

Energiomställningens påverkan på kärnkraft

Professor em. Peter D. Lund

Aalto Universitetet

Kärnkraft igår, nu och i framtiden
30 mars 2026



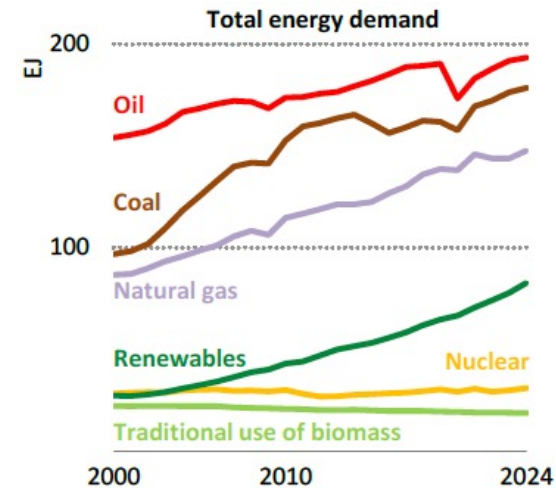
Outline

- Global trends in energy
- System changes in energy systems
- Cost and value of produced electricity

Global trends in energy

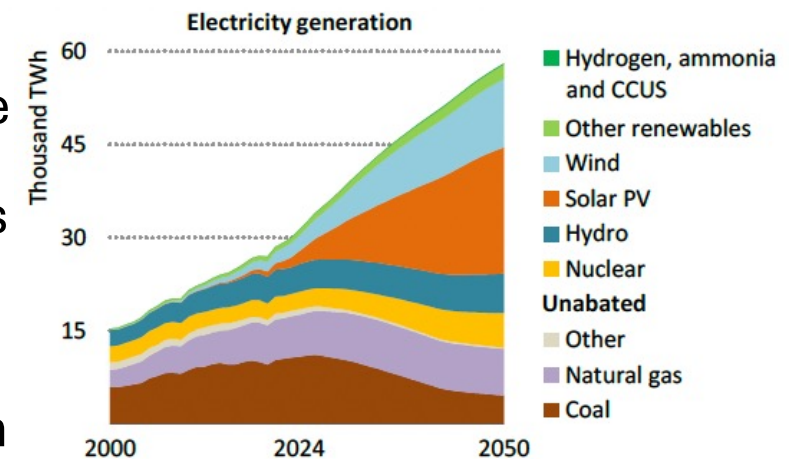
Climate, security, economy, social aspects, innovations, etc. drive the energy transition

- **Emissions** are growing (but may start to level out)
- **Fossil fuels** dominate and remain for a long time
- **Electricity** demand and electrification grows fast
- **Renewables** (solar/wind) accelerate across the globe
- **Hydrogen** (synthetic fuels) still needs major cost cuts
- **China** plays central role in clean energy technology
- **Nuclear** (start 2017-) 100% of Russian/Chinese origin



