Finland’s power system outlook for 2027 & 2030

Wärtsilä

2024

Contents

Wärtsilä's modelling experience

200+ Country and system studies made by Wärtsilä all over the world with PLEXOS software

- +10-year experience with PLEXOS
- Industry-leading modelling capabilities
- Tailored modelling approach

Benefits and goals

- Understand operations and fundamentals of increasingly complex power and energy systems
- Quantify system level benefits of different generation and storage technologies
- Understand and promote high quality modelling

Inputs and assumptions

Inputs and Assumptions, Modelling the Finnish Energy System in 2027 & 2030

Approach

Model type

- Fundamental dispatch model
- Co-optimized heat and power, incl. reserve markets
- 1-hour resolution, chronological model
- Modelling years 2027 and 2030
- 35 weather years based on historical climate data

Regions and generation technologies

- Generation fleet based on the target years 2027 & 2030
- Nordic & interconnected countries

Costs and bidding

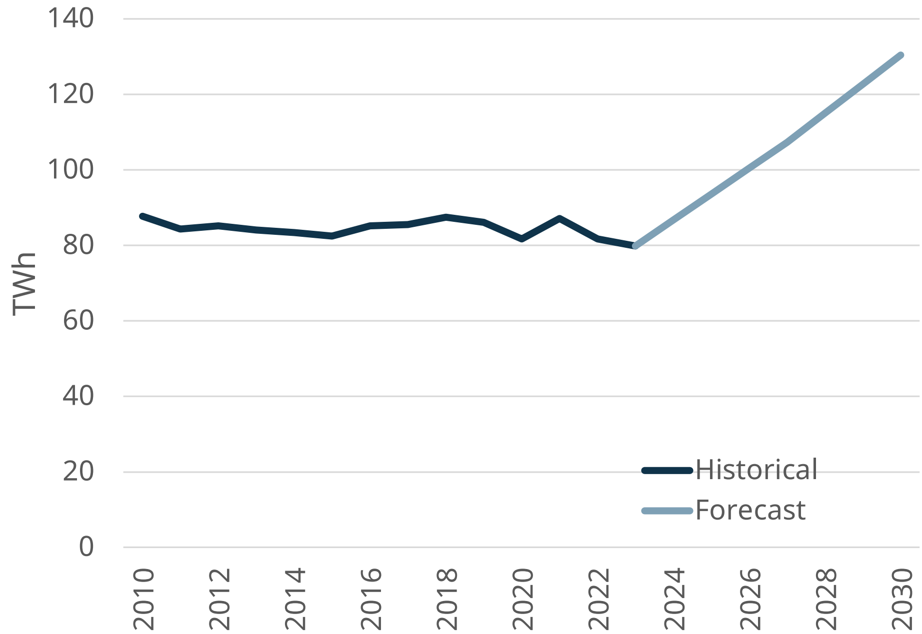
- Cost-driven dispatch of available resources based on total cost minimisation
- Hourly price formation for each price area based on the short-run marginal costs of the marginal unit (marginal pricing)

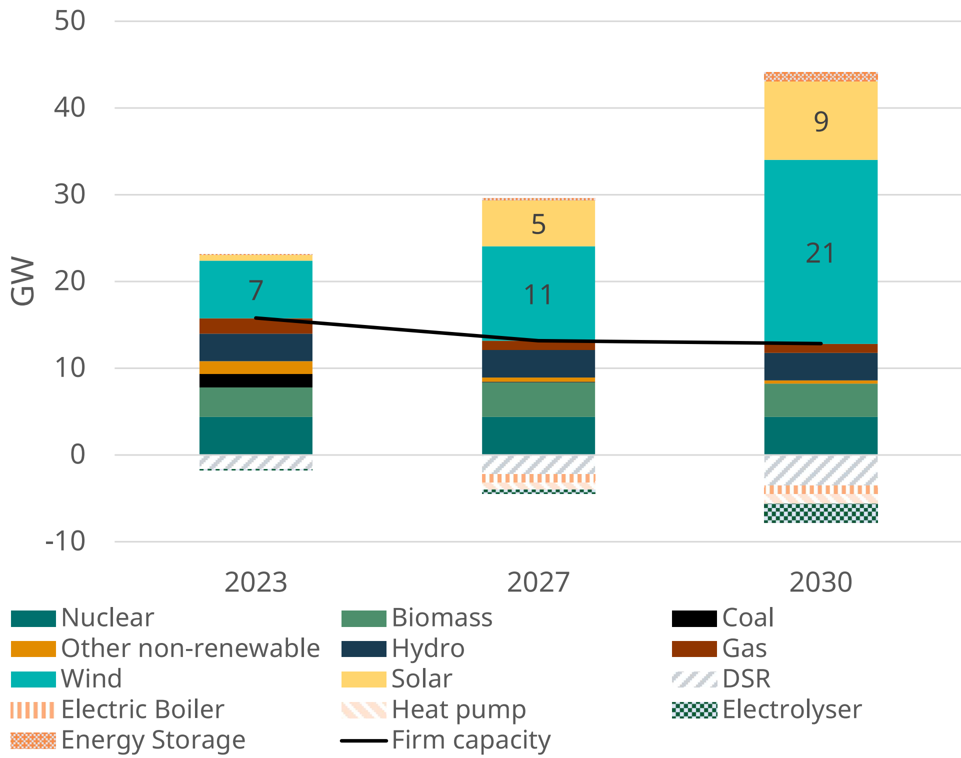
Assumptions

Type	Source
Power generation fleet	entsoe ERAA by ENTSO-E (2022)
Renewable profiles	entsoe ERAA by ENTSO-E (2022)
Demand side response	entsoe ERAA by ENTSO-E (2022)
Electricity demand	entsoe ERAA by ENTSO-E (2022)
District heating demand	Tilastokeskus
Hourly district heating	HELEN
District heating fleet	Energiateollisuus
Fuel costs	Bloomberg
CO_2 cost	Bloomberg

