North Sea Offshore Network – Denmark (NSON-DK)

Conclusions and recommendations

Presented at stakeholder meeting 30. September 2020

NSON-DK

DTU

Ea Energianalyse

Poul Sørensen, DTU Wind Energy

Introduction to NSON-DK and the stakeholder meeting

NSON-EU

SINTEF

University of Strathclyde Glasgow

The North Sea Offshore Network (NSON) is an international research collaboration with the purpose to advance the realisation of an efficient and secure energy transmission system in the Northern Sea Region

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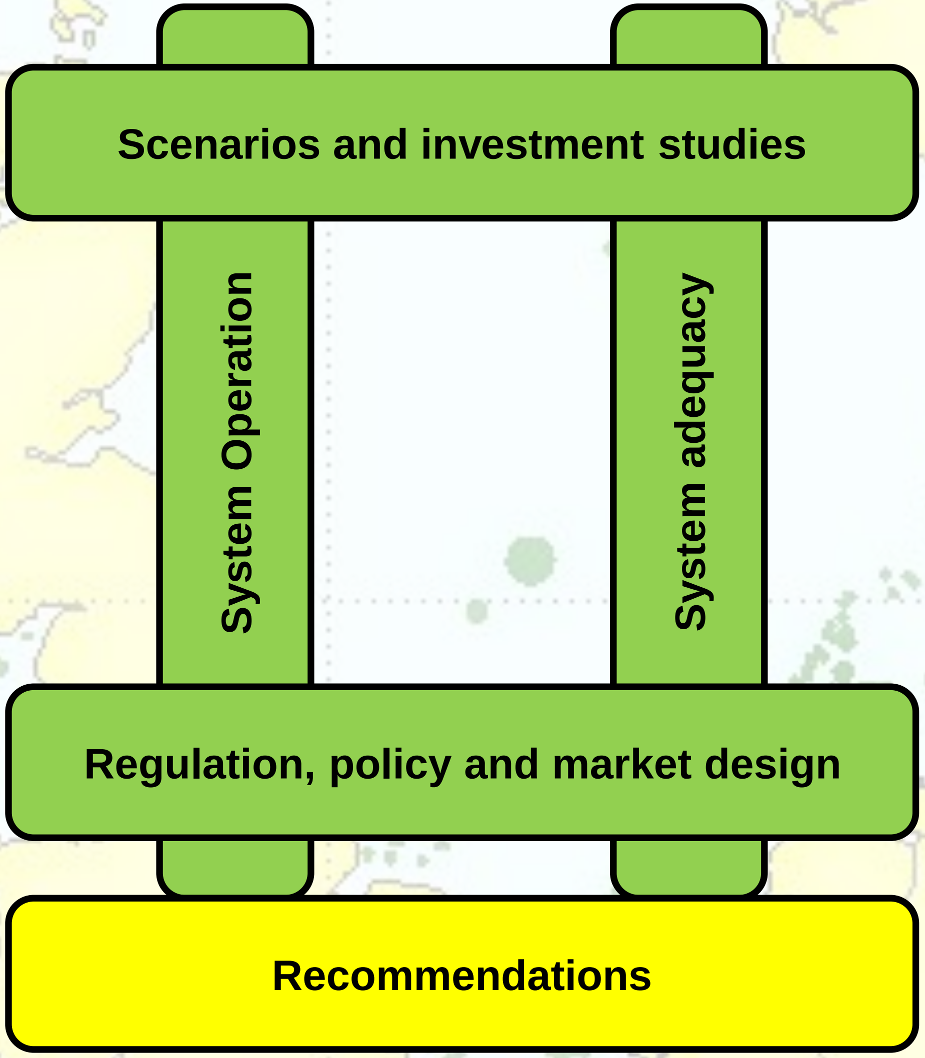

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Program for the stakeholder meeting

Presentations (10:00 – 11:00)

