DTU

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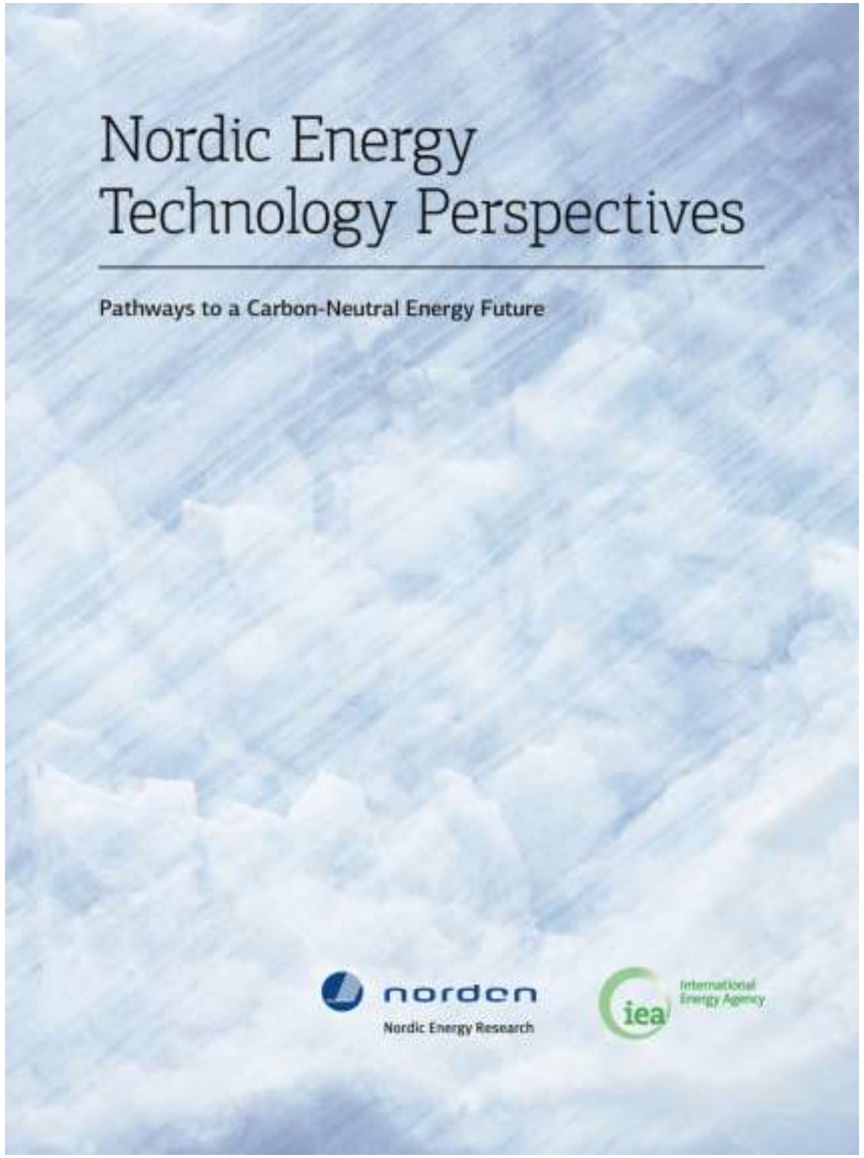
Planning with high share of VRE in the Nordic energy system



https://www.nordicenergy.org/project/nordic-energy-technology-perspectives/

Nordic Energy Technology Perspective 2016

Launch events

Stockholm
23rd of May
Featuring Swedish Energy Minister Ibrahim Baylan, the IEA's Kamel Ben Naceur, and key members of the Swedish Energy Commission

Oslo
26th of May
Parallel session at Norwegian Energy Research Conference (Energiforsknings-konferansen)

Copenhagen
10th of June
Featuring speakers from the Danish Energy Agency, DTU, Ea Energy Analysis, and the Danish Energy Association

Reykjavik
13th of June
Featuring Icelandic Energy Minister Ragnheiður Elín Árnadóttir

Helsinki
16th of June
Featuring Finnish Energy Minister Olli Rehn

International Energy Agency
norden – Nordic Energy Research, Nordic Council of Ministers
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IFE
University of Iceland
Ea Energy Analyses
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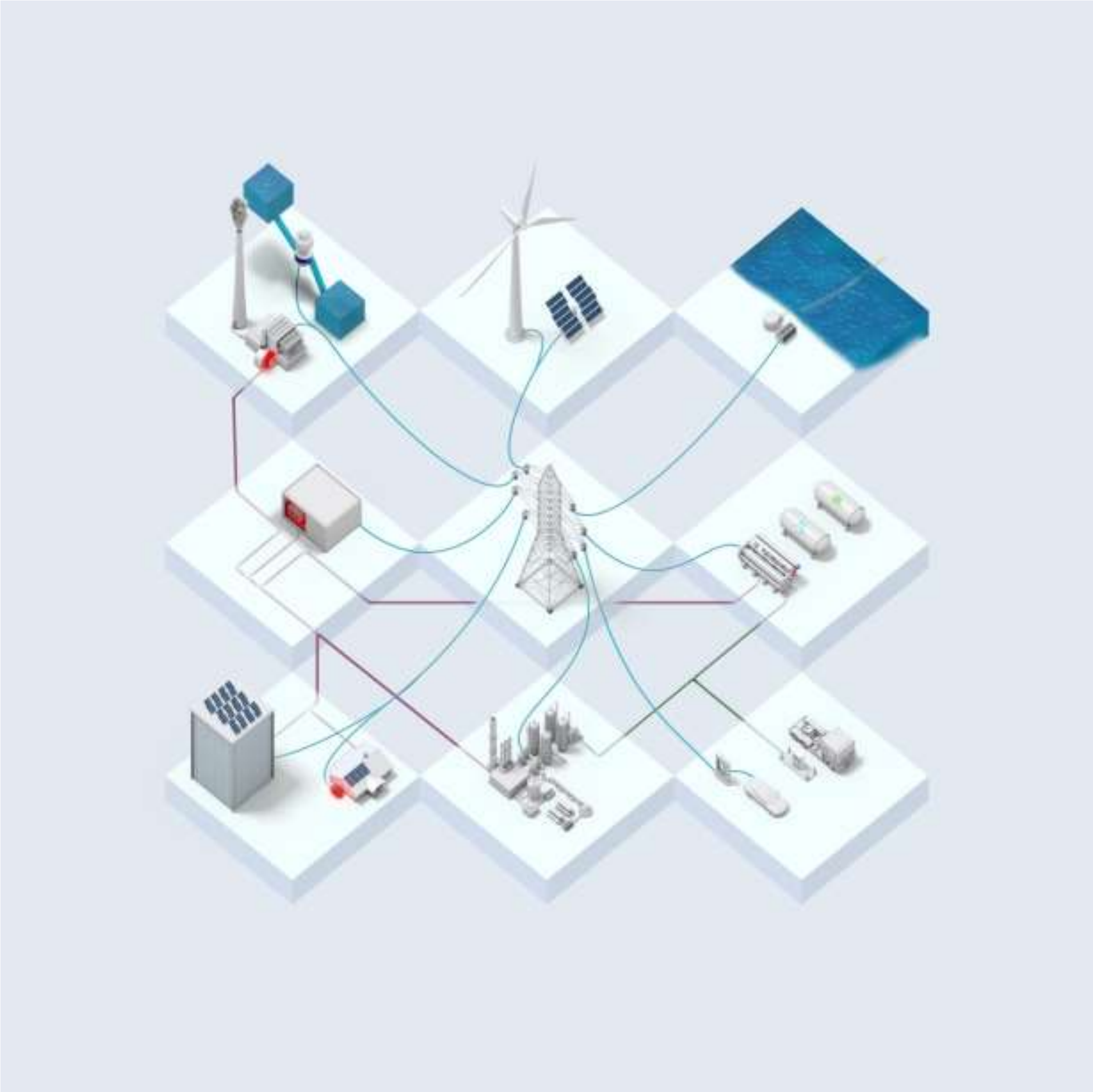
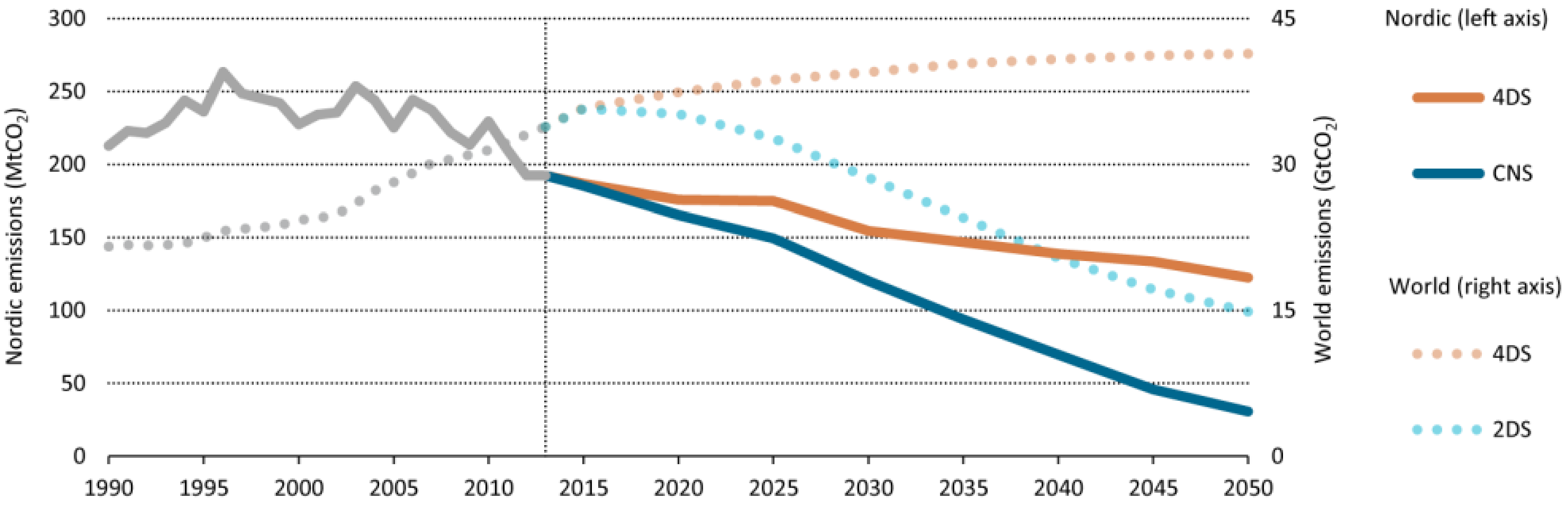
Future Energy Systems



