Study Release Event

Enabling cost-efficient electrification in Finland

A study commissioned by SITRA

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The study was carried out by a **three member consortium** combining **international and local** experience and knowledge

Compass Lexecon	**Enerdata**	**LUT University**
About: ▪ International Economics consultancy ▪ Helsinki and Paris based members of the EMEA Energy Practise led the study	About: ▪ International energy intelligence and consulting company	About: ▪ Finnish University
Role: ▪ Consortium leader ▪ Power market modelling	Role ▪ Full energy balance modelling	Role: ▪ Finnish energy sector expertise ▪ Power transmission & distribution system analysis
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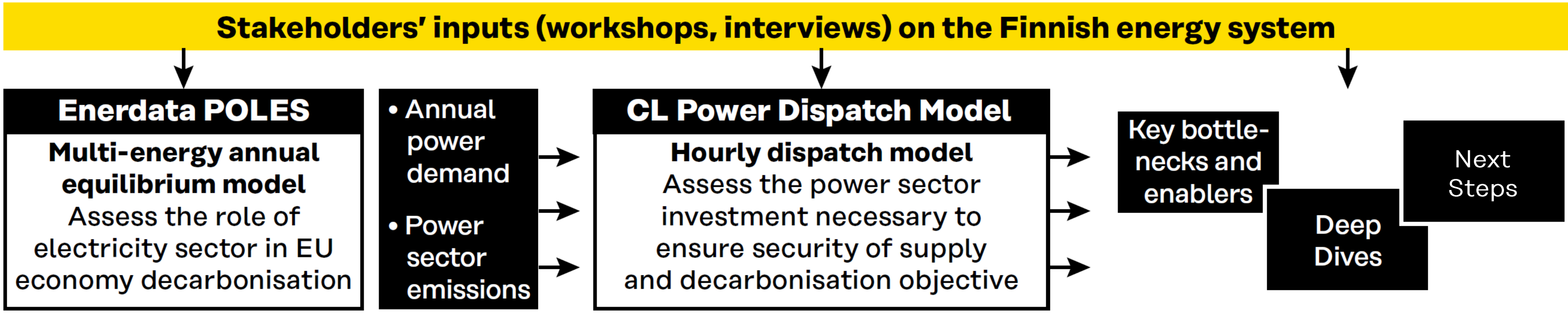
The modelling covers the **full energy system**, further **detailing the power sector** and was complemented with **qualitative analysis**.

Overview of the applied methodology



Quantitative Modelling approaches

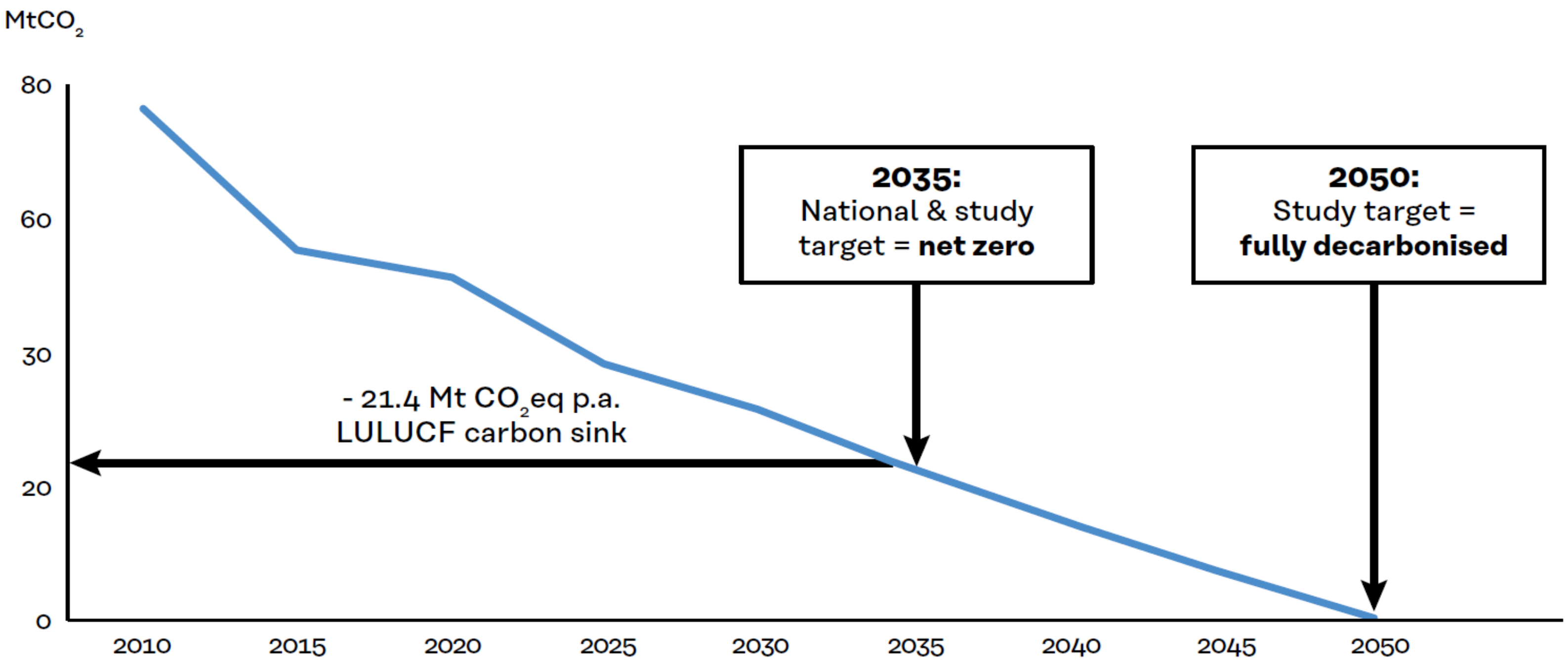
- the **POLES-Enerdata full-energy balance model** and
- the **Compass Lexecon** (CL) **power dispatch model** (incl. a **capacity expansion** optimization).

