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Interconnection of Denmark and UK power markets through Viking Link: Impact on social welfare and wind integration

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Viking Link

- Connecting UK and Danish power systems for the first time
- Project plan approved in Aug 2019, the line will be in use 2023
- 770 km HVDC cable with 1400 MW capacity
- Investment estimated 1.9-2.3 billion euro

Questions:

Quantifying the impact of the link on:

power prices and power exchange in the region,

distribution of social welfare, wind integration and emissions



Modelling Method

A market-based operation and dispatch simulation model

- Multi-region electricity market and district heating model of the North-West Europe
- Myopic (short-sighted) simulation as opposed to perfect foresight models
- Hourly simulation, 365 runs per year (resembles the day-ahead power market)
- Adaptive behavior of power producers based on the feedback from the market
- Combining long- and short-term information in estimating water value of hydropower

More info about the model:

Zakeri et al. *Impact of Germany's energy transition on the Nordic power market—a market-based multi-region energy system model*. Energy, 115, pp.1640-1662, 2016.

Open access: <https://github.com/energysystemmodels/Enerallt> (needs MATLAB License)

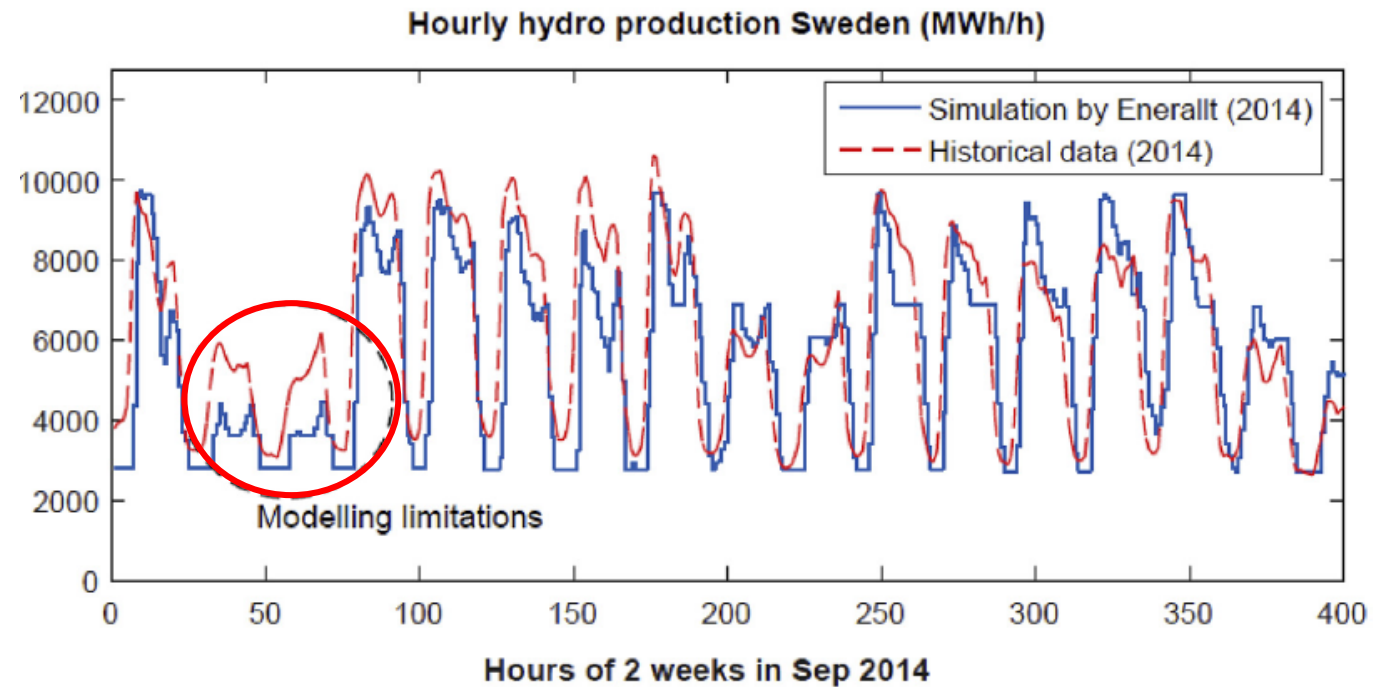
Validation and Limitations of the Model

Validation based on historical data

- Yearly average prices of electricity within 1-3% error
- Hourly prices and hourly production of hydropower validated

