Northern Seas Offshore Network (NSON)

Challenges and its way forward

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Trondheim, January 18, 2018

Agenda

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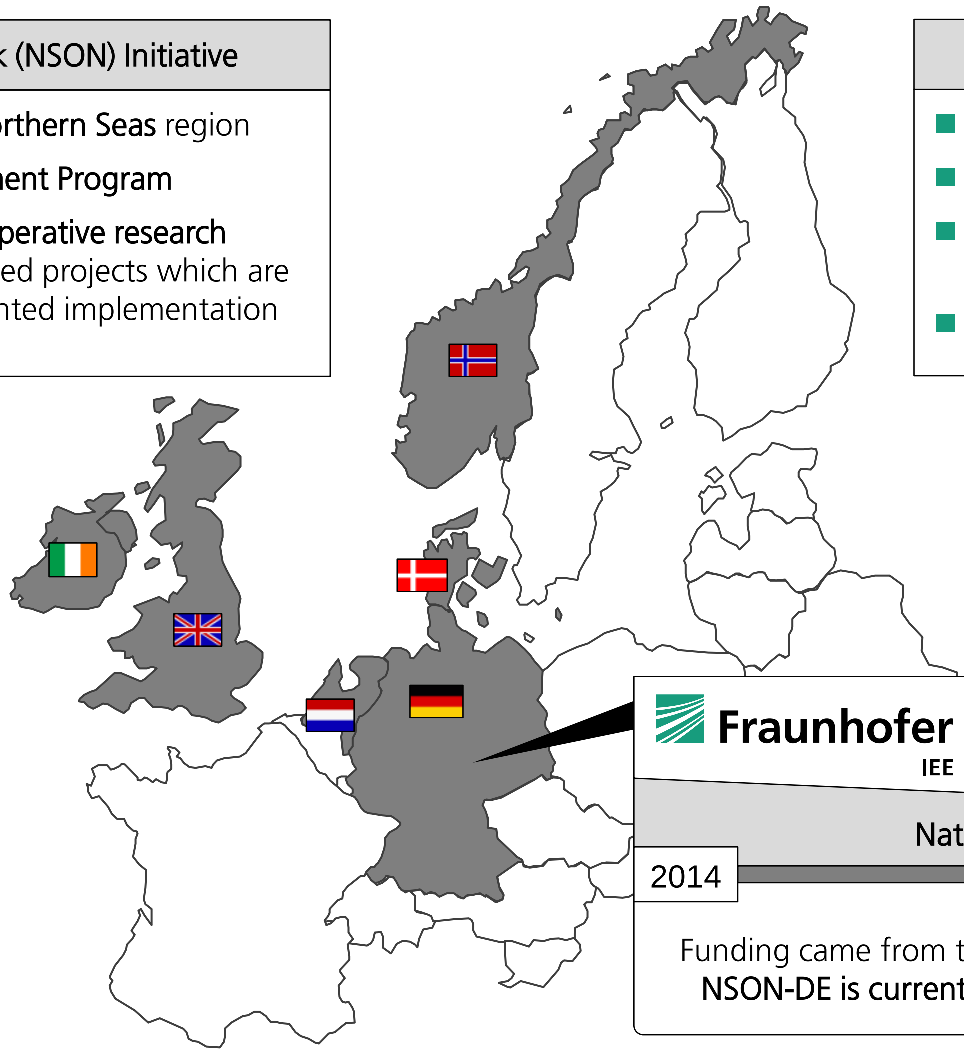
University of Kassel, IEH of Leibniz University Hannover and Fraunhofer IEE are the partners of the national project in Germany (NSON-DE)

Northern Seas Offshore Network (NSON) Initiative

- Pursuing an **offshore grid in the Northern Seas** region
- **Research, Development & Deployment Program**
- **Following the Berlin Model for cooperative research** activities in Europe: nationally funded projects which are guided by a simple and target-oriented implementation

Objectives of the NSON Initiative

- **Harnessing**, **sharing**, and **trading of offshore wind** resources
- Supporting the **utilisation** of **offshore** region's **wind resources**
- Making the **national markets more effient** by increasing connection capacities
- Providing **balancing from Nordic hydropower**



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National NSON project in Germany (NSON-DE)

2014 → 2017

Funding came from the Federal Ministry for Economic Affairs and Energy (BMWi)
NSON-DE is currently being finalised - report to be published by June this year

Agenda

NSON-DE has four modelling stages to investigate potential NSON configurations and their impacts on both the German and European energy supply system with consistent data sets and feedback loops

Modelling stages		Geographical focus
Market-based grid planning	1	European energy market areas + offshore grid region (offshore hubs)
Technology-based grid planning	2	Offshore grid region (single wind farms)
Offshore grid validation	3	Offshore grid region (single wind farms)
Onshore grid repercussions	4	Onshore transmission system (German market area)

The market-based grid planning determines and assesses market-driven investment decisions in a potential NSON, adequately accounting for the directly and indirectly connected onshore market areas