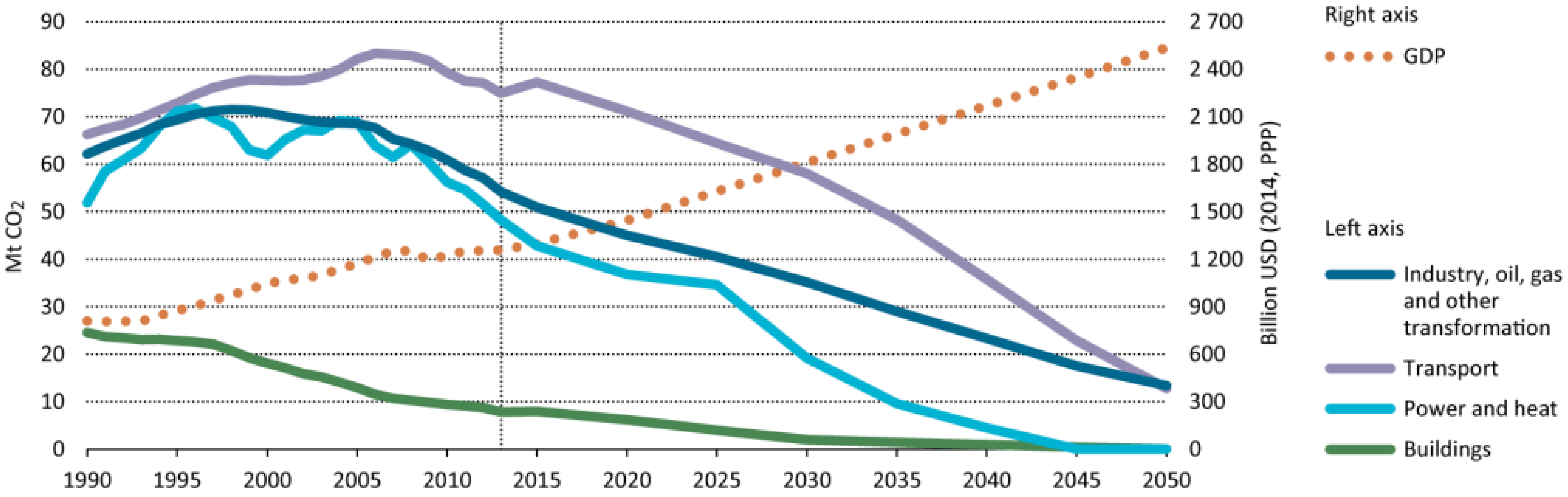
Electricity as main energy carrier

Reduction pathway for energy-related CO2 in the 4DS, 2DS and CNS



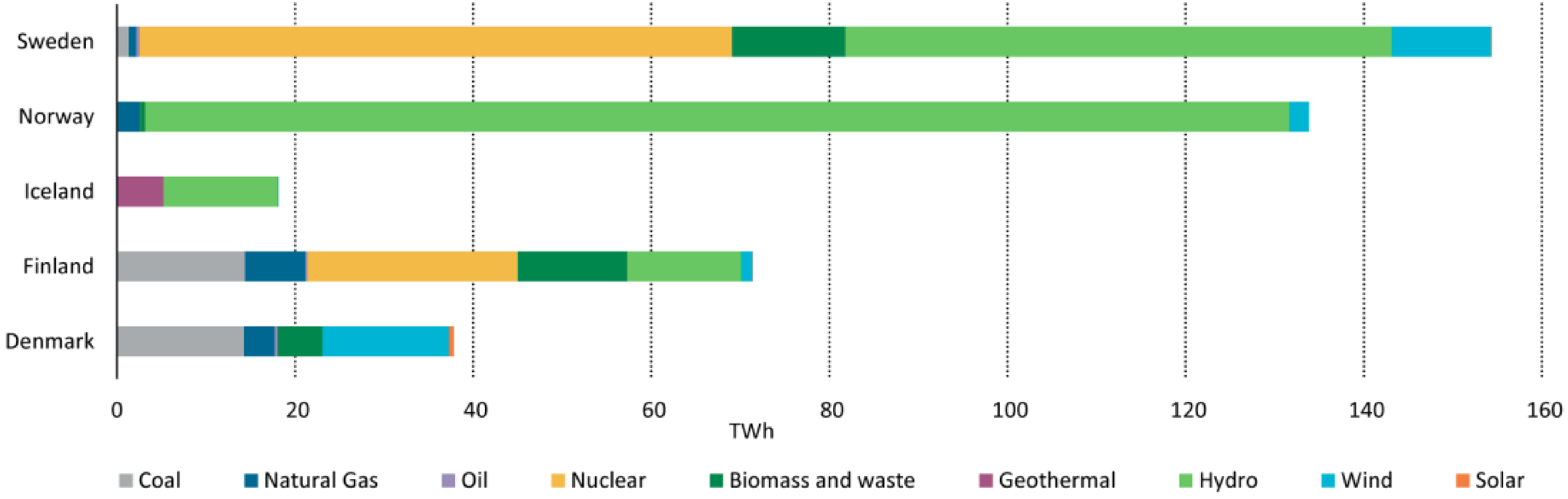
The Carbon-Neutral Scenario sees Nordic emissions drop 85% by 2050 compared to 1990 levels, with the rest of the world pursuing the 2C scenario.

Nordic GDP and CO2 emissions by sectors in CNS



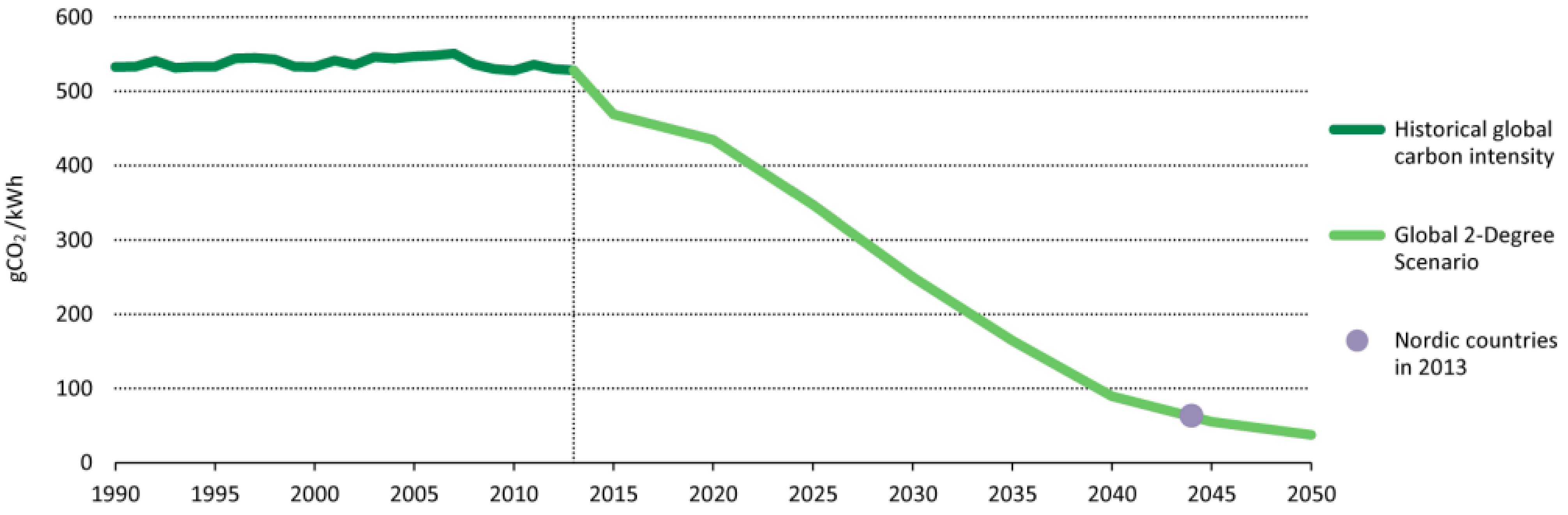
While emissions from all sectors have already decoupled from Nordic GDP, decarbonisation is first achieved by power, heat and buildings, followed ny more challenging industry and transport

Electricity generation in the Nordic countries in 2013



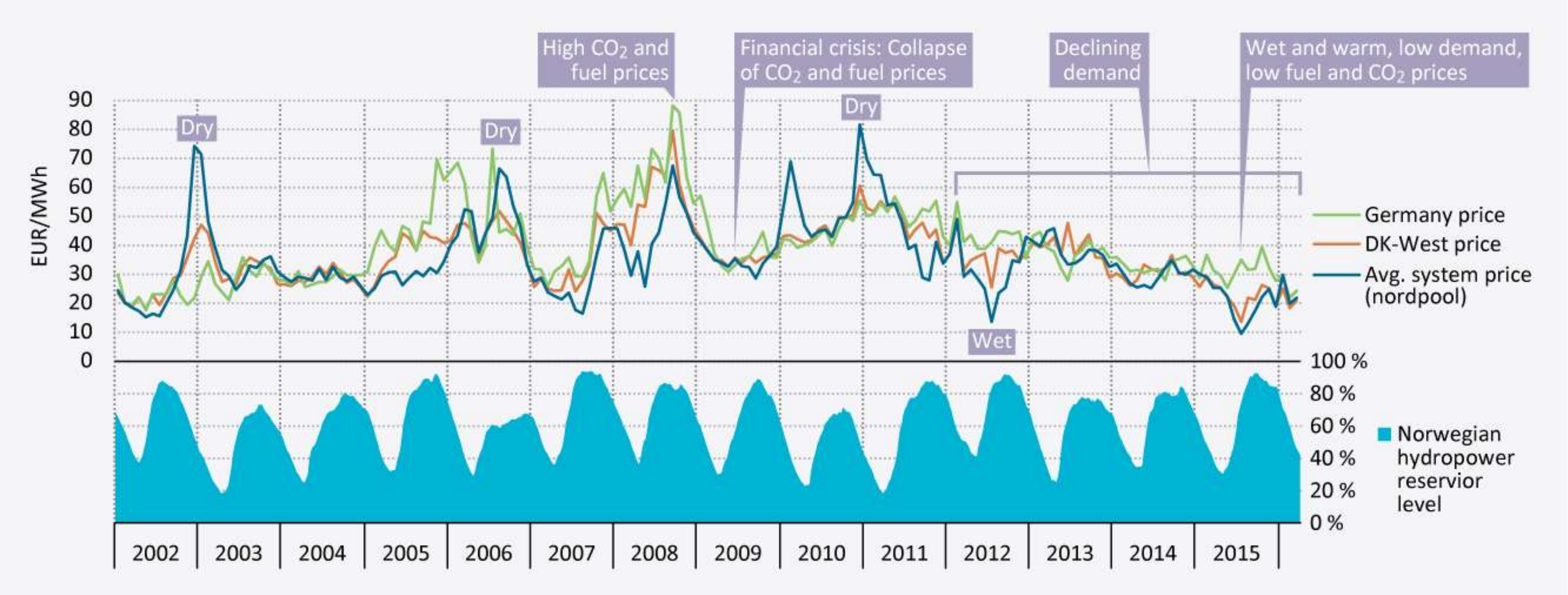
At present, 83% of the electricity production in the Nordic countries is carbon neutral, of which 63% is renewable.

Electricity generation in the Nordic countries, 2013



The Nordic carbon intensity of electricity supply was 63 gCO2/kWh in 2013 – where it will be in 2044 in the global 2DS.

Historical electricity prices in the Nordic power market and hydro power reservoir level

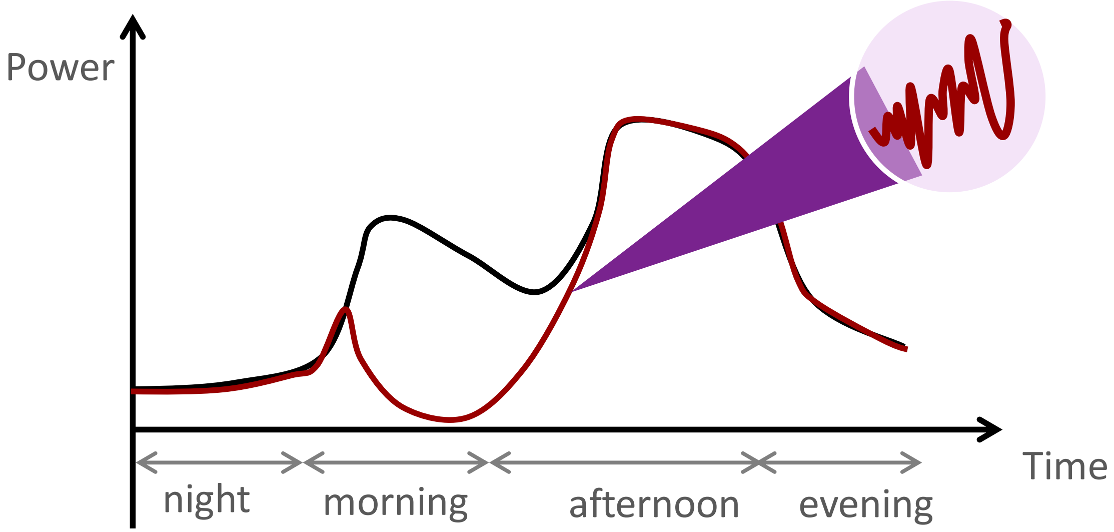


The electricity price fluctuations can be partly explained by the amount of precipitation, CO_2 and fuel prices, and developments in the electricity demand.

What are the challenges with VRE

Electricity production from variable renewable energy (VRE) technologies are characterised by:

- *Variable* electricity production
  - Determined by temporal weather conditions
- *Uncertain* electricity production
  - Due to forcasting errors
- *Location specific* electricity production
  - Since the primary energy source cannot be transported



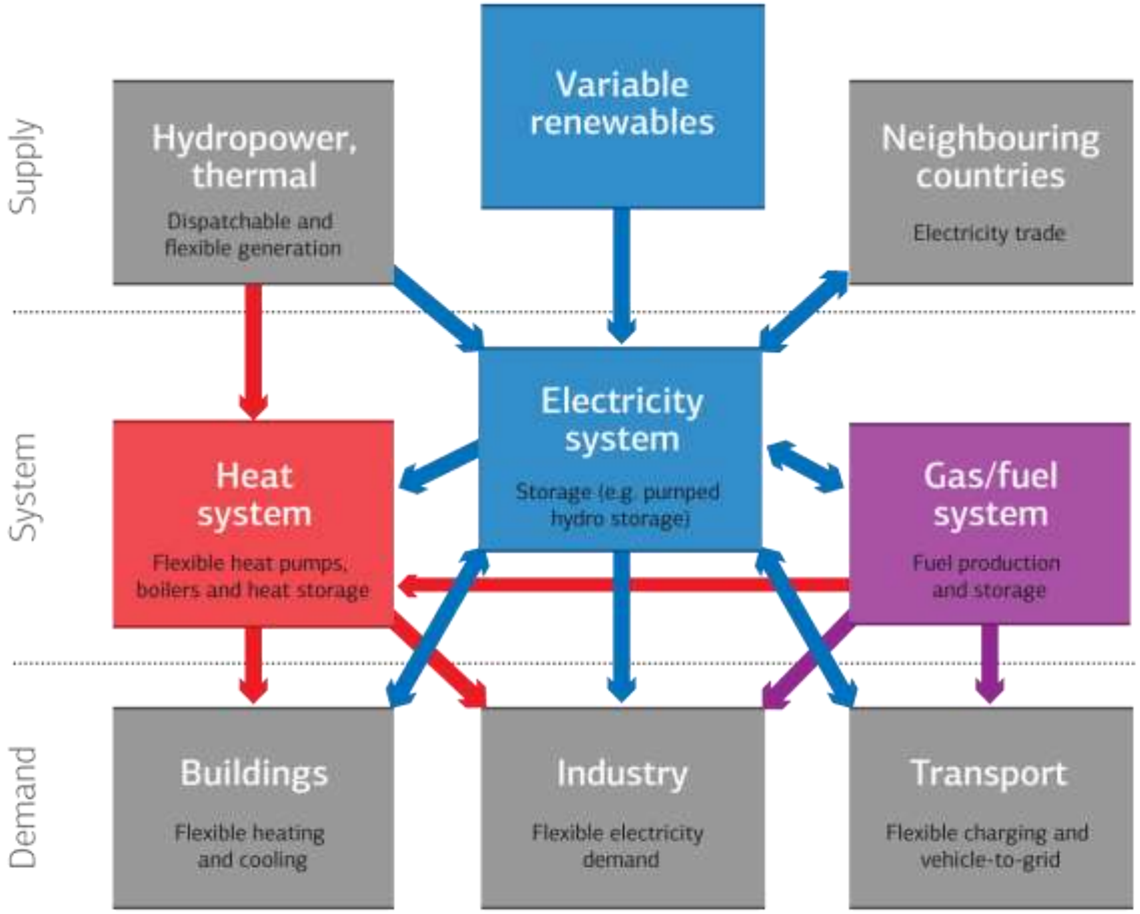
Managing a system with high shares of VRE

