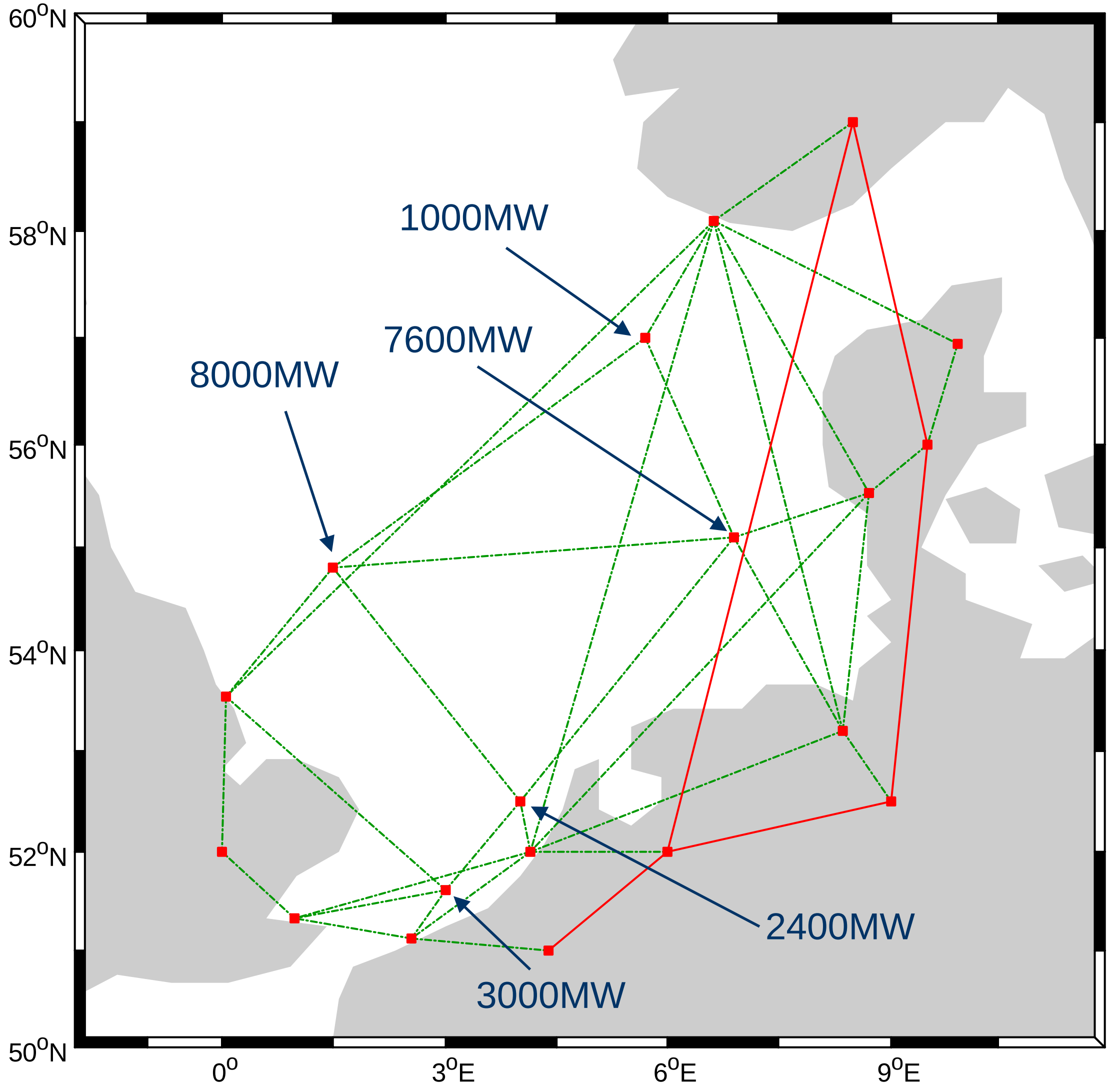
“Trade- and wind-driven approach”



