Outlook for Generation and Trade in the Nordic and German Power System

Dissemination Event 11-06-2015
NH Hotel Berlin Friedrichstraße

Anders Kofoed-Wiuff and János Hethey

DTU
Ea Energy Analyses

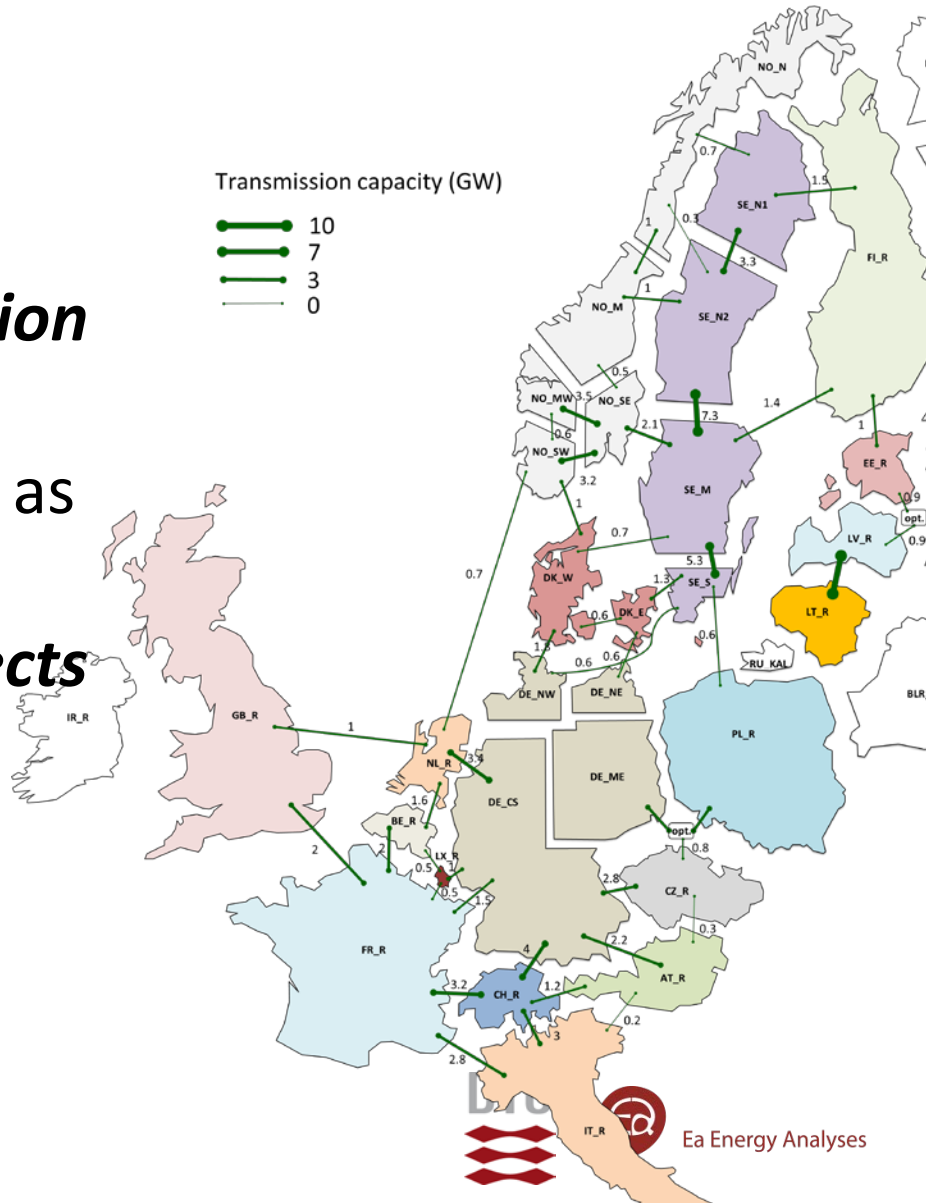
Agenda

- Introduction
- Methodology
- Results and findings
  - Power generation
  - Climate effects
  - Power prices
  - Trade
  - Value of transmission
- Perspectives

Why increase transmission grid capacity?

Motivation for closer grid integration

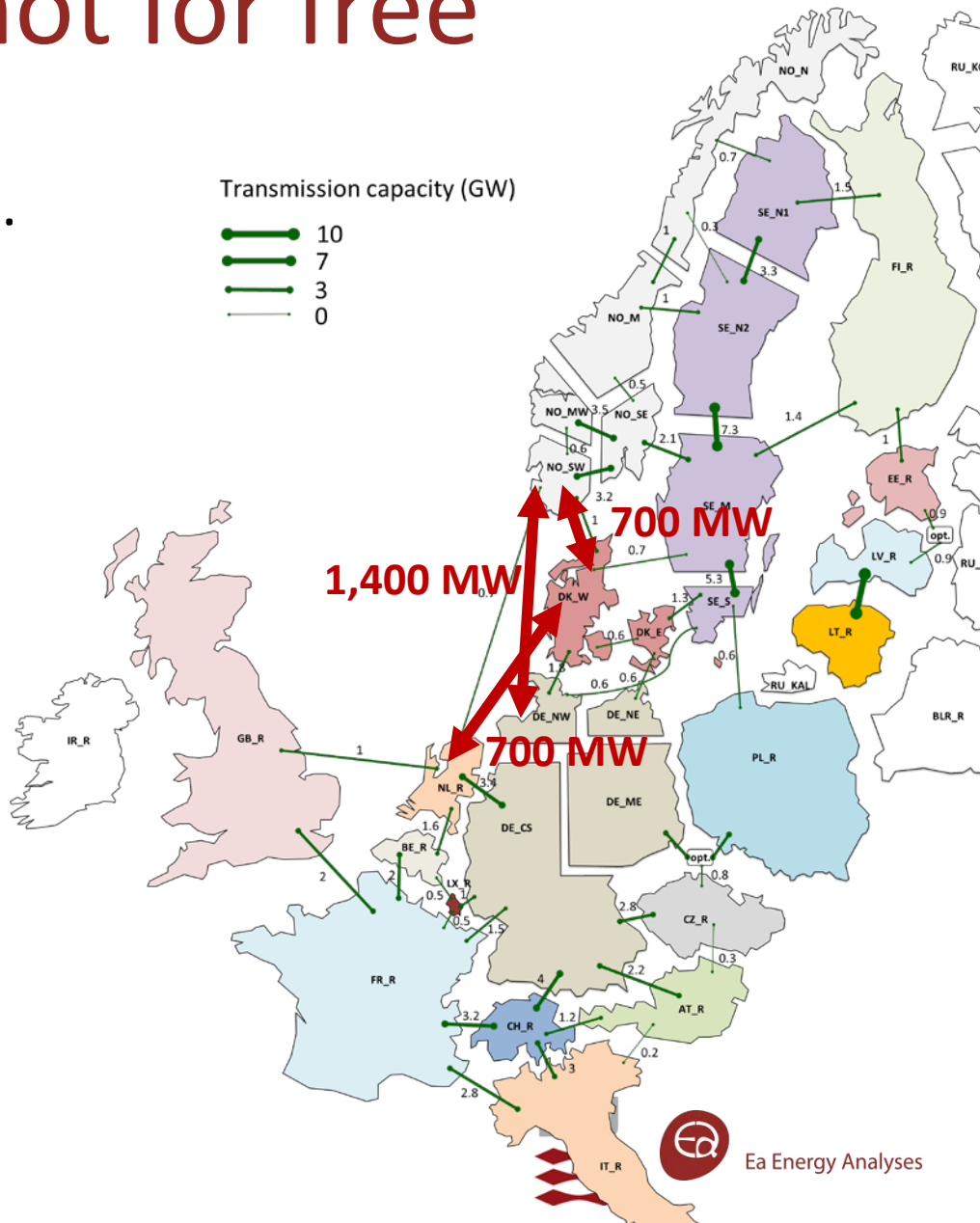
- Potential for ***green generation surplus*** in the Nordics
- Nordic hydro power can act as a ***very efficient battery***
- ***Geographic smoothing effects*** *for variable generation*
- ***Resource sharing*** across regions for back-up and ancillary services



Transmission is not for free

- Investment in generation vs. transmission
- Other options
  - Flexible demand
  - New types of demand
  - Curtailment

	M€	M€/MW
Skagerrak IV	440	0.6
NordLink	2,500	1.8
Cobra	620	0.9
Onshore wind		1.3
Offshore wind		3.6
Solar power		1.3