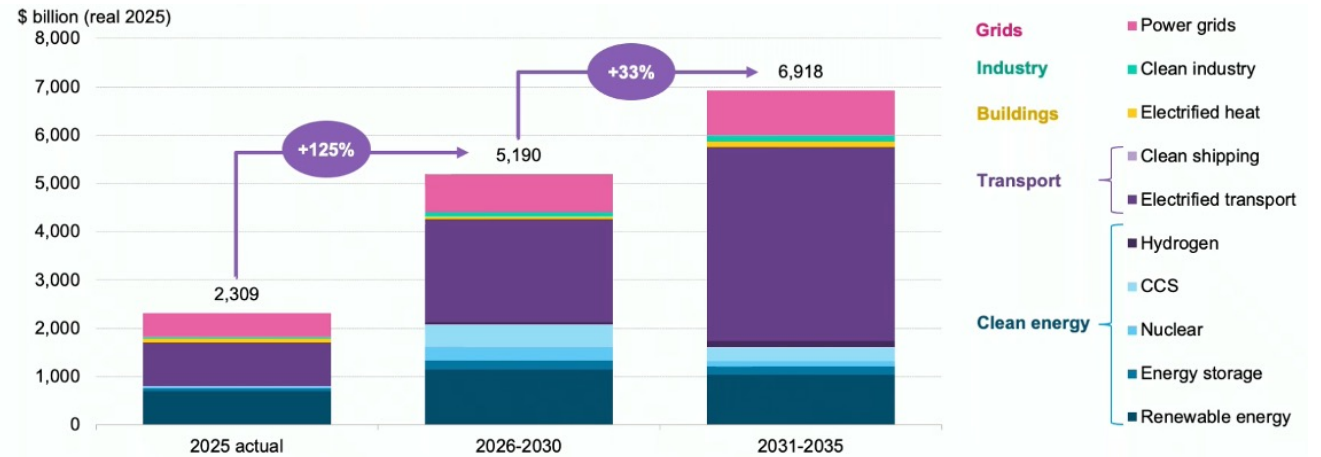
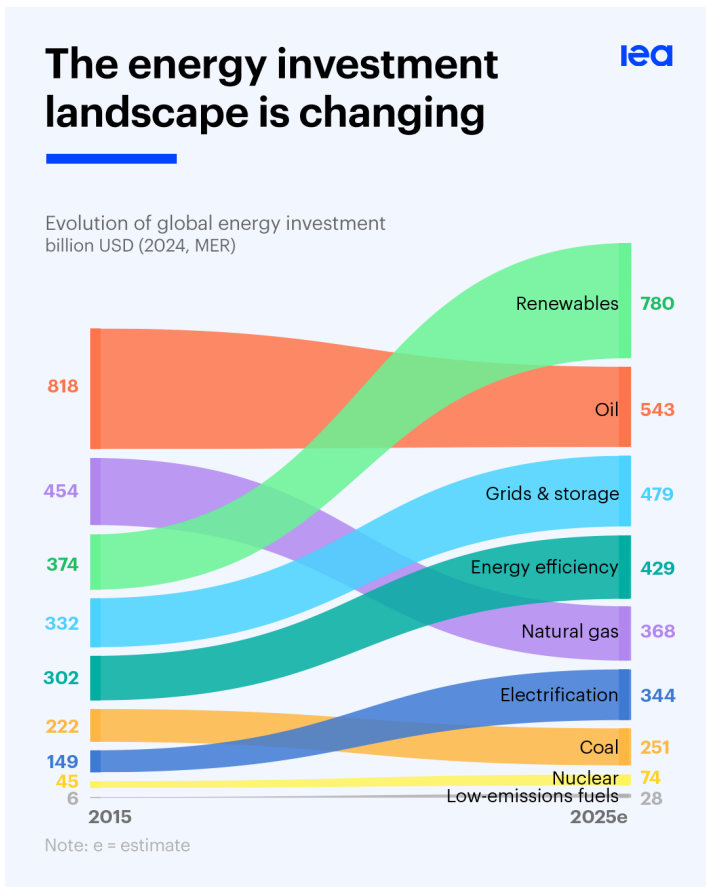
World energy: fossil 80%/clean 20% (RE 15%)

World electricity: fossil 60%/clean 40% (RE 30%)



Global energy investments and trends

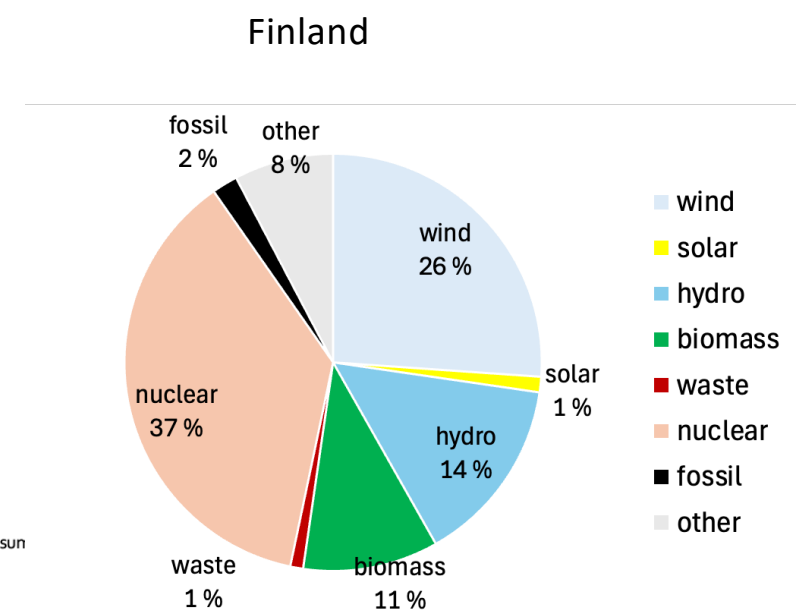
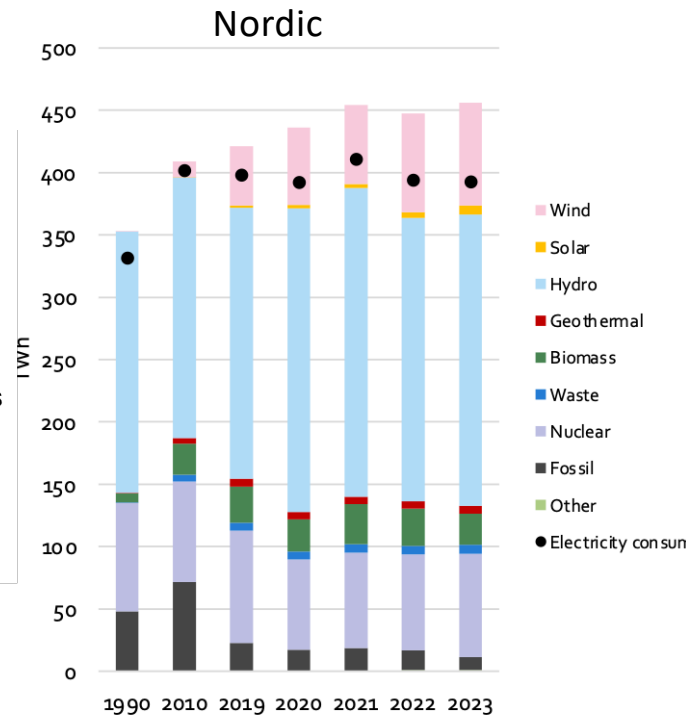
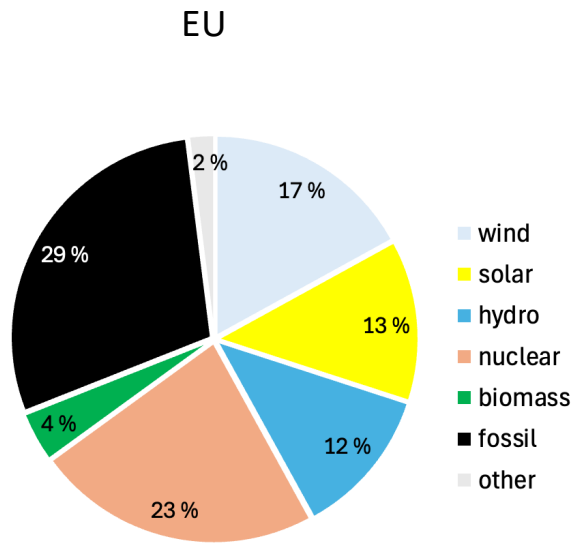
- >60% of all energy investments went into clean energy; grids, el. transport and renewables, the trend is expected to prevail with transport dominating by 2035