Offshore grid optimization



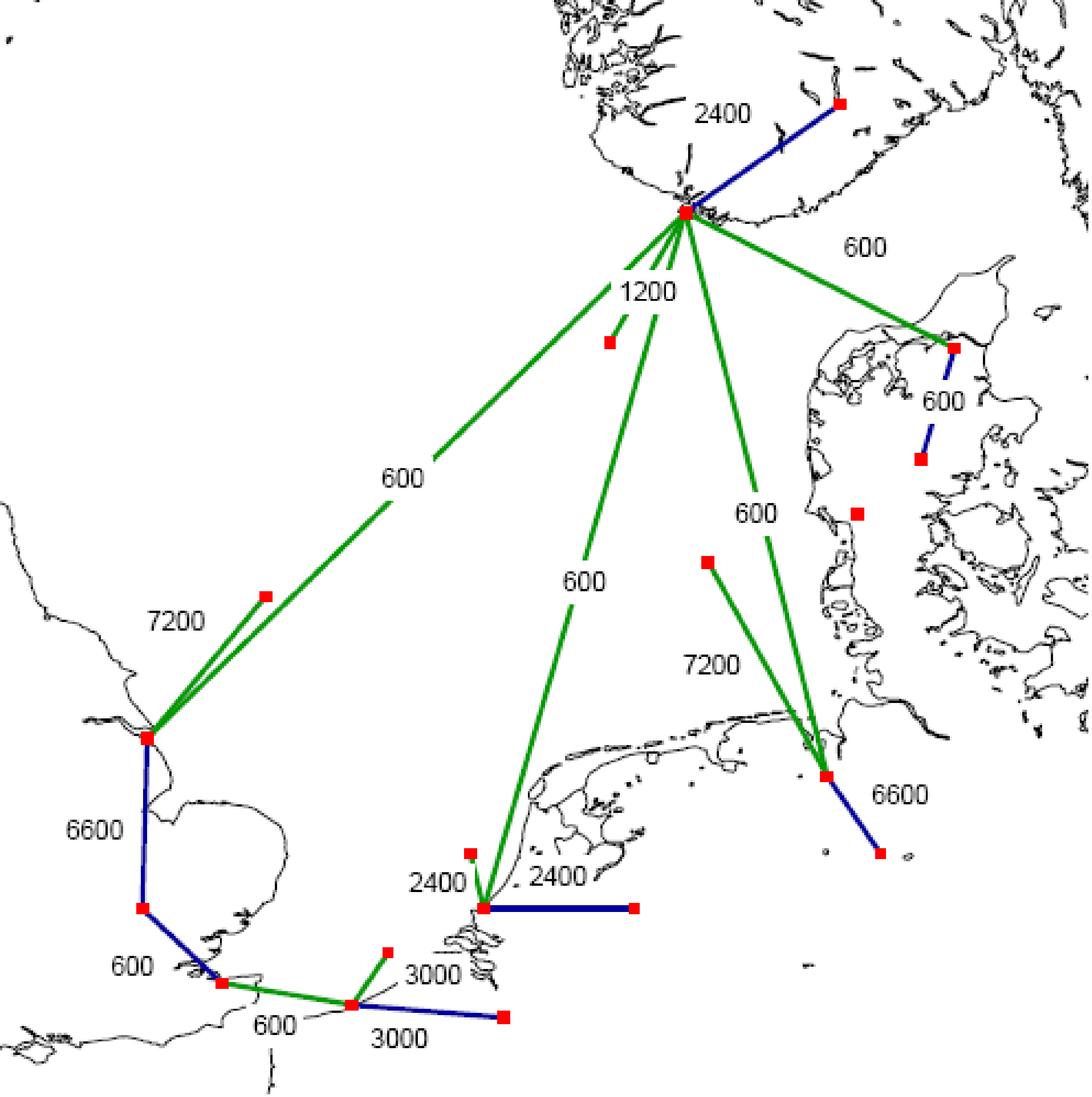
- Find an optimal grid structure taking into account:
  - Wind power variations
  - Stochastic power prices
  - On- and offshore load and generation scenarios
- Use formal optimization for a structured approach to finding good grid layouts
  - Difficult to solve ”by inspection”
  - Huge number of possible grid structures
  - → Combinatorial problem solved efficiently by optimization tools
- Results:
  - Which cables to build
  - Capacity on the cables
- Gives valuable decision support, but:
- Must be combined with market/network model in an iterative procedure