Load growth and capacity mix in Finland

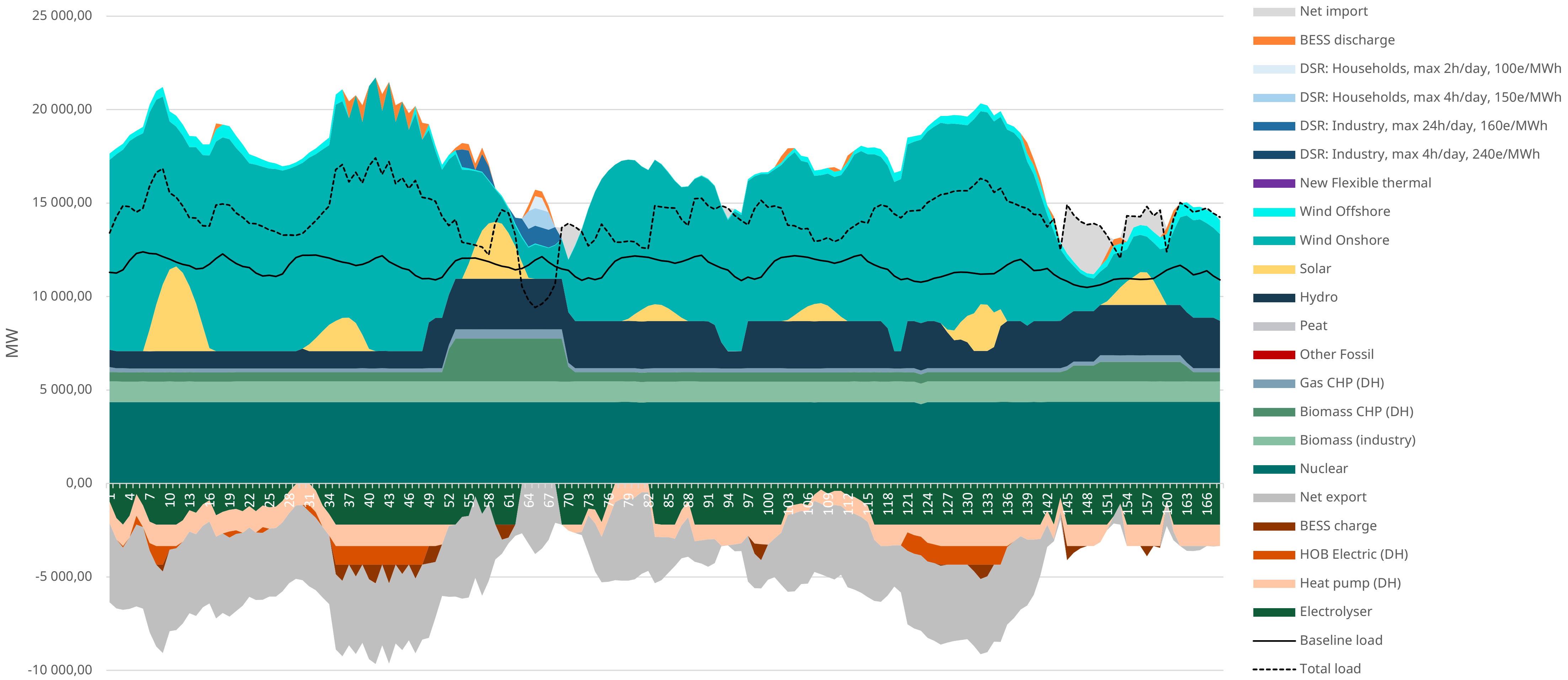
According to ERAA 2022 & Fingrid





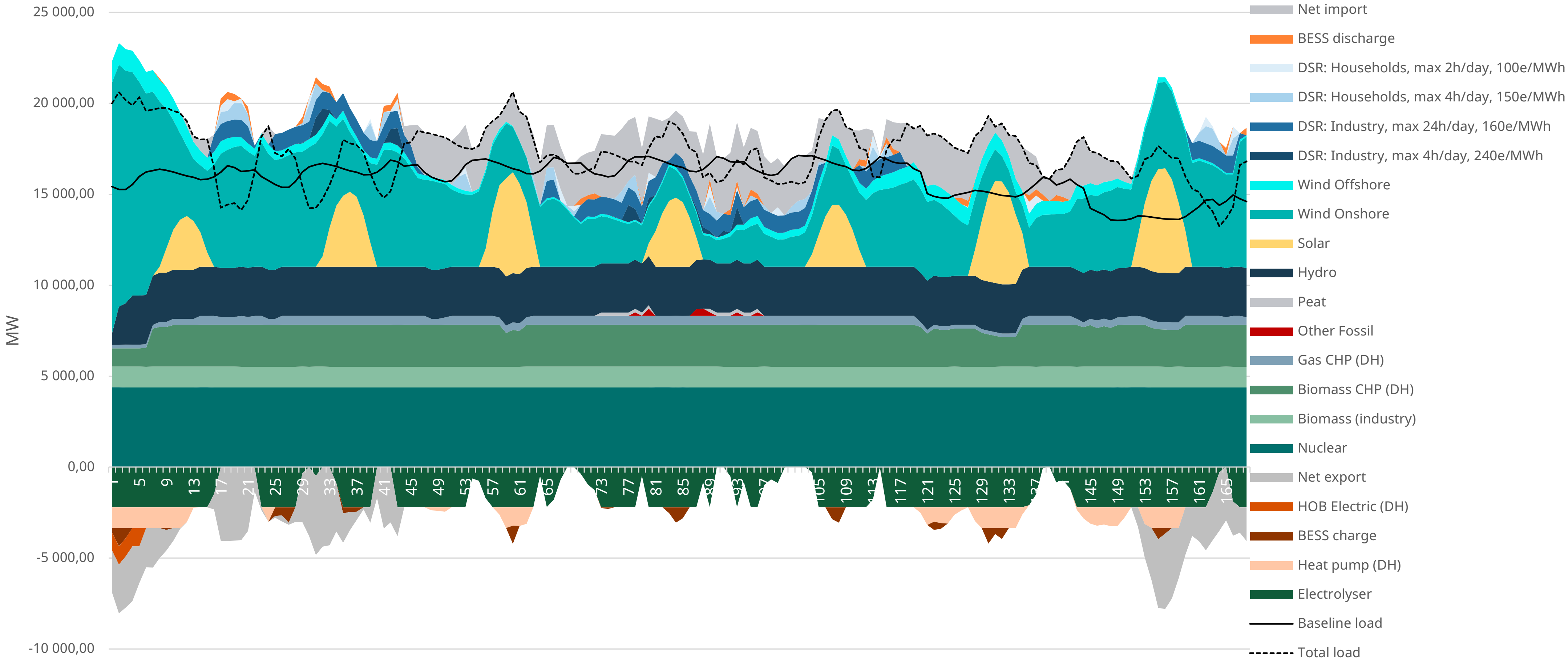
Example week from the model

Average week in October (8.-14.10.2030), weather year 1991



Example week from the model

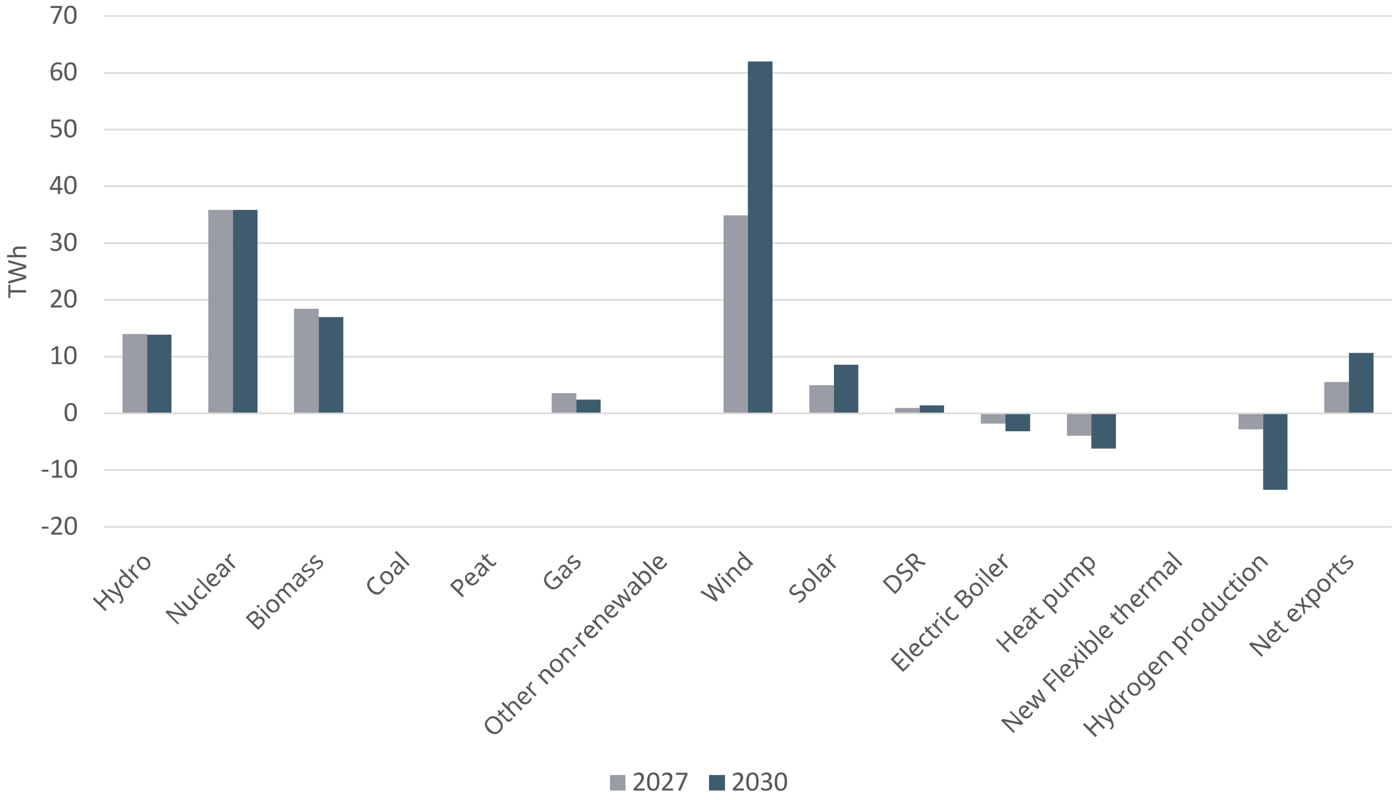
High demand & low wind week in February (12.-18.2.2030), weather year 2011