Ref: BloombergNEF, 2026; 2025

Comparison of electricity mix: Finland, Nordic, EU

- Nordic power system almost fossil free, **hydropower >50% of all electricity** (2023)
- Finland has largest share of nuclear power in the Nordic region (2025)
- New renewables largest source of electricity in the EU and Nordics (2025)



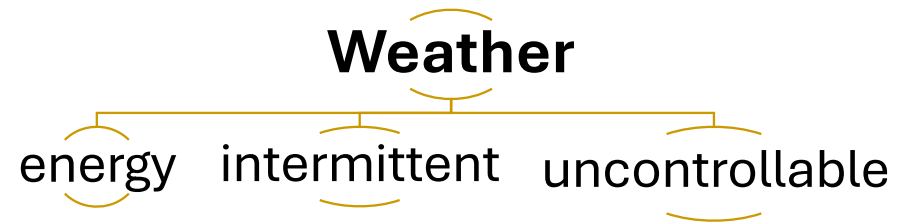
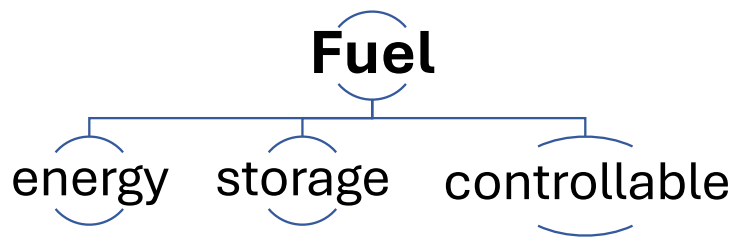
Ref: Ember 2026, Finnish Energy Industry 2025, Norden 2024