- Introduction to NSON-DK and the stakeholder meeting.
  Poul Sørensen, Technical University of Denmark
- NSON-DK energy systems scenarios.
  Matti Koivisto, Technical University of Denmark
- Market operation and balancing.
  Kaushik Das, Technical University of Denmark
- System adequacy of Danish power system.
  Peter Børre Eriksen, Ea Energy Analyses
- Policy and regulatory issues.
  Lena Kitzing, Technical University of Denmark
- NSON-DK Recommendations.
  Poul Sørensen, Technical University of Denmark

- **Discussion (11:00 – 11:30)**







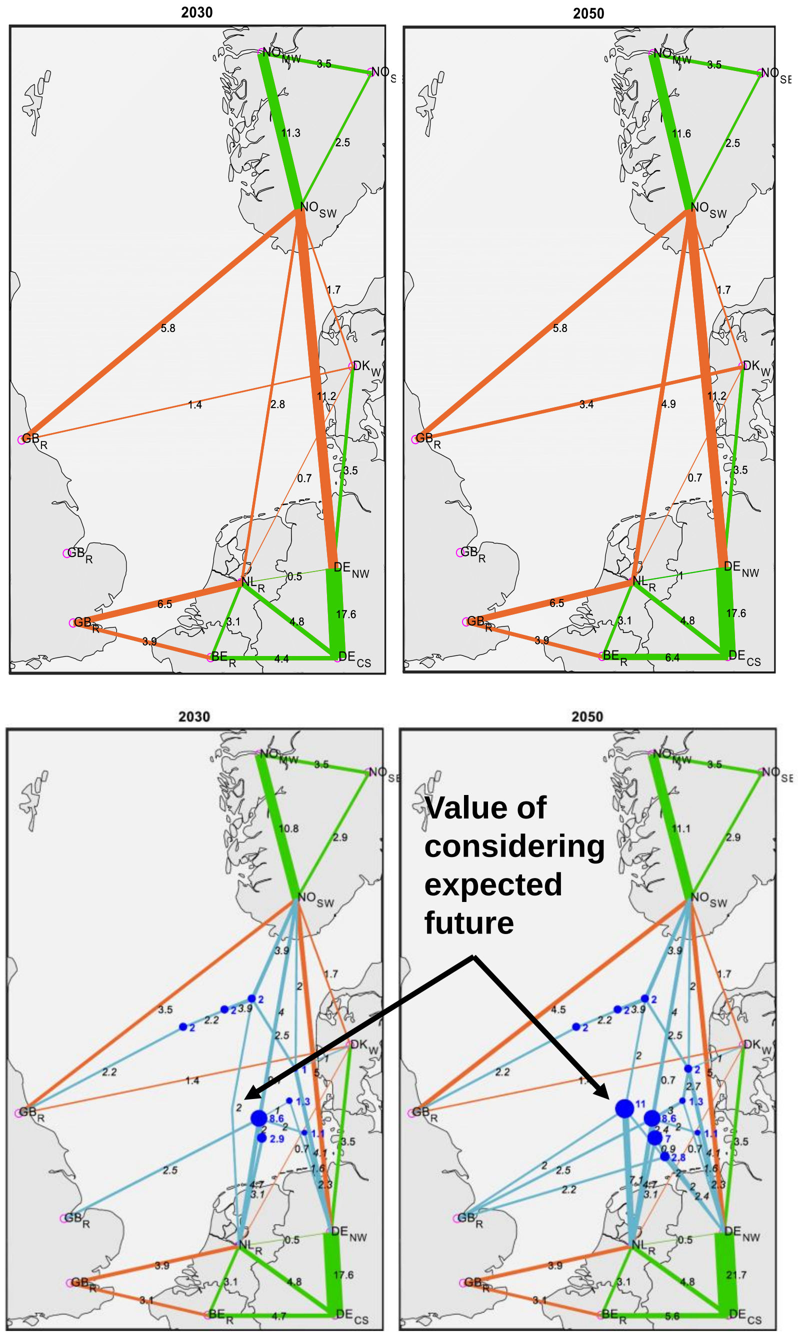
Matti Koivisto, DTU Wind Energy and
Juan Gea-Bermudez, DTU Management