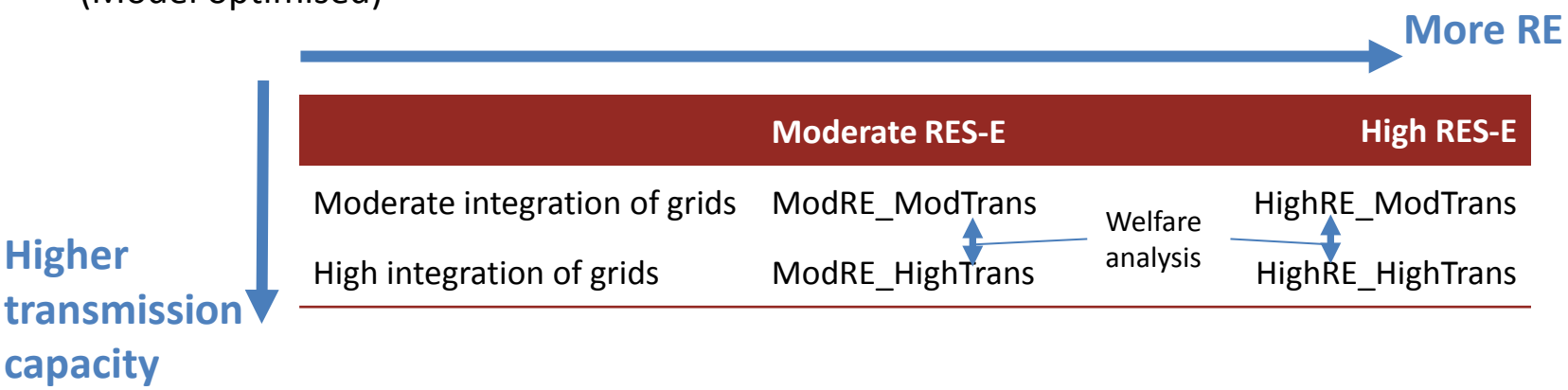
Scenario design

Variation

- **RE deployment**
- **Grid expansion Nordics and Germany – (TYNDP 2020 and 2030)**
- Investment in new generation capacity (Model optimised)
- Decommissioning of existing capacity (Model optimised)

Common assumptions

- RE deployment + other investments in neighbouring countries
- Grid development in neighbouring countries: TYNDP until 2025
- Fuel and CO2-prices
- Electricity and heat demand



DTU

Ea Energy Analyses

Modelling tool – Balmorel

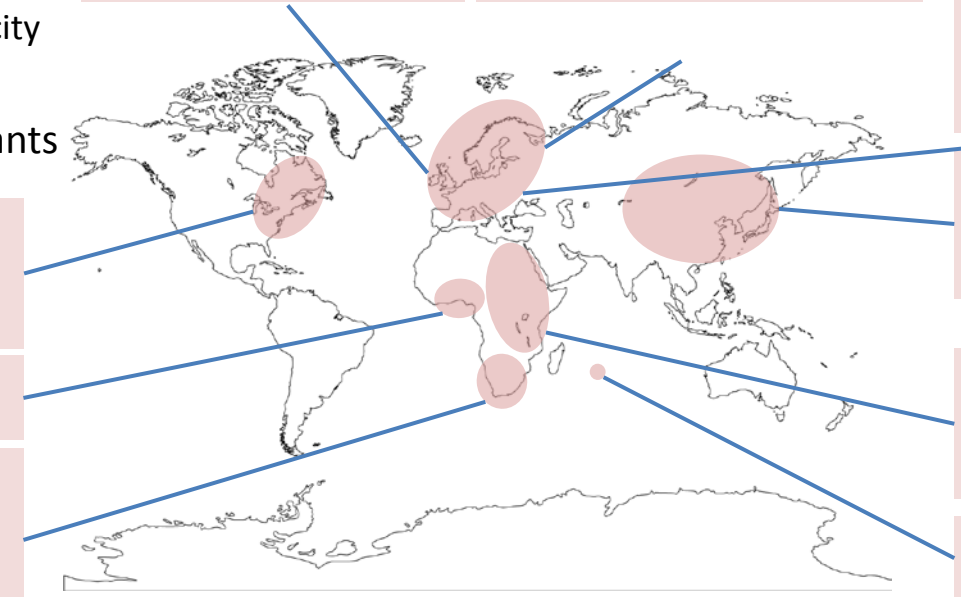
- Power and district heating
- Linear model, programmed in GAMS
- Least cost optimisation based on framework conditions
  - Investments
    - Generation capacity
    - Transmission capacity
    - Storage
  - Dispatch of power plants

Denmark
-District heating analysis
-Analysis of geothermal heat in DK
-Heat Plan for Greater Copenhagen
-Danish Commission for climate change: 100% Renewable energy

+ many other projects

UK/Ireland
-Large scale wind integration

Baltic Sea region
-Transmission interconnector study Estonia
-Energy scenarios 2030 and 2050 for Estonia
-Wind power in Estonia
-System adequacy in Lithuania
-Post-Kyoto Energy Scenarios for the Baltic Sea Region



China
-Wind integration in Heilongjiang
-2050 Scenarios for China

North America
-Wind integration in East Canada and North-East USA

Western Africa
-West African Power Pool

Eastern Africa
East African Power Pool: Regional Master Plan update

South Africa
-Costs and benefits of renewable energy
-Transmission lines and new generation (hydro and coal)

Mauritius
Energy Policy for Mauritius

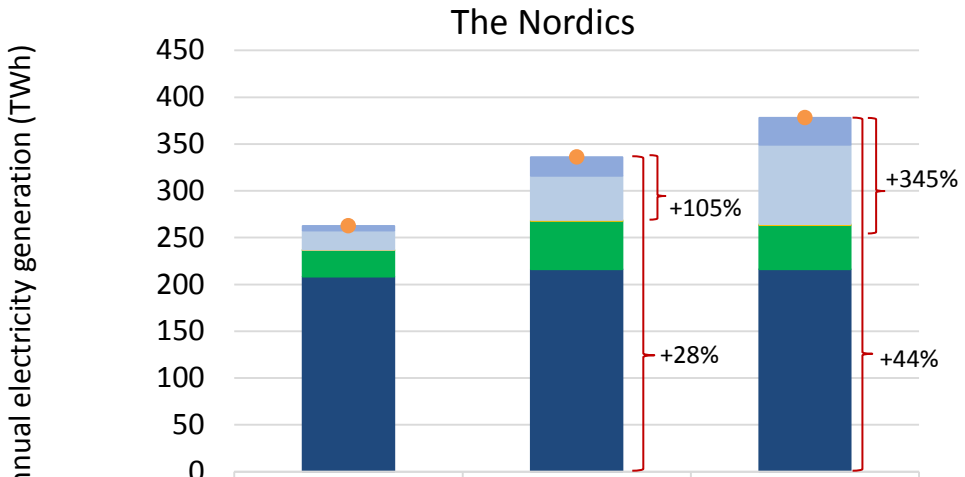
See: www.eaea.dk/themes/111_theme_modelling_of_energy_systems.html for project description and reports

DTU

Ea Energy Analyses

RES-E deployment Nordics

- Wind generation expected to double by 2030.
- Some hydro development in Norway
- Biomass increase in Denmark and Sweden
- Solar power could have larger share depending on price development



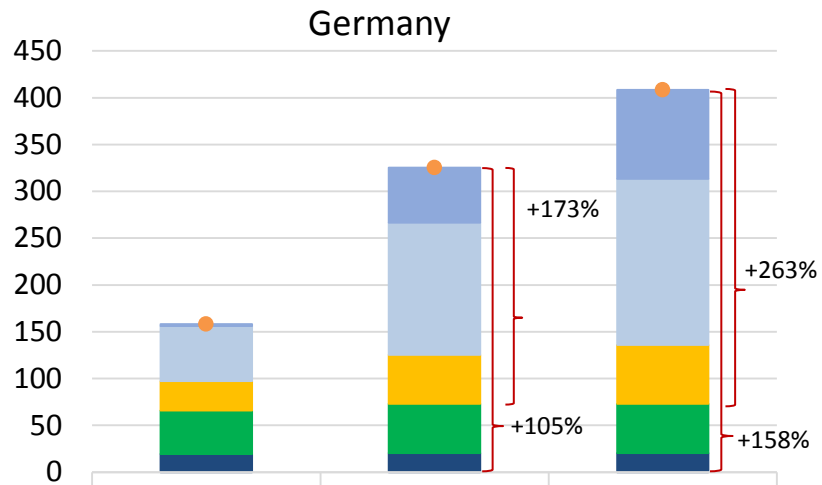
	2013	2030 - ModRE	2030 - HighRE
Offshore wind	5	20	29
Onshore wind	21	47	85
Solar	0	1	1
Biomass	28	52	47
Hydro	209	216	216
Total RE	263	336	378

DTU

Ea Energy Analyses

RES-E deployment Germany

- Significant increase towards 2030 – approaching total level of the Nordics
- Total RES-E doubles
- Variable RES-E increases up to +260%
- No new investments in coal capacity allowed