Outlook 2027 & 2030
Modelling results

Generation mix in 2027 & 2030

Wind, nuclear, hydro and biomass continue to provide most of Finland's electricity needs



Average of 35 weather years

Scenarios modelled

Normal year

Crisis 1

Olkiluoto 3 unavailable (-1.6GW)

Crisis 2

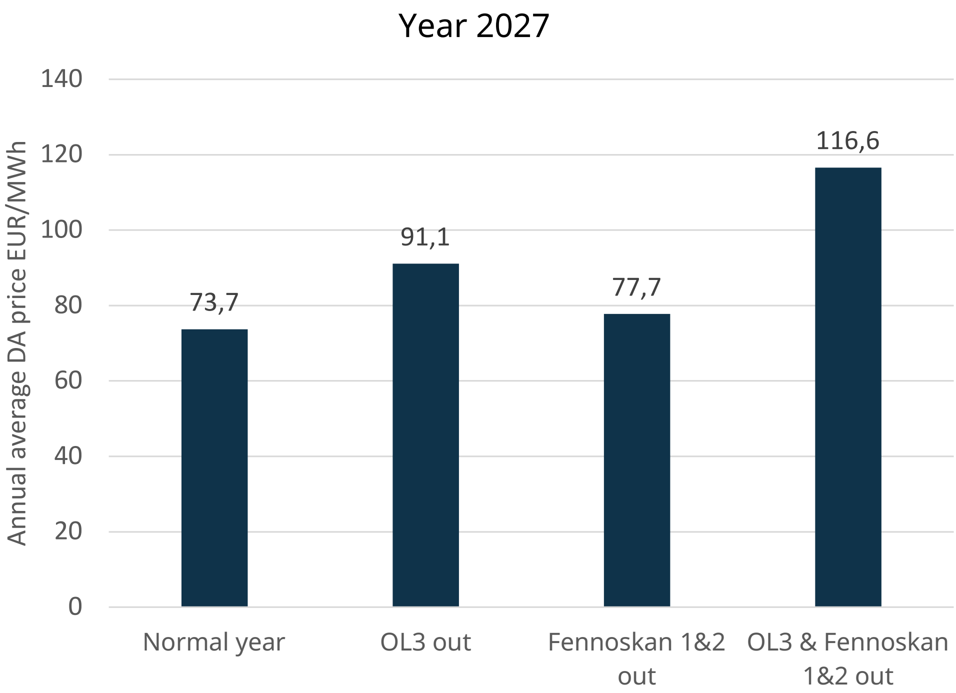
Fennoskan 1&2 unavailable (-1.2GW)

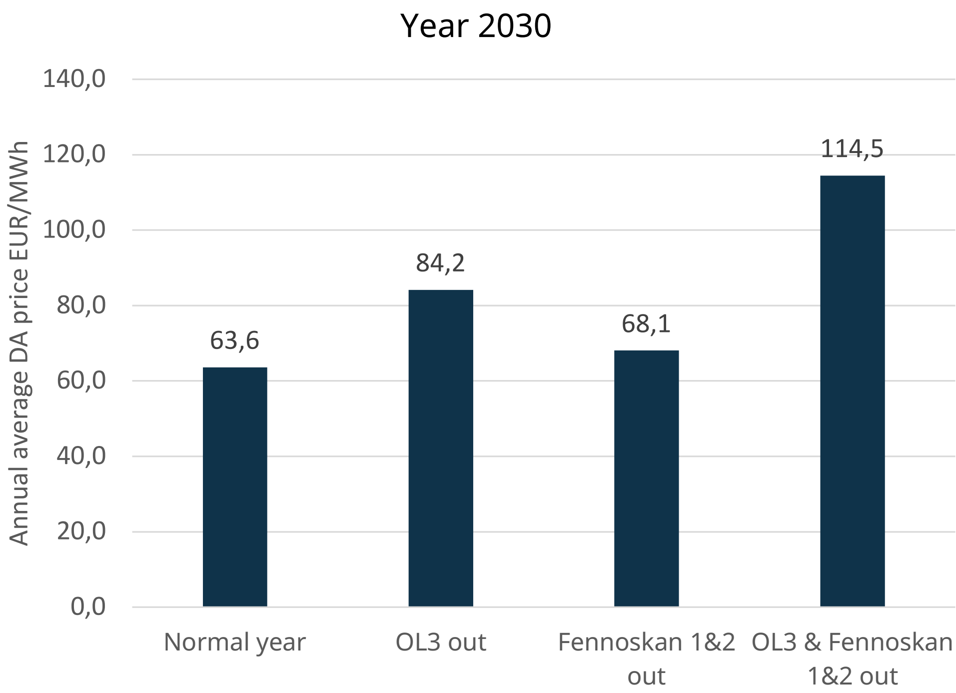
Crisis 3

OL-3 and Fennoskan 1&2 unavailable (-2.8GW)

Finland area prices in 2027 and 2030

Price levels to increase in the short-term and decrease in the long-term due to load growth. Possible crises would have an impact to the price levels.