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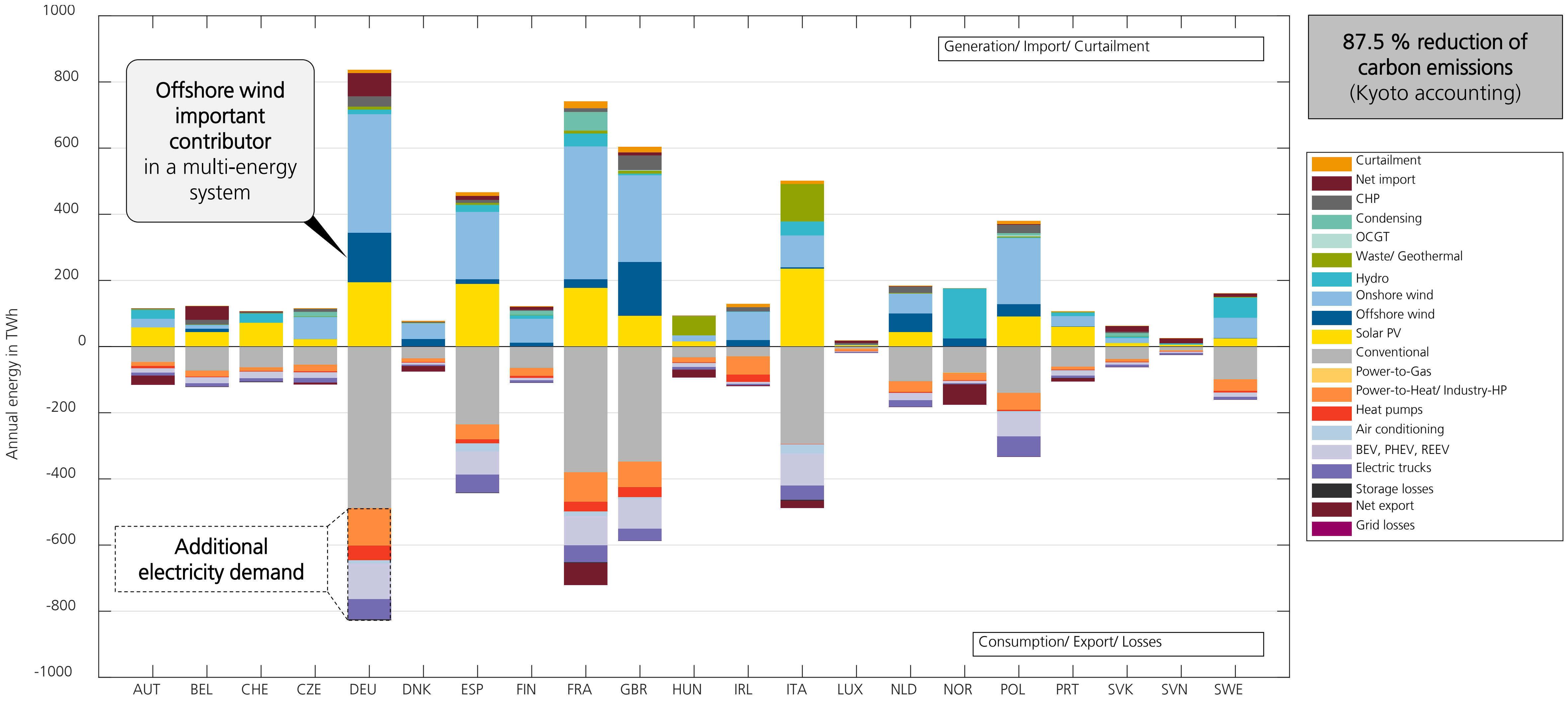
Long-term NSON 2050 scenario features high level of decarbonisation due to coupled operation of energy sectors – capturing interaction and flexibility is essential in offshore grid expansion planning



87.5 % reduction of carbon emissions (Kyoto accounting)

NSON scenarios were created with the cross-sectoral dispatch and investment model SCOPE at Fraunhofer IEE.

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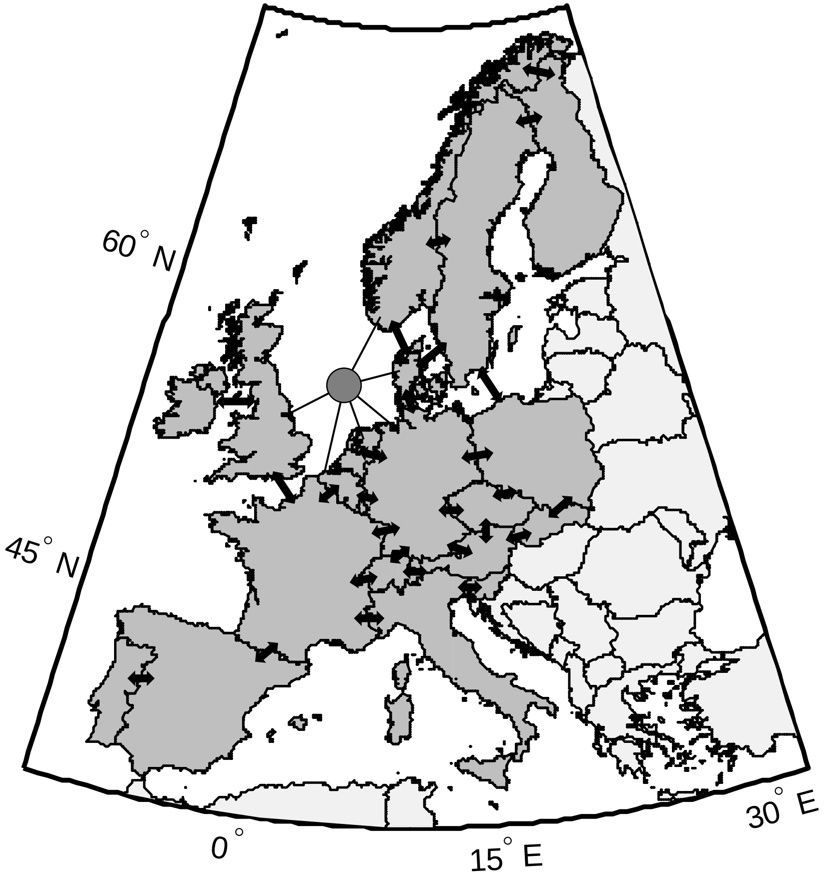
The large-scale offshore grid expansion planning model has a particular focus on capturing future energy system flexibility in the onshore market areas