	2013	2030 - ModRE	2030 - HighRE
Offshore wind	2	59	95
Onshore wind	59	141	178
Solar	32	52	63
Biomass	46	53	53
Hydro	19	20	20
Total RE	158	325	409

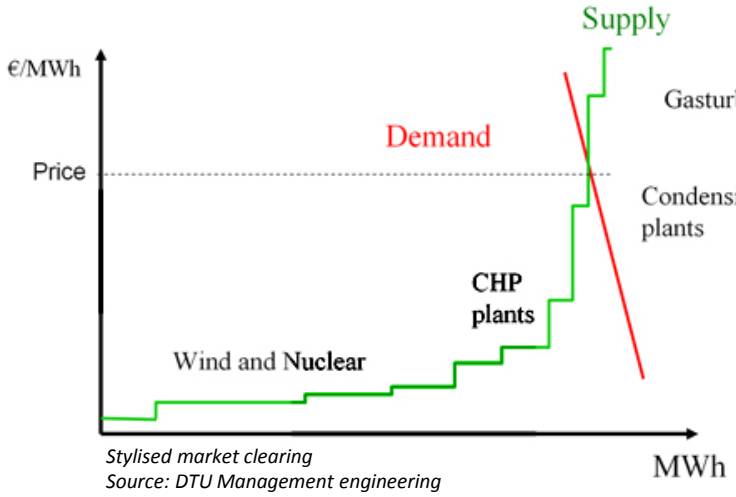
DTU

Ea Energy Analyses

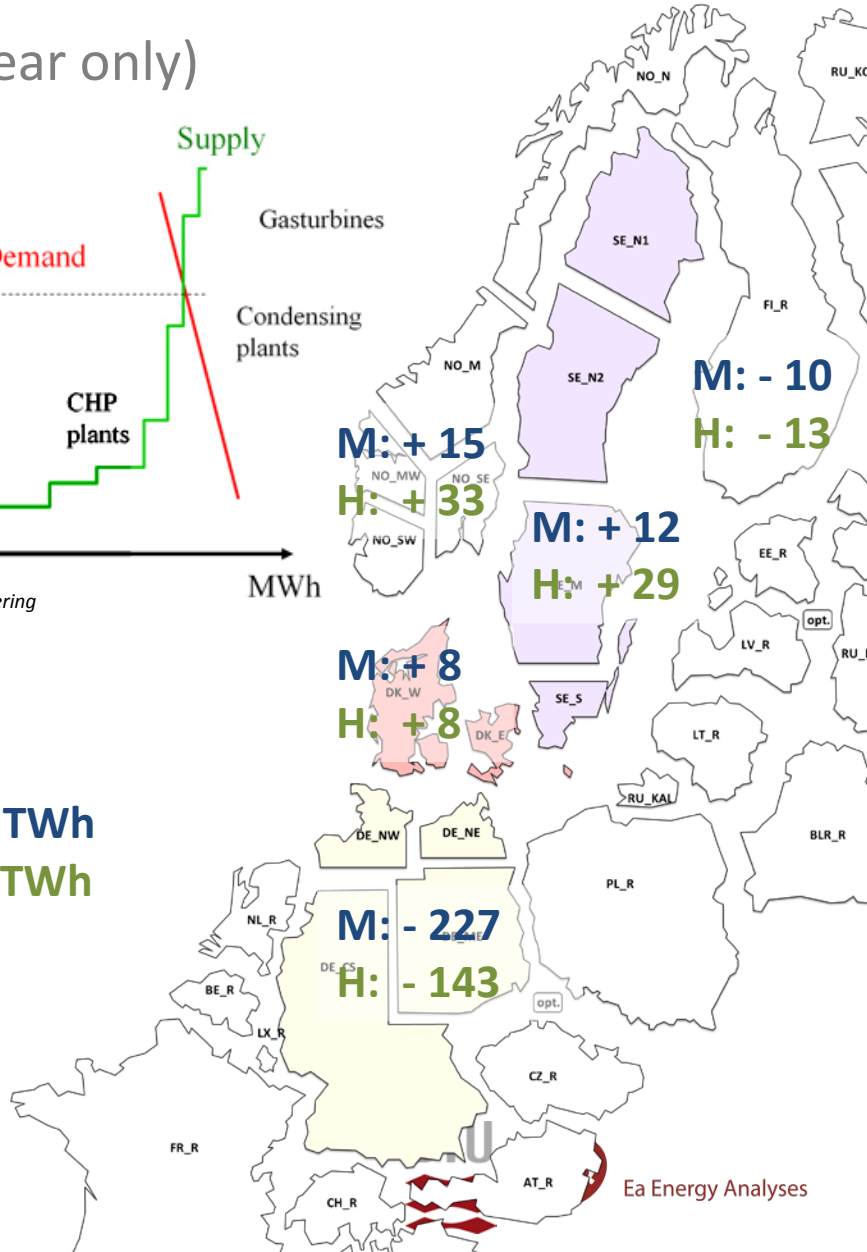
Power balance

(RES-E and Nuclear only)

- Integration challenge
  - Wind/solar:
    - Variable/Non dispatchable
    - Relatively low capacity factor
  - low short run marginal cost: Wind, Solar, Biomass*, Nuclear
- Significant surplus in the Nordic countries
- Potential room for import in Germany
- Transmission system stressed – increased importance in the HighRE-scenarios