Changing 'typology' affects power system functionalities

Fuel-based centralized electricity systems



Weather-dependent renewable decentralized electricity systems



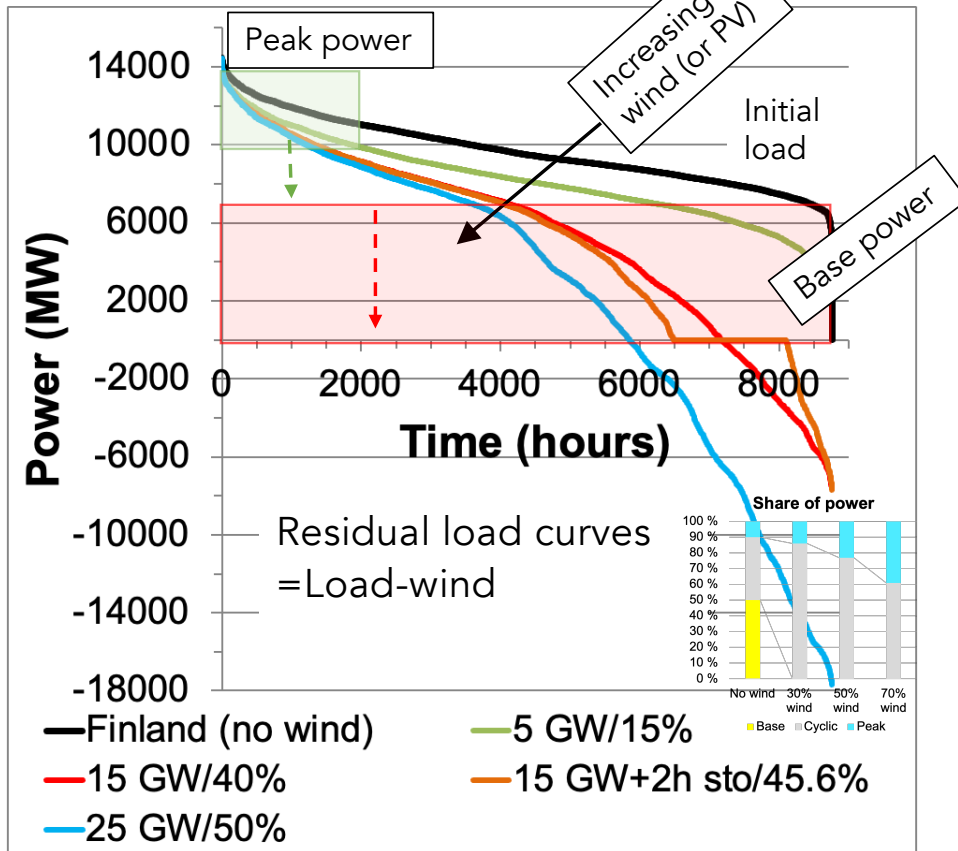
Flexible demand and supply, EN storage

Flexibility deficit

Increasing RE causes oversupply and shifts remaining supply more towards peak power

Load duration curve + cost curves of power plants

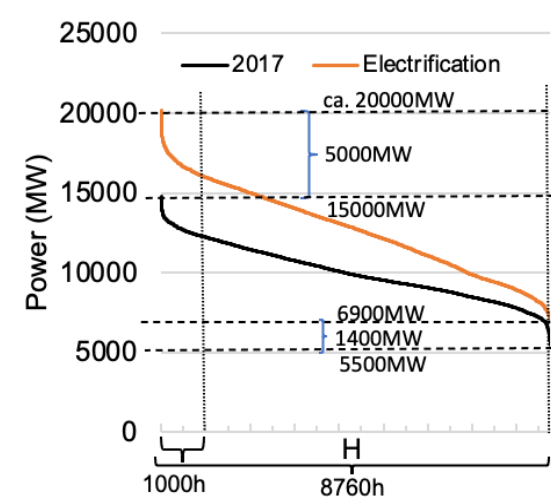
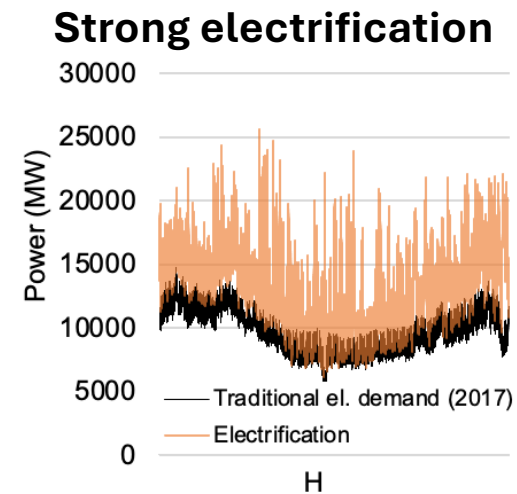
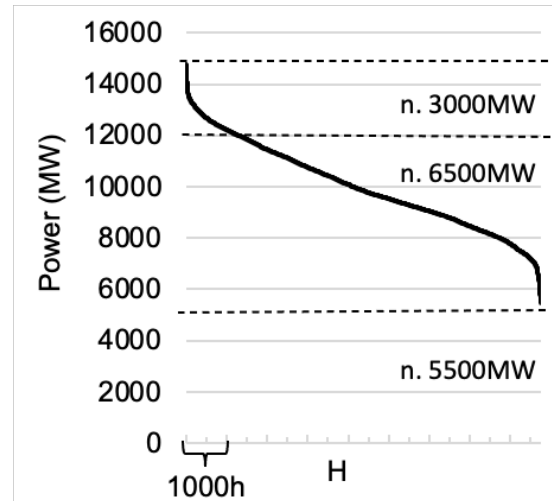
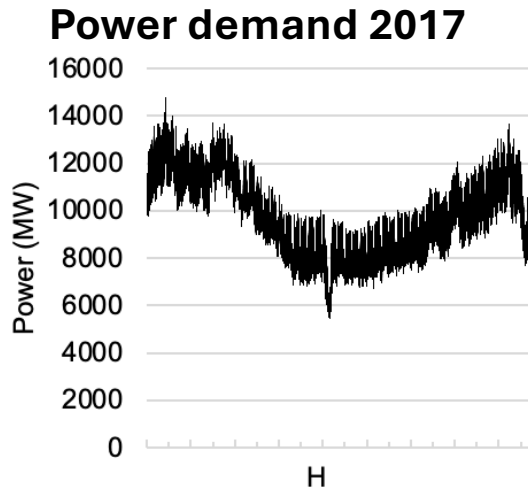
→ optimum power mix



• Increasing solar & wind:

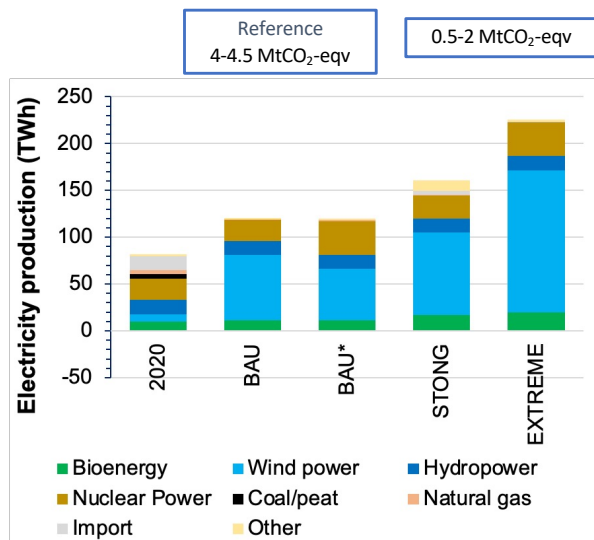
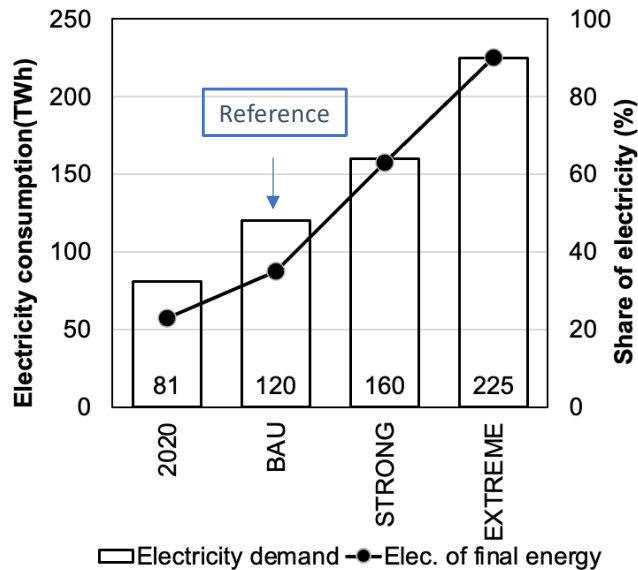
- Shifts optimal power mix of residual load = (initial load – RE power) towards cyclic & peak power plants, i.e. more flexible power plants
- More negative residual load (oversupply) with negative power price
- Base power plants economics affected unless more demand, exports, or other agreements
- Transnational power transmission and the Nordic electricity market mitigate above effects

Electrification increases load variability



- Electrification of energy demand (in particular heat, but also EVs) increases load variability and demand for supply flexibility
- Balancing of demand and supply becomes important
 - Volatility increases
 - Importance of Nordic power market
 - New flexibility strategies
- In this example peak power demand increases by 2/3

Scenarios for strong electrification in Finland by 2050



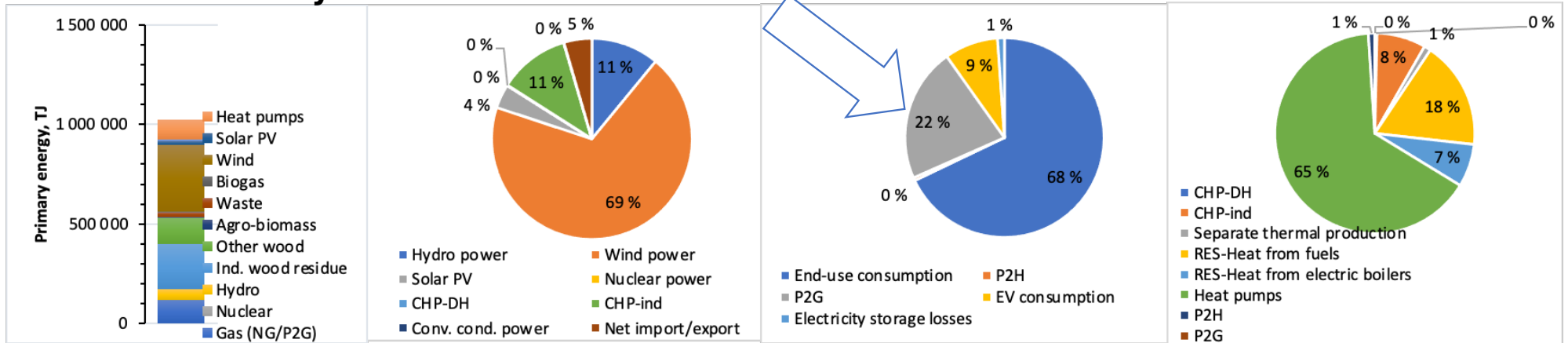
- Finland negative emissions 2050
- Electricity demand could even double, becomes more weather and behaviour dependent, peak power demand increases
- Reference scenario (2050): The most cost-effective solution shown (BAU) with given assumptions and boundary conditions.
- Wind and nuclear power replacing each other (BAU vs. BAU*)
- More flexibility needed (e.g. sector coupling, demand response, etc.)
- Need of fuel: bioenergy vs. electrofuels (PtX)