All considered interconnectors

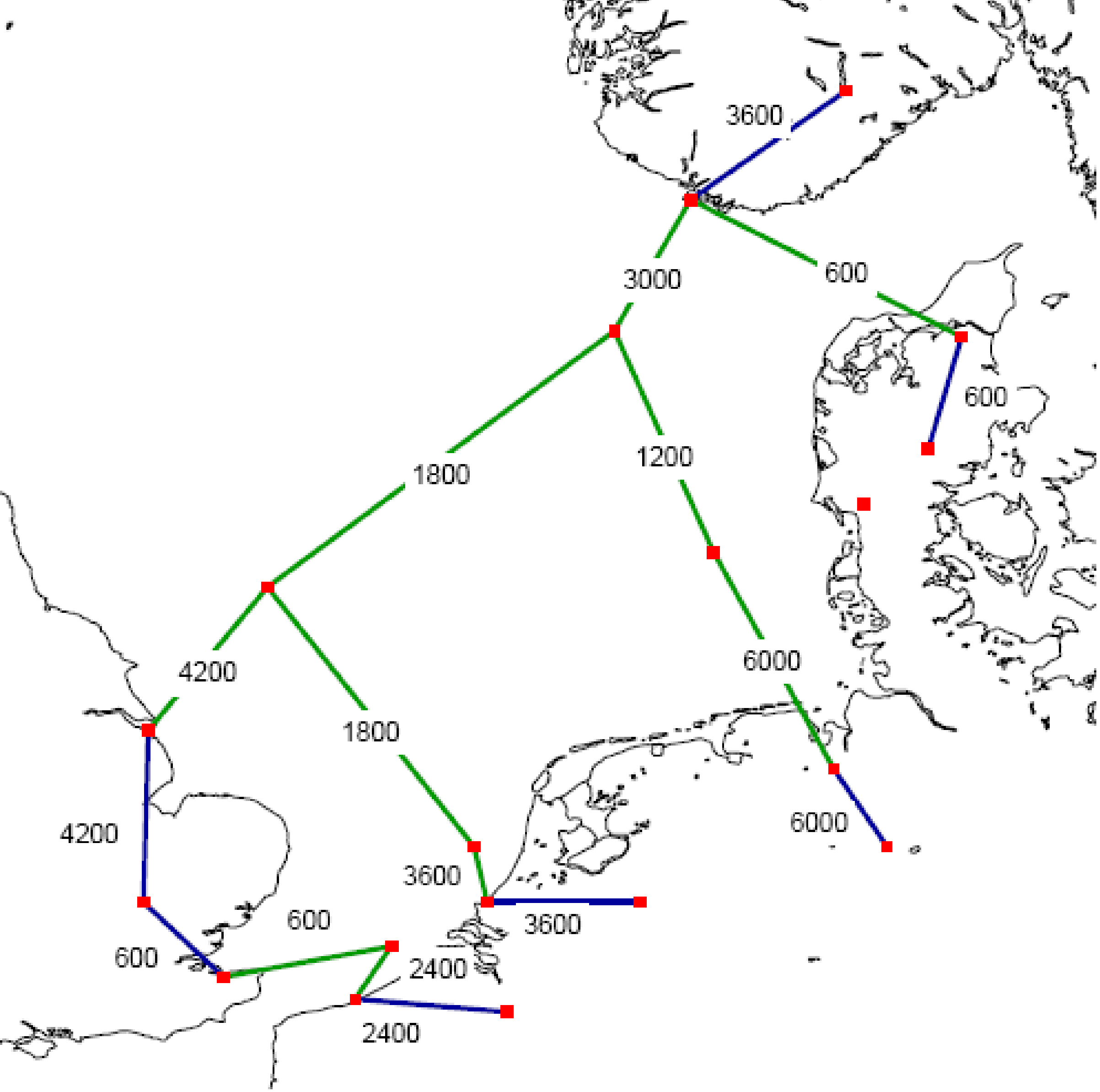
- 33 considered projects
  - Leads to 1e25 possible configurations
  - Impossible to enumerate
- Onshore wind and other offshore wind, TradeWind ”2030 medium wind” scenario
  - Norway: 4980MW
  - Denmark: 7291MW
  - Germany: 46606 MW
  - Netherlands: 13246MW
  - Belgium: 2026MW
  - UK: 35312MW