Qualitative approaches

- Extensive **literature review** to assess:
  - the status of Finnish **energy system studies**,
  - assumptions underlying the **sectoral demand** evolutions, and
  - assumptions underlying **supply side modelling**
- Comprehensive **Stakeholder involvement**
  - **8 stakeholder workshops** (regulators, ministries, research institutes, network operators, key sectors, professional associations, …) with a focus on (a) **modelling inputs** and **assumptions**, and (b) **modelling results**
  - **5** follow-up **interviews**

The scenarios developed achieve **net-zero emissions in 2035** and **full decarbonisation in 2050**

Targets for domestic gross CO_2 equivalent emissions in Finland excluding LULUCF[1]



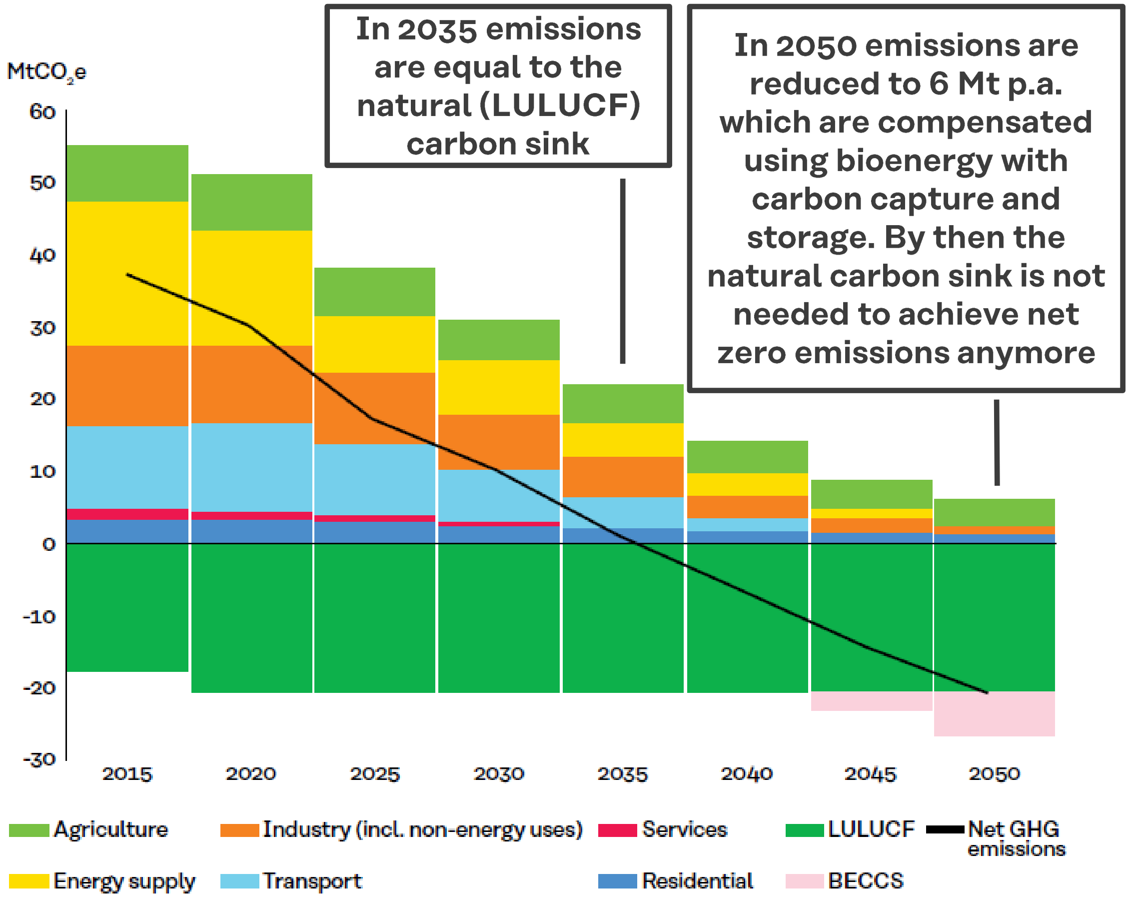
Notes: LULUCF – Land Use, Land Use Change and Forestry
Source: Compass Lexecon; LULUCF carbon sink size based on Seppälä et al., 2019

- **2035** carbon sink target based on the Finnish Climate Panel (2019), 21.4 Mt CO_2e to reach carbon neutrality.
- **Carbon sink** level is very much dependent on the use of forest-based biomass.
- In this study the wood-based **bioenergy use** is limited to the present level and the minimum of 21.4 Mt CO_2e carbon sink is maintained throughout the studied horizon.