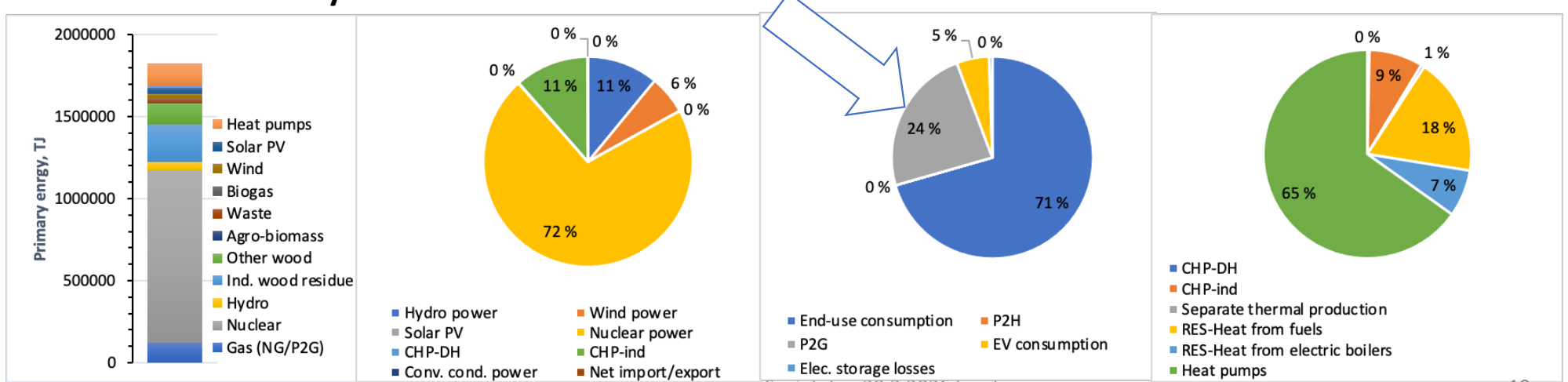
P.D. Lund: Effects and possibilities of electrification in the Finnish energy system, Report 1/2022.