The NETP divides flexibility into four flexible resources:

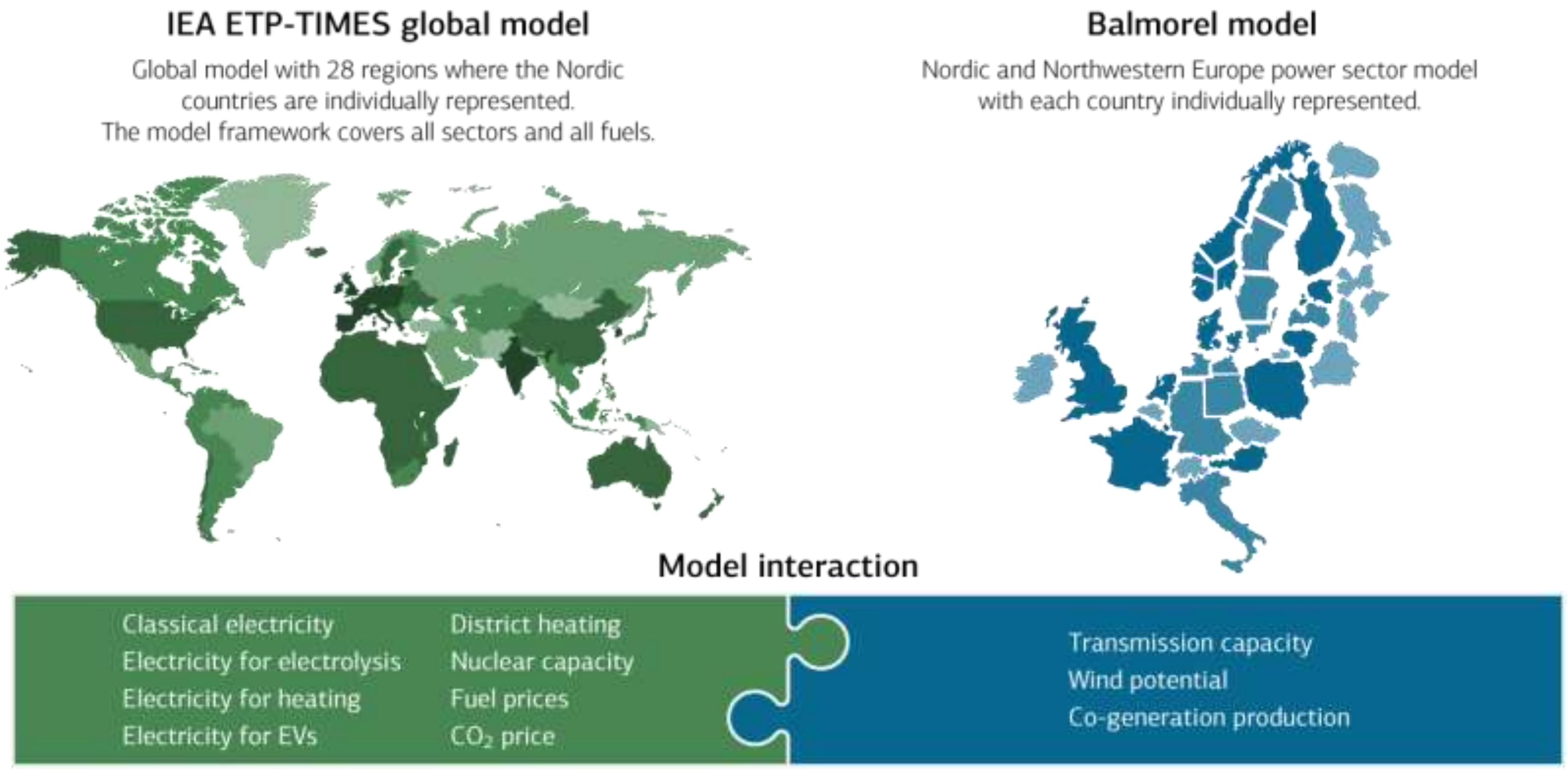
flexible power generation,

demand-side management,

energy storage facilities and interconnection with adjacent markets



Connection between ETP model results and Balmorel simulations

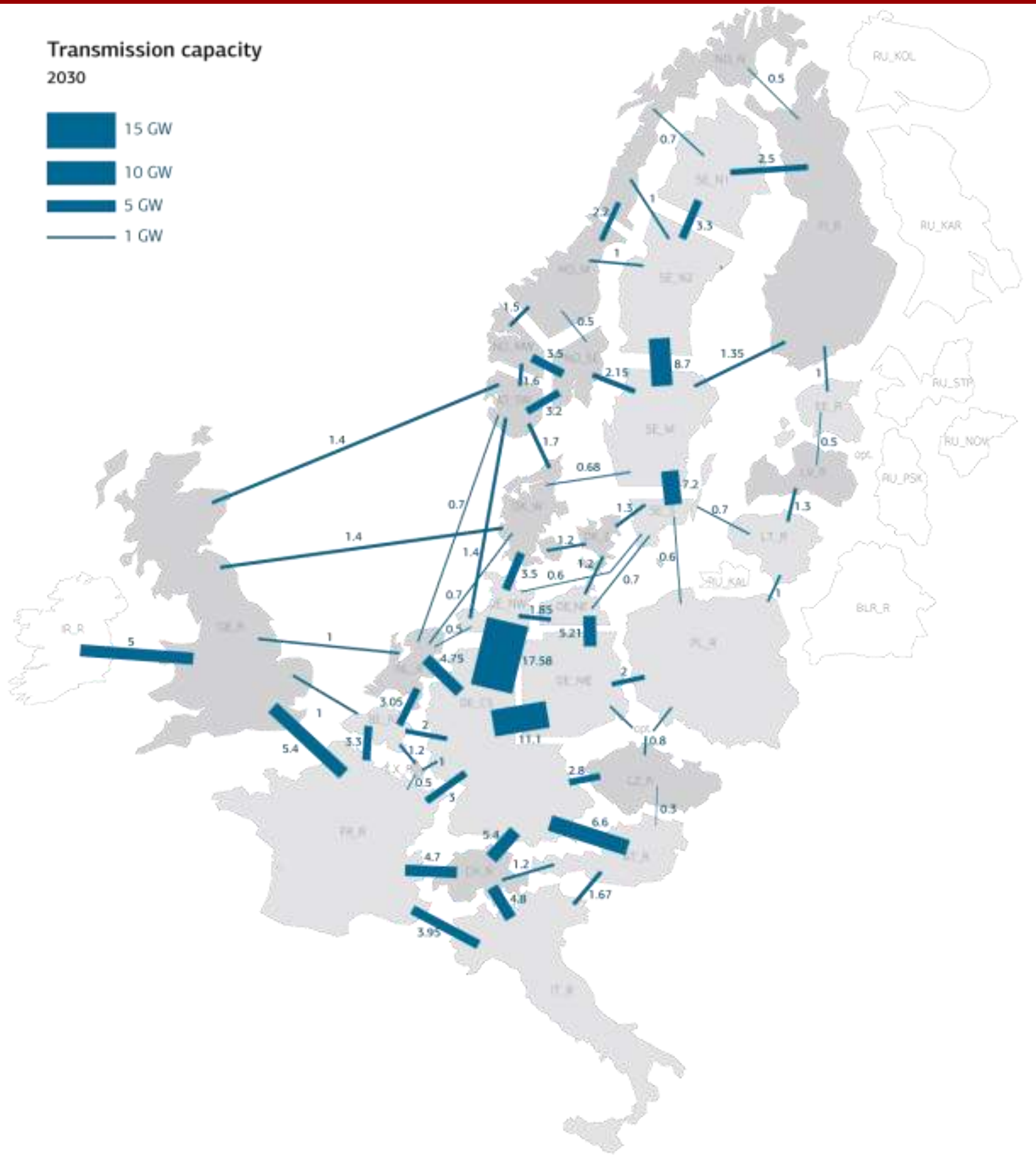


The CNS assumptions and results, such as electricity demand, are used as input data for the Balmorel model; thereafter, Balmorel outputs, e.g. transmission capacities, are used in the ETP-TIMES model.

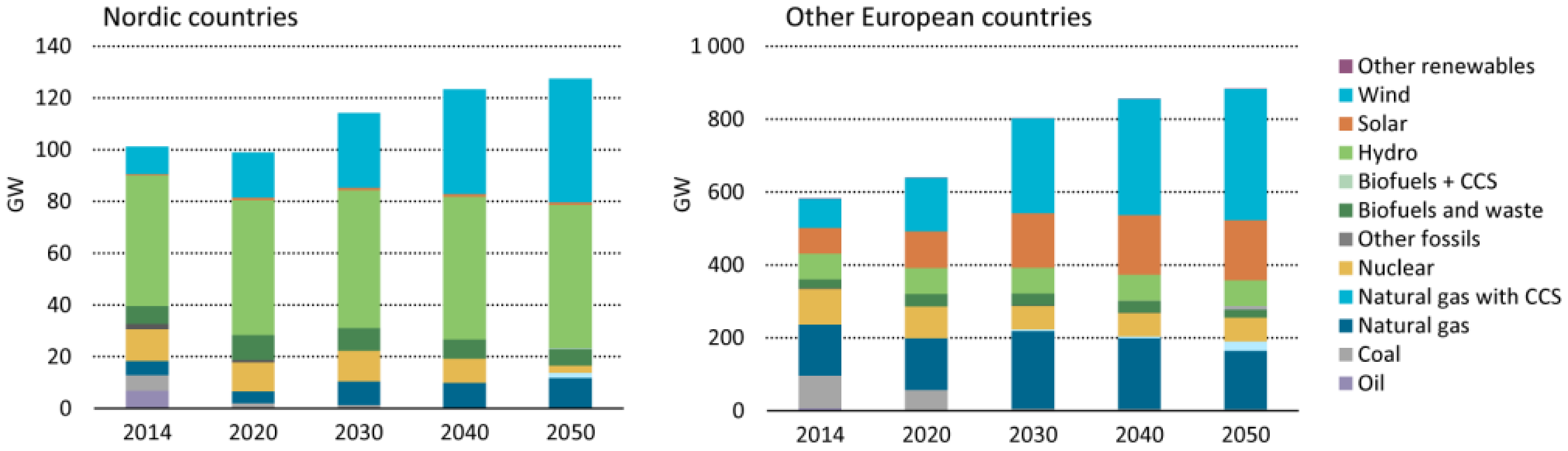
Transmission system

Modelled transmission system in 2030 with price zones and transmission lines (existing and planned transmission lines until 2030)

The electricity grid in Europe connects all the countries and thereby their electricity producing units and consumers