Both scenarios **achieve the emission targets** by significantly reducing fossil fuels and without heavy reliance on CCS

- Emission reduction is achieved through strong electrification and **phasing out fossil fuels in energy sector**.
- The **governmental target of carbon neutrality is reached in 2035** in both scenarios, with net GHG emissions around 1 $MtCO_2e$. This corresponds to gross GHG emissions of around 22 $MtCO_2$, 60% lower than the 2015 value.
- **Full decarbonisation of the economy is achieved in 2050** in both scenarios, and net GHG emissions therefore decrease to -21 $MtCO_2$, the level of the "land-use, land-use change and forestry" (LULUCF) carbon sink*.
  - In 2050, around 6 $MtCO_2$ of gross emissions are compensated by **carbon removals by "bioenergy with carbon capture and storage"** (BECCS)
  - The remaining gross emissions are the hardest-to-abate, from agriculture, waste and industrial process emissions (such as cement production).
- The scenarios do not use carbon capture and storage (CCS) of fossil emissions.

Pathways of gross and net Greenhouse gas (GHG) emissions in Finland [$MtCO_2e$]



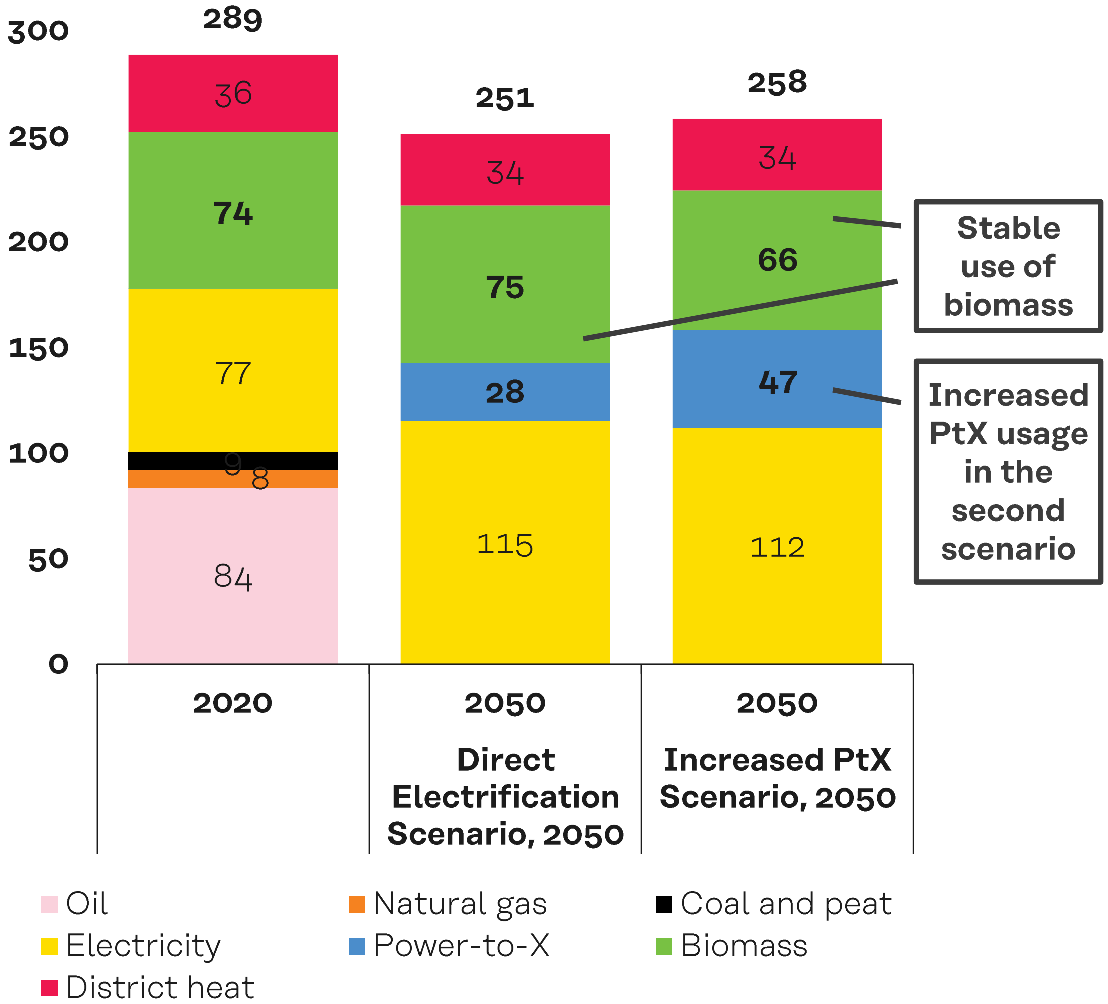
Source: POLES-Enerdata model results by Enerdata

*LULUCF emissions are not modelled and assumed constant on the forecast period.