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



Optimization locked to radials and point-to-point connections only…

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

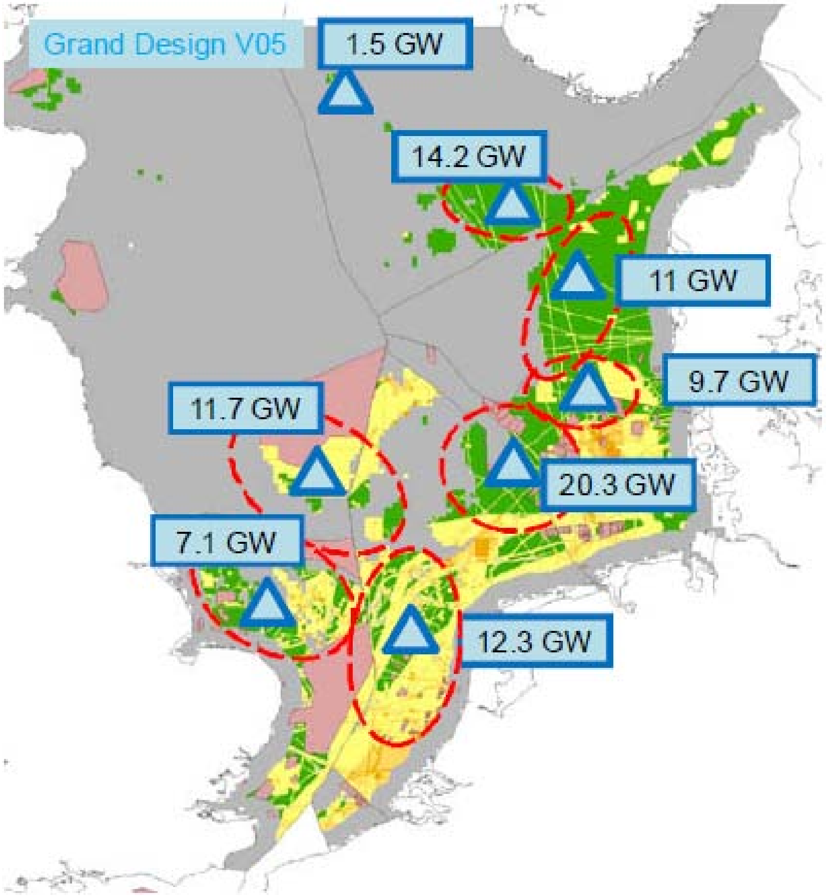


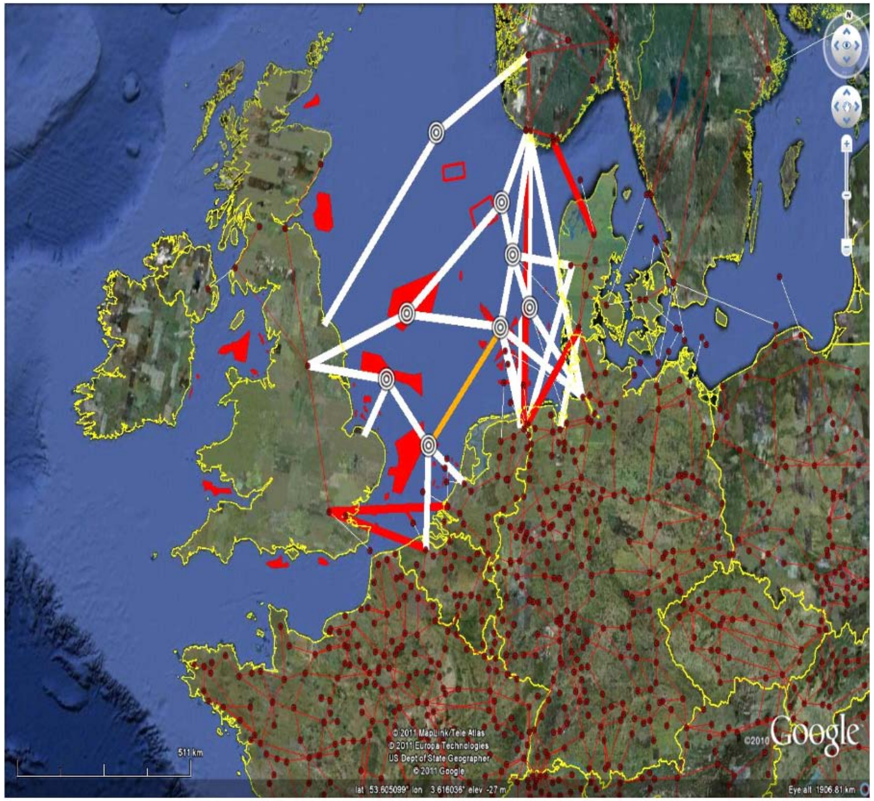
Enabling meshed structures…

- Investement in grid infrastructure approx. 27 billion. €
  - Depending on cost scenario
- Savings by allowing a meshed grid: approx. 2 billion €
- Increased cable utilization
  (70 % vs 45 %)
- Meshed grid is more complex to operate
- Uncertain costs of t-offs/circuit breakers

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

Using the grid optimization tool for the "Grand design" scenario in the WINDSPEED project