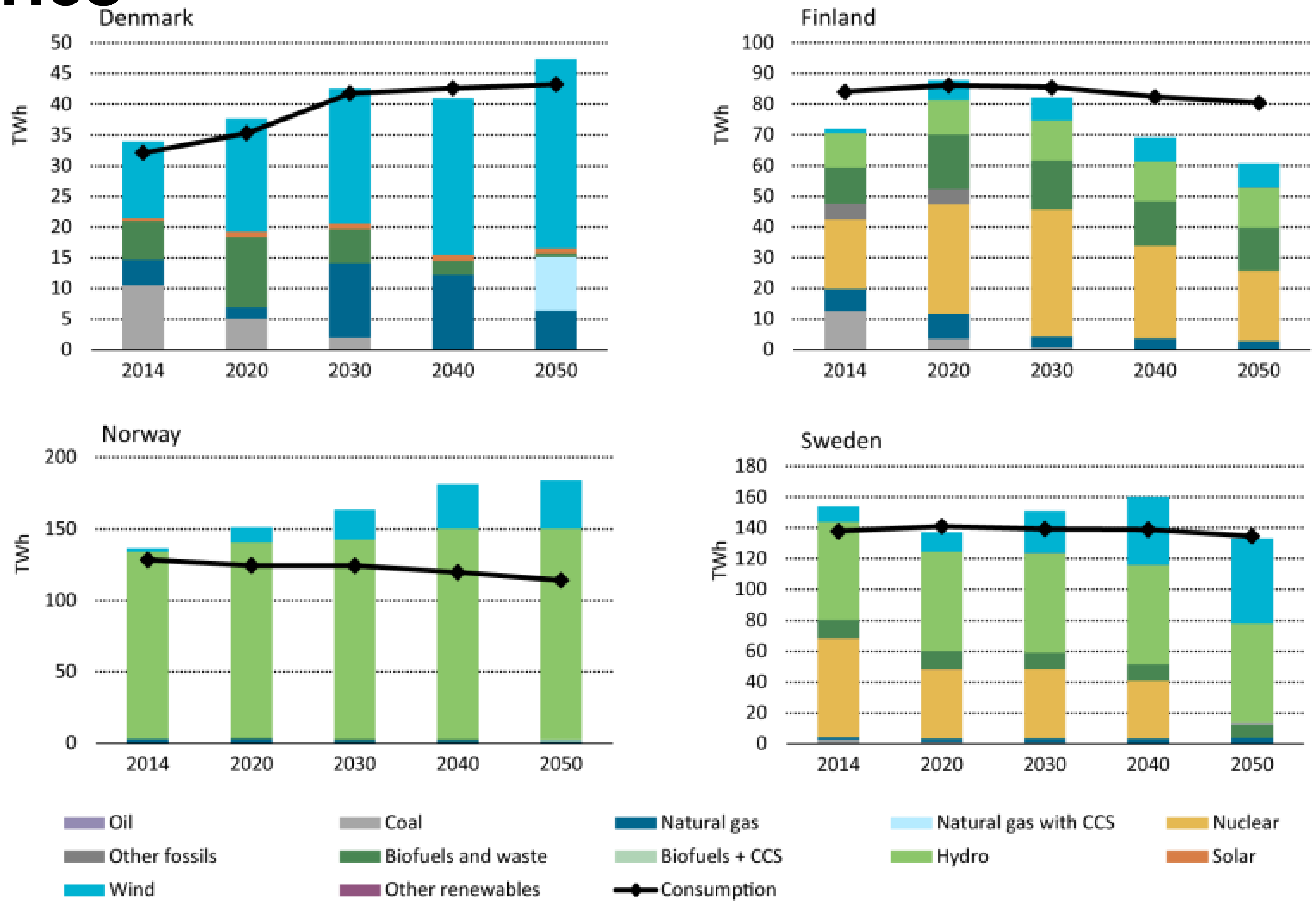
Development of electricity generation capacity in the overall power system



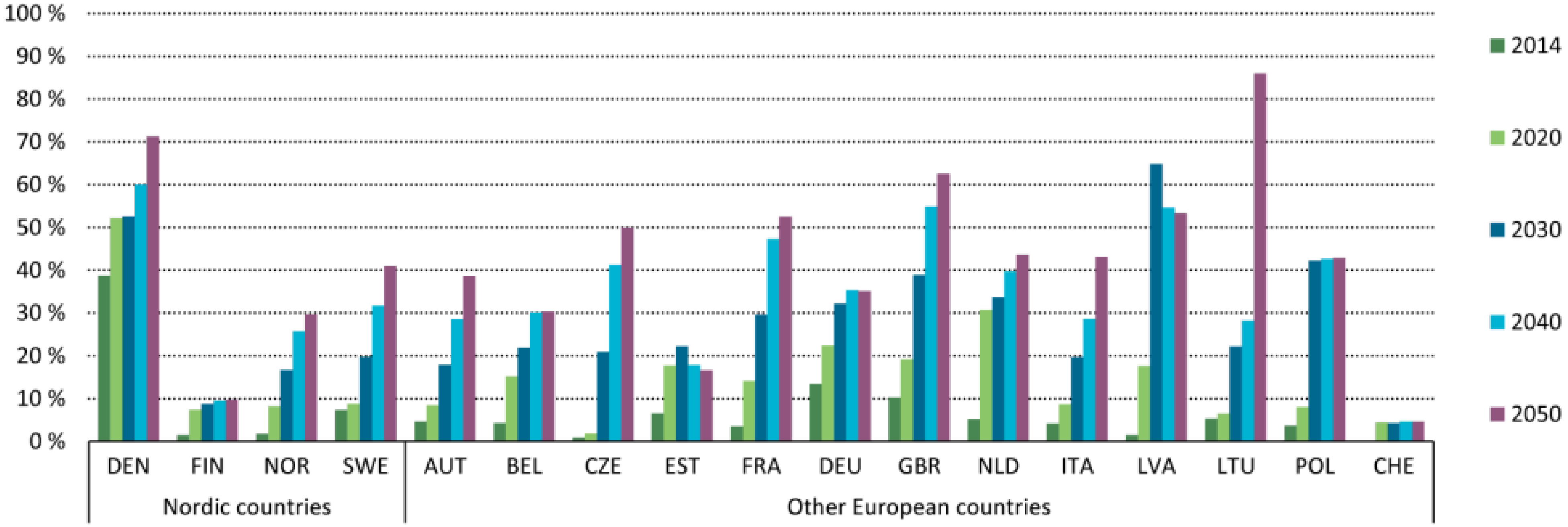
In both the Nordic and other European countries conventional generation decreases while wind capacity increases. Solar capacity increases in the other European countries in the long term.

Development of electricity generation in individual Nordic countries

By 2050, Sweden will have phased out its nuclear capacity while Finland will have decreased its nuclear-based electricity generation. Denmark will have deployed significant generation capacity based on gas co-generation with CCS capability.

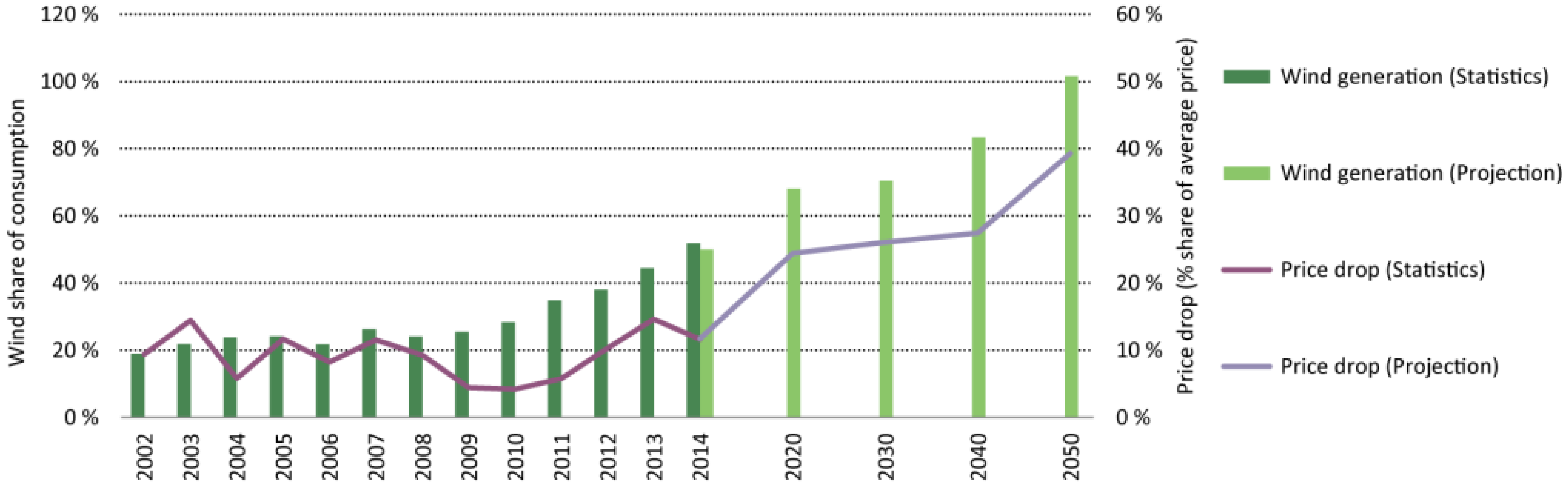


Wind capacity build-outs for 2050



In most of the Nordic countries and in other European countries, the share of electricity consumption provided by wind resources will increase constantly from 2014 to 2050. By 2050, Denmark will have steadily deployed wind power, reaching about 70% of total electricity consumption; Norway and Sweden will respectively see 30% and 40% wind penetration.

Price drop compared to the wind share in Western Denmark, statistical and model results



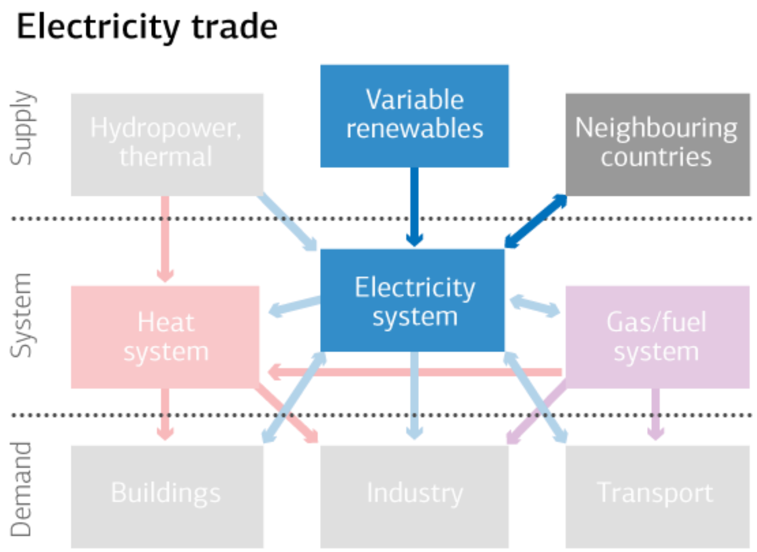
The greater the amount of wind power fed into the system, the more the system's price drops; however, this is not only dependent on increases in wind power, but also on the overall flexibility of the power system, such as links to hydropower systems, the flexibility of power plants and the availability of interconnectors. In Western Denmark, the price drop of wind power will increase as its share of generation increases towards to 2050.

The wind share of about 100% by 2050 results in a 40% electricity price drop.

Electricity trade:

Sufficient transmission capacity will become increasingly important in the future power systems to smoothing variabilities in the power system

- Interconnectors give continental Europe assess to balancing power from Nordic hydropower, and contribute to smoothing wind power production between Nordic regions