NSON-DK
energy systems scenarios

Investment studies

- Cost assumptions:
  - VRE costs from the Danish Energy Agency
  - Offshore hub & transmission costs from [1]
- NETP 2016 is used as the background[2]
- Optimal investments using Balmorel[3,4]
  - 8 weeks spread over the year; 1 every 2 hours
  - Investments towards 2030 and further to 2050
- Two NSON-DK scenarios (focus on offshore) [4]:
  - Individual **project-based**, with
    - OWPP to shore (full transmission capacity)
    - Country-to-country offshore interconnectors
  - **Integrated offshore grid** (see right)
    - Lower system costs than project-based[4]
- Recently, additional studies have been made including sector coupling

		Renew. in elect. (%)	Offshore wind [GW]
Approx. 2020		46	22
2030	Project-based	75	64
	Integrated	76	69
2050	Project-based	88	92
	Integrated	89	102



[1]P. Härtel et al., "Review of investment model cost parameters for VSC HVDC transmission infrastructure", *Electric Power Systems Research*, vol. 151, pp. 419-431, 2017.

[2]Nordic Energy Technology Perspectives 2016 (NETP 2016) report: http://www.nordicenergy.org/project/nordic-energy-technology-perspectives/

[3]J. Gea-Bermúdez et al., "Optimal generation and transmission development of the North Sea region: impact of grid architecture and planning horizon", *Energy*, vol. 191, 116512, 2020.

[4]M. Koivisto et al., "North Sea offshore Grid development: Combined optimization of grid and generation investments towards 2050", *IET Renewable Power Generation*, vol. 14, no. 8, pp. 1259-1267, 2020.

Conclusions from investment studies

- **Integrated scenario shows lower system costs than project-based**
  - **And ~10 GW more offshore wind by 2050**
  - Hubs allow for high capacity factor OWPP investments & integrated transmission expansion
- Due to smoothening (negative correlations), a combination of wind and solar PV is beneficial to the energy system
- **Although the costs of offshore wind are higher than onshore, massive offshore wind power will be needed to implement the green transition**
  - Driven by limited land availability and social acceptance of onshore wind power development
- Compared to 2030, average electricity prices in 2050 are lower and more volatile
  - There is no significant difference between the price volatility in project-based and integrated scenario
- The recent Danish policy regarding energy islands is not investigated explicitly in NSON-DK
  - But the large offshore hubs found in the integrated grid supports the feasibility of energy island solutions
- **Denmark is expected to be a significant electricity exporter by 2050**
  - Driven by good wind conditions and transmission connections to neighbouring countries

- Distinguishing between investments up to 2030 and further to 2050, optimal investment analysis without sector coupling places majority of offshore wind power investments in 2030
  - Including sector coupling in the investment study increases the offshore wind investments, but most of this additional investment is later than 2030
  - **Sector coupling will increase massively the need for offshore wind, especially after 2030**[1]

[1]M. Koivisto et al., "North Sea region energy system towards 2050: offshore grid and sector coupling drive offshore wind installations", *WindEurope Offshore 2019*, Copenhagen, 26-28 November 2019: https://windeurope.org/offshore2019/conference/presenters/?presenter_id=550 (presentation to be made available).