The two scenarios **differ in usage of PtX-fuels** to arrive at the climate targets but keep **biomass usage at current levels**

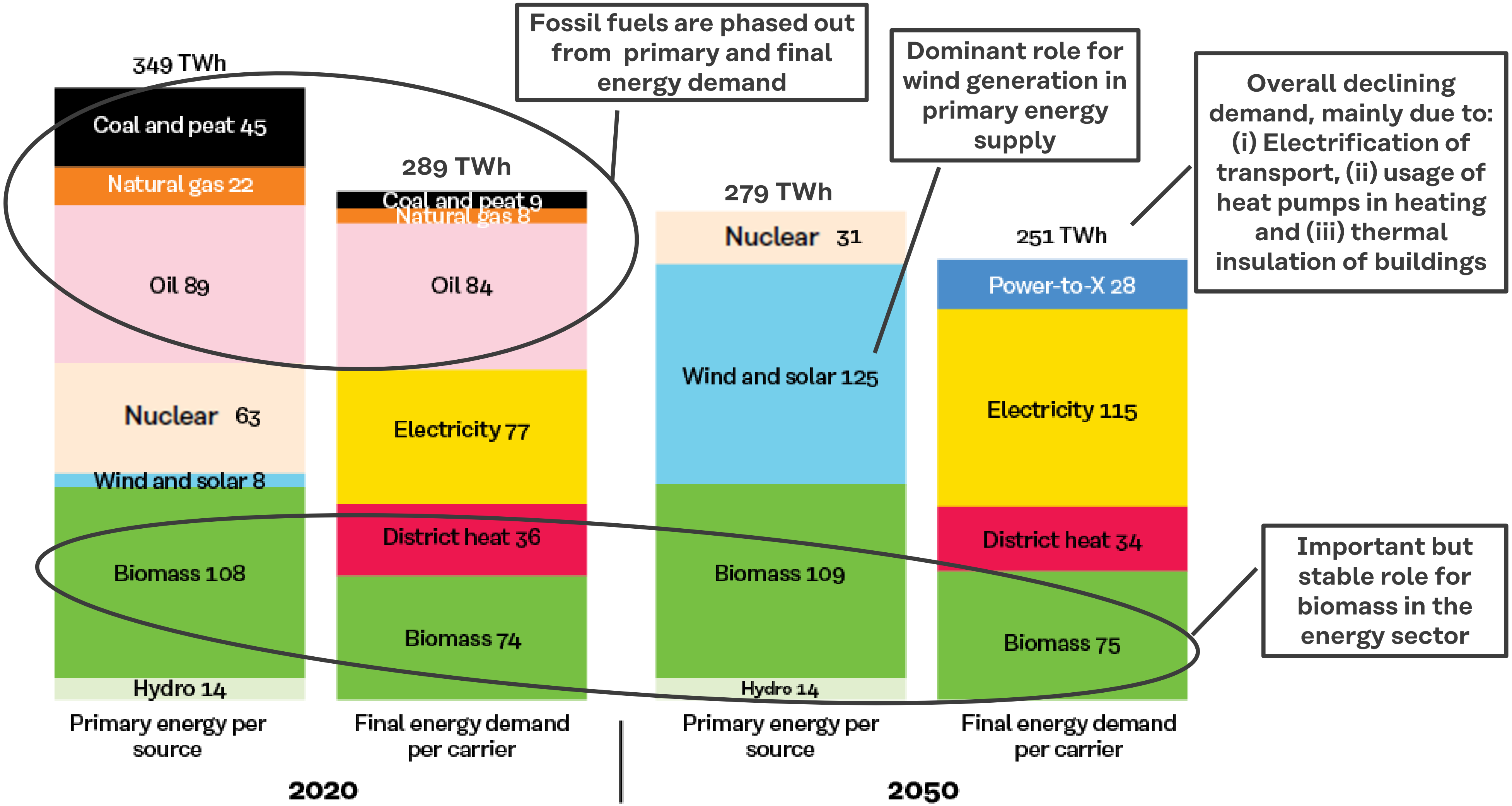
- The study determines the cost efficient decarbonisation of the Finnish Energy system by developing and comparing **two scenarios**:
  - Scenario 1 – **Direct electrification scenario**
  - Scenario 2 – **Increased PtX scenario**
- The **key difference** between the scenarios is the extend Power-to-X fuels are used
  - **Power-to-X** refers to the production of hydrogen from electricity using electrolysis and the potential subsequent transformation of hydrogen to other synthetic fuels
  - In the increased PtX scenario, additional demand (in heavy transport and industry) is **indirectly electrified using PtX-fuels**
- In the long-run, **biomass** usage remains similar or less compared to the current levels.

Final energy consumption by fuel [TWh]