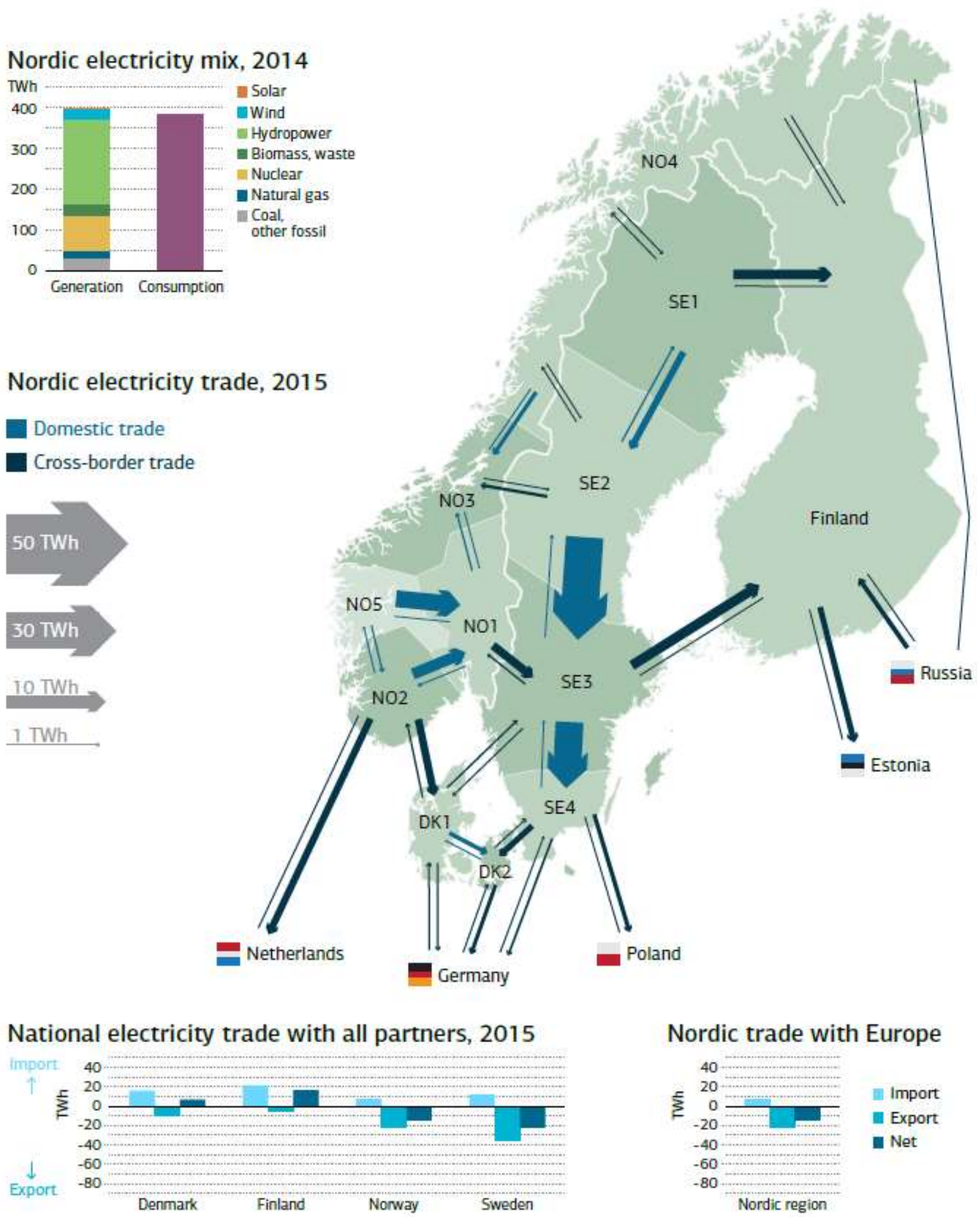


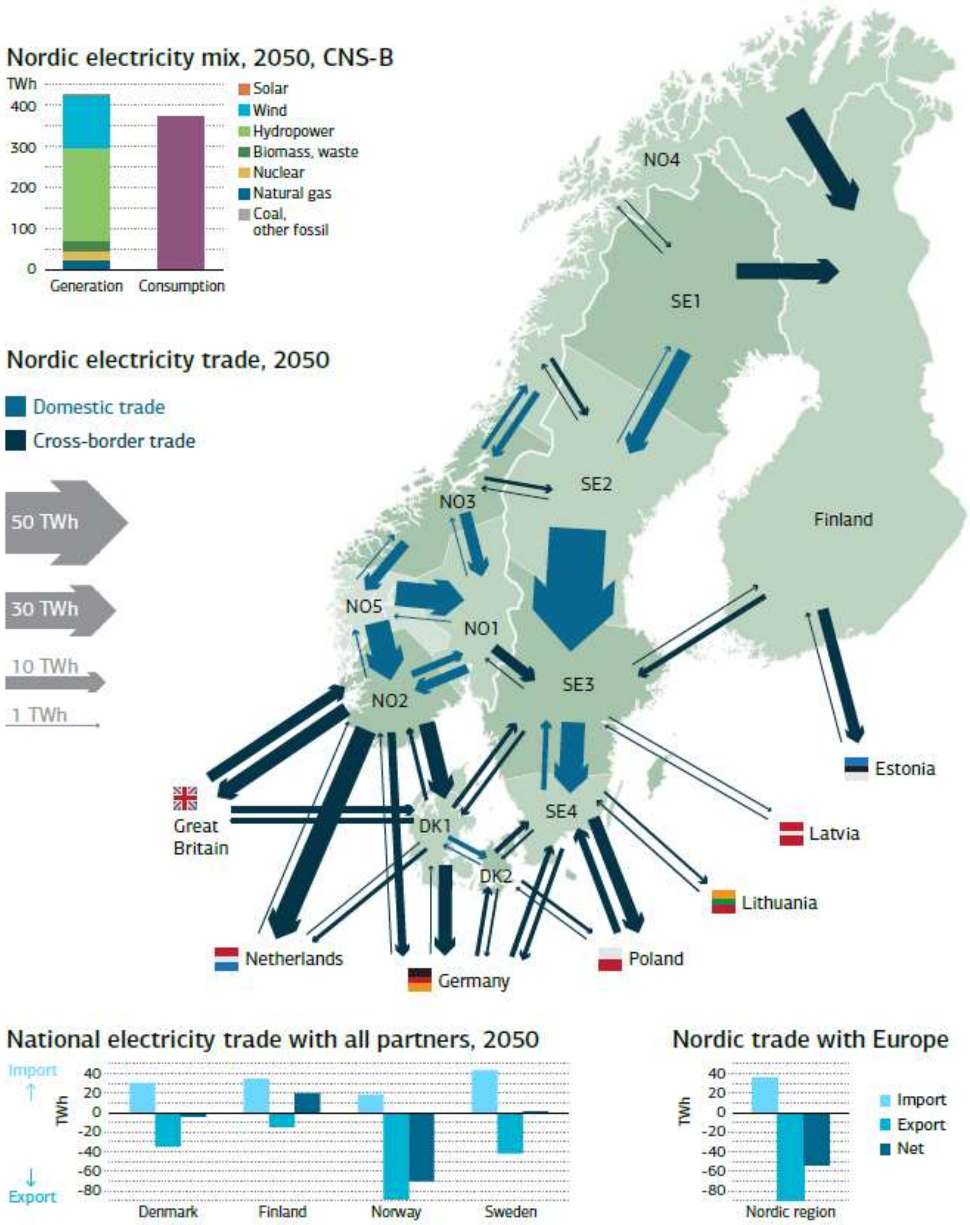
With increasing shares of VRE it will become economically attractive to increase transmission capacity both in the Nordic region, and across the whole of Europe

The Nordic region become strong electricity exporters in the CNS-B, exporting 50-60 TWh per year to continental Europe from 2030

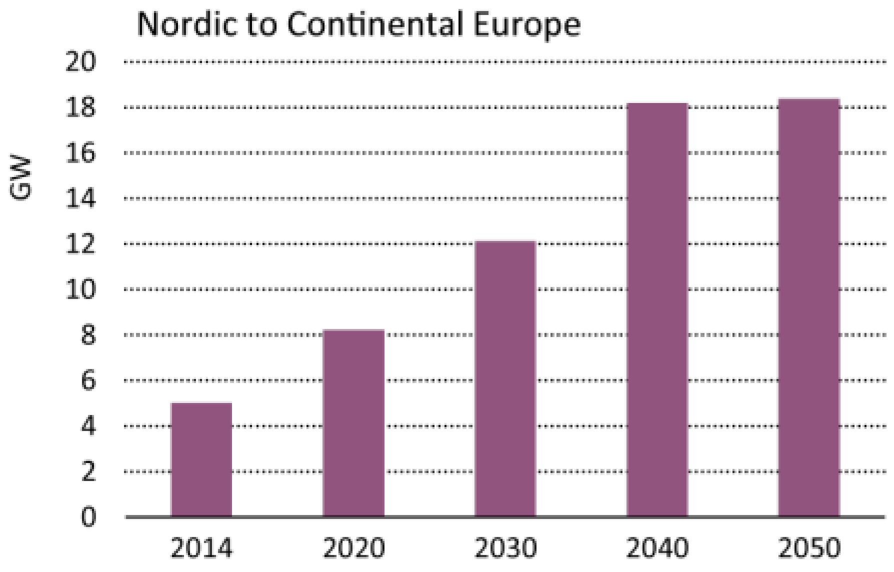
It is important to continue strengthening European collaboration on infrastructure planning, to ensure optimal investments are made and to avoid bottlenecks in the grid

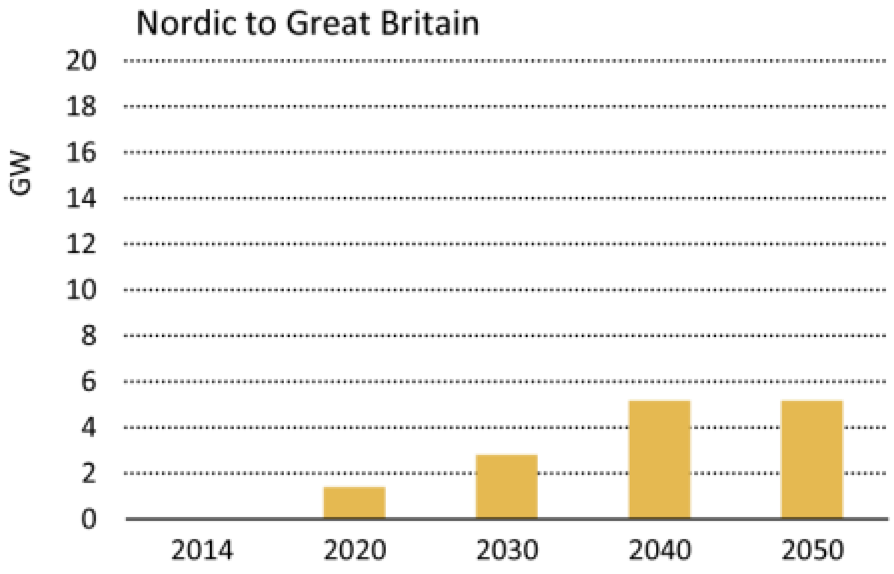
Electricity trade:





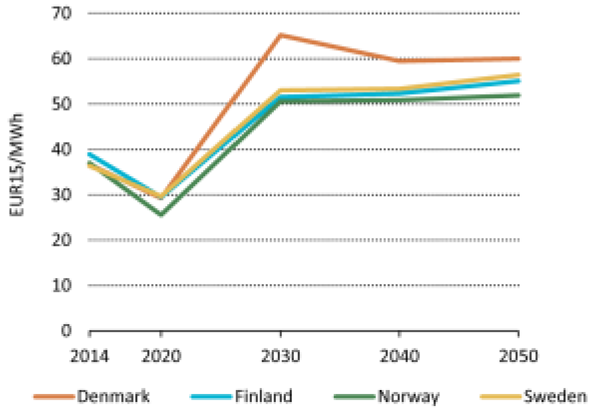
Development of transmission capacity between the Nordic countries and their vicinity

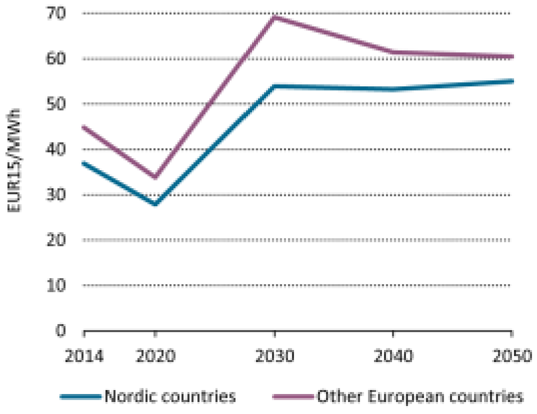


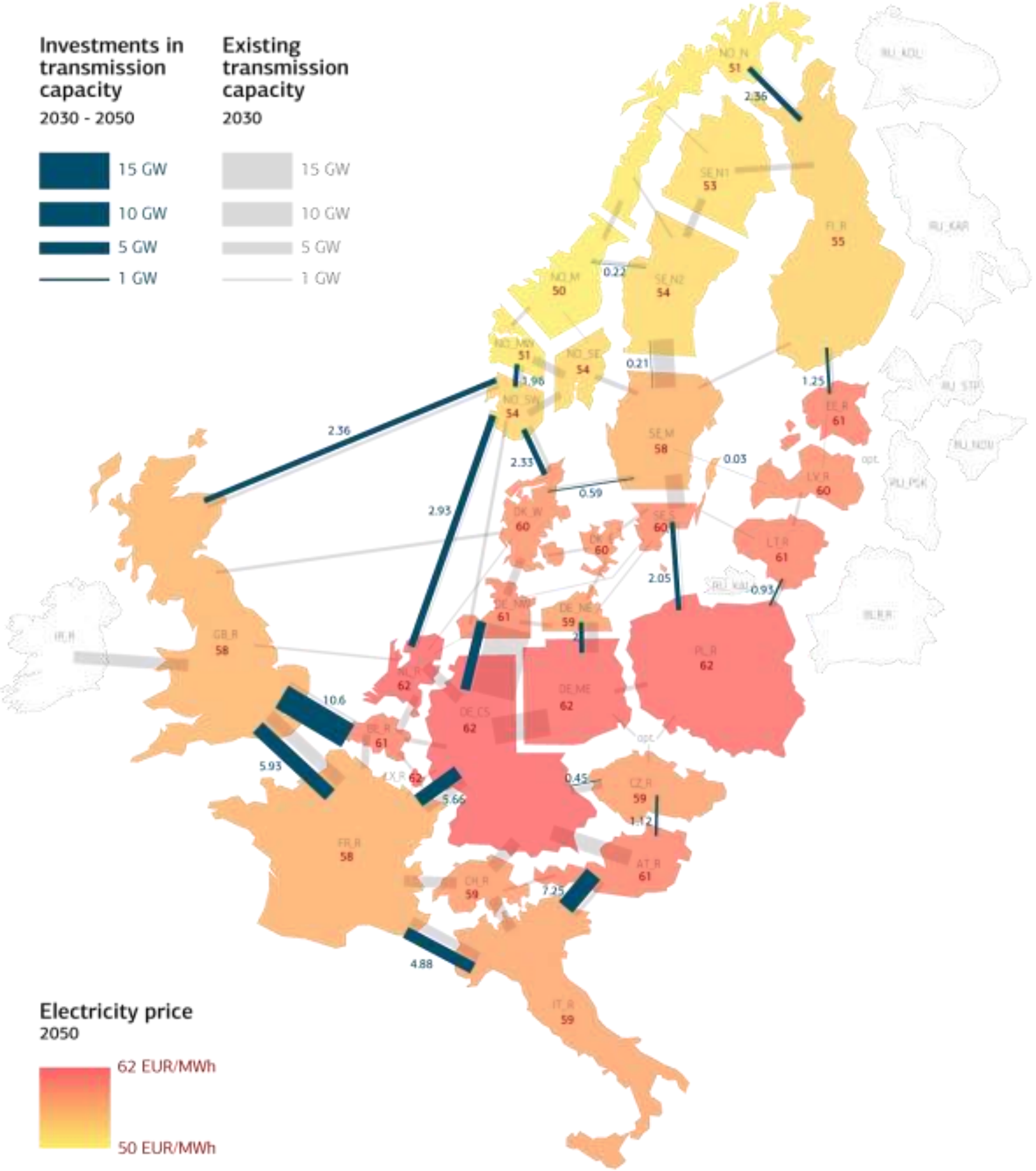


Transmission capacity between the Nordic countries and continental Europe will steadily increase from 2014 until 2040, while it will remain constant from 2040 until 2050. Similar behaviour is expected between the Nordic countries and Great Britain.