<u>Multi Market Area Dispatch and Offshore Grid Expansion Model (static, deterministic TEP)</u>

Onshore market area

- Load coverage of residual load
- Technical restrictions of the hydro-thermal plants
- Technical restrictions of other flexibility options (such as battery storage, heat pumps, flexible CHP, electric vehicles and trucks)

Offshore grid region (area)

- Load coverage/ node balance of offshore hubs with wind generation/ curtailment/ storage
- Investment decision variables in AC/DC offshore grid infrastructure (including integers for fixed costs of cables, converters, and platforms)[1)]

Power exchange between areas

- Im-/ export between onshore market areas
- Im-/ export between onshore market areas and offshore grid region

! **Centralised/ closed solution of the full-year problem** (i.e. consecutive 8760 h) **with high unit** (blocks) and **investment details** (integer cable and platform costs) **is not tractable**

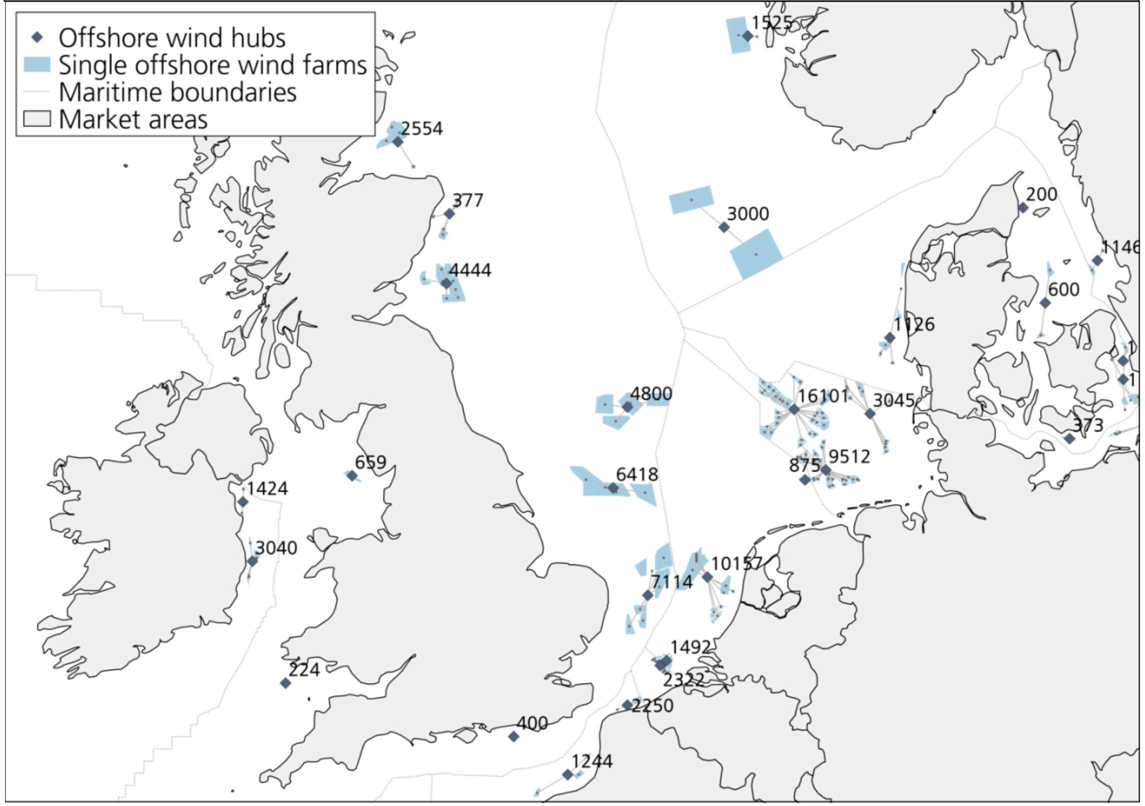
➡ **Careful aggregation of unit details + Regional decomposition approach (proximal bundle)** applied to improve the solvability of the offshore grid planning problem

[1)] Härtel et al. 2017 Review of investment model cost parameters for VSC HVDC transmission infrastructure *Electric Power Systems Research* **151** 419.

Consistent spatial and meteorological data is used to adequately capture the offshore grid region – final case studies will investigate three topology paradigms for NSON 2030 and 2050

Spatial and structural offshore wind data set

Single offshore wind farms[1)] and **clustered offshore wind hubs** relevant **for offshore grid investment decisions** in the NSON 2050 scenario
(values indicate installed generation capacity at offshore wind hubs in MW)



Meteorological data set

Meteorological data from the COSMO-EU model is used to obtain

- site-specific **offshore wind production profiles**
- site-specific **CAPEX** , **OPEX** , and **LCOE data**

for **different investment periods** (5 year stages)