Details on two approaches to decarbonize Finnish energy system by 2050

Wind dominated system



Nuclear dominated system



Primary energy

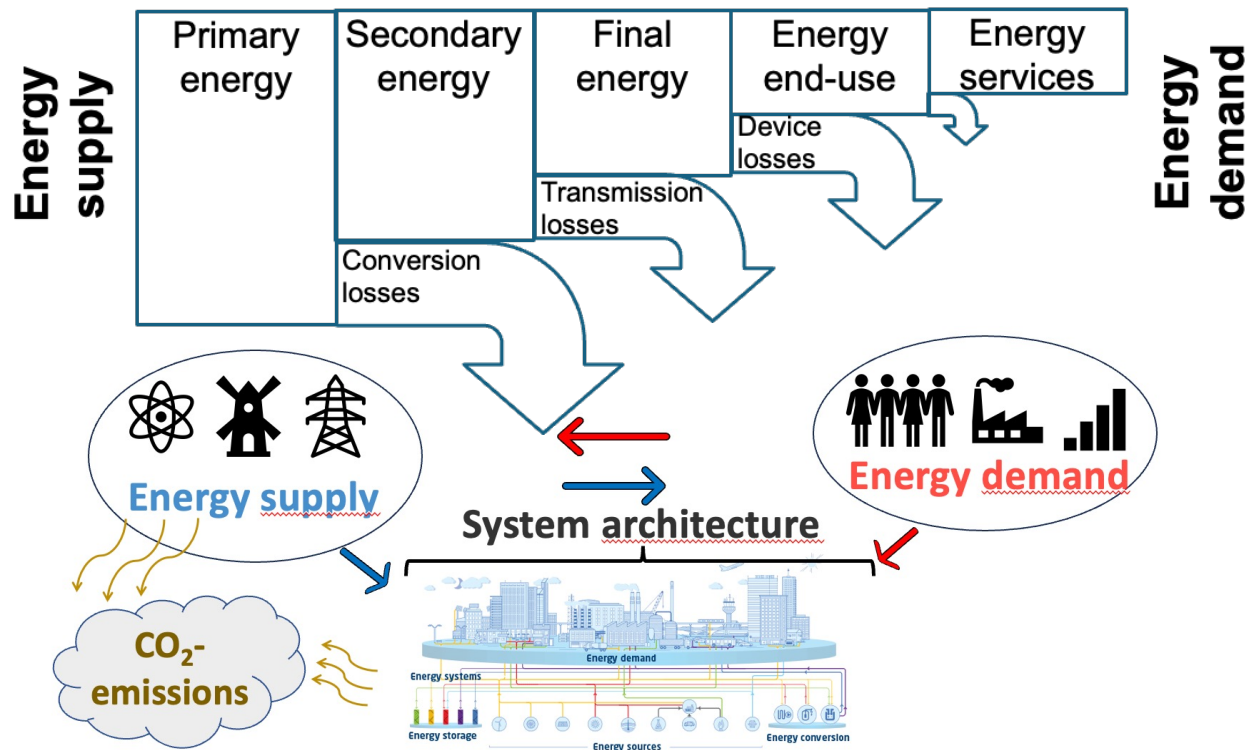
Power production

Electricity use

Heat production

Energy efficiency is important in energy transition

- **Energy efficiency** and savings in end-use side reduce demand for supply, materials, flexibility, fuels, etc. over the whole energy-chain, also easing integration of variable renewable electricity and nuclear



Economics as driver for new investments

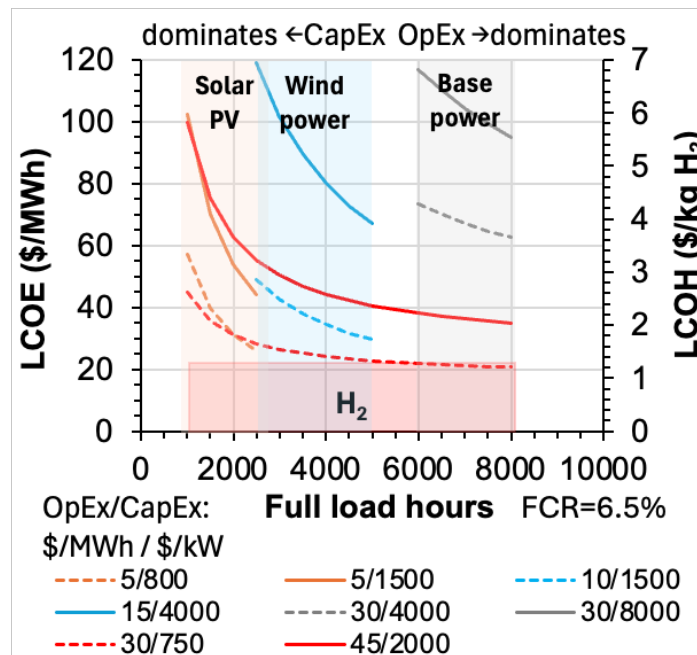
- Core technology typically 25-35% of total costs; BOP, BOS, soft costs dominate in new energy technology
- From cost of pure energy production (LCOE) to value provided by technology to energy systems (VALCOE)
- High VALCOE vs LCOE motivates to find effective system and engineering solutions to provide more value

Cost of produced energy (LCOE)

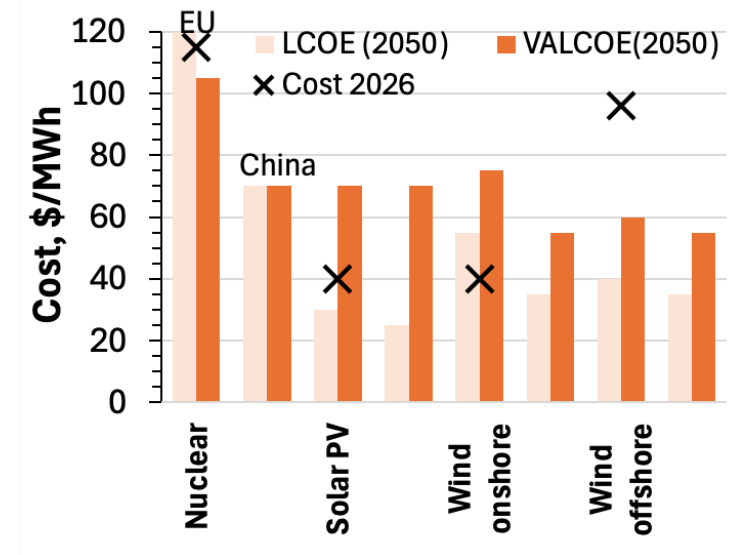
$$LCOE = OpEx + \frac{FCR}{FLH} \times CapEx$$

LCOE	Levelized cost of energy
LCOH	Levelized cost of H ₂
VALCOE	Value-adjusted LCOE
CapEx	Capital expenditure
OpEx	Operational expenditure
FCR	Fixed charge rate
FLH	Full load hours