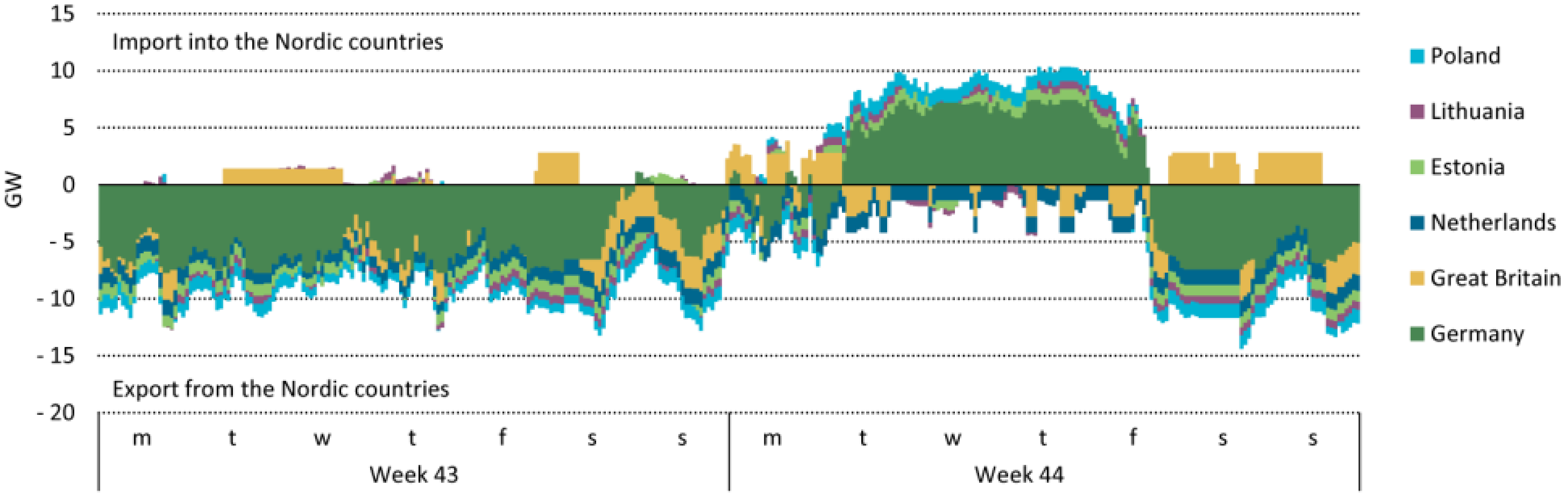
Investments in transmission capacity and resulting electricity prices







Hourly transmission between the Nordic region and surrounding countries for two weeks in 2030



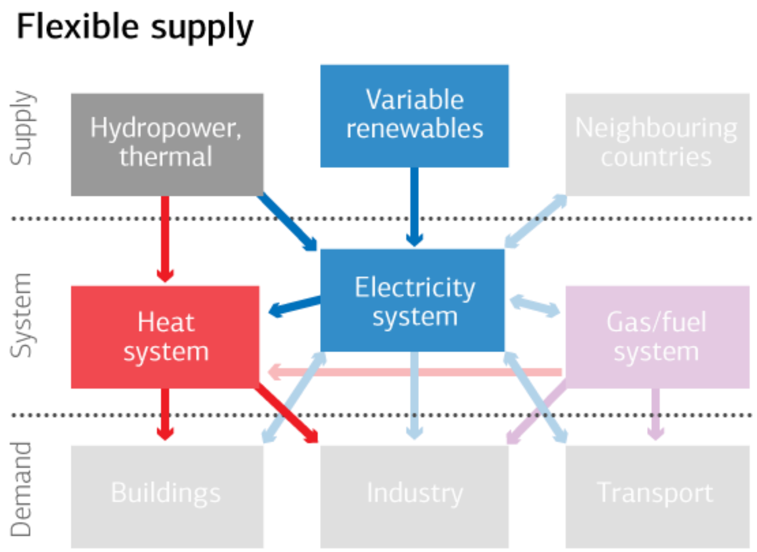
Germany plays the most important role in imports to and exports from the Nordic countries.

Flexible generation

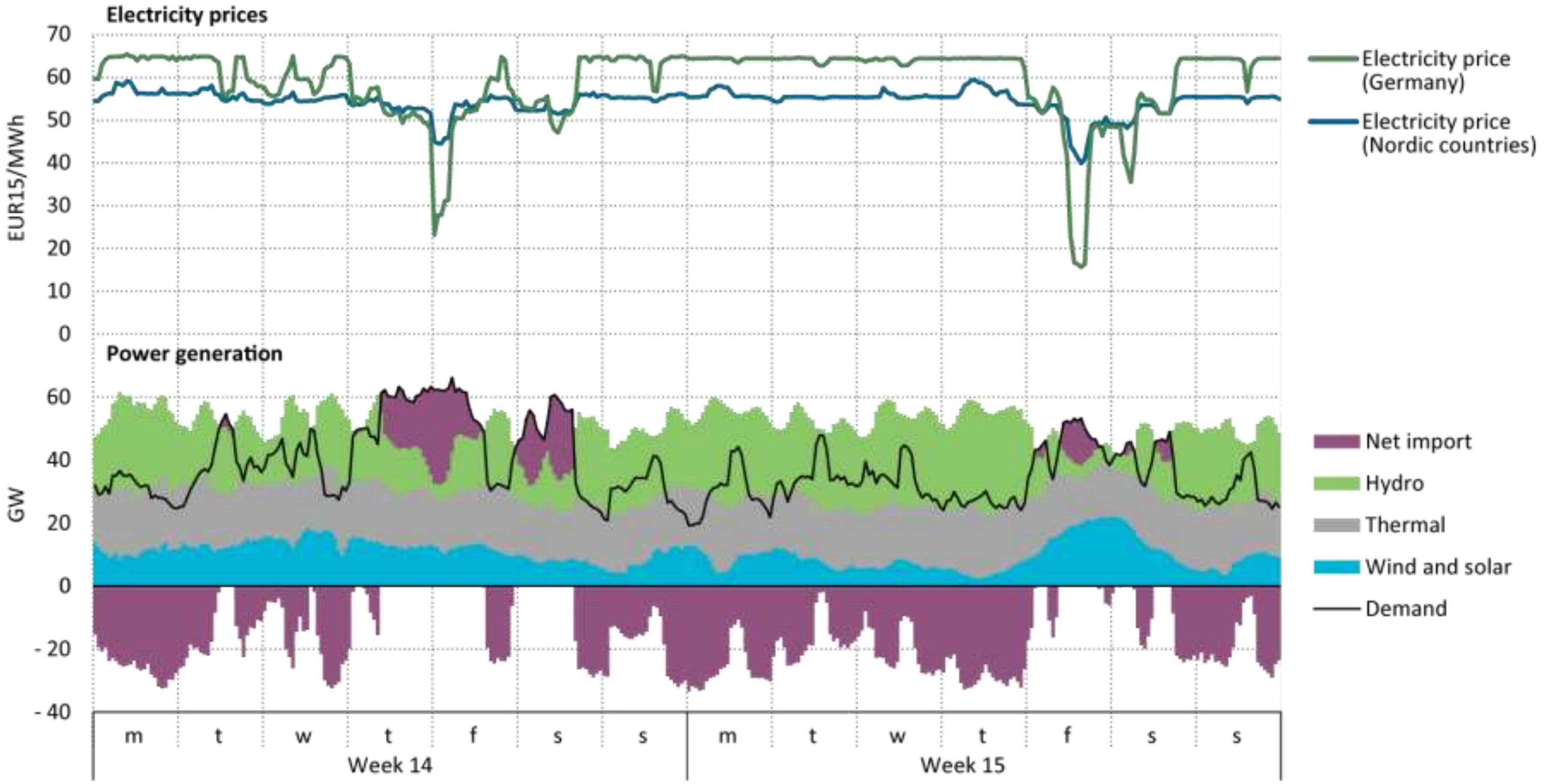
Flexible generation will become increasingly important in the future power systems to adjust production according to the variable residual demand

Flexible generation:

- Hydropower
- Thermal power
- Linking the electricity sector and district heating
  - Co-generation
  - Power to heat



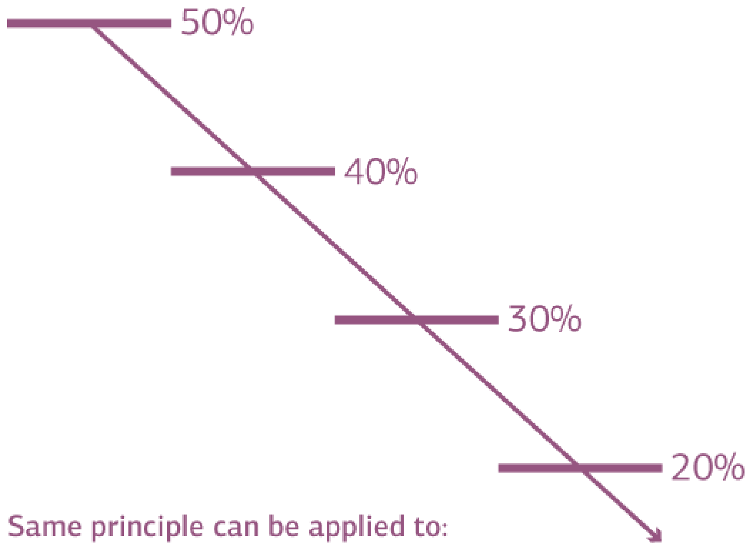
Operation of the Nordic power system during week 14 and 15 in year 2030



Nordic hydropower works as a buffer that absorbs the power fluctuations of the system

A stepwise approach to improve power-plant flexibility

Reduction of minimum load



Same principle can be applied to:
- Increased load gradients (ramp rates)
- Start-up optimisation

Optimisation approach

A 50-45-40% minimum load may be achievable through trial and error.

An increasing number of alarms and trips must be addressed through control optimisation, careful component analyses and possibly component redesign, and eventually component replacement earlier than anticipated.

Typical challenges
- Firing stability
- Feed water pump flow stability
- Minimum steam flow through turbines
- Distributed Control System (DCS) programmable limitations
- Control room operators must participate actively

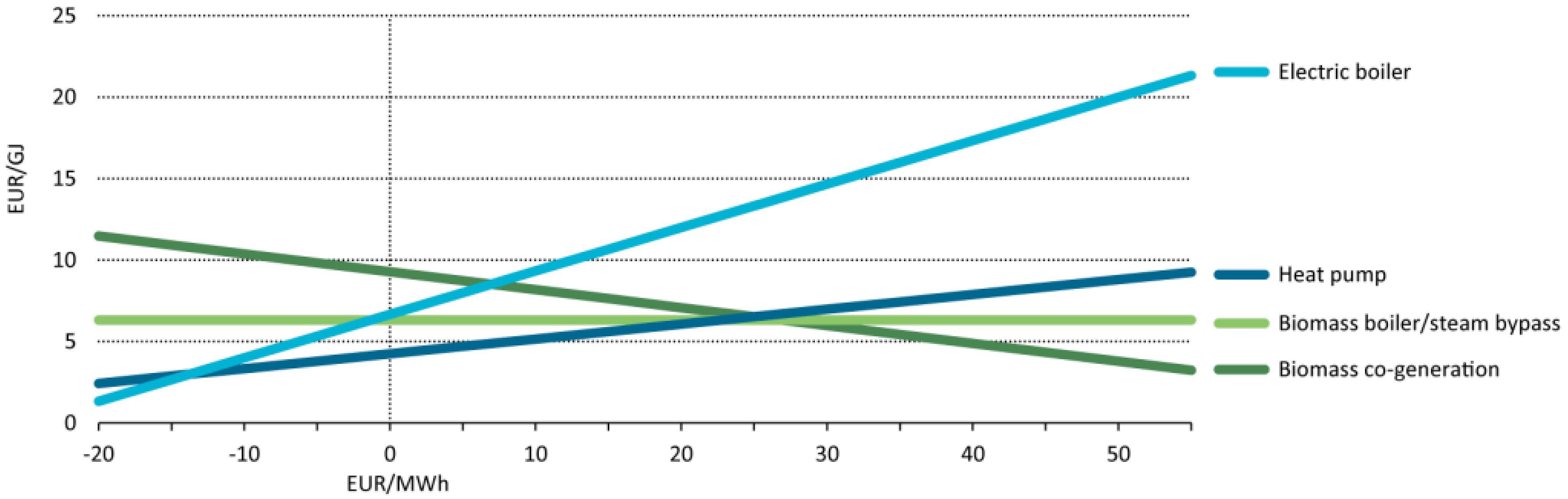
(Among others, challenges differ from power plant to power plant)

Plant flexibility is optimised by improving certain part-load characteristics. Lack of flexibility in thermal power plant operation will ultimately lead to lower system value of VRE.