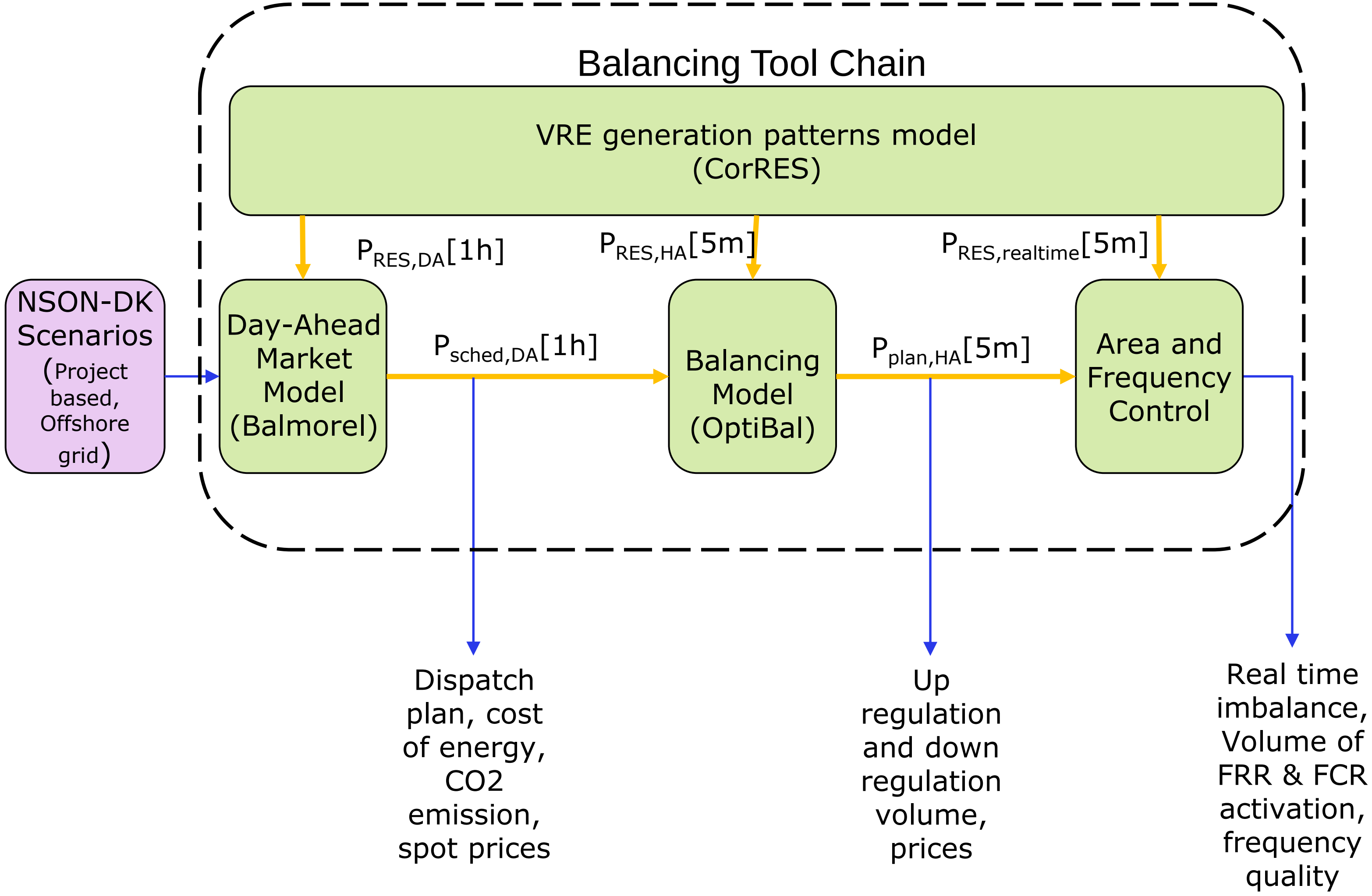
 

Kaushik Das, DTU Wind Energy and
Juan Gea-Bermudez, DTU Management

Market operation and balancing

System operation

- Assumptions:
  - Based on the 2 NSON-DK scenarios
- Method:
  - Tool chain
  - Outputs:
    - Unit commitment and dispatch (spot market)
    - Society cost of energy
    - Balancing volume and costs (balancing model)
    - Real time imbalance
    - Frequency quality



Conclusions energy market

- More trade and more efficient hydro dispatch are some of the key features of the energy system in 2050
- The offshore grid architecture seems to be the most cost-efficient way to operate the future energy system of the North Sea region, especially to integrate offshore wind.
- The impact of the offshore grid architecture in the DA market operation is found rather limited (D3.1 conclusion without sector coupling)

- Added investment costs of offhore grid (compared to project base) is fully compensated by reduced operational costs.