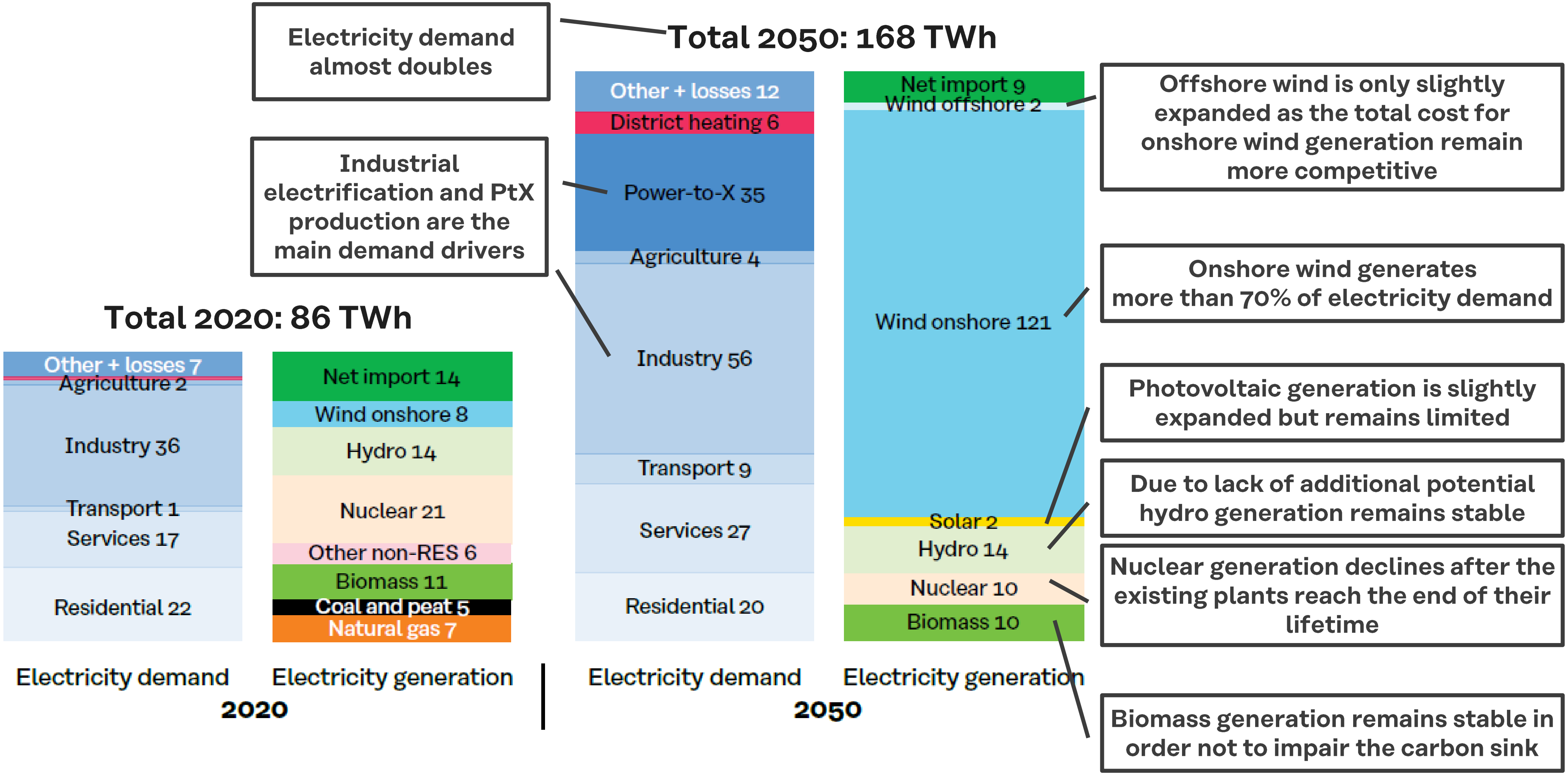
Final energy use declines due to **efficiency gains** – fossil fuels are replaced largely with **electricity produced from wind**

Primary and final energy demand 2020 and 2050 (TWh) – Direct Electrification Scenario