Stylised market clearing
Source: DTU Management engineering

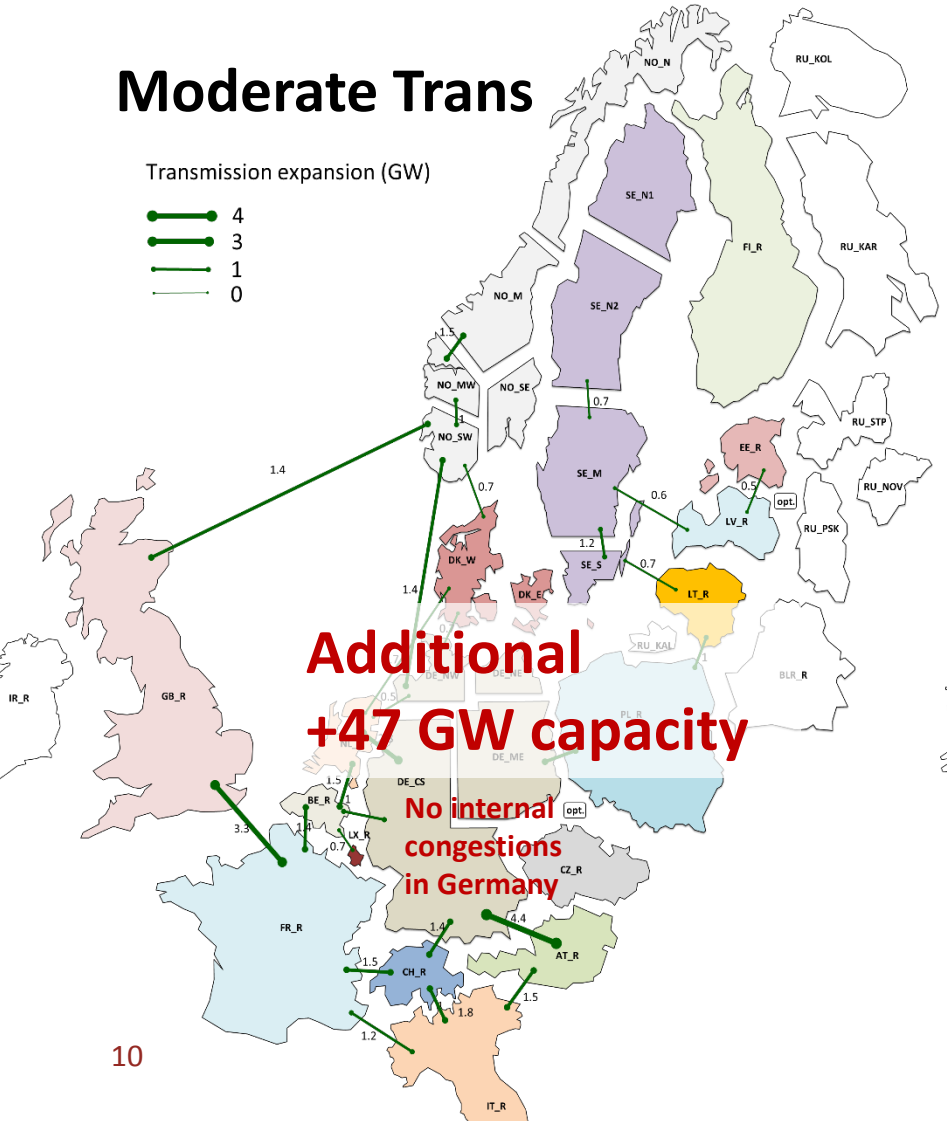


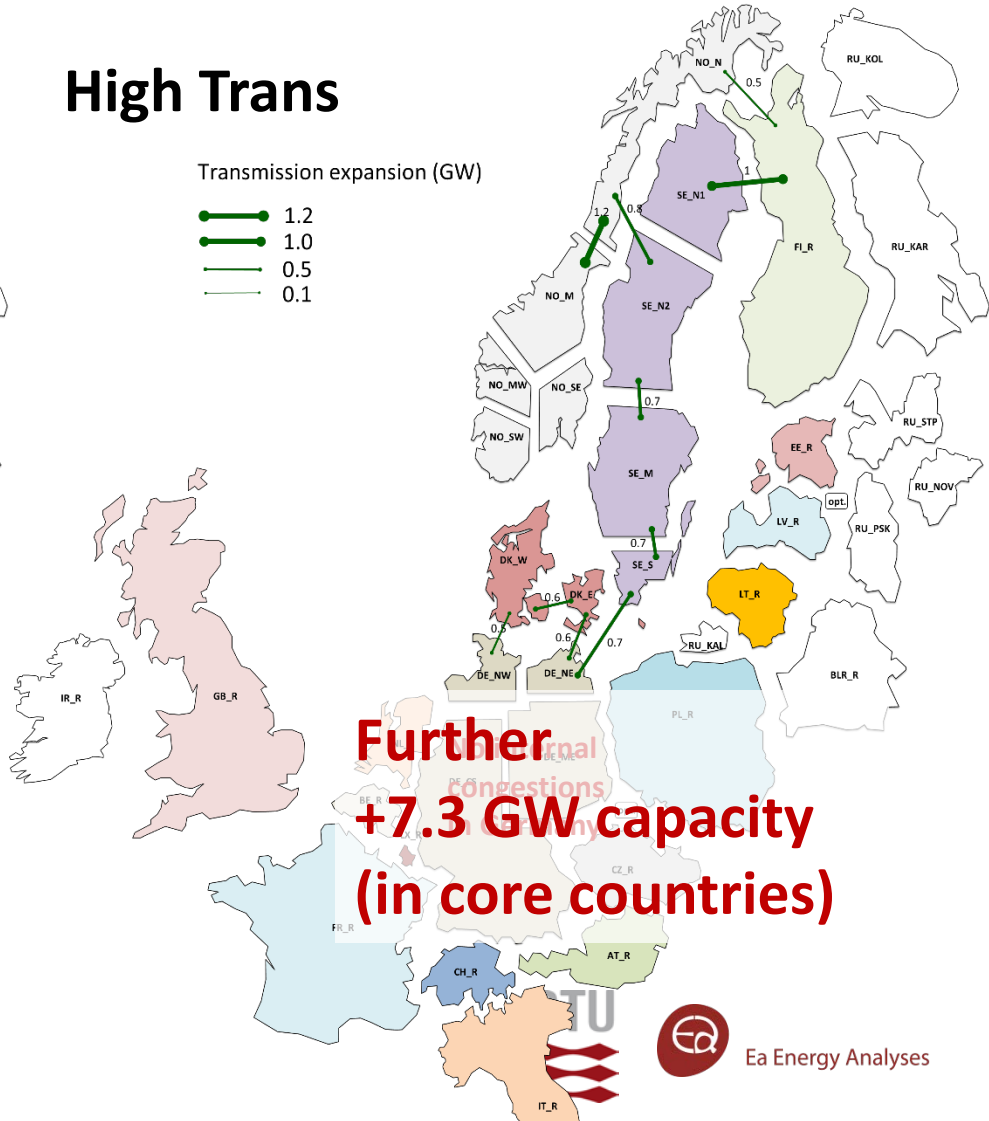
ModRE: + xx TWh

HighRE: + xx TWh

* Model perspective due to scenario setup with predefined biomass production amounts

Grid development 2013-2030





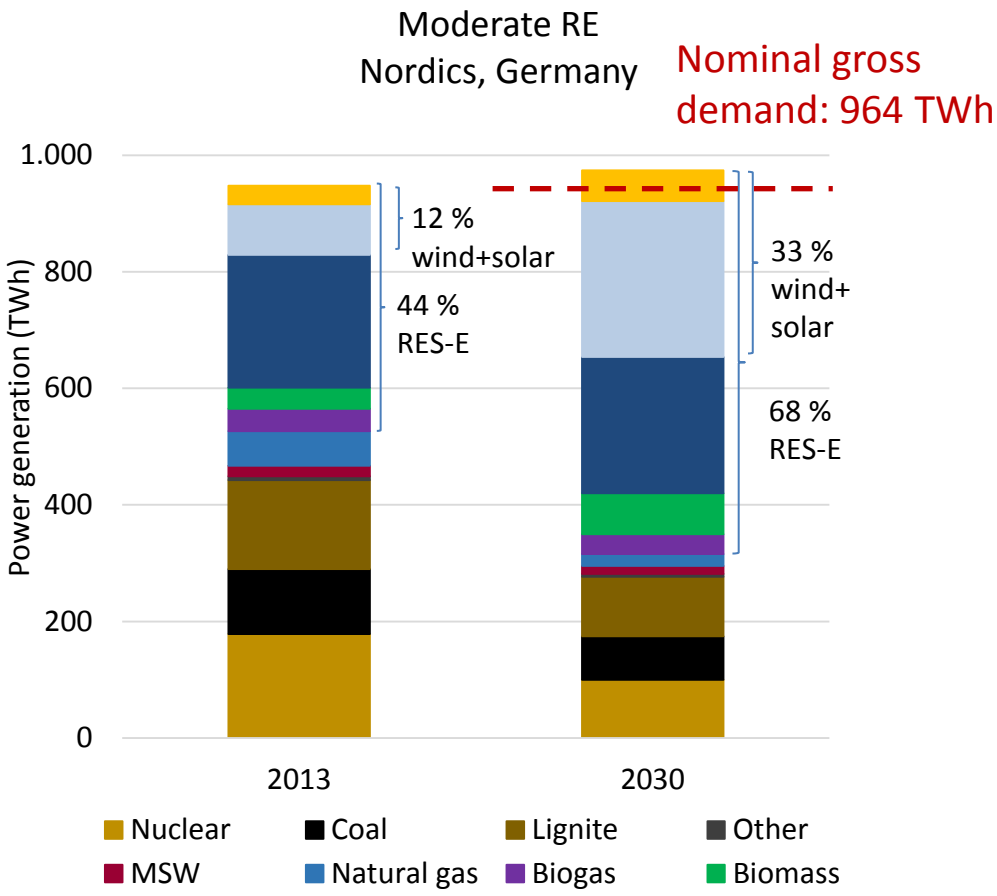
Ea Energy Analyses

Generation mix

- Increasing share of RES-E, in particular variable RES-E
- Reduced generation from fossile fuels
- Region as a whole is a net exporter

- **HighRE-scenarios**
  Additional potential
  +130 TWh wind and solar

  Total >75% RES-E



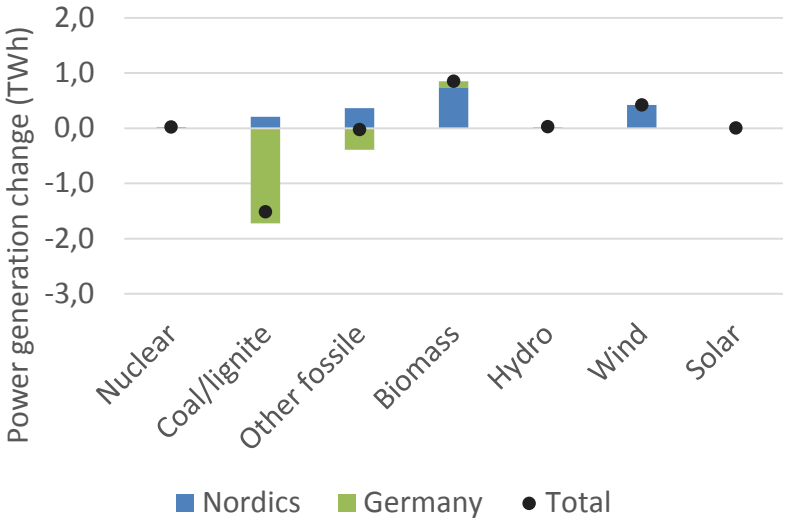
DTU

Ea Energy Analyses

Generation mix
Moderate vs. High Transmission

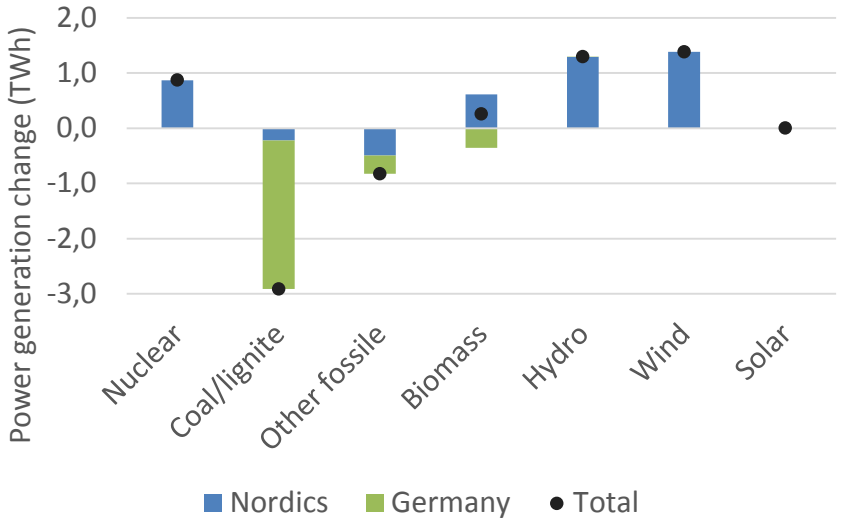
Moderate RE

- Better utilization of wind and biomass



High RE

- Better utilization of wind and biomass
- Reduced curtailment (2 TWh)