Limitations of the model

- Considering fixed capacities for transmission lines
- Aggregate representation of some price areas
- Based on one weather year

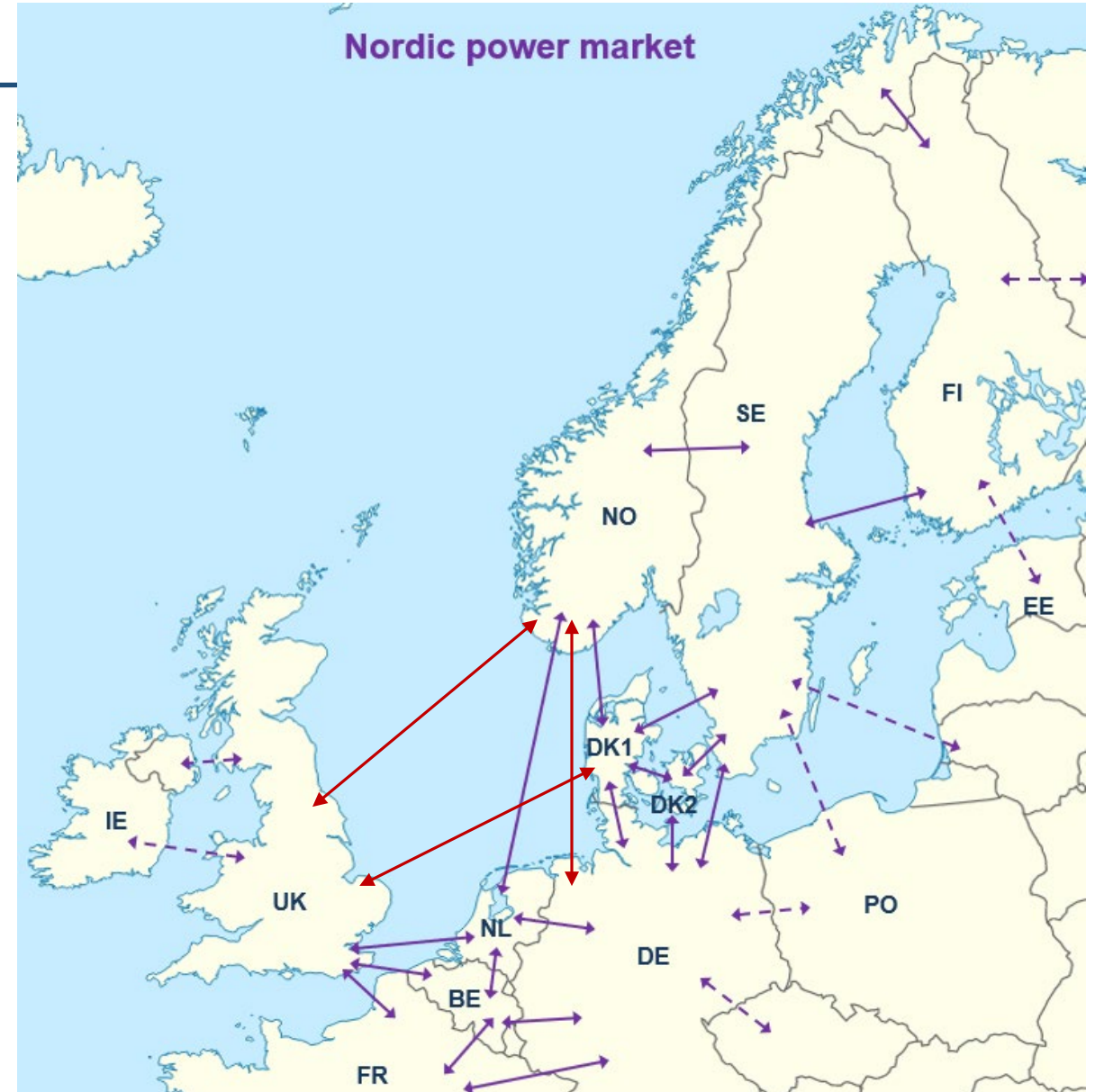


Scope of this Analysis

- 10 model areas (West and East DK)
- Dynamic power flow between the areas
- Static hourly power flow with other areas