Year	Capex [M€/y]	Opex [M€/y]	Total [M€/y]
2030	213	-408	-195
2050	642	-660	-18

Difference between costs of offshore grid and project-based

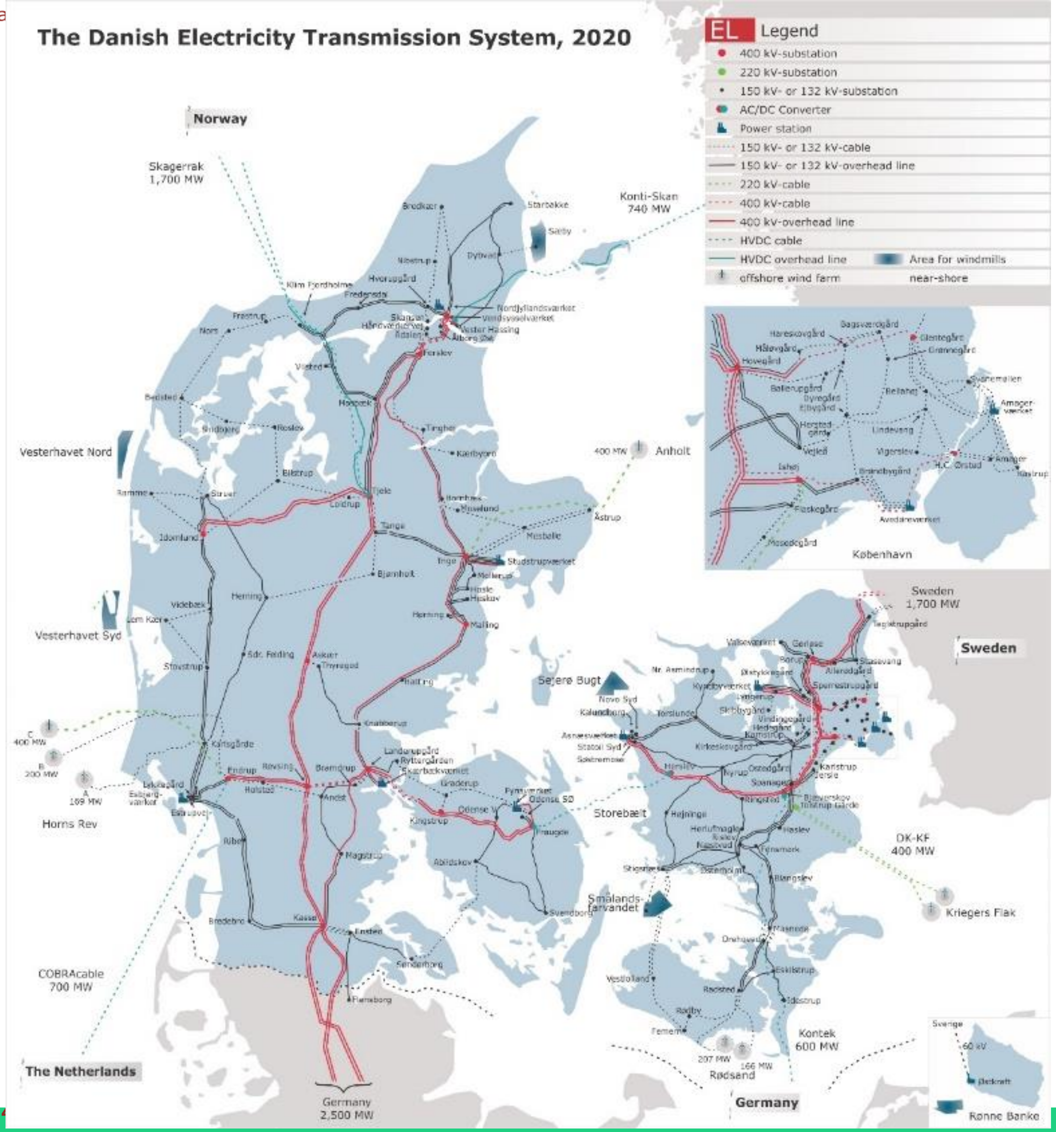
Conclusions balancing

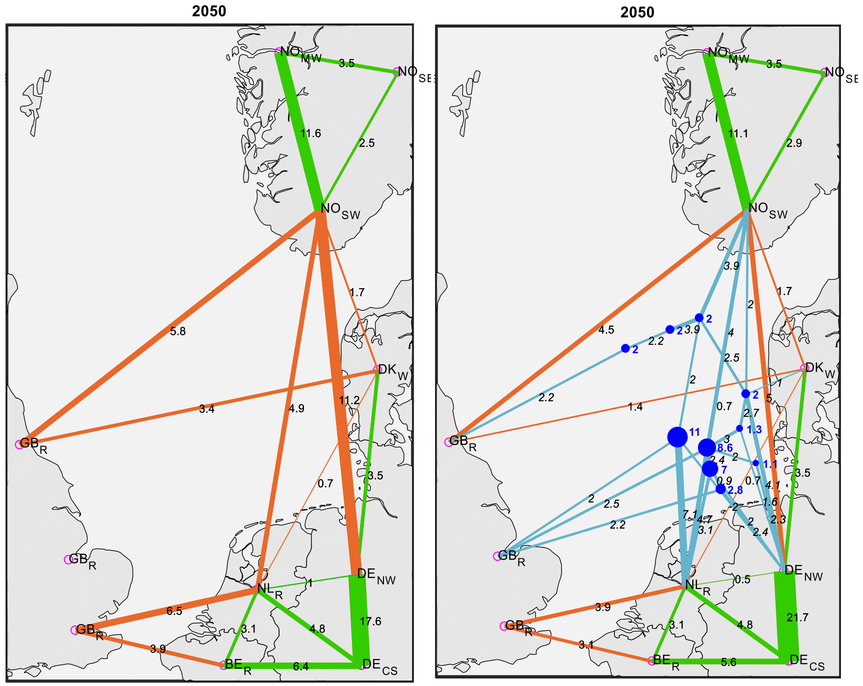
- The power imbalances in all the North Sea countries increase substantially towards 2050 from 2020 values with increasing shares of offshore wind power, therefore, would require much higher volume of reserves.
- Although majority of the imbalances can be handled through slow manual balancing reserves based on hour ahead forecasts; nevertheless, much higher volume of automatic frequency restoration reserves will be required to handle the real-time imbalance and maintain the frequency quality. Automatic frequency restoration reserves are recommended to be dimensioned probabilistically for efficient utilization of resources.
- The simulation results clearly show that for continental Europe, the offshore grid scenario has very similar impact on balancing of reserves to project based scenario.
- On the other hand, real-time imbalance in Nordic network is much lower in case of offshore grid scenario as compared to project based scenario owing to more wind power installation in Norway for project based scenario as compared to offshore grid scenario.
- Unintended curtailed offshore wind in spot market has been found useful as up-regulation balancing reserve and other services like power2x, resulting in more value streams for wind power beyond spot market and also reducing requirement for reserves from other technologies.