Final NSON case studies

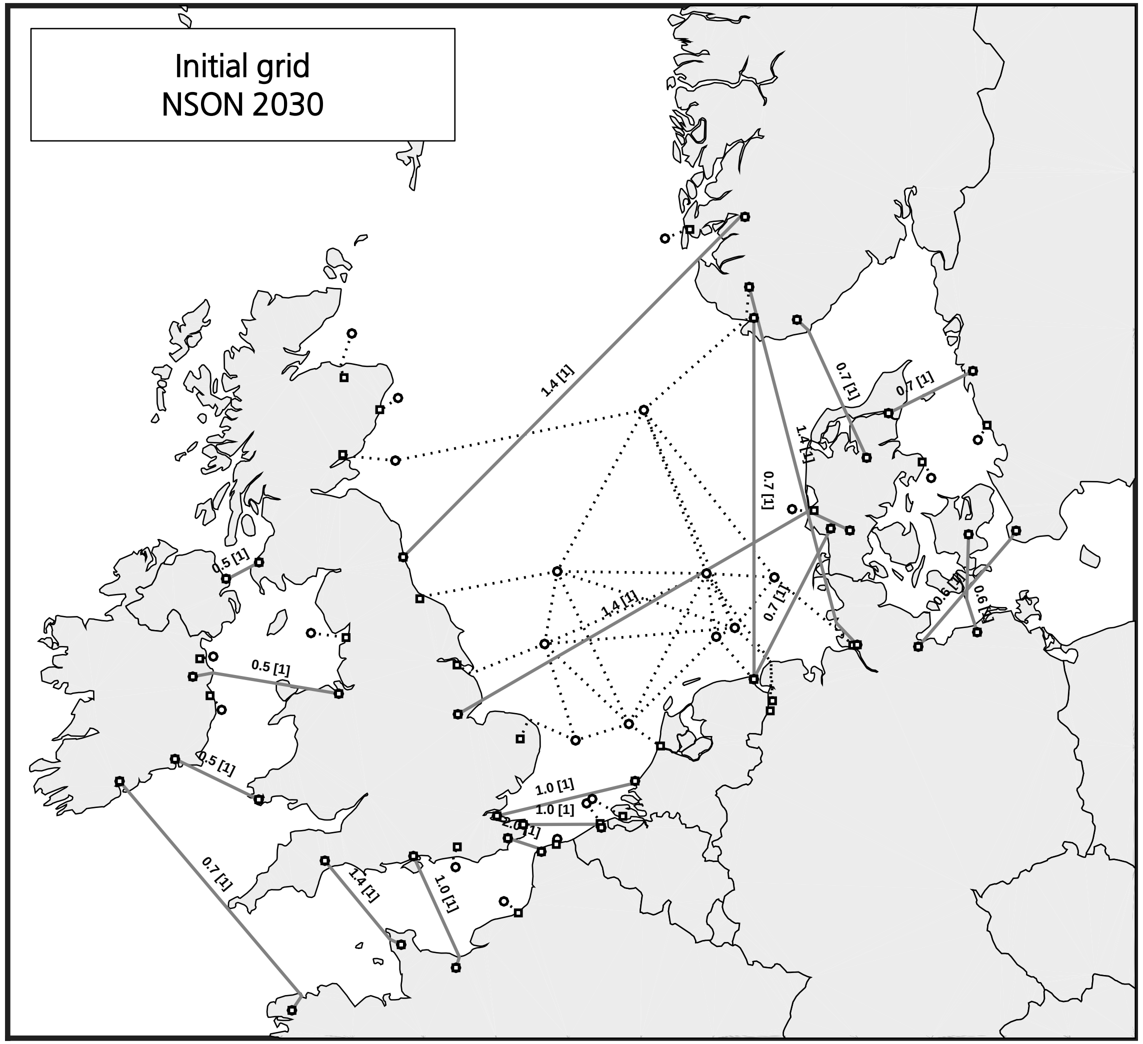
NSON 2030	NSON 2050

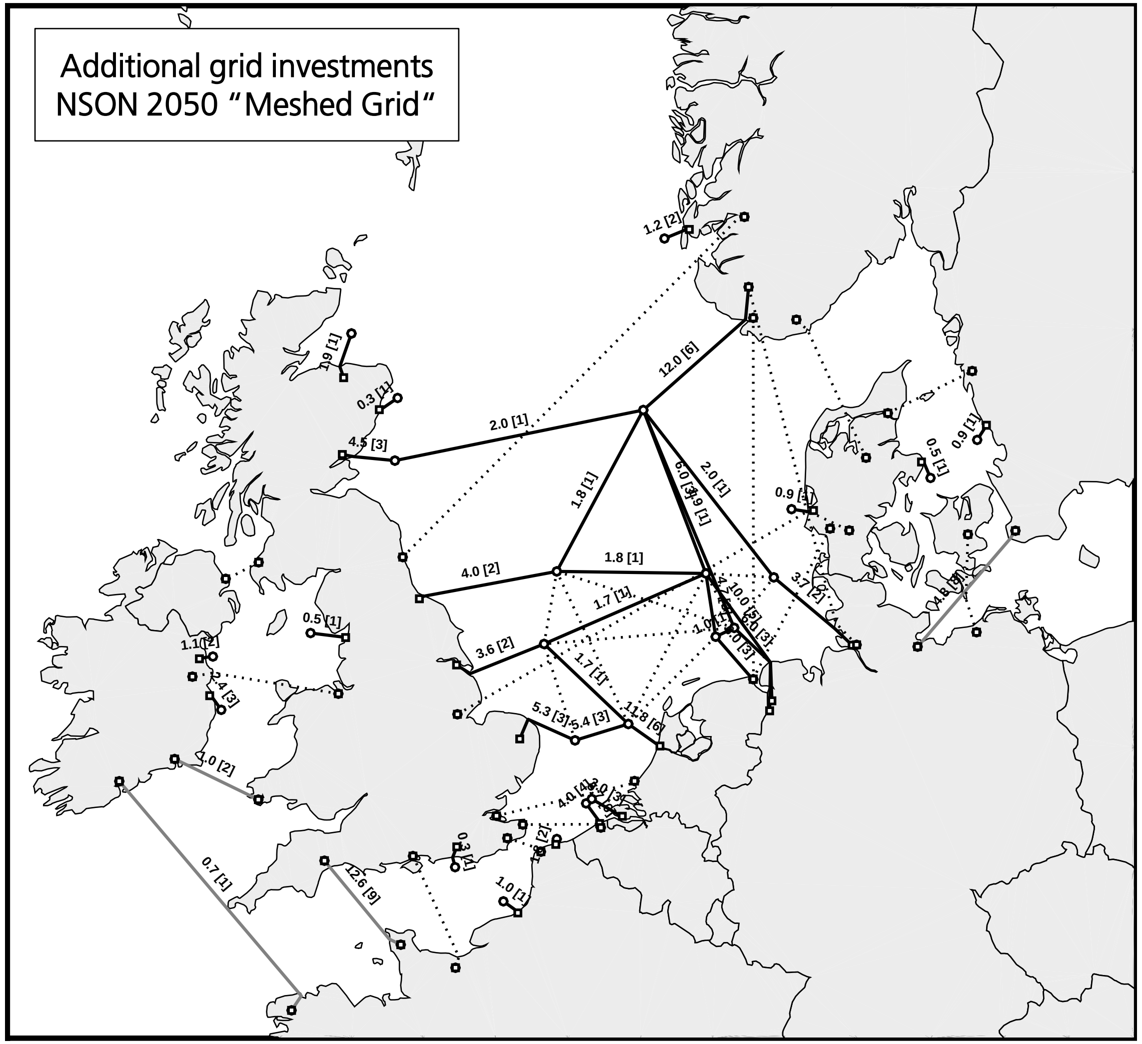
Topology paradigms:

- **"Status Quo"** allowing radial offshore hub connections and no expansion on existing interconnector corridors
- **"Business as Usual"** allowing radial offshore hub connections and expansion on existing interconnector corridors
- **"Meshed Grid"** allowing meshed offshore hub connections and expansion on existing interconnector corridors

[1)] Based on 4C Offshore 2017 Offshore Wind Farms Intelligence Database (Suffolk) https://www.4coffshore.com/.

Initial grid configuration shows realised and planned interconnector projects in Northern Europe – "Meshed Grid" shows investments in both interconnector and integrated offshore wind connections





The technology-based grid planning stage narrows the focus to the offshore grid region and investigates it with a higher level of detail

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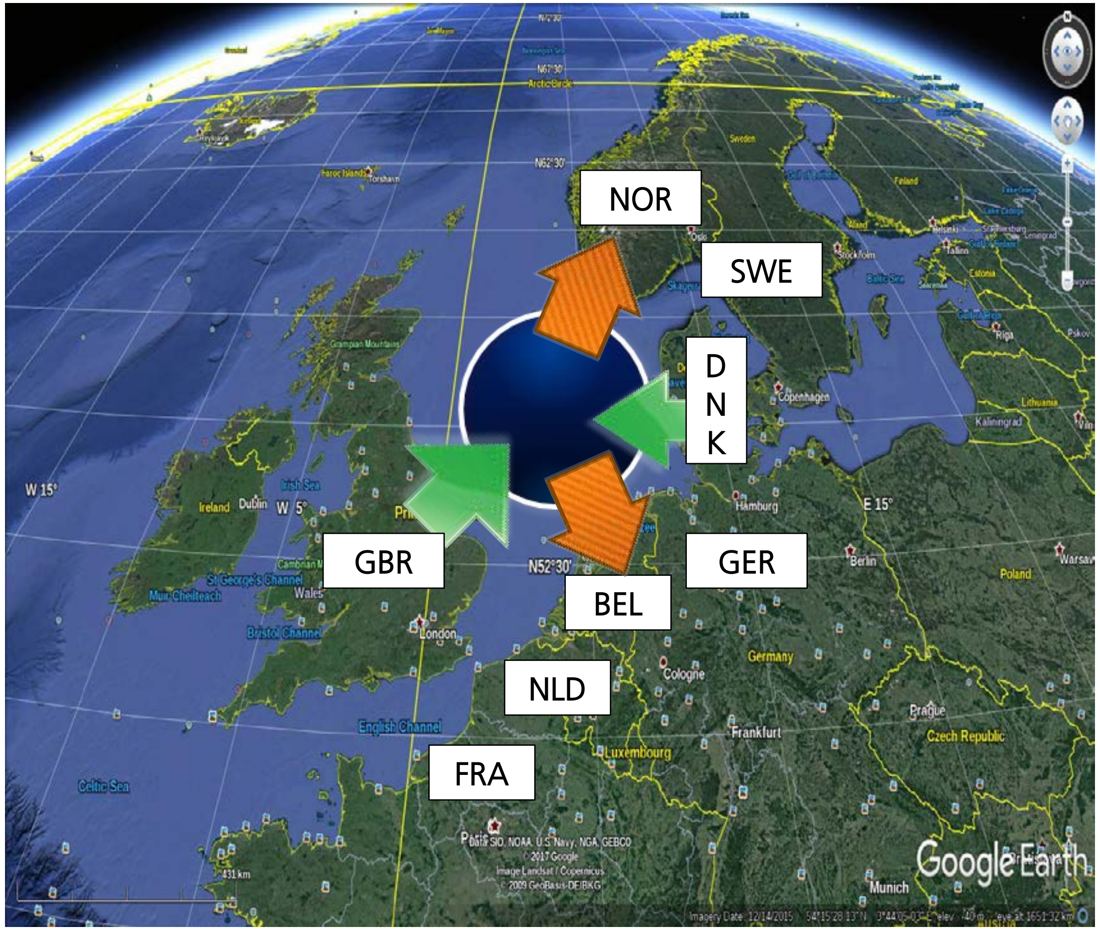
Technology-based grid planning stage simultaneously optimises locations of future wind farms, their connection(s) to shore, and the main technical components