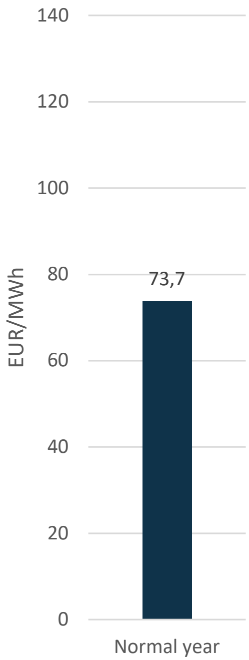




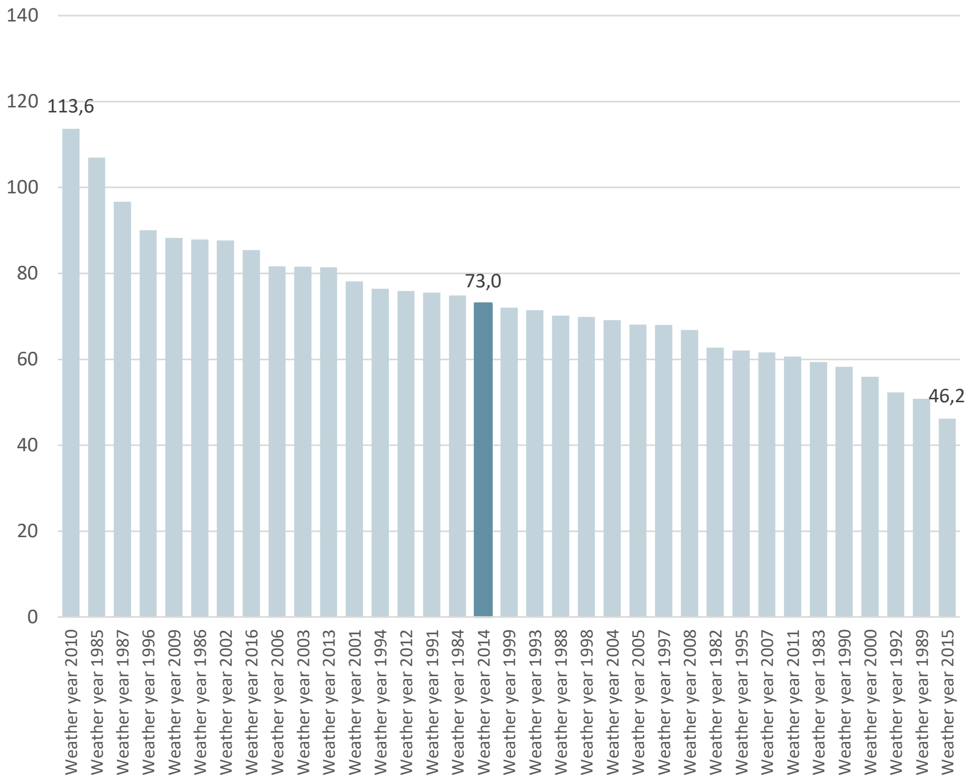
Average of 35 weather years

Finland area price in 2027 depends on the weather conditions

Yearly average price can be low or very high depending on wind and hydro conditions on the given year



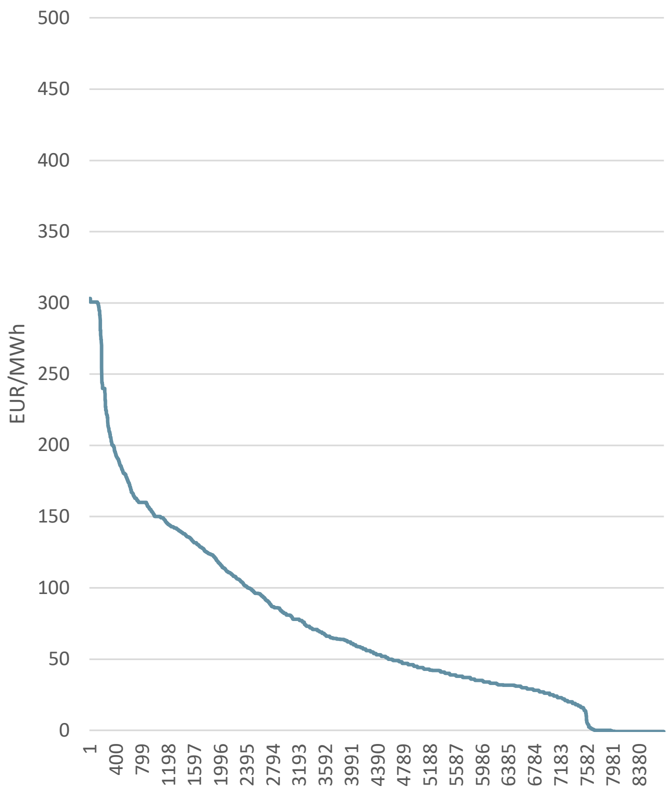
Average of 35 weather years



35 samples (weather years)

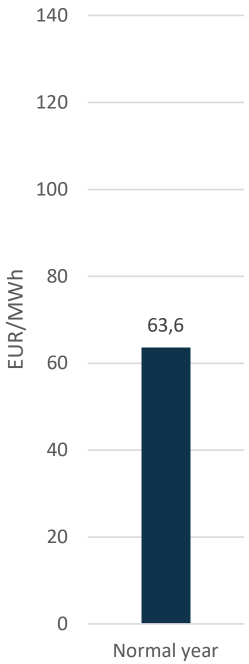
Duration curve example (1 sample)

Example price duration curve
(the sample based on weather year 2014)

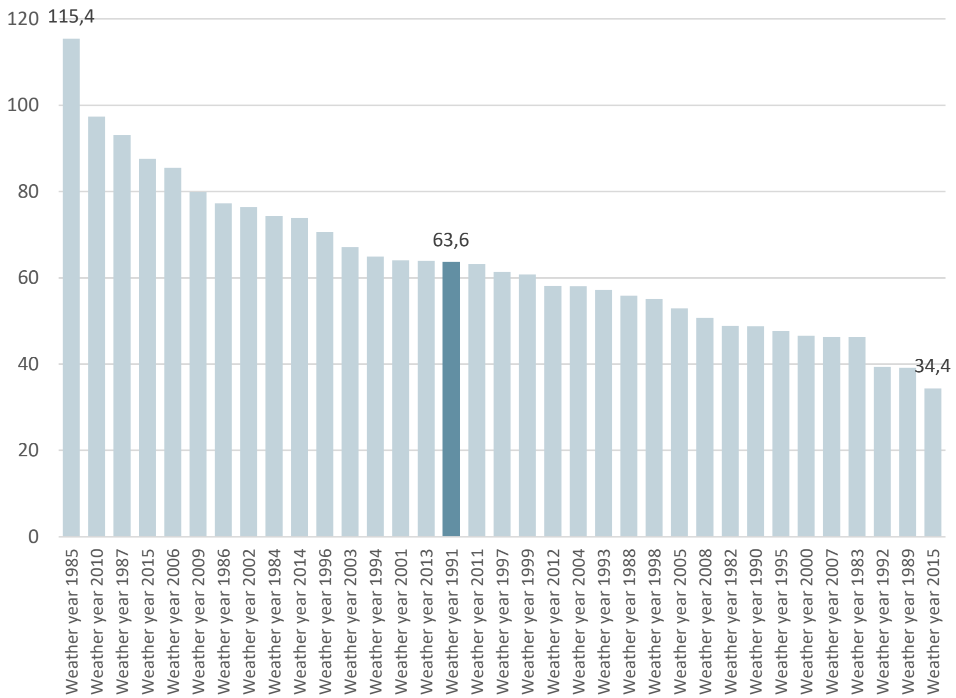


Finland area price in 2030 depends on the weather conditions

Yearly average price can be low or very high depending on wind and hydro conditions on the given year



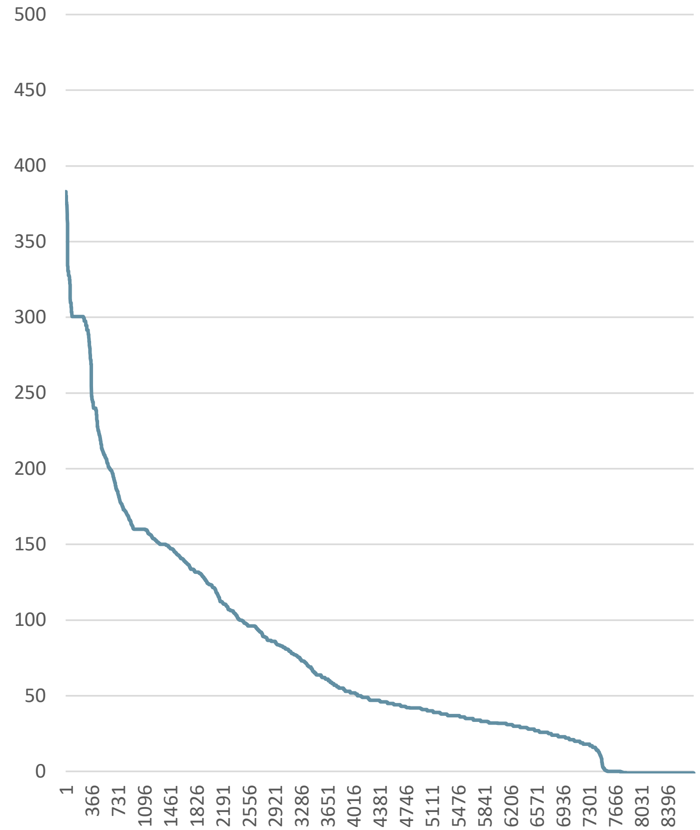
Average of 35 weather years



35 samples (weather years)