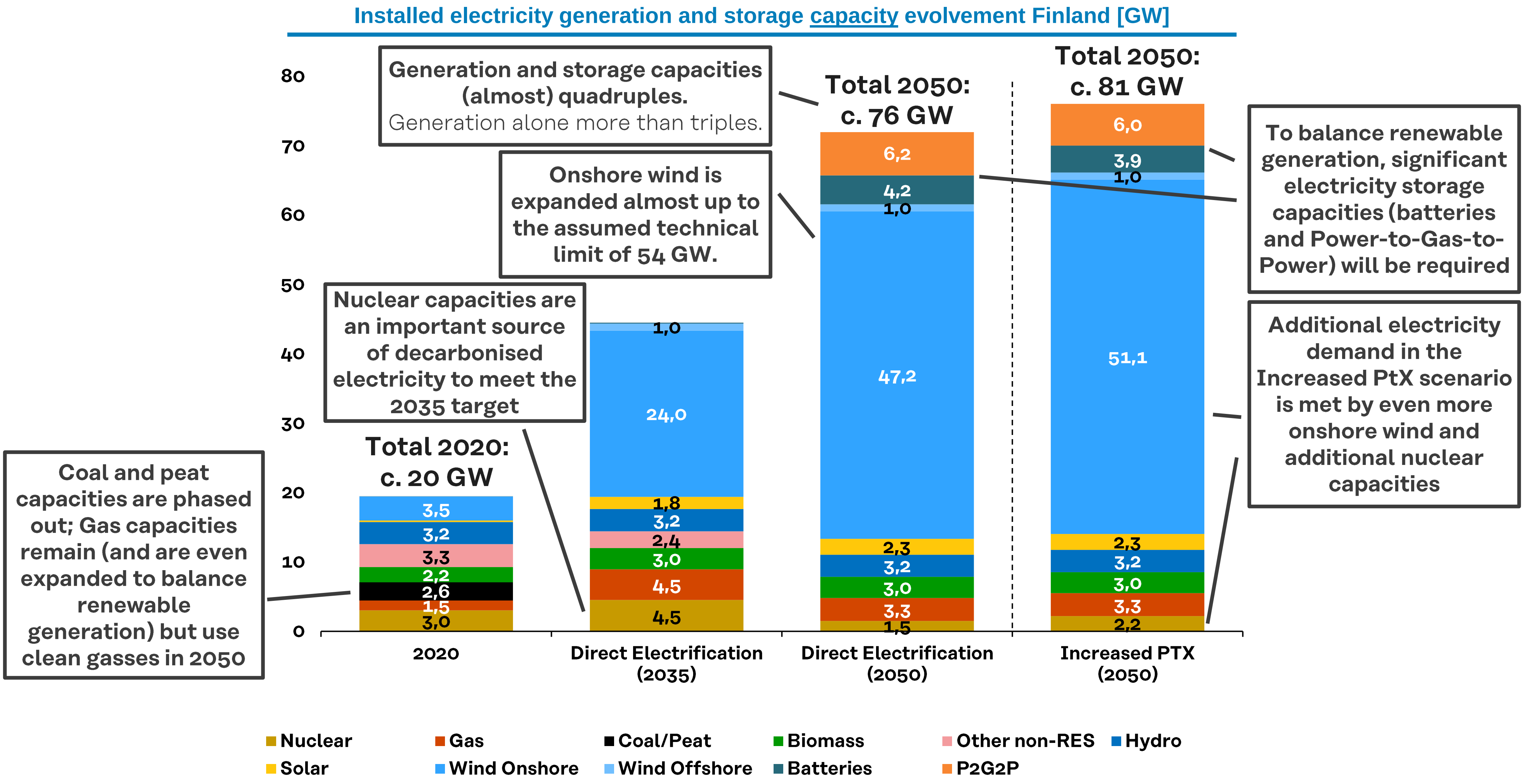


Industrial electrification and **PtX** production are the main drivers of electricity demand – **onshore wind** is the most important source

Sectoral electricity demand and electricity generation 2020 and 2050 (TWh), Direct Electrification Scenario



Cost-efficient decarbonisation relies on significant **wind generation capacity expansion**



* Other non-RES refers to small thermal units.

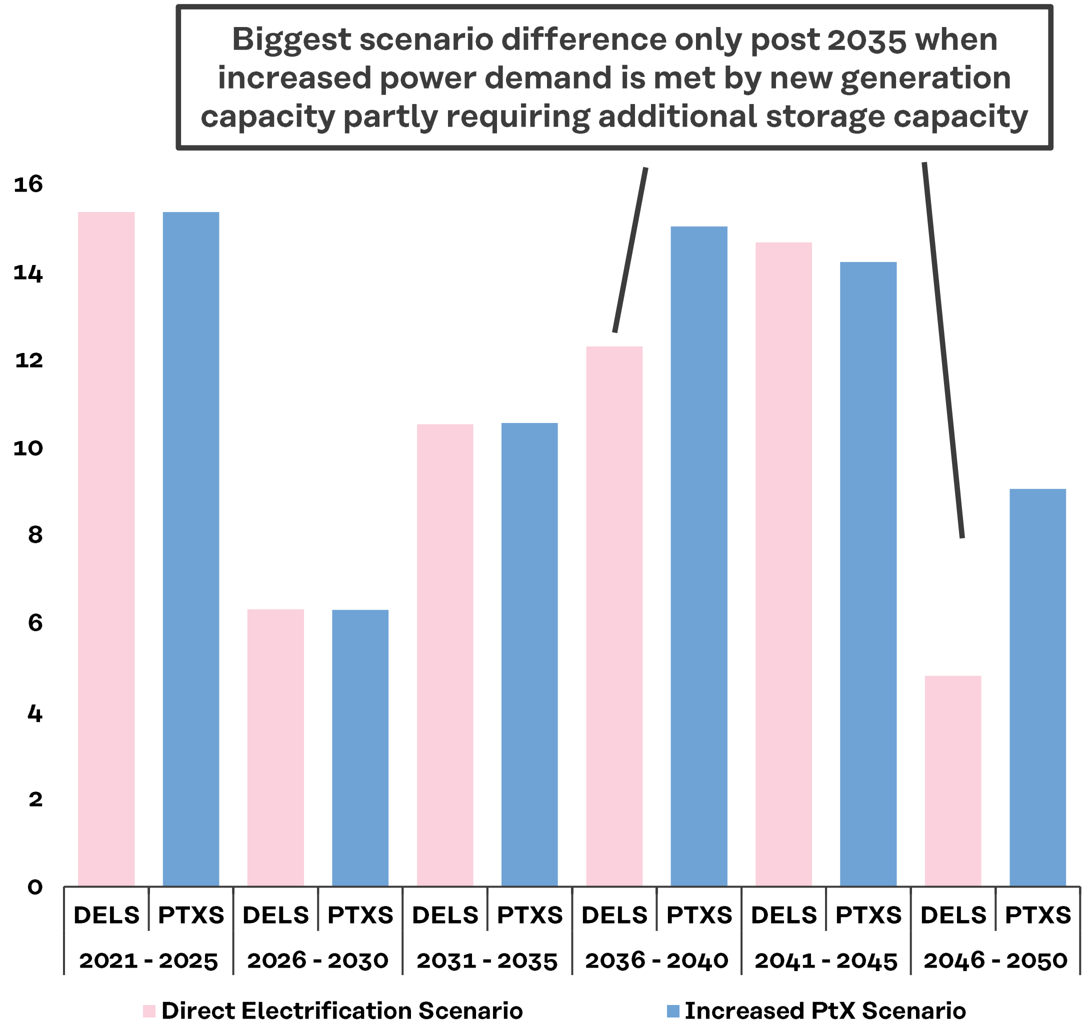
Both scenarios require **significant investment** in electricity generation and storage

- Both analysed scenarios require significant investment in generation and storage capacity up until 2050.