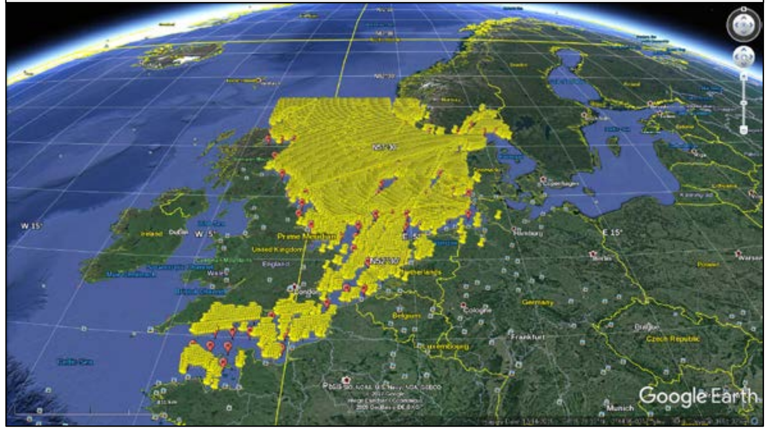
Market-based grid planning	**Resulting output data** ■ **Full-year time series data of power exchange** between offshore region and onshore market areas ■ Country-specific **offshore wind capacity targets**

Input

Technology-based grid planning	**Goals** ■ **Planning a detailed offshore grid** with its spatial and technical configuration ■ **Co-optimise single wind farm investments** ■ Considering **incremental expansion** of the offshore grid **for a long-term horizon** 2050 (multi-stage) ■ Satisfying **exchange demands** and offshore wind **capacity targets**



Planning aspects and technical requirements demand some simplifications when co-optimising grid planning and wind farm locations

Offshore region	Raster hubs	Potential wind farm locations
		

Planning aspects	
Vast number of potential locations	Incremental construction plan

Technical requirements		
Technical equipment (converters, transformers, switches)	Platforms for the equipment	Various line types (AC, DC, voltage levels, etc.)

Necessary simplifications

- **Neglecting physical laws of power flow**
- **Temporal resolution** (consider subset of weather year)

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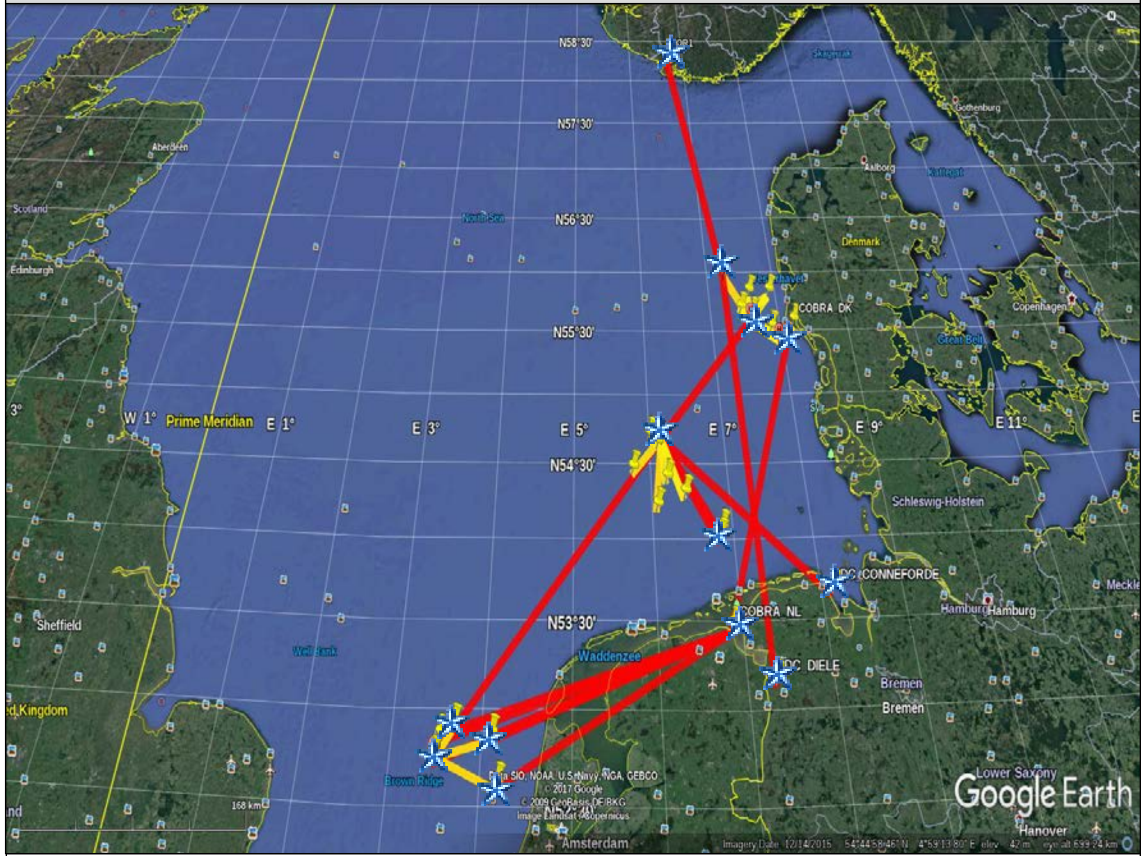
EXEMPLARY

A test grid instance was used to test the mixed-integer linear program and newly developed heuristics to quickly compute feasible initial solutions

Test grid instance



DC lines AC lines Converter

Benchmark test system for the offshore grid in the North Sea[1)]