Co-generation and power-to-heat

In a future Nordic energy system, a stronger linkage between elements of the energy system e.g. electricity and heating, will be needed

- Co-generation plants can provide flexibility to an energy system by switching between producing only electricity, and producing both district heat and electricity
- Power-to-heat technologies can provide flexibility by producting heat at times with low electricity prices



Short-run marginal cost of heat production by technology depending on electricity prices

Storage

Storage facilities will become increasingly important in the future power systems since it can take up energy when there is surplus production and give it back to the system when it is needed

<u>Heat storage:</u>

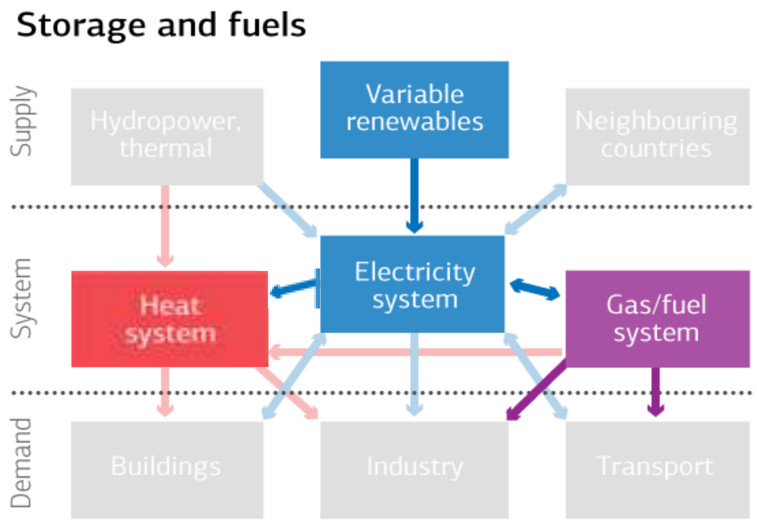
Heat storage in district heating systems can increase the flexibility of thermal power plants, or other options for heat generation, by decoupling heat generation and heat consumption through time.

<u>Chemical storage :</u>

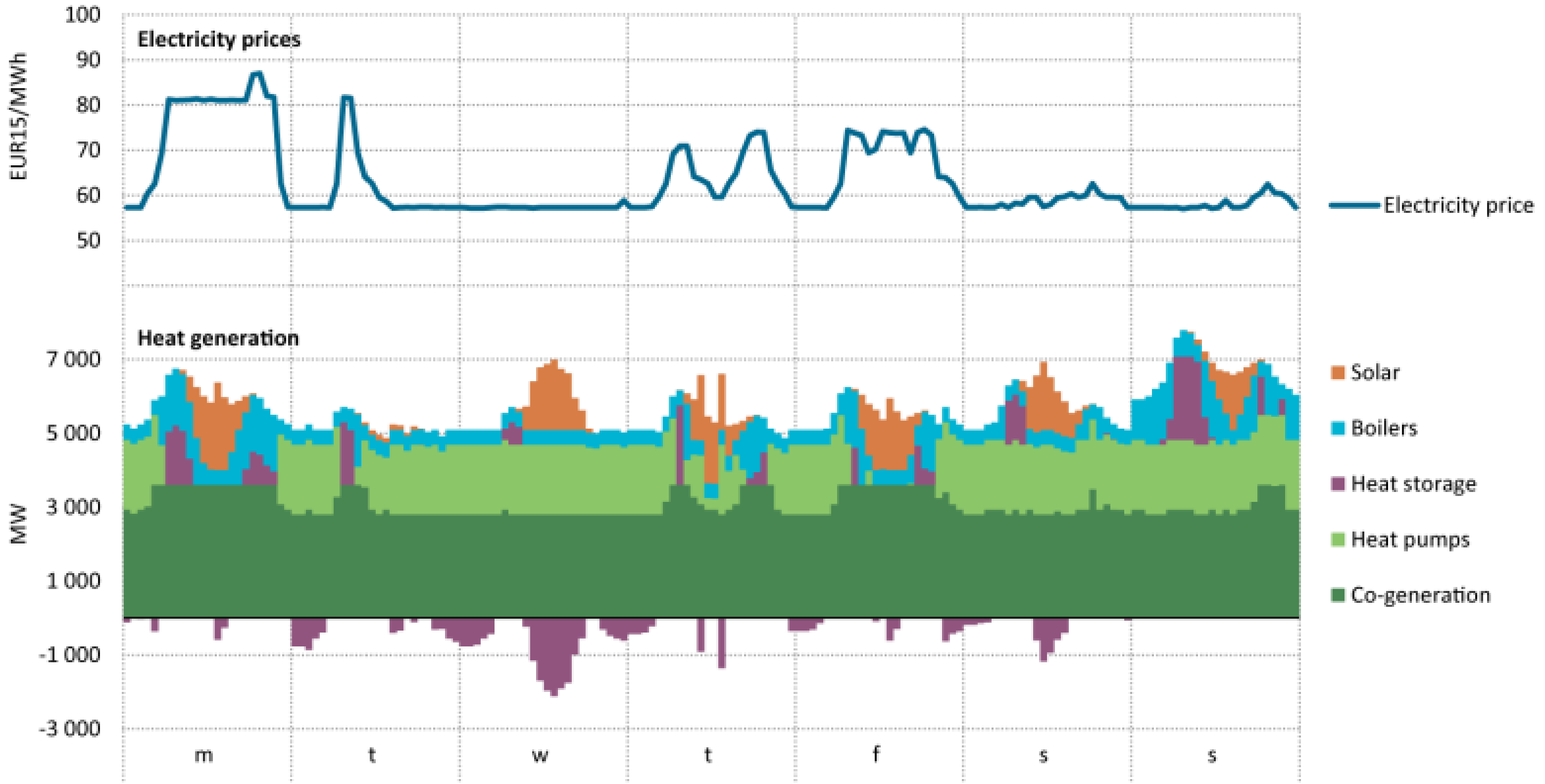
Can be used to link together the different energy carriers in the system

<u>Electricity storage:</u>

Can be a way to secure the value of VRE generation by providing the option to decouple electricity generation and consumption over time, thus providing electricity when electricity prices are high. However, the efficiency and investment cost of storage technologies continue to be a challenge from an economic perspective.

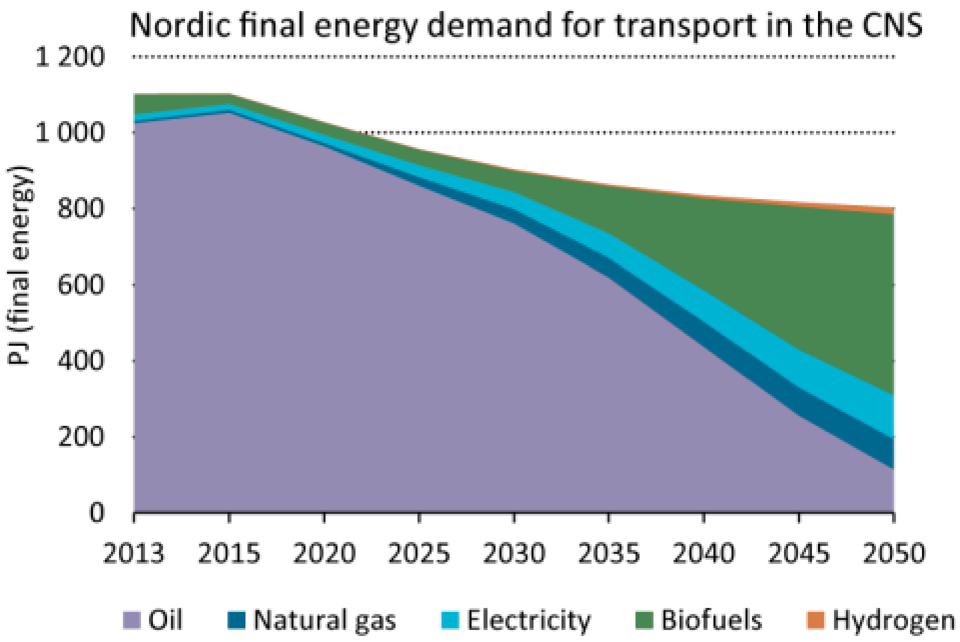


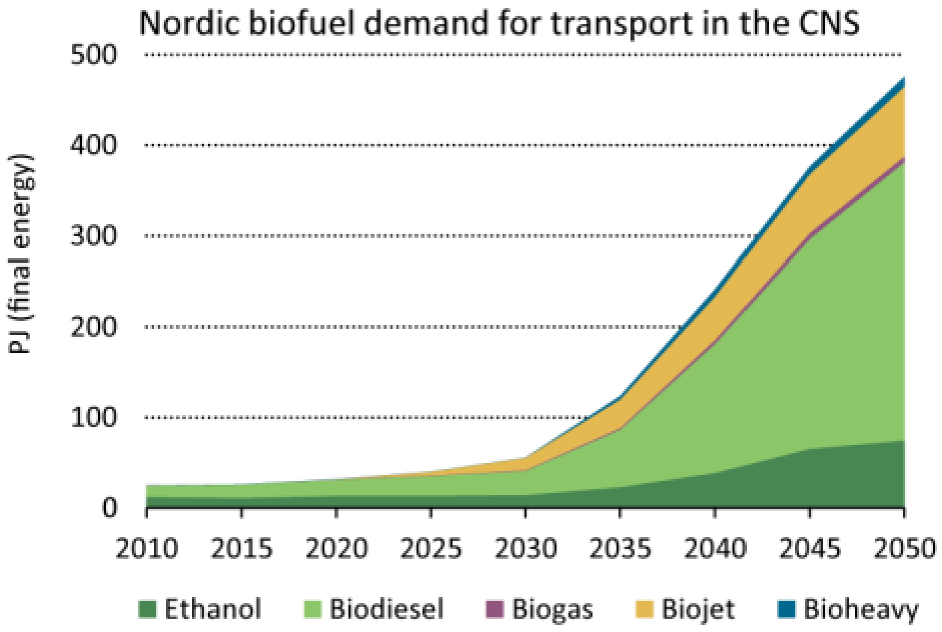
Hourly heat generation for one week in Central Sweden in 2030



In Central Sweden in 2030, heat pumps shut down when the electricity price is high; under these conditions, mainly co-generation, boilers, solar and heat storage supply the heat demand.

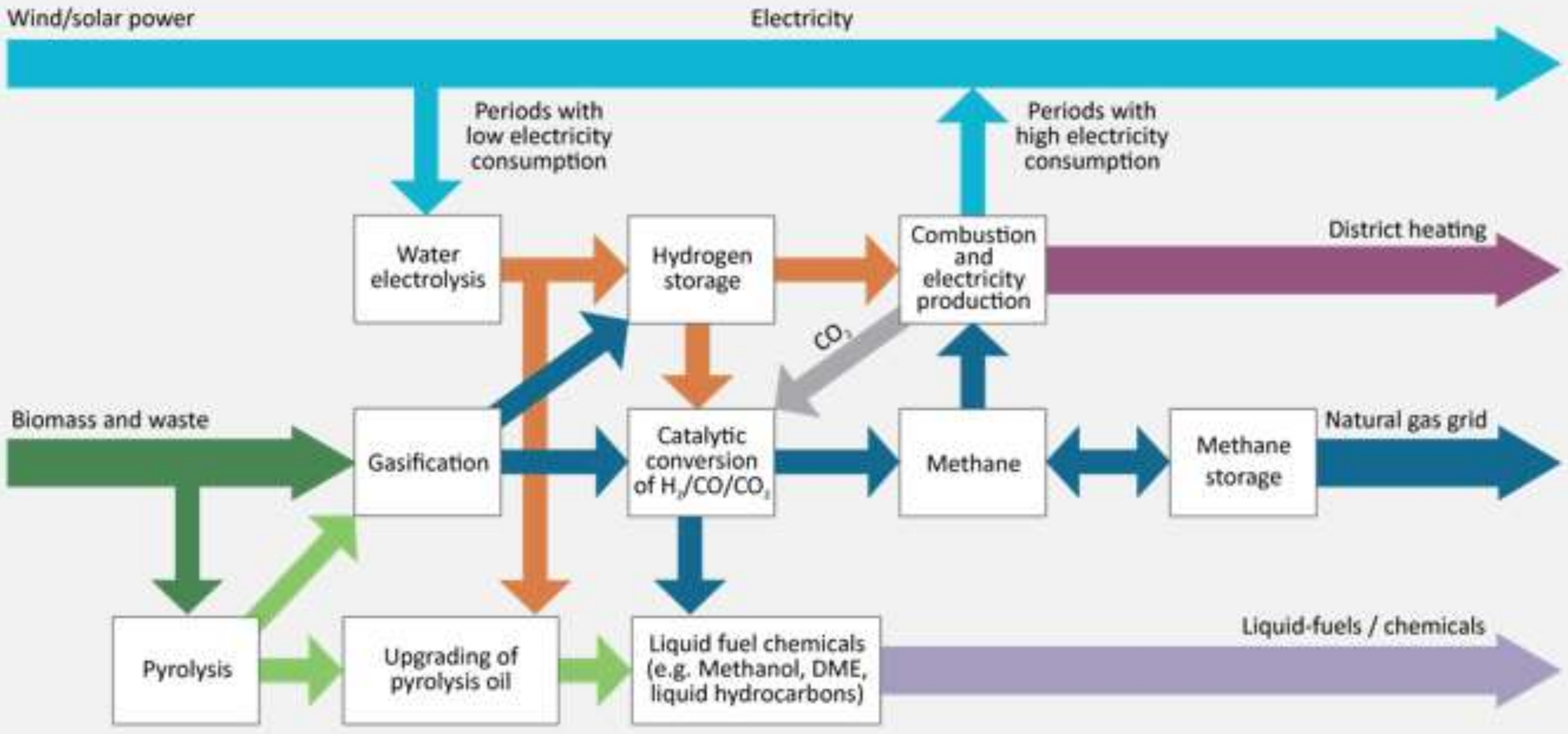
Chemical storage – demand for biofuels





By 2050, biofuels will play a critical role in phasing out oil use for transport in the Nordic countries.