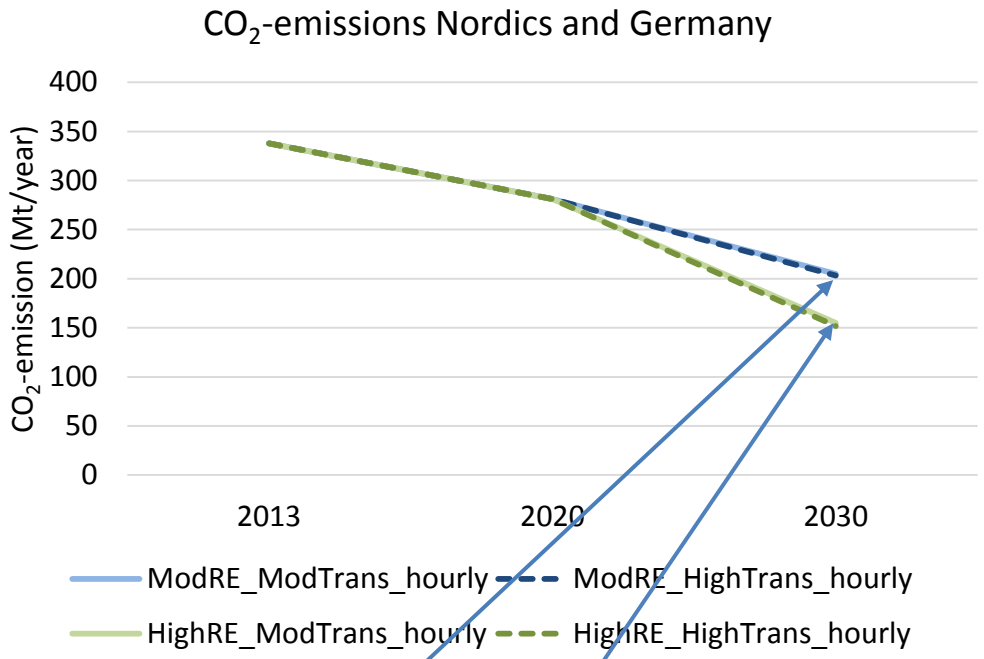


DTU

Ea Energy Analyses

Climate effects

- CO_2 savings Nordics and Germany:
  - Additional RE: CO_2-savings 25%
  - Additional transmission: CO_2-savings 1-2%
- No effect on CO_2-prices taken into account
- European Emissions Trading System: Short term effect of CO_2-savings -> price decrease

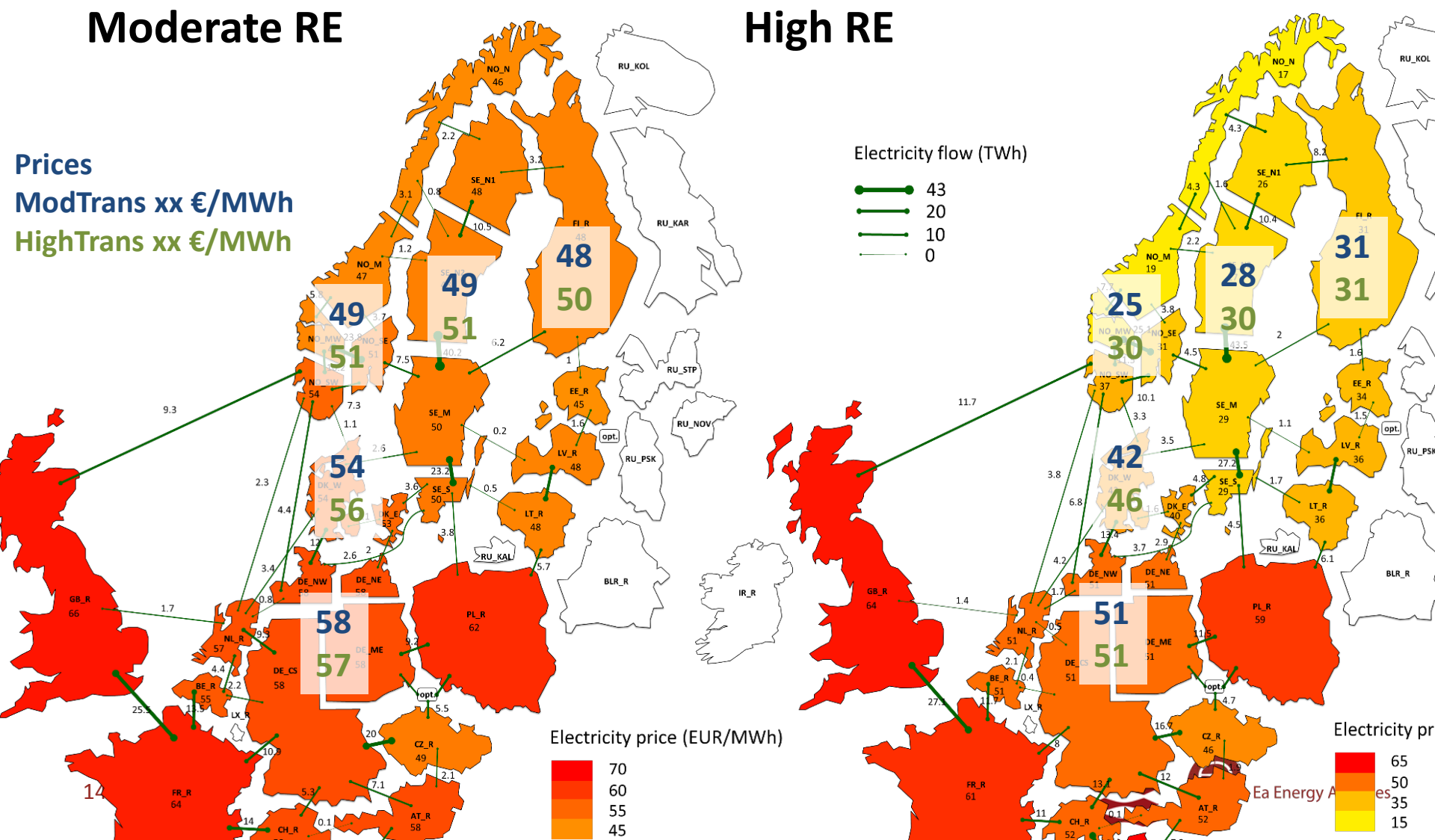


	Moderate RE	High RE
	%	%/year
Nordics + Germany	-0.7%	-2.1%
Surrounding countries	-0.1%	-0.5%
Nordics, Germany and surrounding countries	-0.3%	-1.1%