Peter Børre Eriksen/Lars Bregnbæk, Ea Energy Analyses

System adequacy

Focus the Danish grid

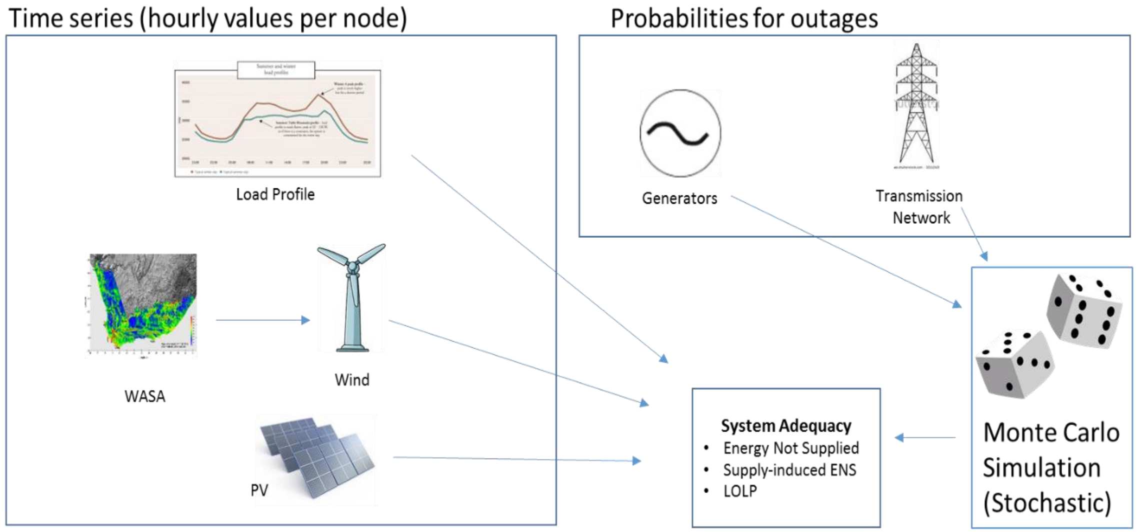


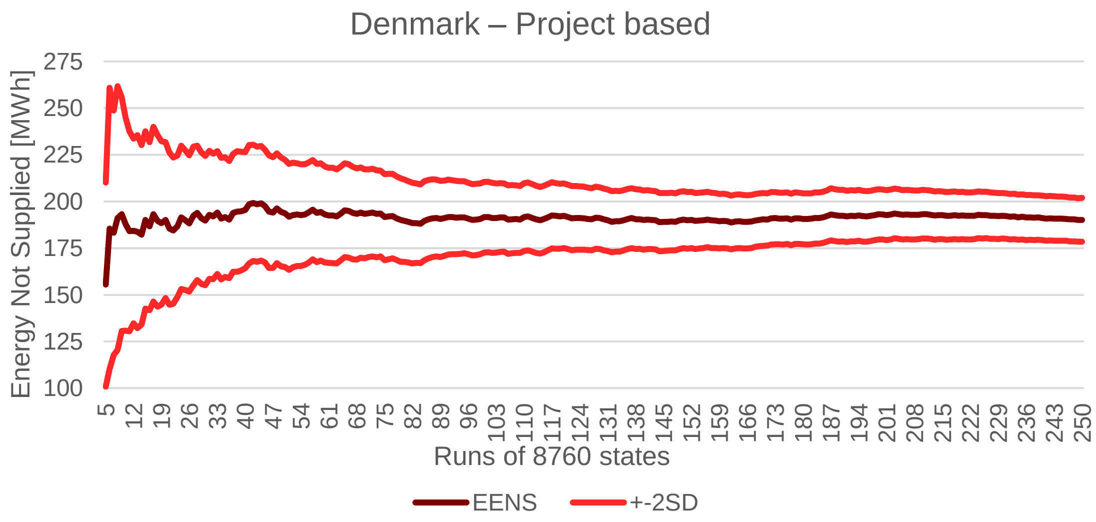


- 100+ kV transmission grid
- Import and export lines included
- Broader region included
  - Baltics, Scandinavia, Northern Continental Europe, Great Britain
- 'Copperplate' assumption within non-DK price regions

SISYFOS-R: Assessment of power supply adequacy

- Initially developed by Danish Energy Agency (DEA)
- Now joint development in DEA & Ea
- Narrow focus on 'Adequacy' – not security etc.
- Monte Carlo simulations
  - Testing situations with many potential simultaneous outages (different from e.g. N-1)
  - Probability of outages weighted in results
- Per scenario year: 2.2 million independent system states simulated
  - Corresponding 250 years





System adequacy - conclusions

- A massive wind power development onshore and offshore in the countries around the North Sea including Denmark will not compromise the system adequacy in Denmark.
- Adequacy calculations indicate a downward trend in outage minutes towards 2050 for both Eastern and Western Denmark. On average in Denmark, adequacy numbers are improving from about 3.5 to 2.5 power outage minutes per year in both scenarios from 2020-50.
- Adequacy results are very similar in project-based and offshore grid solutions, as is the overall development of the generation portfolio of wind and PV, both on system level and in Denmark.
- Internal grid in Denmark is responsible for most unserved demand (in Denmark)
- Simulation results and conclusions depend on your inputs
  - Thermal capacity to Peak demand ratio
    - NSON scenarios – increasing
    - Danish TSO calculations – decreasing
  - Lower outage minutes in NSON