Interlinkages among the different energy carriers in the energy system



Chemical storage can connect four main energy carriers in the energy system

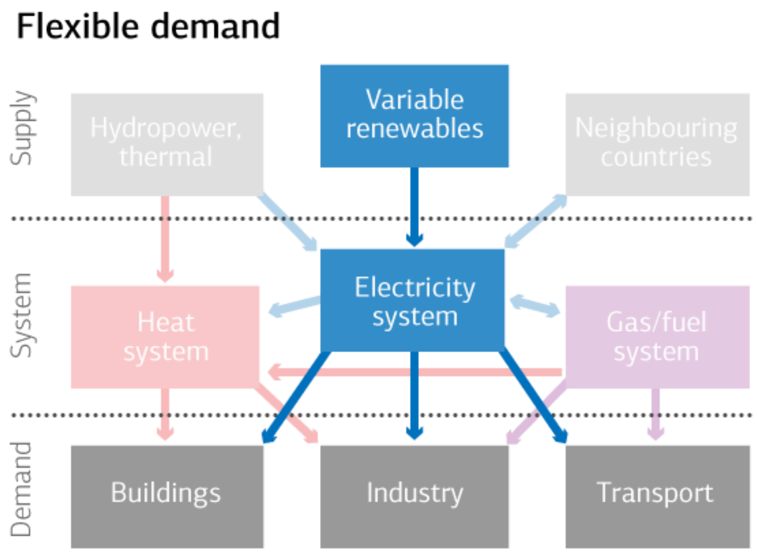
Demand side flexibility

Demand response will become increasingly important in the future power systems to:

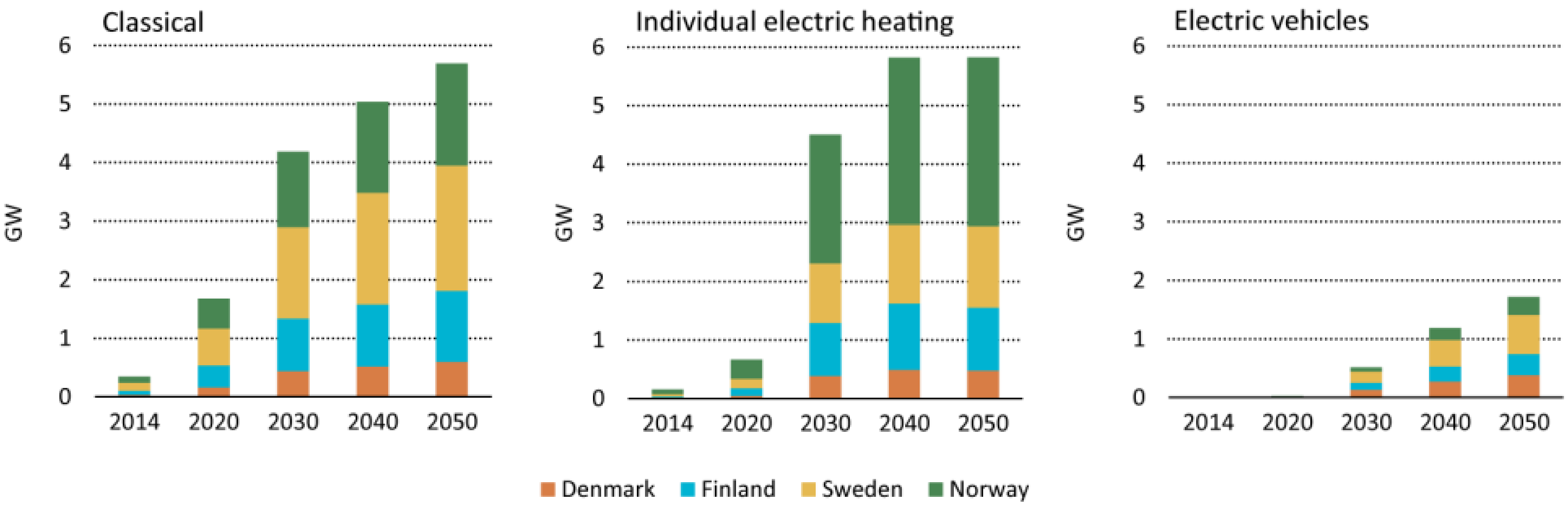
- Provide cost-efficient back-up when variable renewables are not producing.
- Increase the value of variable renewables in situations with high production.
- Balance VRE minute-by-minute and hour-by-hour.

Flexible demand (load shifting) in transport, industries and buildings are means to integrate more VRE with same amounts of transmission and thermal capacities

By introducing demand-side flexibility into the power system, the analysis shows that the electricity prices stabilises and the need for natural gas peak capacity reduces



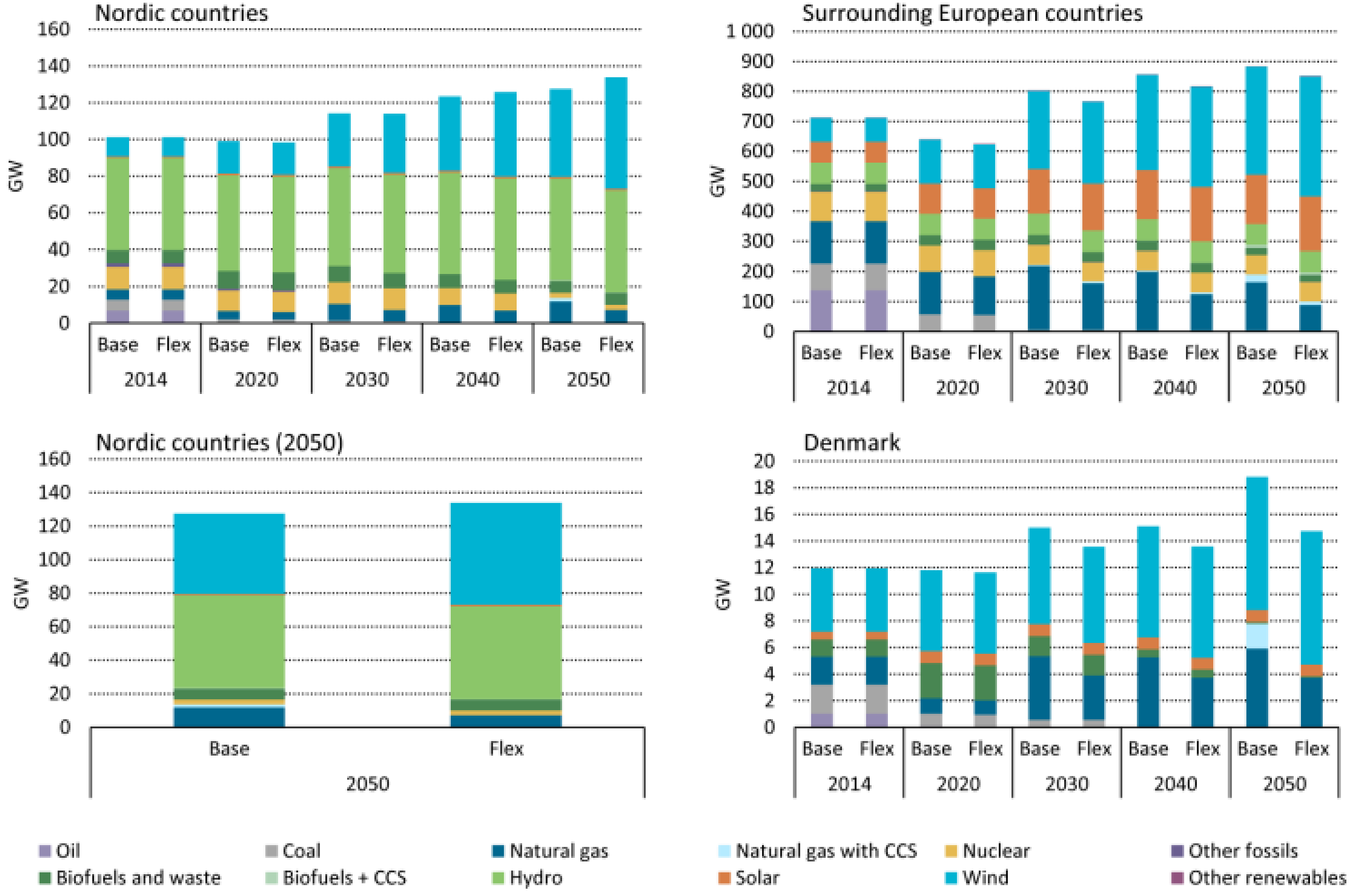
Development of demand response - a sensitivity analysis



The demand response capacities are gradually phased in up to 2050.

Comparison of development of power capacity with and without flexible demand

In the Nordic countries, the impact of flexible demand on capacity development is rather limited
(from 2014 until 2040), but it has a big impact in gas power capacity by 2050. Meanwhile in the other European countries this impact is reflected from 2030 onwards.



Key findings:

The Nord Pool area is extremely well suited to the integration of VRE production as wind and solar power - due to the presence of storable hydropower, adequate transmission capacity and a well-functioning electricity market.

By 2050 in the CNS-B, VRE is expected to command a share of 30% of electricity production in the Nordic countries on average (and more than 70% in Denmark) and up to 60% in continental Europe.

Emissions from power and district heating generation in the Nordic countries decreases from about 50 $MtCO_2$ in 2014 to 10 $MtCO_2$ in 2050

The Nordic region become strong electricity exporters in the CNS-B, exporting 50-60 TWh per year to continental Europe from 2030

In a future Nordic energy system, a stronger linkage between elements of the energy system - transport, electricity use, heating and fuel production – will be needed to reduce the cost of reducing CO_2 emissions and to integrate VRE

Thermal power plants need to be flexible in ramping up and down, while flexible electricity demand (load shifting) in transport, industries and buildings are all means to integrate more VRE

With increasing shares of VRE it will become economically attractive to increase transmission capacity not just in the Nordic region, but also across the whole of Europe.

Thank you for attending.   Affiliations:

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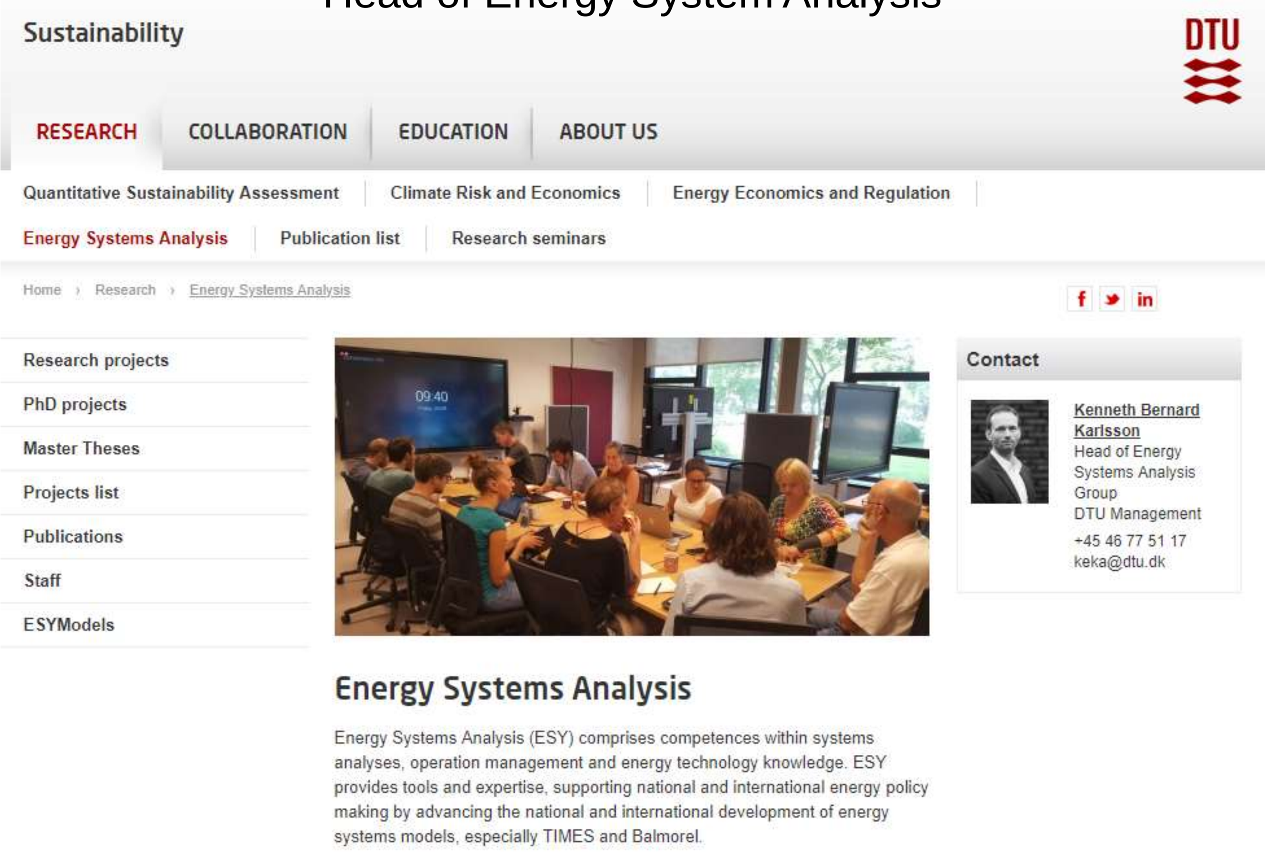

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