Planned and under construction links

- NordLink (between Norway and Germany)
- North-Sea Link (between Norway and UK)
- Viking Link (between Denmark and UK)



Scenarios

- No link between UK and DK (the benchmark scenario)
- Viking Link (1.4 GW)
- Increasing wind capacity in different areas

Danish and UK power systems:

- DK: well interconnected, CHP, wind
- UK: low interconnection, gas, nuclear and Wind recently

GW	UK	Denmark
Maximum load	50	6
Average load	32	4
Interconnection	4	6
Total installed capacity	78	15
Thermal fossil	46	10
Wind power	21	5

Results: Impact of Viking Link on power prices

- Electricity price decreased in UK by -3.8%
- Increased power prices in West Denmark by +4.9%
- Price increase in all other Nordic countries (and slightly in Germany)

Average electricity prices per year (€/MWh)	UK	DK1	DK2	NO	SE
2016 historical data	46.2	26.7	29.4	26.4	29.2
2016 modelled	47.4	26.9	29.8	25.9	28.7
After Viking Link (modelled)	45.6	28.3	30.7	26.2	29.1
Relative difference due to the link (%)	-3.8%	+4.9%	+2.9%	+1.0%	+1.3%

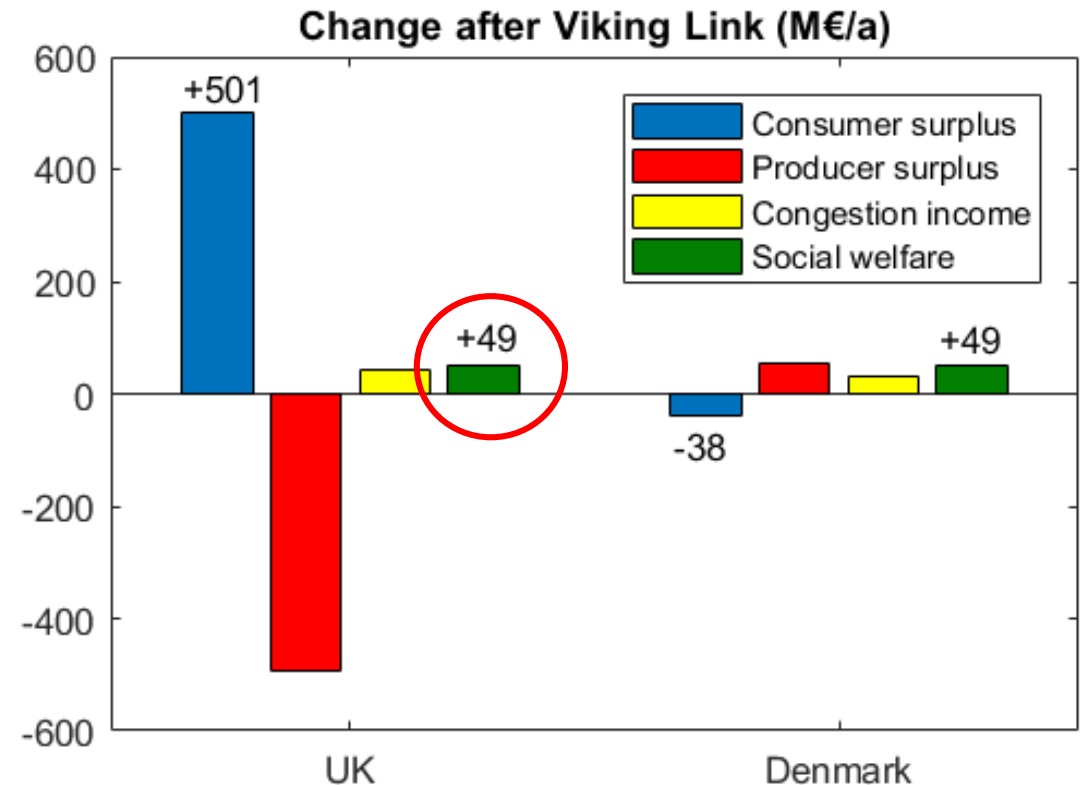
Results: electricity exchange and congestion