Duration curve example (1 sample)

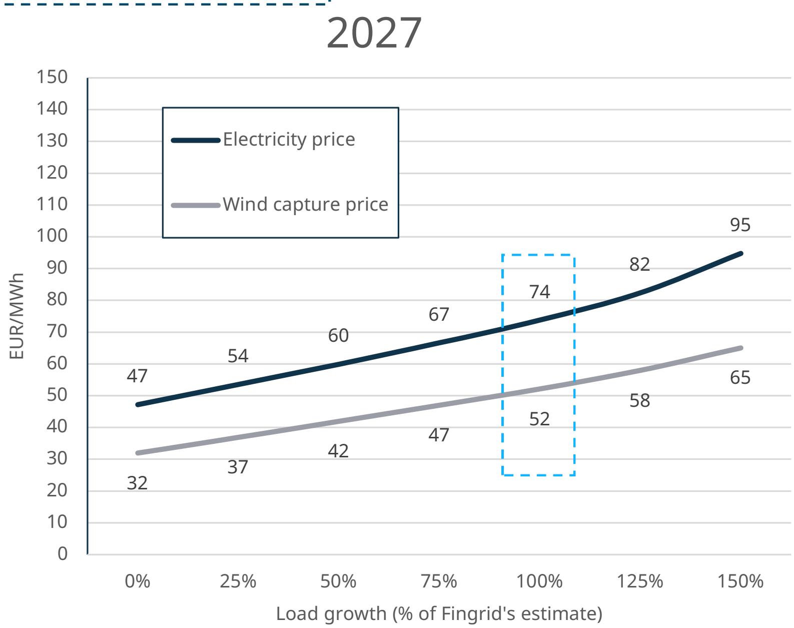
Example price duration curve
(the sample based on weather year 1991)

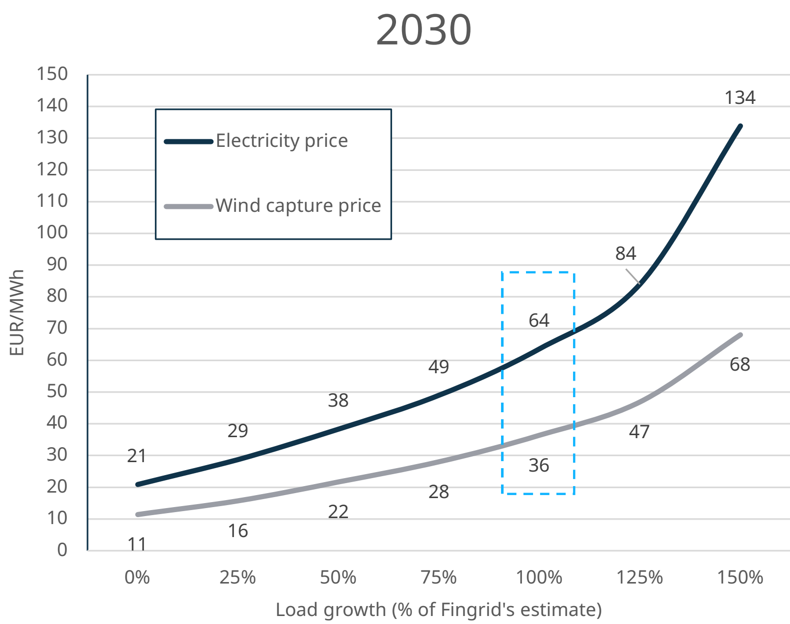


Electricity prices and wind capture prices are highly dependent on load growth

Additional load growth sensitivities modelled for 2027 and 2030

Basecase: 100% of Fingrid's load growth estimate





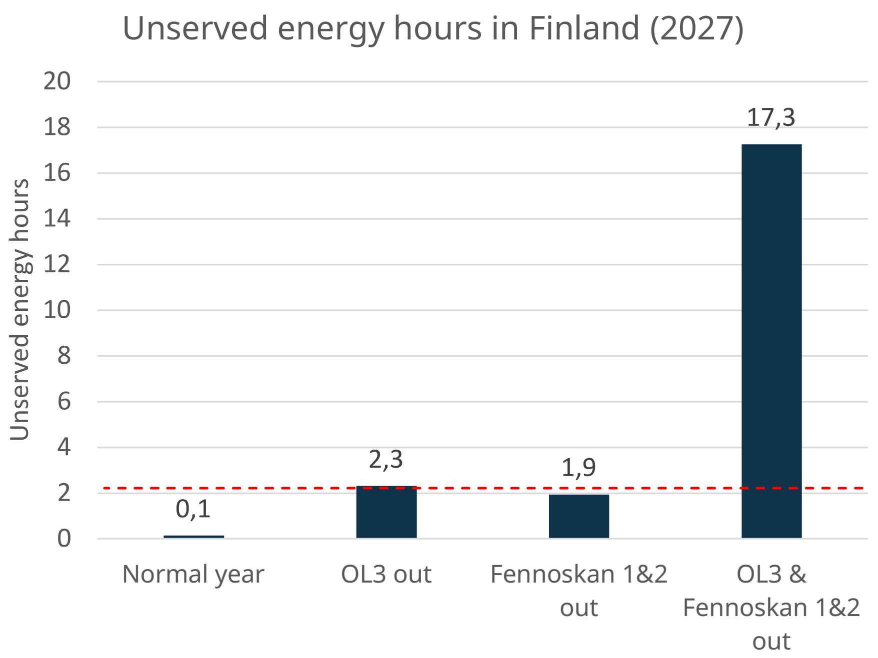
Without load growth, electricity prices remain the same in 2027 and decrease sharply in 2030

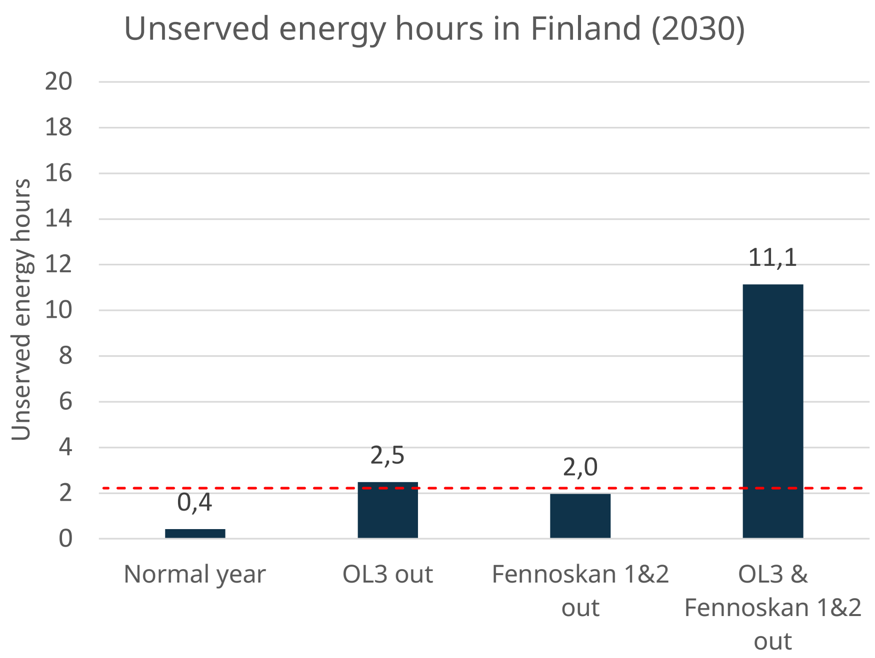
Wind capture price needs to be 30-40 €/MWh in order for them to get built

Average of 35 weather years

System reliability in 2027 and 2030

In 2027, Finnish power system can handle one crisis but two simultaneous crisis would cause problems to system reliability. In 2030, Finnish power system can operate normally in the absence of a crisis but cannot handle a disruption in OL-3 or Fennoskan.