Lena Kitzing, DTU Management

Policy and regulatory issues

Policy brief

- Policy measures to promote offshore grids should include an incentive package that provides clear incentives for R&D, full cost recovery of R&D spending, and that recognizes the effective investment risk in deployment by establishing risk-limiting financial measures, and by coupling profits to benefits through OPEX-related incentives.
- A super-shallow approach for grid connection cost allocation (allocating most of the costs to the TSO) is necessary to remove risks and reduce the complexity associated with the legal definition of the assets. It also reduces the financial risk for the wind farm developer.
- If grid access charges are applied to producers, they should contain an energy component only. Locational signals should be avoided, thereby enhancing the chances for the development of an offshore grid.
- Among the North Sea countries, Germany's regulatory framework is best suited to the development of an offshore grid, followed by Denmark and Norway. The regulatory framework of Belgium needs to be adjusted somewhat to support offshore grids, whereas there are several regulatory barriers in the Netherlands towards the development of an offshore grid. Finally, the regulatory framework of the UK is lacking behind with respect to supporting an offshore grid.

Policy and market design

- For the offshore grid scenario to become real, there is great need for international cooperation.
- Our quantitative analyses confirm that integrated offshore solutions connecting different North Sea countries (Denmark, Germany and the Netherlands) will create total net societal benefits. The benefits and costs, are however not equally shared across the countries.
- Cost-and-benefit sharing mechanisms and benefit transfers between countries will be needed to achieve a fair allocation and therewith adequate incentives for the realisation of interconnected offshore hubs in all countries.
- Market arrangements play an important role in this, as they reallocate surplus between different types of actors and between countries.
- Creating a separate offshore bidding zone can lead to a more efficient energy system set-up than sending the electricity to a home country market or granting Financial Transmission Rights to the offshore wind farm operators

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Poul Sørensen, DTU Wind Energy

Recommendations

Recommendations

- Based on the following NSON-DK findings, it is ***recommended*** to replace the precent "project based" practice connecting wind power plants directly to shore and building bilateral interconnectors with the development of an ***integrated offshore grid in the North Sea*** which supports trade between countries as well as offshore connection of wind power:
  - The offshore grid will increase power trade across the North Sea countries
  - The offshore grid supports integration of more renewable generation which will be needed to implement the green transition
  - The investments in an offshore grid will be fully recovered by savings in operation costs
  - The spatially dense offshore wind power development does not increase the need for balancing compared to similar onshore wind and solar power development
  - The adequacy of the Danish power system is not reduced by the offshore grid

Recommendations – continued

- Important that offshore grid does ***not prevent the stepwise development*** of offshore wind power and country interconnection capacity.
- ***Long-term planning of the offshore grid*** is important to ensure that the right investment decisions are taken
- It is recommended to ***advance offshore grid in time*** as much as possible. Faster offshore development will not only support faster green transition but also be economically beneficial which is seen by the optimal investment studies.
- It is recommended to ***include balancing and frequency control in planning studies*** because massive shares of renewable generation will increase forecast errors and therefore more balancing capacity will be needed.
- In order to deal with increasing imbalances caused by uncertainties in massive shares of wind and solar power, it is recommended to develop methods to ***dimension the allocation of automatic frequency restoration reserves probabilistically***

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Recommendations – continued

- The regulatory framework should aim to ***reduce risks*** to lower the financial costs of the offshore development
- A ***super-shallow approach for grid connection cost allocation*** (allocating most of the costs to the TSO) is recommended to remove risks and reduce the complexity associated with the legal definition of the assets.
- ***Coordination of the regulatory framework*** across the North Sea countries is required for a timely realisation of offshore grids. Also the EU framework will need to be revisited to optimally support the development of an offshore grid.
- ***Cost and benefit sharing mechanisms*** are needed to equalize costs for development of the offshore grid in some countries with benefits in other countries
- Creation of ***offshore bidding zones*** should be considered to take full advantage of the offshore grid

Discussion

Presentations

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- **NSON-DK Recommendations**.

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Thank you

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