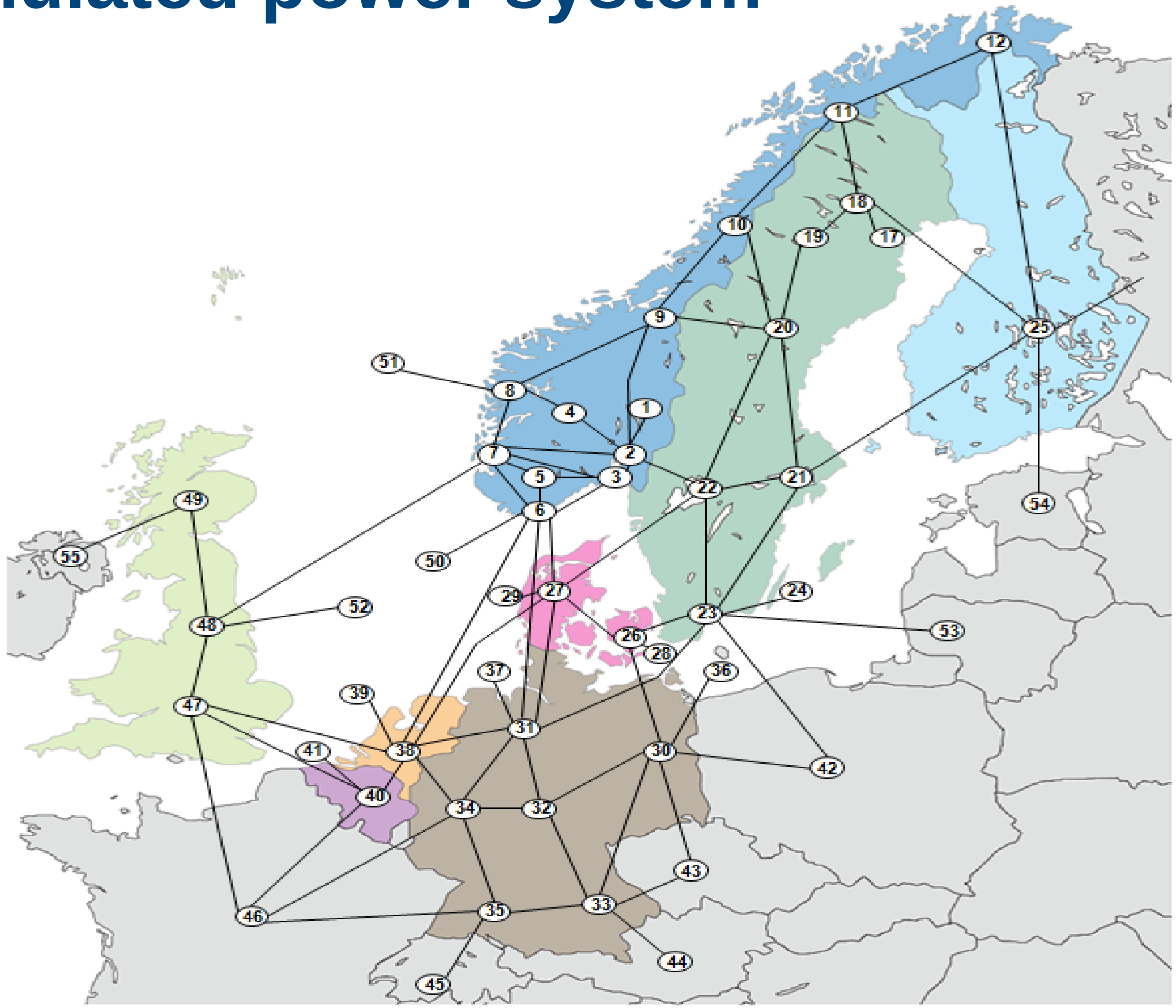
SINTEF project "Role of North Sea" funded by the Norwegian Research Council and industry partners

- **Work package 2: Quantify energy system effects in 2020 of different offshore grid configurations in the North Sea**
  - Prices
  - Transmission
  - Energy balances
  - Socio-economic benefits
  - Reservoir utilization

Important mechanisms under study

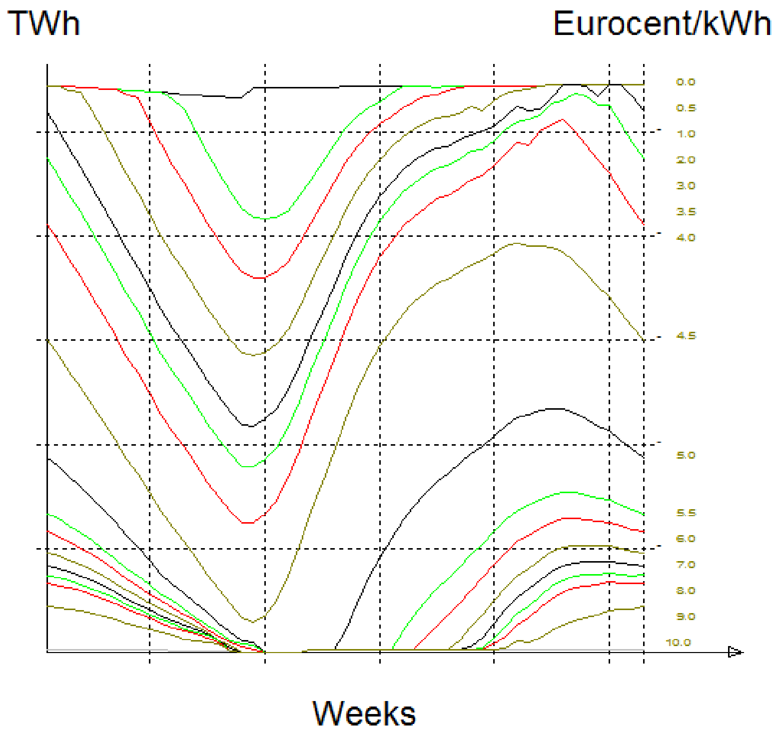
- National goals: large wind-power investments within 2020
- Varying wind-power – and prices
- This adds value to:
  - Transmission capacity in general
  - Flexibility in the transmission system (cf. radial vs. integrated grid)
- We focus on spot market – not balancing market