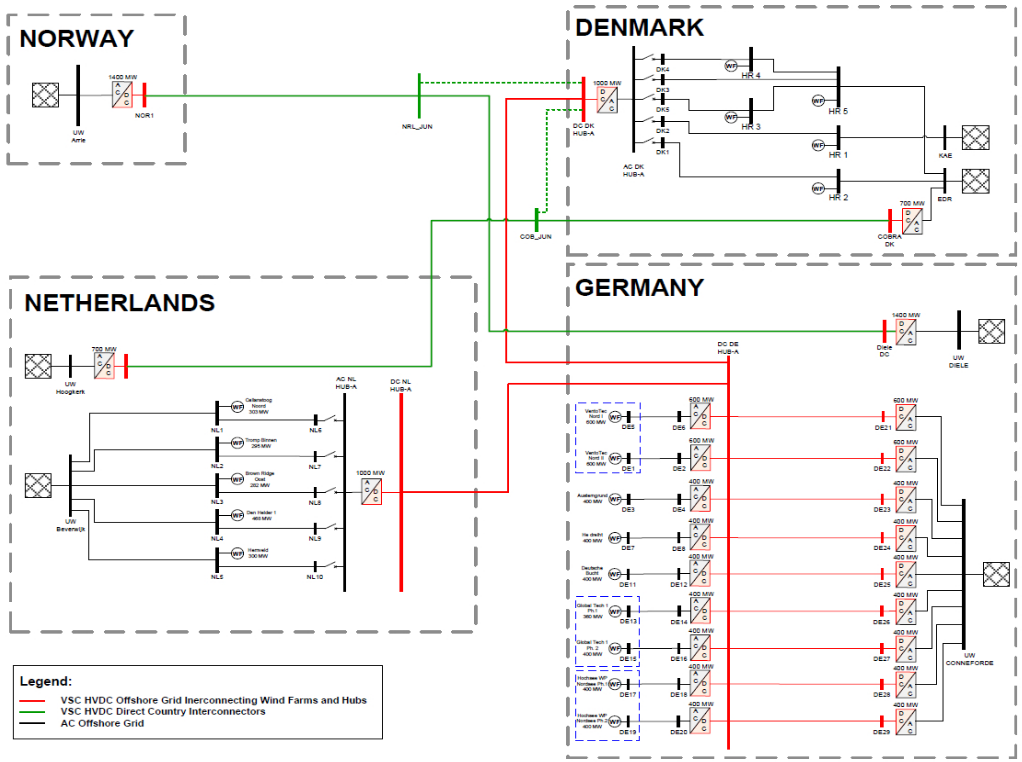


Fig. 7. Scheme of the benchmark test system for implementation into system simulator

[1)] Rudion et al. 2010 Toward a Benchmark test system for the offshore grid in the North Sea *IEEE PES General Meeting,* Minneapolis, 1-8.

The offshore grid validation stage tests the grid planning results using power system analysis software assessing approximation errors

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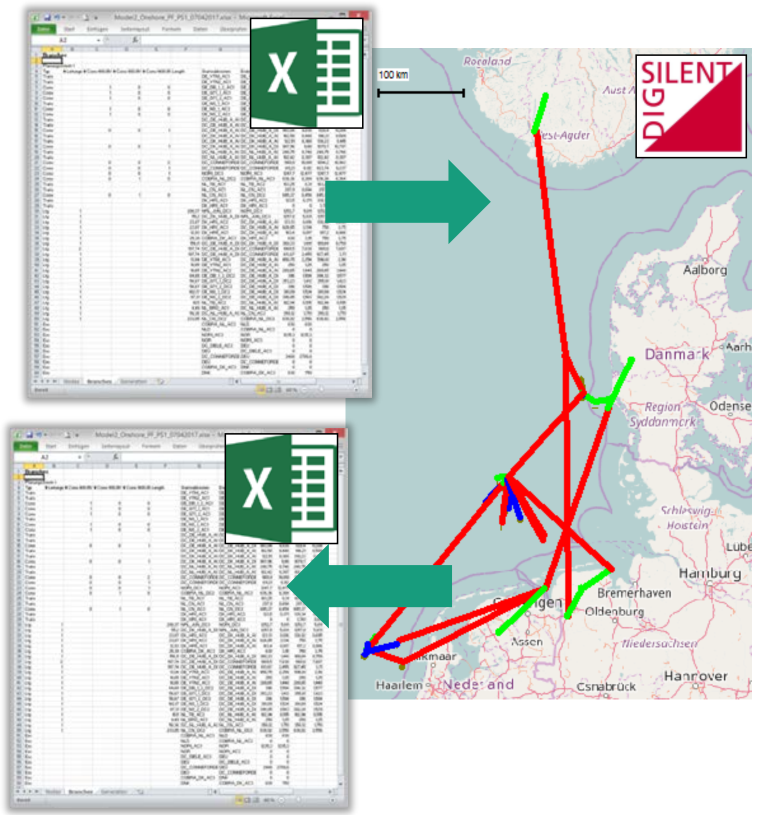
Due to a large number of time steps and scenarios, an automated approach was developed to electrically validate the market- and technology-based grid planning results



Electrical data of components

Grid topology & connection of elements

Definition of node types and control schemes

Power flow calculation

Documentation of data and power flow results

Comparison with grid planning assumptions

Component powers	Power flows in the grid	Losses of elements

Onshore grid repercussions induced by different offshore grid topologies are assessed for the onshore transmission system of the German market area