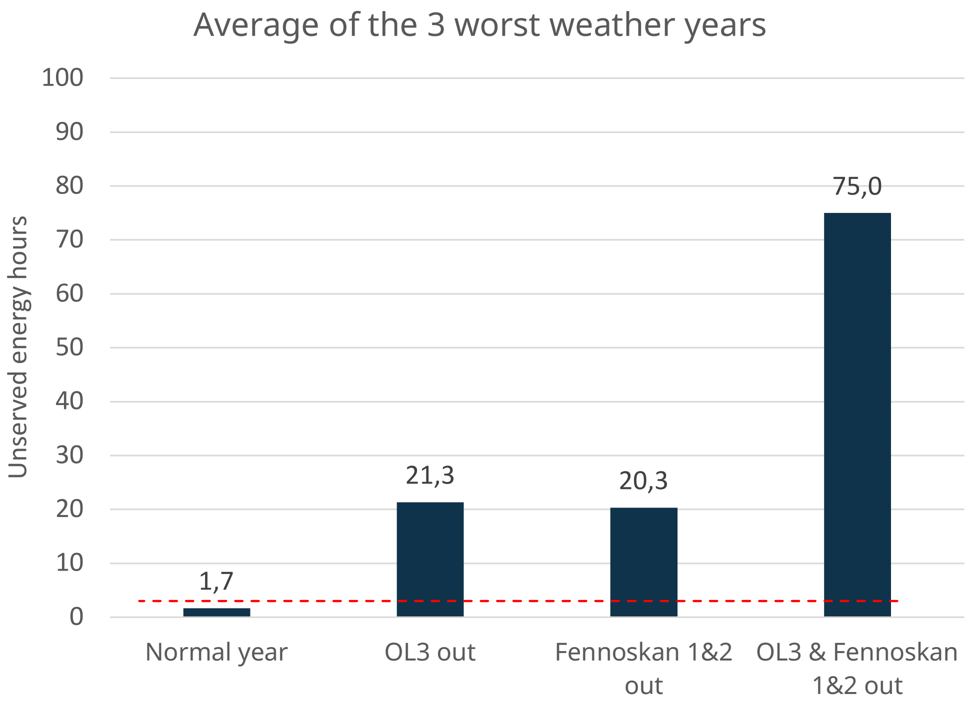


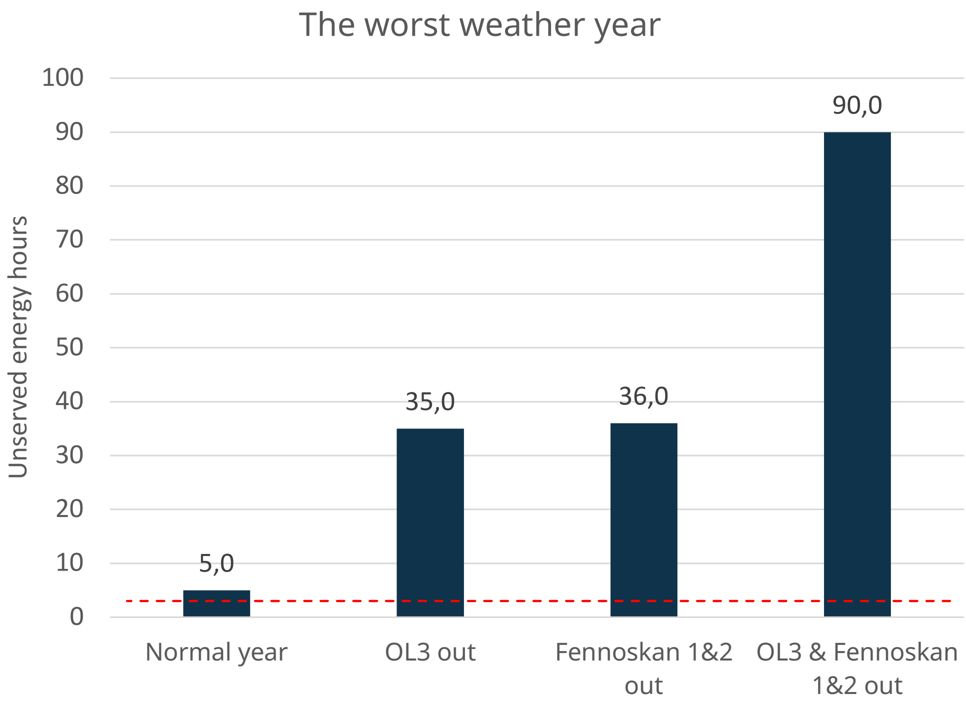
Finnish reliability standard for loss of load expectation (LOLE): < 2.1 hours/yr

Average of 35 weather years

System reliability during worst weather years, 2027

In 2027, Finnish power system would operate normally in the absence of a crisis even during the worst weather year but the system cannot handle a crisis.