DTU

Ea Energy Analyses

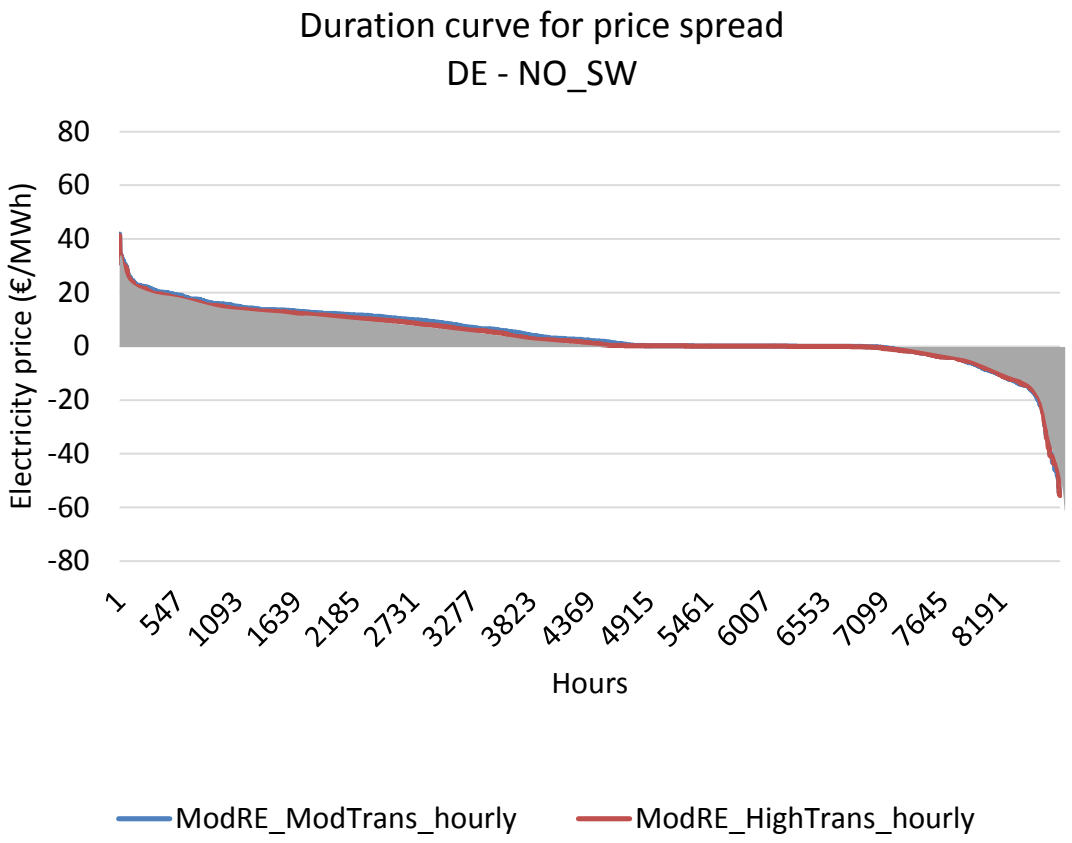
Annual electricity prices



Electricity price variation

- Main flow direction: South
- Number of hours with price difference

	ModRE
Norway < Germany	6200
Equal	550
Germany < Norway	2000



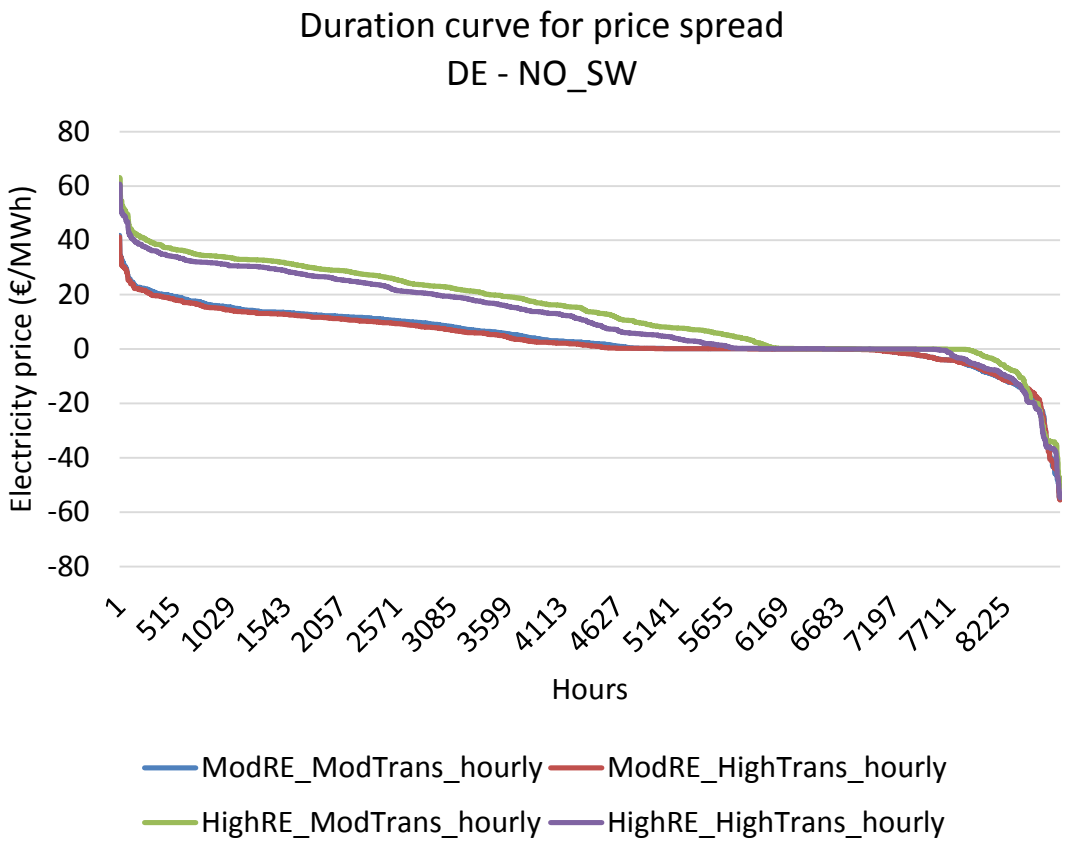
DTU

Ea Energy Analyses

Electricity price variation

- Main flow direction: South
- Number of hours with price difference

	ModRE	HighRE
Norway < Germany	6200	7000
Equal	550	550
Germany < Norway	2000	1200

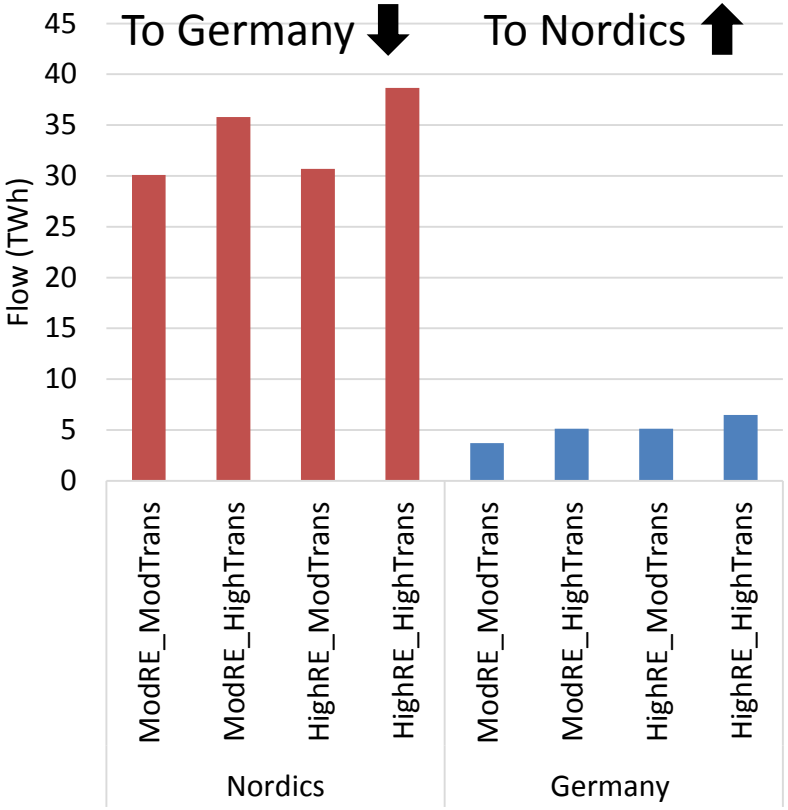


DTU

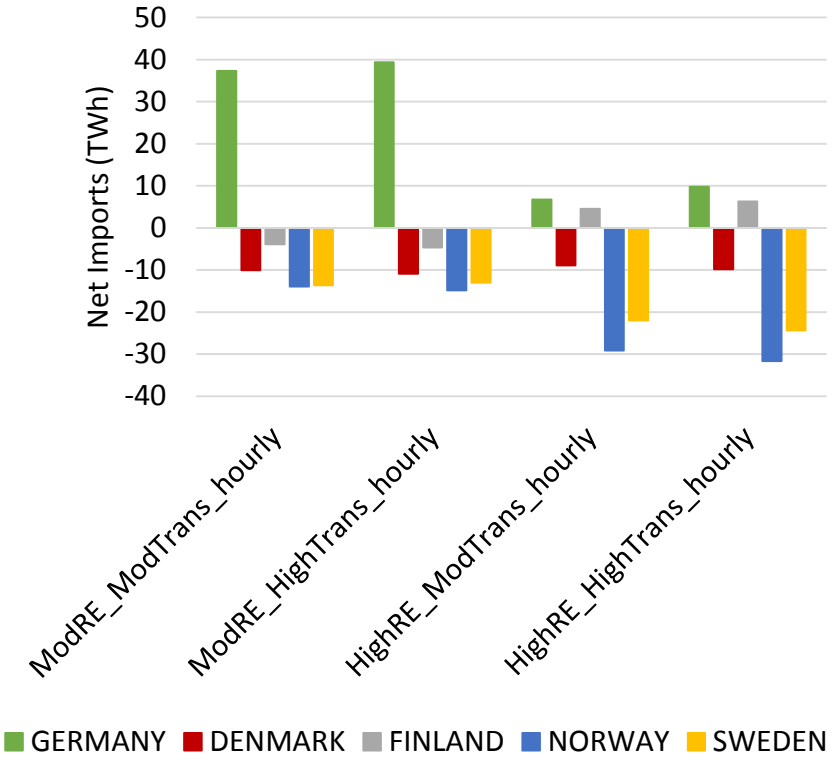
Ea Energy Analyses

Flows between Nordics and Germany

Gross flows between Nordics and Germany



Net flows (from all neigbouring countries)