Effect of key factors on LCOE



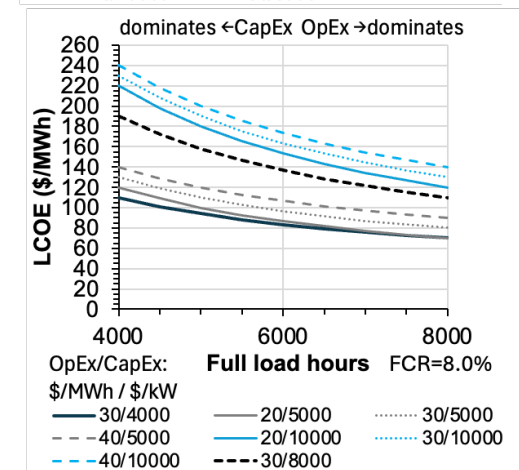
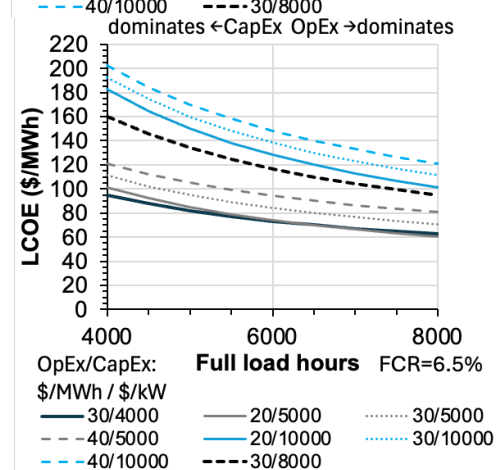
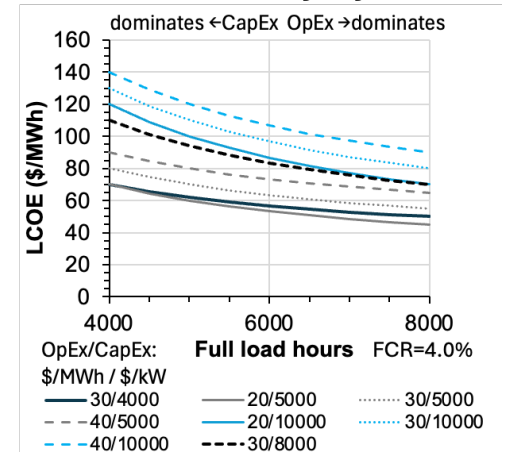
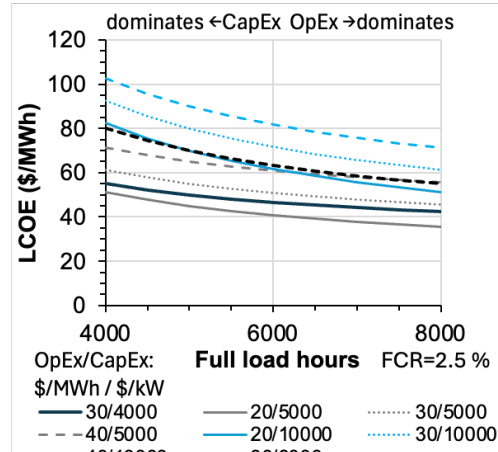
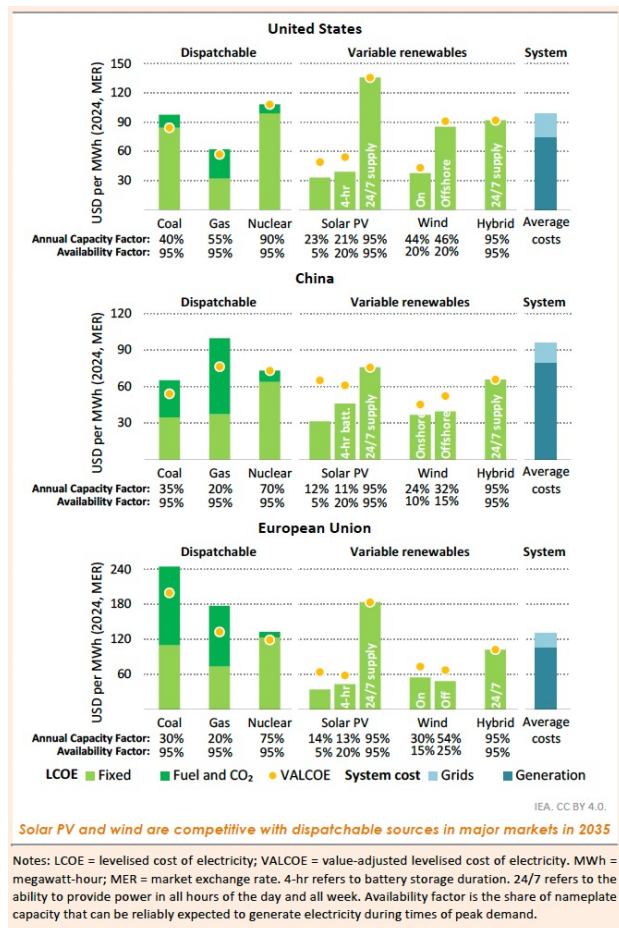
Value-adjusted LCOE



Ref. IEA World Energy Outlook 2025

Sensitivity analysis

- Assumptions influence the estimated cost (LCOE; e.g., interest rate, CAPEX, OPEX, FLH)
- Value of produced electricity (VALCOE) depends much on the structure of the electricity system



Summary

- Future energy/power system architecture is challenging to base-power, and emphasizes 'flexibility'
- Cost of produced electricity is highly sensitive to assumptions, and its value to the power market/system may not coincide with the cost