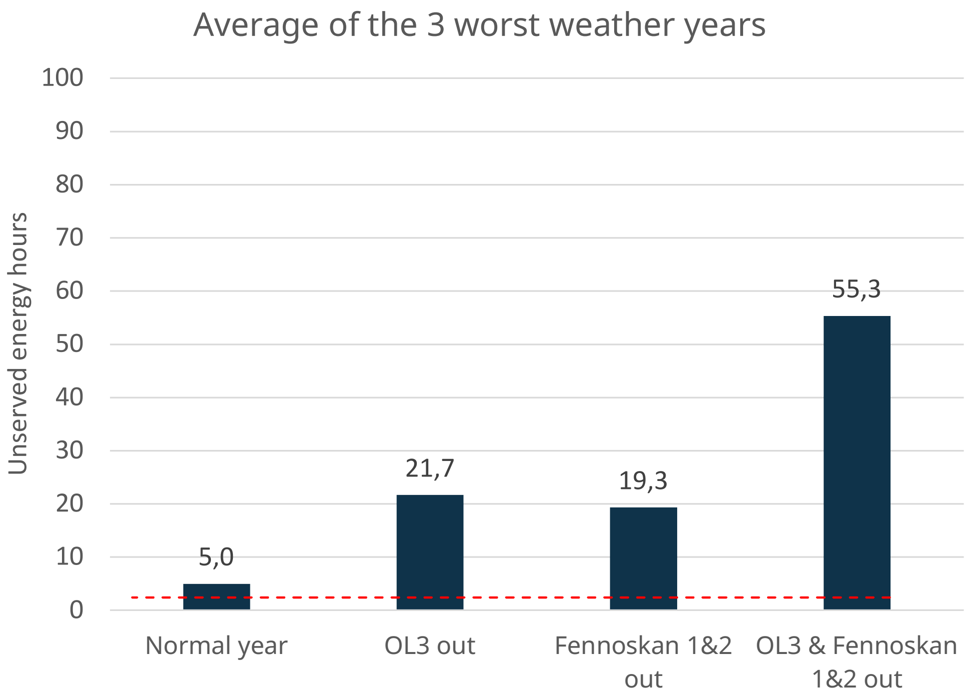


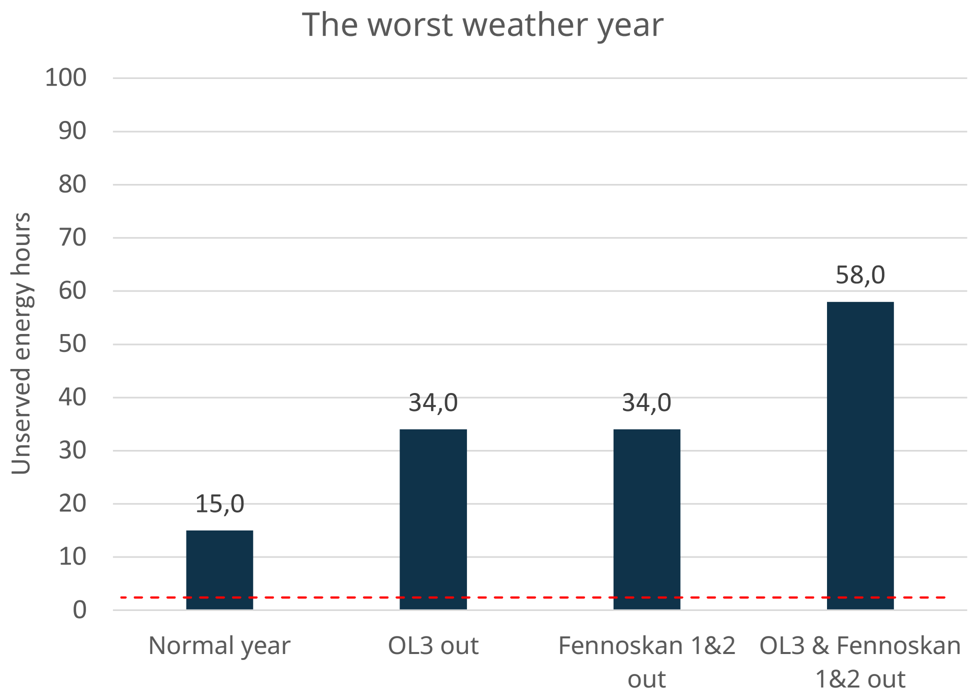


Finnish reliability standard for loss of load expectation (LOLE): < 2.1 hours/yr

System reliability during worst weather years, 2030

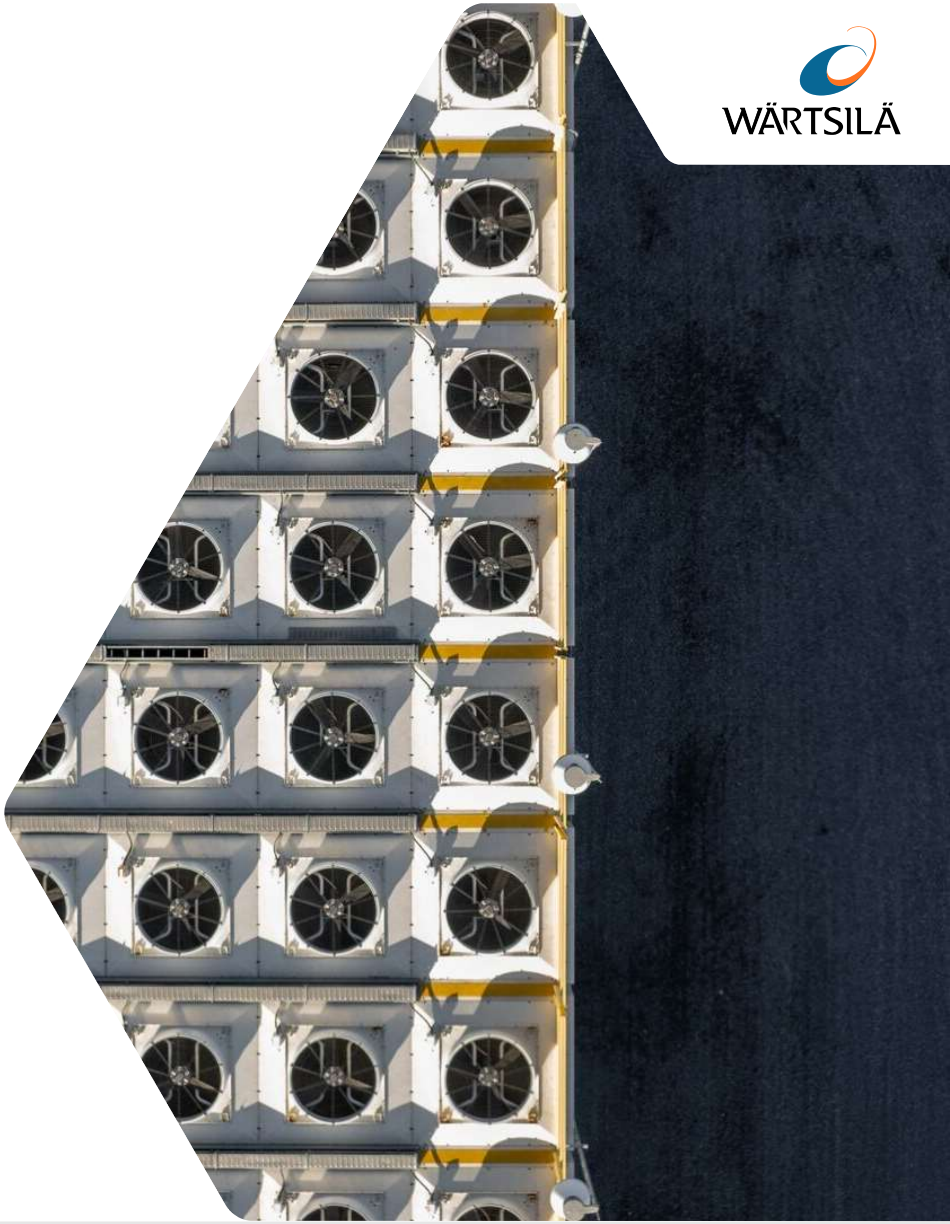
In 2030, Finnish power system would not be able to operate normally during extended persiods of low renewable production even if there were no crises in the country. Any crisis would amplify the problems in the system reliability.





Finnish reliability standard for loss of load expectation (LOLE): < 2.1 hours/yr

Outlook 2027 & 2030 with additional firm flexible capacity
Modelling results



Firm flexible capacity

Five scenarios modelled

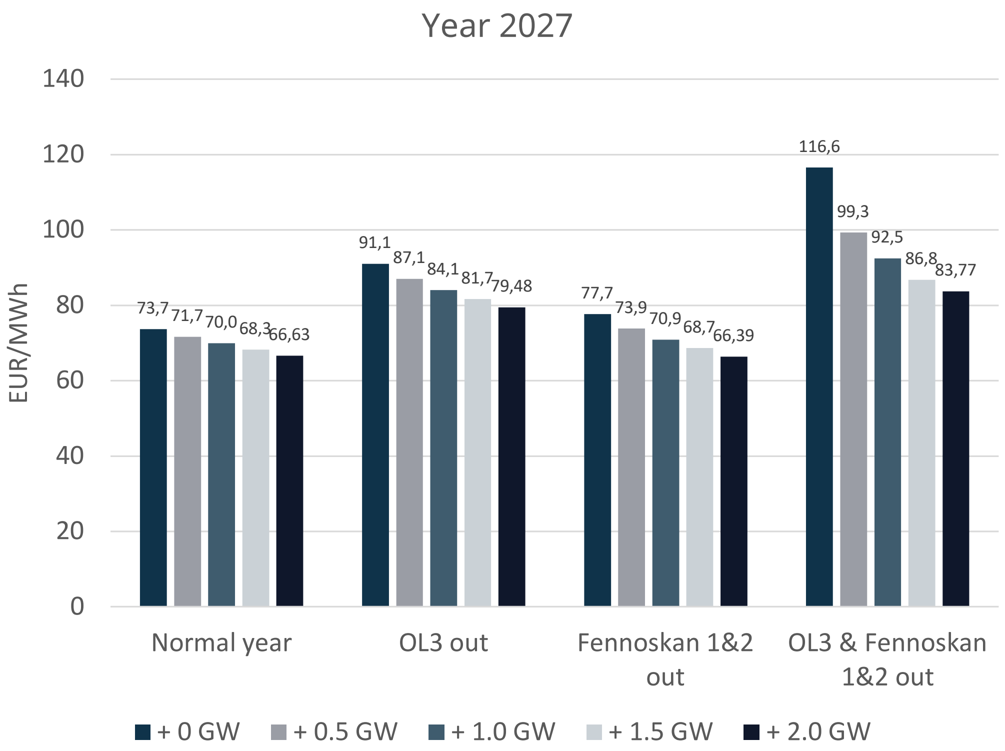
1. No additional firm flexible capacity
2. **+0.5GW** firm flexible capacity
3. **+1GW** firm flexible capacity
4. **+1.5GW** firm flexible capacity
5. **+2.0GW** firm flexible capacity