- **Investment** in new generation capacities follow **similar trajectory in the short-term** in both scenarios
- From 2035 onwards **investments are higher in the increased PtX scenario** to meet additional demand via:
  – Investments into additional nuclear capacity; and
  – Building of additional storage and onshore wind capacity between 2046 and 2050.

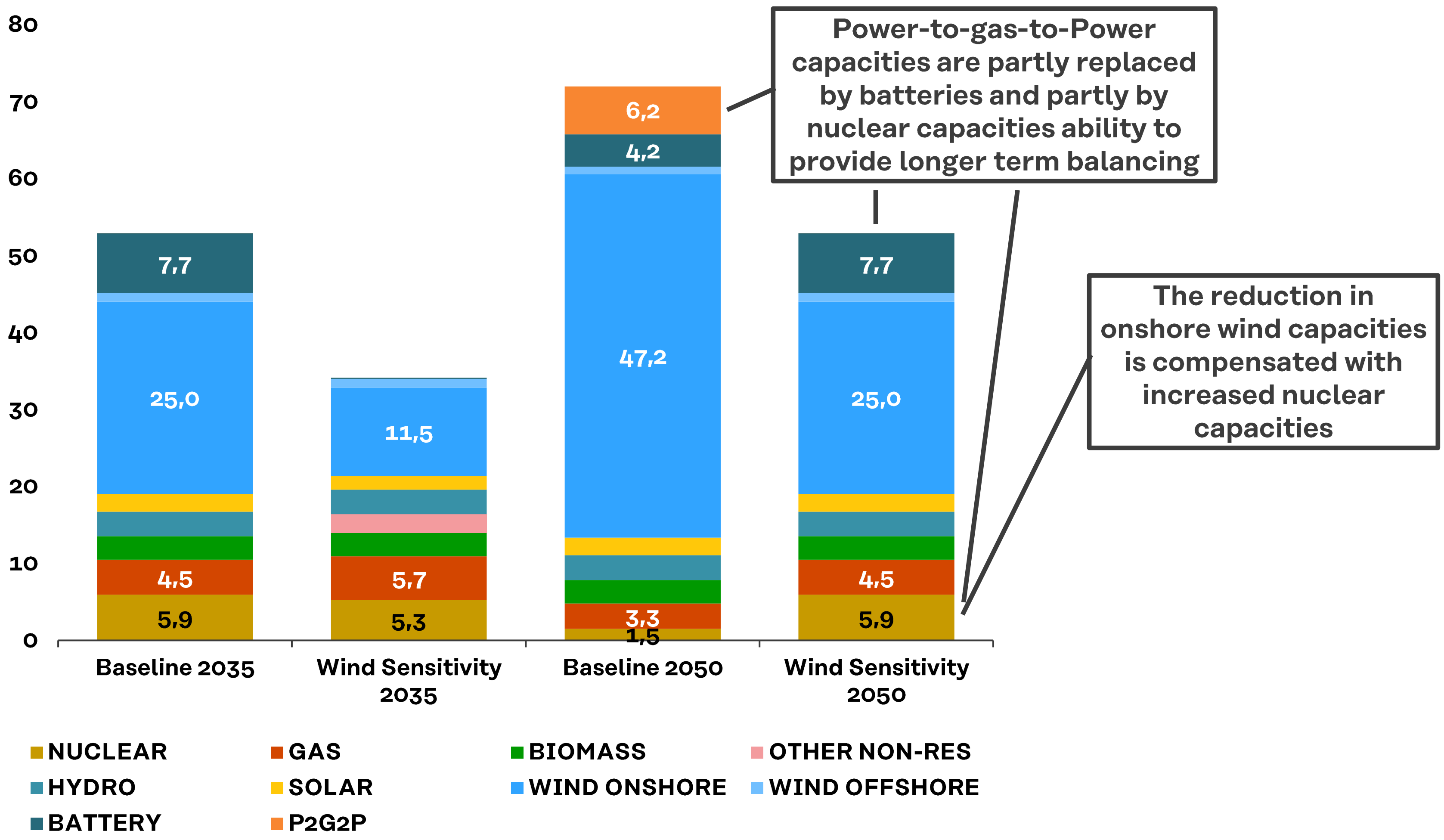
- **<u>Sensitivity analysis</u>: Reduced onshore wind build-up** (due to e.g. military restrictions or NIMBYism) or reduced take-up of **demand side response** would further **increase the need for investment** in generation capacities.