- Electricity exports mainly from Denmark to UK (6.7 vs. 3.2 TWh)
- Increased power flow from Norway and Sweden to West Denmark by 26%
- Net yearly power exchange in Denmark shows little difference after the link
- Congestion time increases in all the DK interconnections (except to Germany)

	UK->DK1	DK1->UK	NO->DK1	SE->DK1
Exchange 2016 modelled (TWh)	0	0	6.1	2.2
Exchange after Viking Link (TWh)	3.2	6.7	7.5	3.0
Congestion time 2016 (modelled)	0	0	28%	30%
Congestion time after the link (%)	19%	46%	42%	46%

Results: Impact on social welfare

- **Note:** *Social welfare = consumer surplus + producer surplus + congestion rent*
(without considering the cost of the link)
- UK consumers the biggest winner
- Danish producers gain 54 M€ more a year
- Social welfare improves in DK and UK
(in total ~ 100 M€/a)
- Congestion rent of Viking Link = 82 M€/a



Results: Viking Link after other new lines

- Viking Link will become operational in 2023 after NordLink and North-Sea link (NSL)

After NordLink and NSL:

- 30% less congestion rent for Viking Link
- 41% lower social welfare expected

Change compared to the no-link scenario	Viking Link today	Viking Link 2023
Congestion rent (M€/a)	+82	+57
Social welfare DK (M€/a)	+49	+35
Social welfare UK (M€/a)	+49	+40
Social welfare region (M€/a)	+78	+46



Results: Viking Link and high wind scenarios

- High wind scenarios (twice installed capacity as today) :