Simulated power system

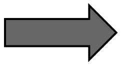


EMPS model: Optimization and simulation

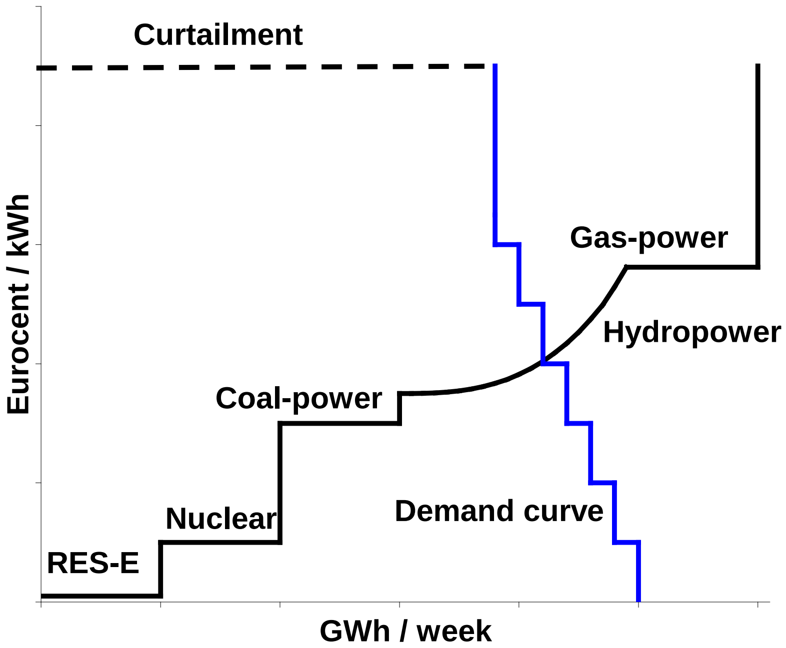
Strategy hydro reservior calculation (SDP)



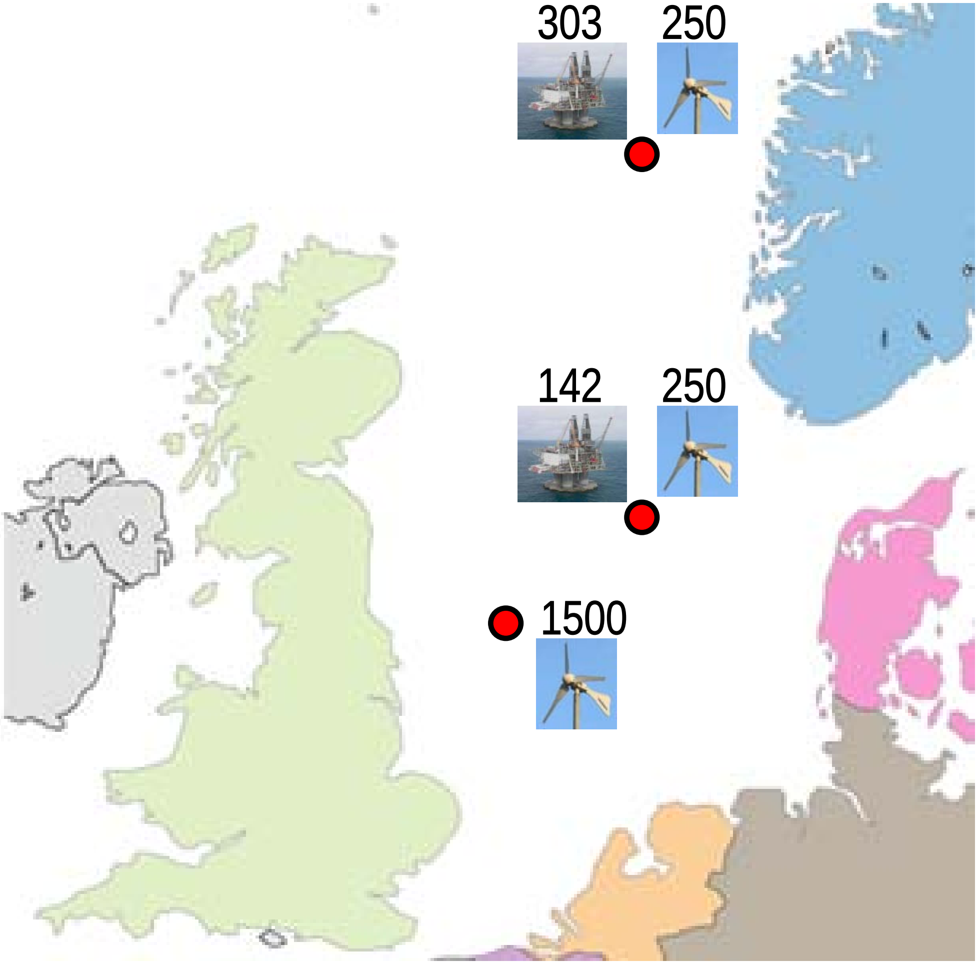
Water value tables



System/market simulation (LP)