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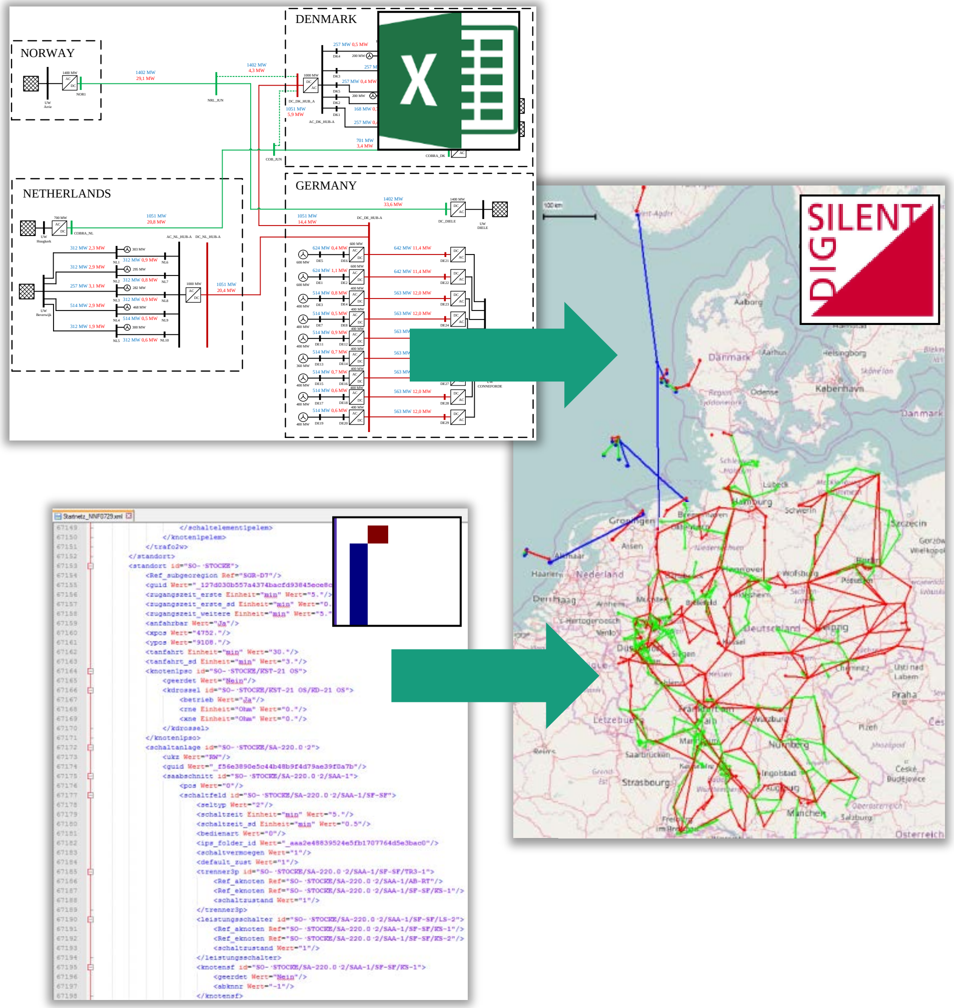
Market simulation data and offshore grid planning data for the NSON 2030 scenario are combined with a detailed model representing the German part of the continental European transmission system

Assessment of onshore grid repercussions

- **Model** of the German transmission system **based on** the **German grid development plan** for 2030
- SCOPE model delivers **unit- and node-specific input data**
- **Implementation of offshore power flows into German grid** (due to market exchanges)
- Comparison of results and **impact analysis of market coupling through meshed offshore system**

Regionalised generation and consumption data sets

- **Renewable generation types:** onshore wind, offshore wind (i.e. offshore grid exchange), roof-top PV, utility-scale PV, flexible and inflexible biomass, waste, scrapwood, conventional and pumped hydro
- **Thermal generation types:** extraction condensing units (CHP), back-pressure units (CHP), condensing units, gas turbines
- **Traditional load types:** households, trade and services, industry, agriculture, public transport, pumped hydro
- **Additional load types:** battery and plug-in hybrid electric vehicles, electric overhead line trucks, industry heat pumps, decentralised air- and ground-source heat pumps, direct electric heating units (CHP and non-CHP), air-conditioning



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Over the course of the NSON-DE project a number of remaining challenges were identified for further research

Flexibility and uncertainty in future energy systems

- **Competition** of offshore grids **with future onshore flexibility options**
- **Uncertainty** from **bottom-up** developments and **top-down** target definitions
- **Simultaneous optimisation of generation and transmission expansion** for a highly decarbonised system heavily relying on wind and solar

Market integration and cost-benefit sharing

- **Harmonised cross-border rules of the involved market areas** (time-scales, market products)
- **Cost-benefit allocation** and **sharing methods** for both directly and indirectly connected market areas

Grid operation

- **Optimized grid and plant control** in normal operation
- **Dynamic control concepts** in normal operation as well as in fault and emergency situations

Grid planning

- Efficiently solving **optimisation problems capturing technical complexity** and **operational flexibility** in the grid planning stages
- **Handling time series data computationally more efficiently**
- Incorporate **statistically known data uncertainties** or **barely predictable** political, technological, or economic **uncertainties**

Power Link Islands (PLI)

- **Artificial island for transnational power exchange** and **distribution of offshore wind resources**, while hosting other services such as operation and maintenance for offshore wind farms
- **High uncertainty** associated with the **investment costs** and **potential locations**
- **Combined assessment of** the investment **costs and** the economic **benefits** a PLI offers

Agenda

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II	Modelling stages of the national NSON project in Germany (NSON-DE)
III	Challenges for future research
IV	Summary

Conclusions

With a growing amount of offshore wind generation being deployed in Northern Europe, the relevance of a Northern Seas Oshore Network (NSON) increases
particularly in light of high cross-sectoral decarbonisation targets

The national NSON project in Germany (NSON-DE) developed a closely linked modelling chain involving several stages
market- and technology-based grid planning, offshore grid validation, and onshore grid repercussions

Flexibility and uncertainty in future (multi-)energy systems, market integration, cost-benefit sharing as well as robust grid planning and operation methods
are important issues for future research

Thank you very much for your attention!

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