Total CAPEX in Electricity generation and storage [bn€$_{2020}$]
Comparison between Direct Electrification and Increased PtX Scenarios



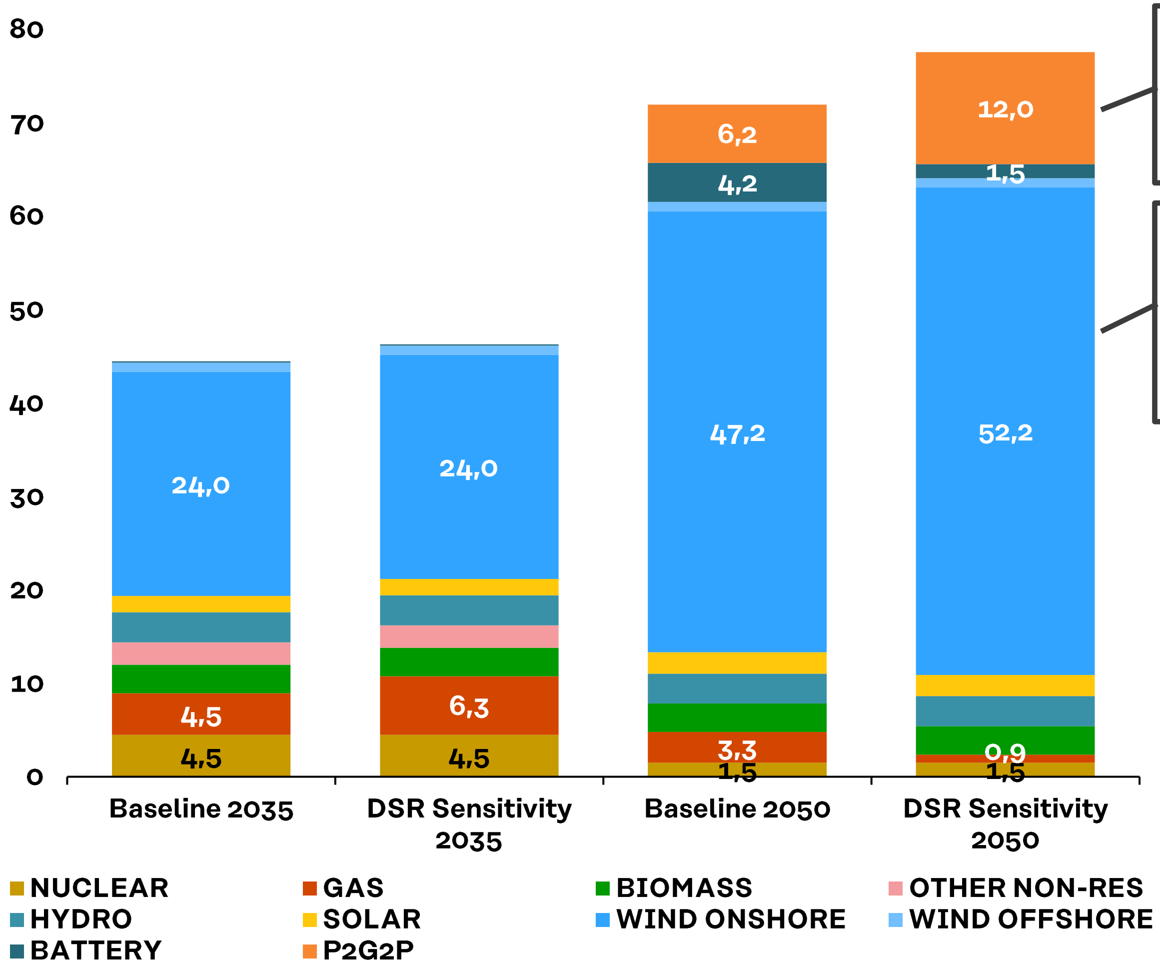
Limiting onshore wind potentials
leads to additional need for nuclear & battery capacities by 2050

Impact of reduced onshore wind potential on generation and storage capacities in the Direct Electrification Scenario [GW]



Demand Side Flexibility (DSF): Reduced DSF uptake increases the need for both supply side flexibility and generation capacity

Impact of reduced demand side flexibility (DSF) uptake on generation and storage capacities in the Direct Electrification Scenario [GW]



Reduced demand side flexibility is replaced by increased supply side flexibility (Power-to-gas-to-Power)

Transformation losses from storage increase the electricity demand and therefore the required generation capacities

Next steps to enable cost-efficient electrification – Selection

Sector	Next steps
Power generation	Explore measures to structurally reduce the impact of the Finnish Defence Forces' requirements on the **build-up of wind generation capacities**
	Explore measures to reduce the effects of **long permitting processes for wind parks** (e.g., public administration permitting capacity and/or courts' resources to handle complaints)
	Follow the process of **nuclear life-time extension permitting** and timely explore options for substituting nuclear generation, if life-time extensions are expected to be not granted.
Supply side flexibility	Regularly review the sufficiency of **investment incentives for supply side flexibilities** and if necessary, explore options to improve these incentives
	Explore necessary support for the **build-up of hydrogen (storage) infrastructure** supporting the build-up of P2G2P capacities required to balance intermittent wind generation
Demand side flexibility	Explore options to structurally **improve the availability of demand side response potentials** (e.g. the requirement for controllability of loads in building regulations) and/or by making demand side flexibility uptake a priority in the national energy and climate plan (NECP).
Transmission network	Integrate the **(spatial) network development planning** for electricity, gas and hydrogen
Distribution network	Explore **incentives for the reduction of peak power demand** e.g., by implementing peak-load-based components in the network tariff incentivizing inter alia smart electric vehicle (EV) charging

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