North Sea nodes



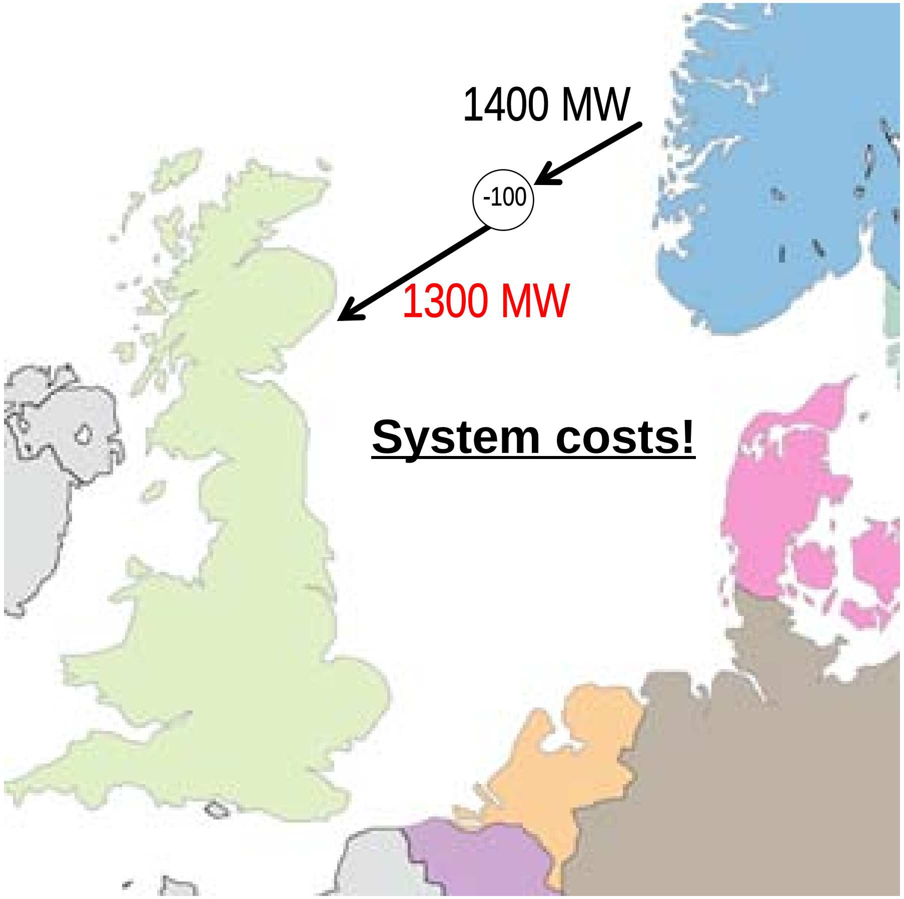
North Sea node

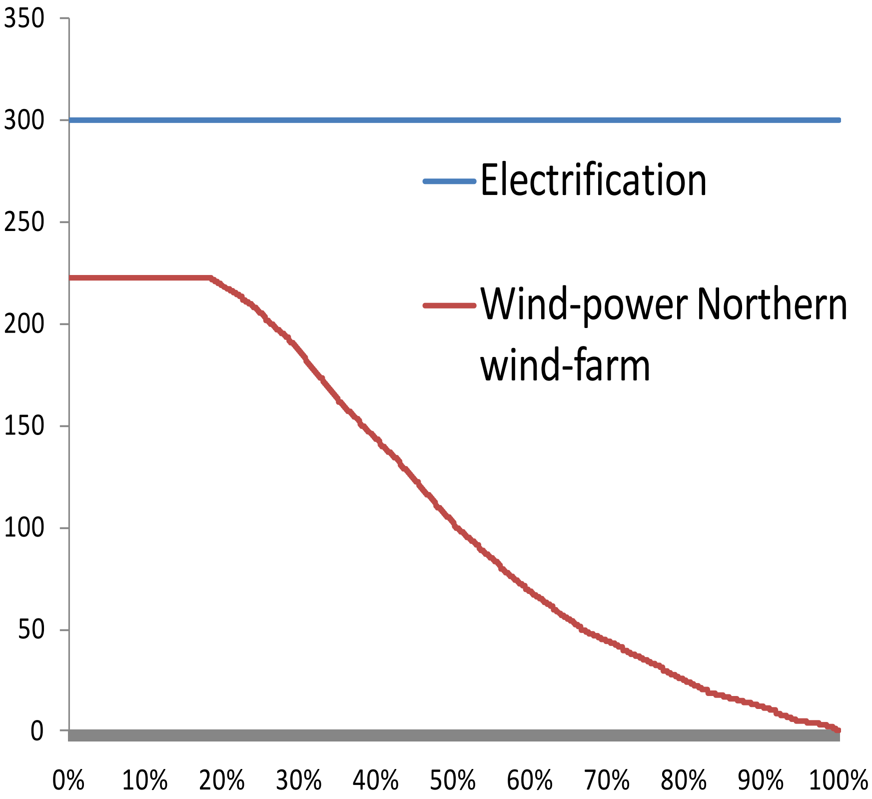
Wind-farm capacity (MW)

Electrification (MW)