DTU

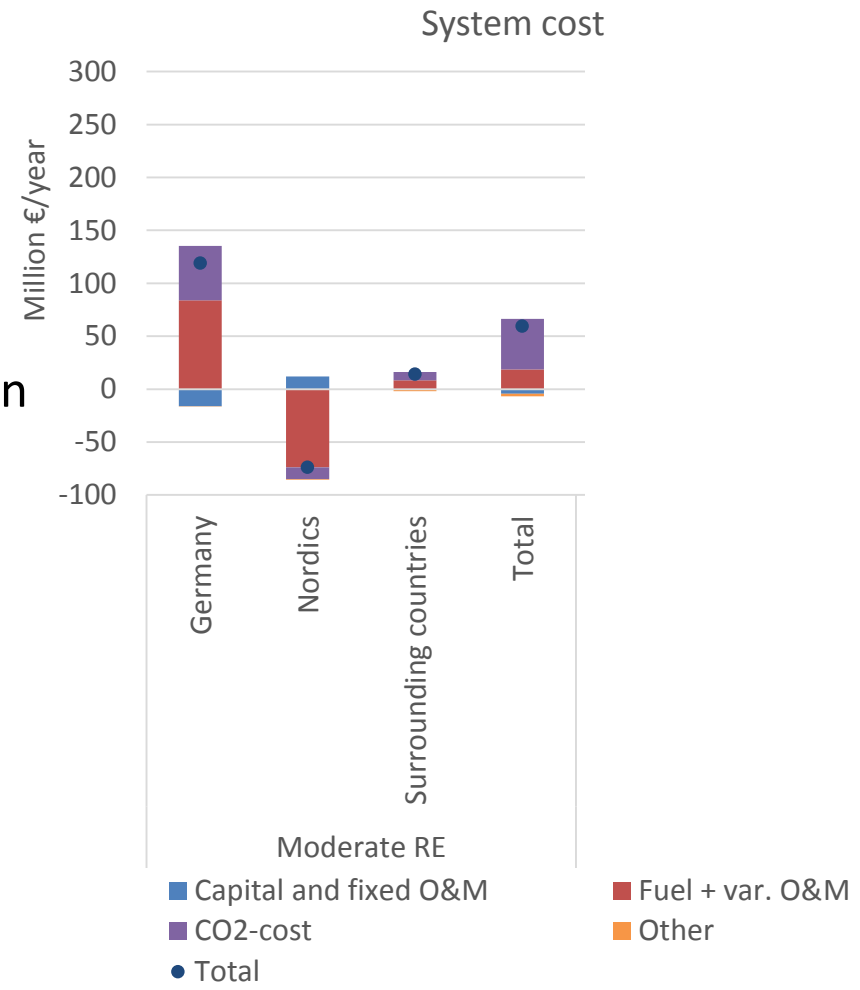
Ea Energy Analyses

System costs

ModRE_ModTrans → ModRE_HighTrans

HighRE_ModTrans → HighRE_HighTrans

- System cost excluding transmission investment
- Redistribution of generation
- CO_2-savings
- High Transmission:
  208 – 348 Million €/year
- **Sensitivities:**
  - **Less nuclear (SE) -> Less benefit**
  - **Flexible demand -> Less benefit**
    - **6-13 Million €/year**