DK high wind = 10 GW wind

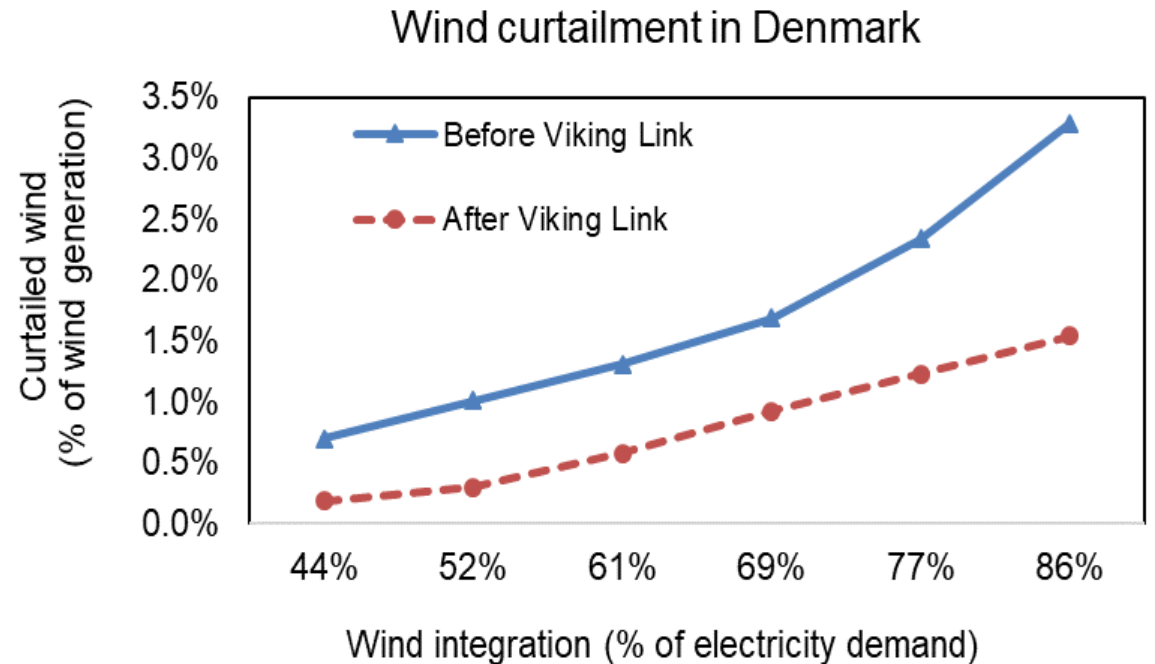
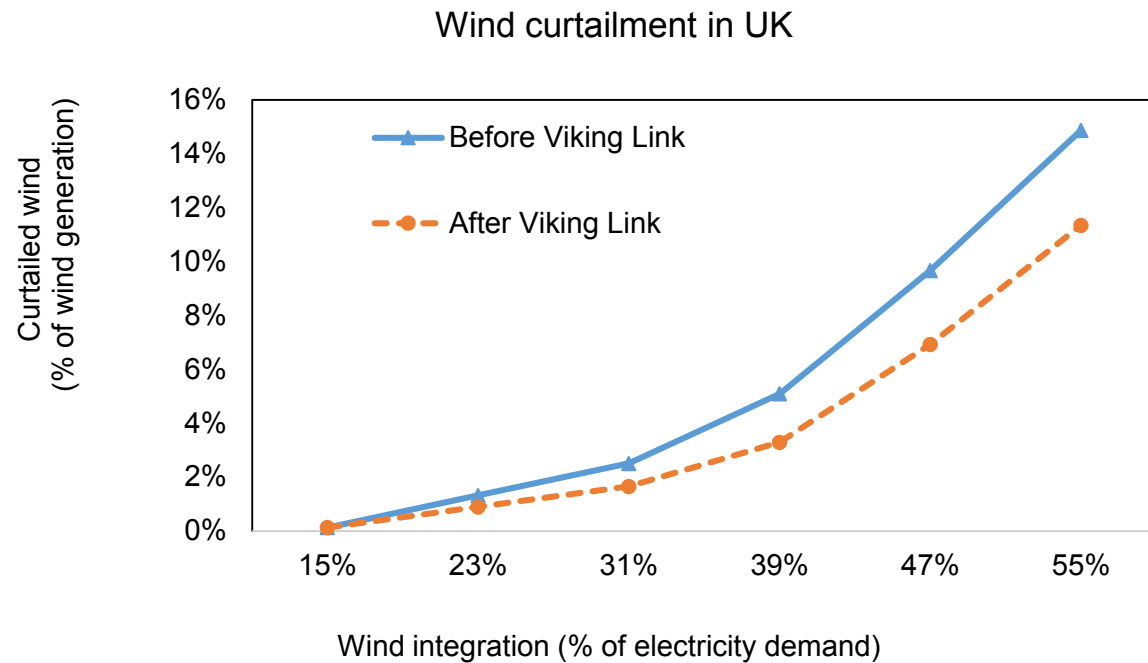
UK high wind = 40 GW wind

➔ Individual high wind scenarios show a higher benefit for the line as opposed to the combined high wind scenario

Change compared to the no-link scenario	Viking Link today	Viking Link 2023	High wind DK	High wind UK	High wind (UK+DK)
Congestion rent (M€/a)	+82	+57	+106	+120	+85
Social welfare DK (M€/a)	+49	+35	+93	+62	+39
Social welfare UK (M€/a)	+49	+40	+63	+78	+55
Social welfare region (M€/a)	+78	+46	+73	+125	+84

Results: Impact on wind integration

- Viking line helps to reduce the wind curtailment
- The extent of flexibility depends on the size of the system in question



Final note (work in progress)

- Congestion rent of the Viking link found to be between 57-120 **M€ per year**
- The benefits of the link diminishes if other new lines become operational in the region
- The link has a positive impact on the flexibility in wind integration (not compared with other alternatives)
- The link increases the use of CHP plants by 6% and the respective carbon emissions in the Danish side
- The profitability of the link declines in high renewable scenarios: lower price gap between Denmark and UK while higher congestion hours
- The distribution of benefits is highly different across areas and sectors

Thank you for your attention!

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