Off-shore integration can reduce export potential

Example 2: Wind 200 MW, electrification 300 MW

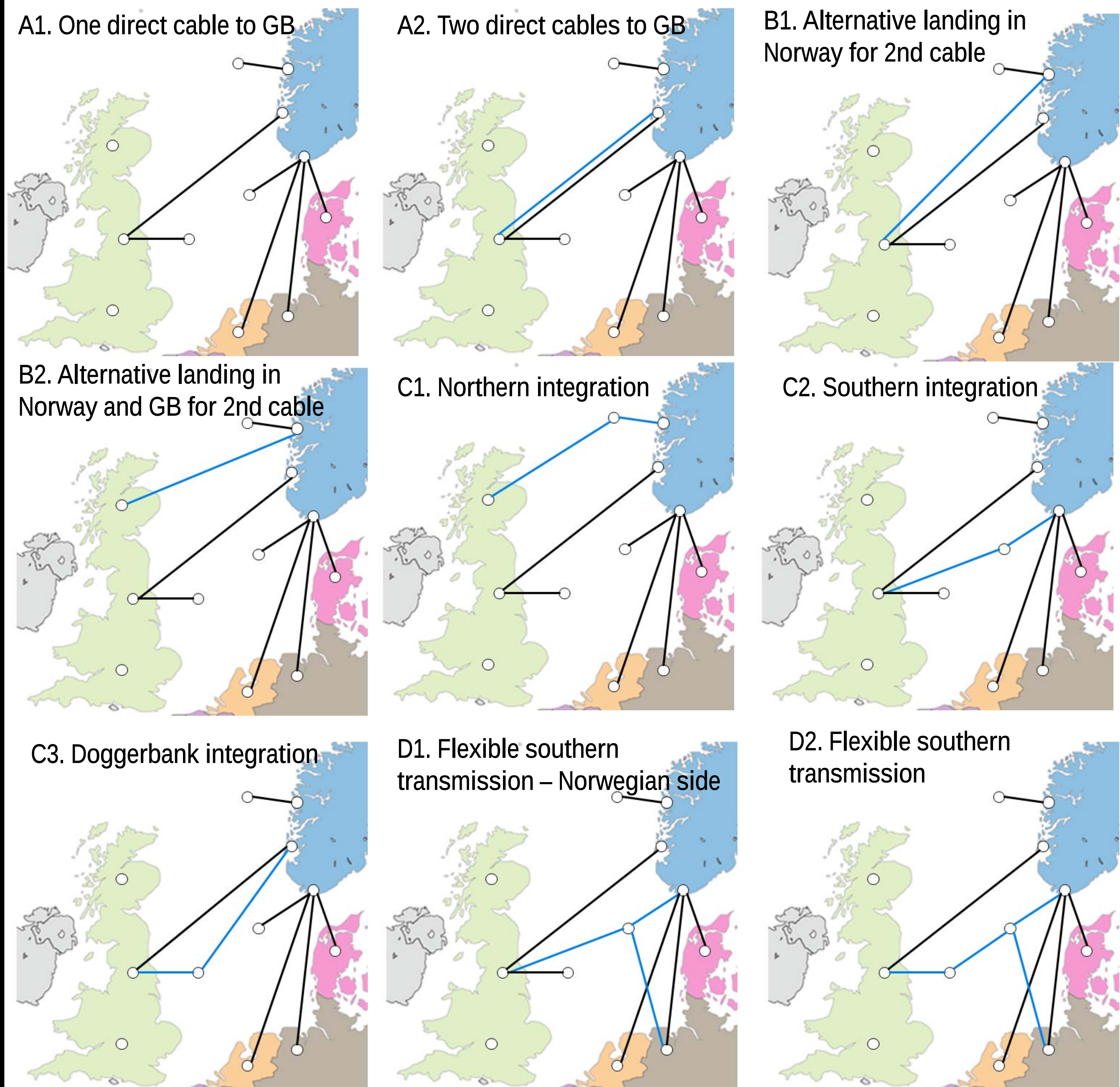




Alternative offshore grid configurations

Case overview

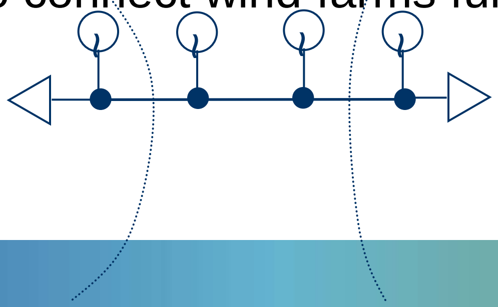
Work in progress



Conclusions I

- Meshed grids may 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



Conclusions II

- The benefits of offshore grids and T-connections heavily depends on the cable sizing
  - A systematic sizing approach is required
- Detailed market/grid simulations is needed to assess the costs and benefits of meshed grid designs vs a “radial and point-to-point” approach to offshore grid planning
- Onshore grid modelling detail influences the simulated utilization of the subsea cables
  - Offshore grid design and building strategy must also reflect the plans and opportunities for onshore grid upgrades
  - Must take into account the expected continued growth in onshore wind development