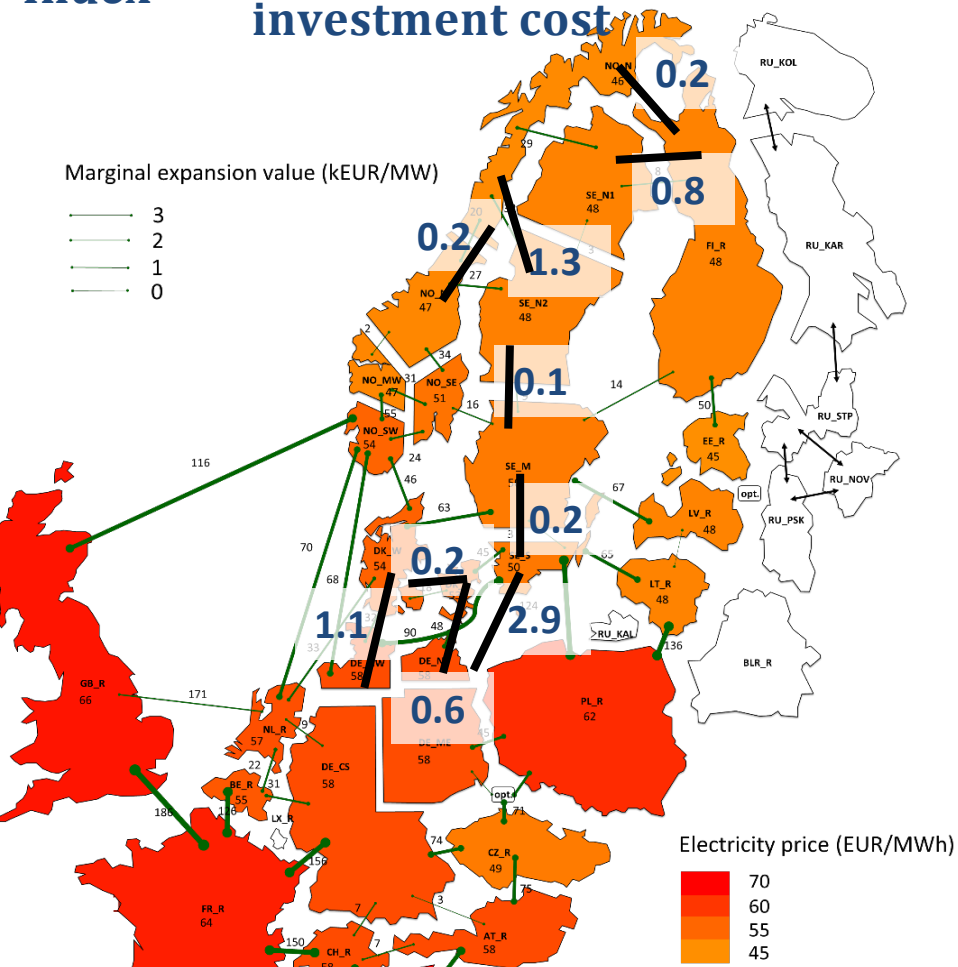
DTU

Ea Energy Analyses

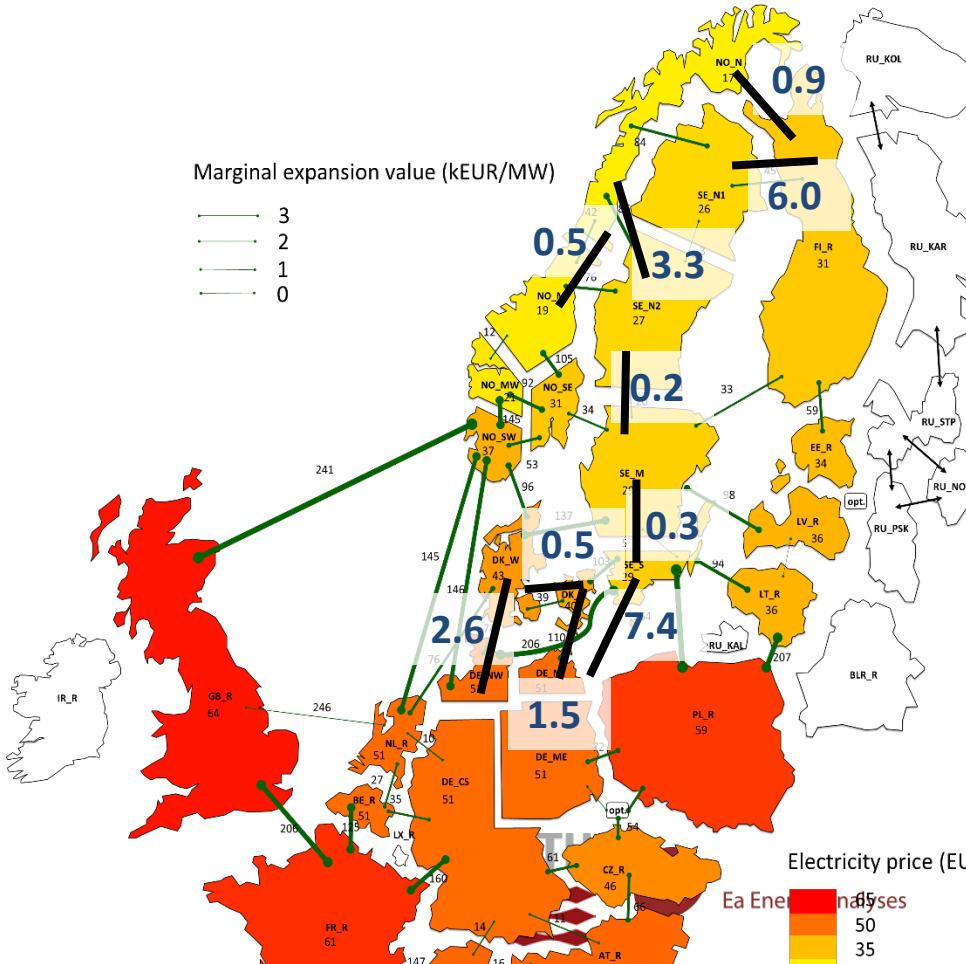
Marginal value of transmission

ModRE ModTrans

$$\text{Index} = \frac{\text{avg. marginal value}}{\text{investment cost}}$$



HighRE ModTrans



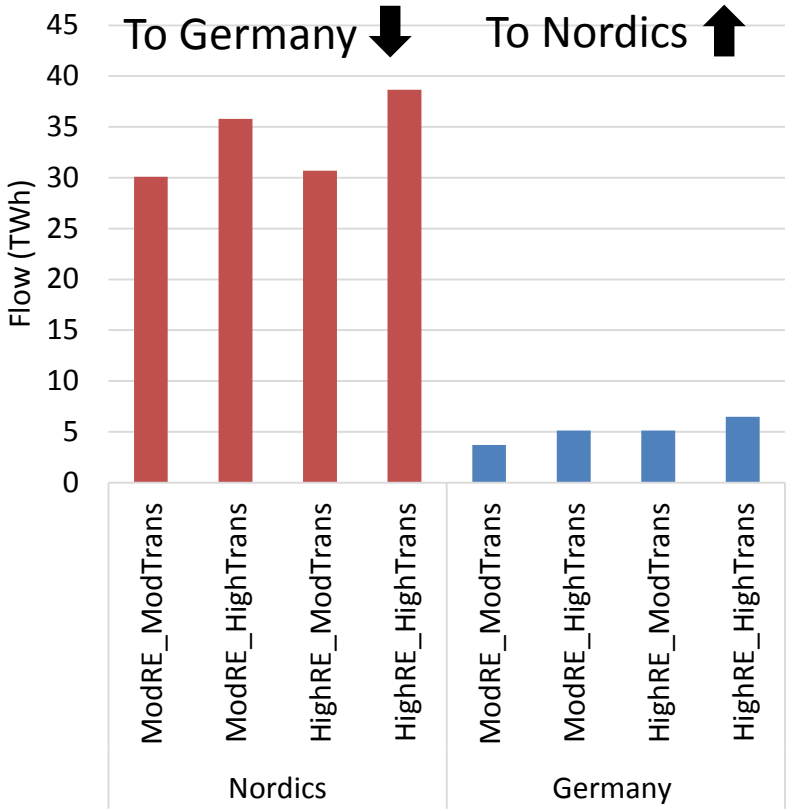
Key observations

- Potential for increased electricity trade between Nordics and Germany compared to today
- Increased transmission capacity ->
  - Better utilization of RES-E
  - Potential for CO_2-savings
  - Convergence of electricity prices -> distribution of benefits differs by country
- Moderate RES-E deployment
  - Different composition of transmission package would be more beneficial from a system perspective
  - Further integration on some lines
  - Careful optimization needed
- High RES-E deployment
  - Potentially large price spreads
  - Chosen transmission package can be beneficial from a system perspective
  - Further integration potential

Drivers for transmission

Motivation for closer grid integration

- Potential for ***green generation surplus*** in the Nordics
- Nordic hydro power can act as a ***very efficient battery***
- ***Geographic smoothing effects*** *for variable generation*
- ***Resource sharing*** across regions for back-up and ancillary services



DTU

Ea Energy Analyses

Perspectives

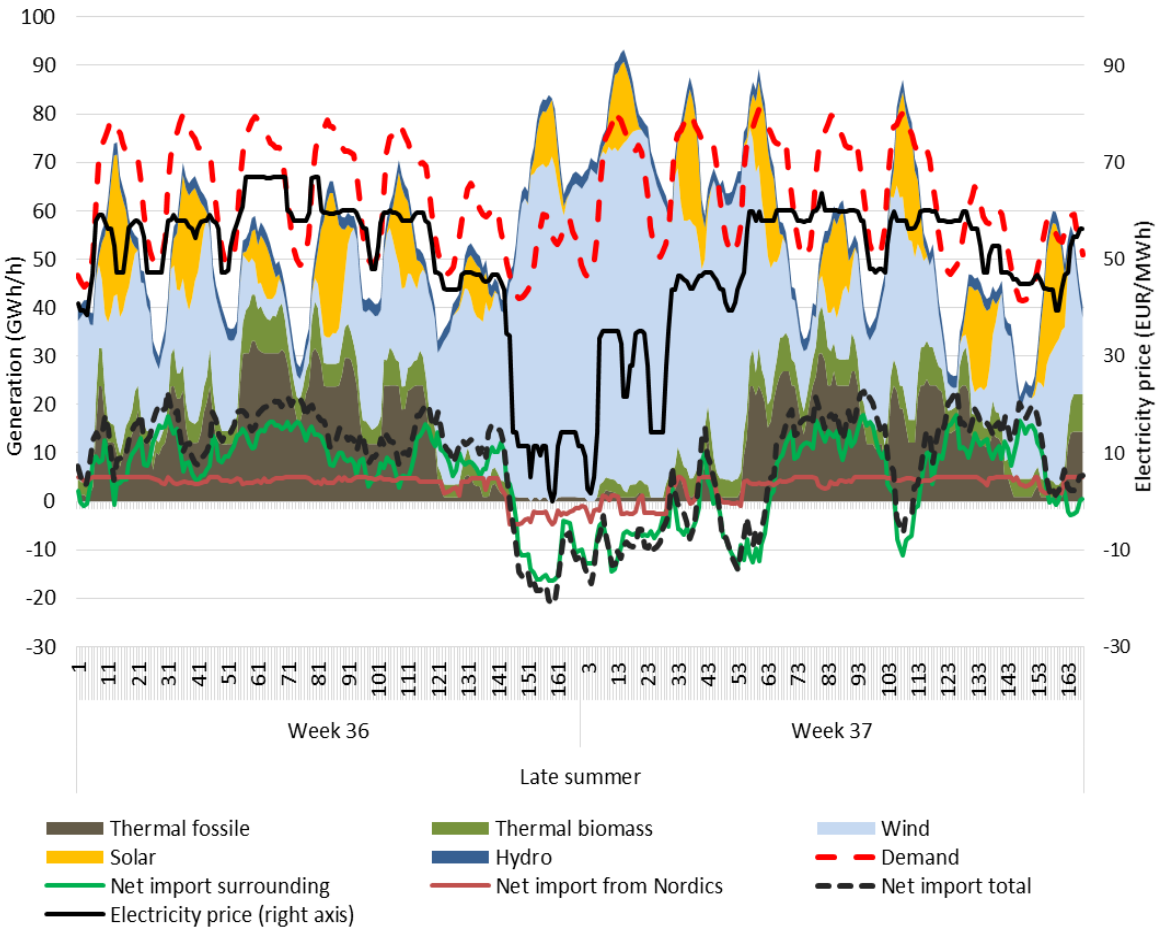
- Optimization of grid planning
- Other important factors to consider
  - Hydro power variability
  - System service requirements
  - Flexibility of power plants
  - Reserve sharing

Discussion – System operation

- System requirements can increase value of transmission

Number of hours in the German system with a dispatchable generation below x GW

	Below 5GW	Below 20GW
Moderate RES-E	600	3,500
High RES-E	1,150	4,700
Curtailment	< 1 %	10-18%



DTU

Ea Energy Analyses