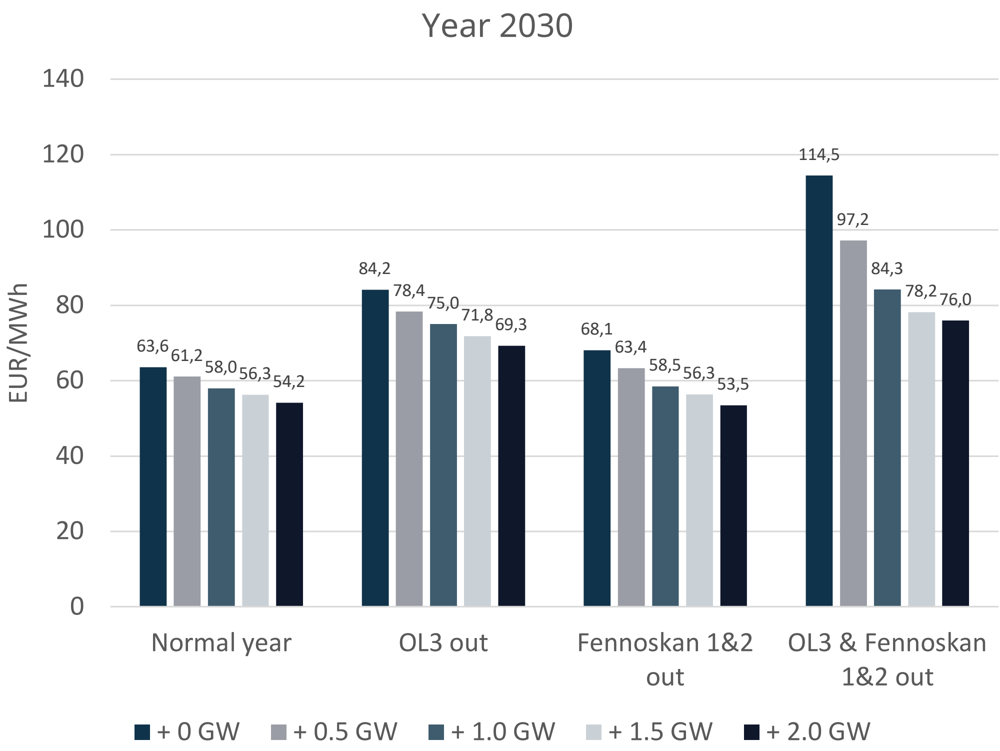
Characteristics of firm flexible capacity

Efficient and low-cost	▪ High efficiency, 48% ▪ No start and shut-down cost
Adapts swiftly to market conditions	▪ Start time 5 minutes ▪ Stop time 30 s ▪ Ramp rate >100%/min
Minimal technical constraints	▪ Minimum up time 0 s ▪ Minimum down time 5 min ▪ Minimum stable load, 10% (unit)
Multiple fuel options	▪ Main fuel: natural gas ▪ Optional fuels and future fuels: Diesel, biofuels, hydrogen, ammonia, methanol

Electricity price in different scenarios

Years 2027 and 2030 & impact of additional firm flexible capacity

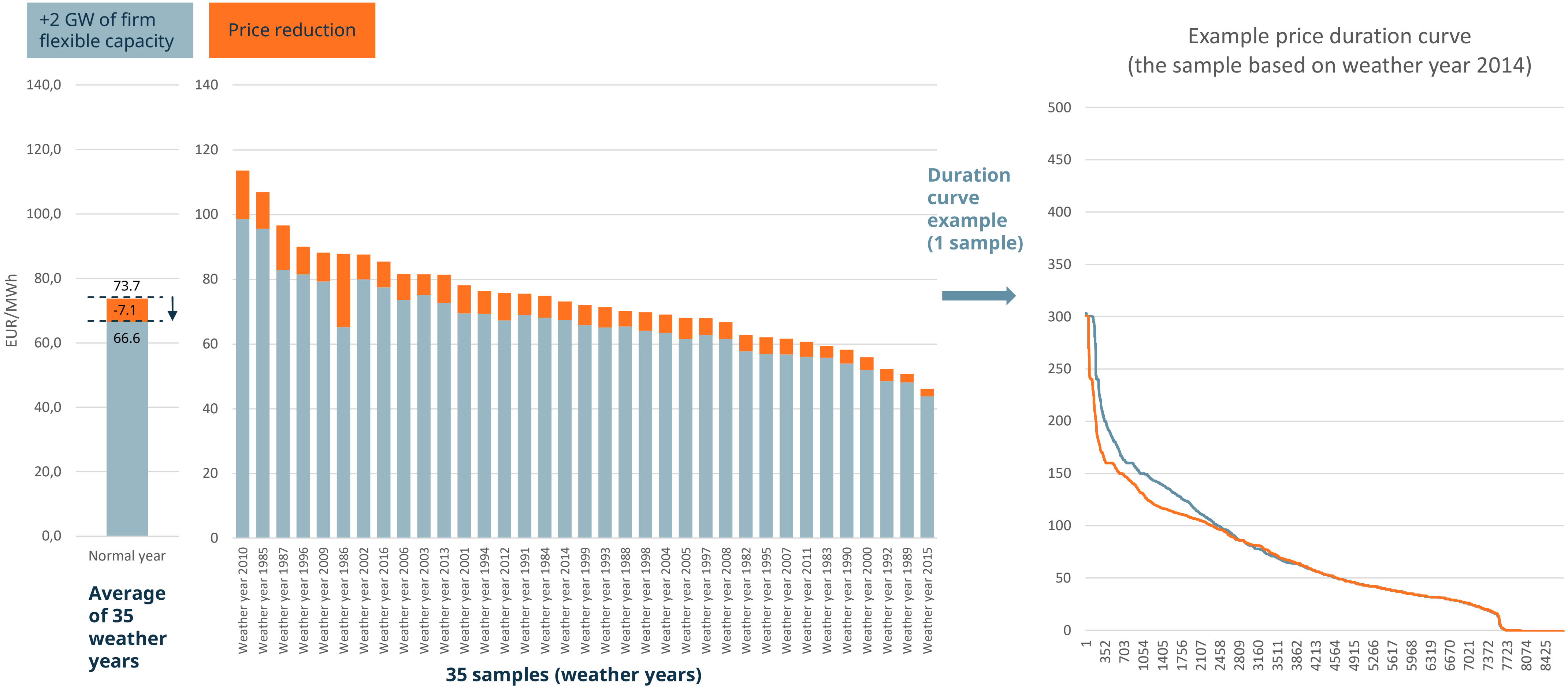




Average of 35 weather years

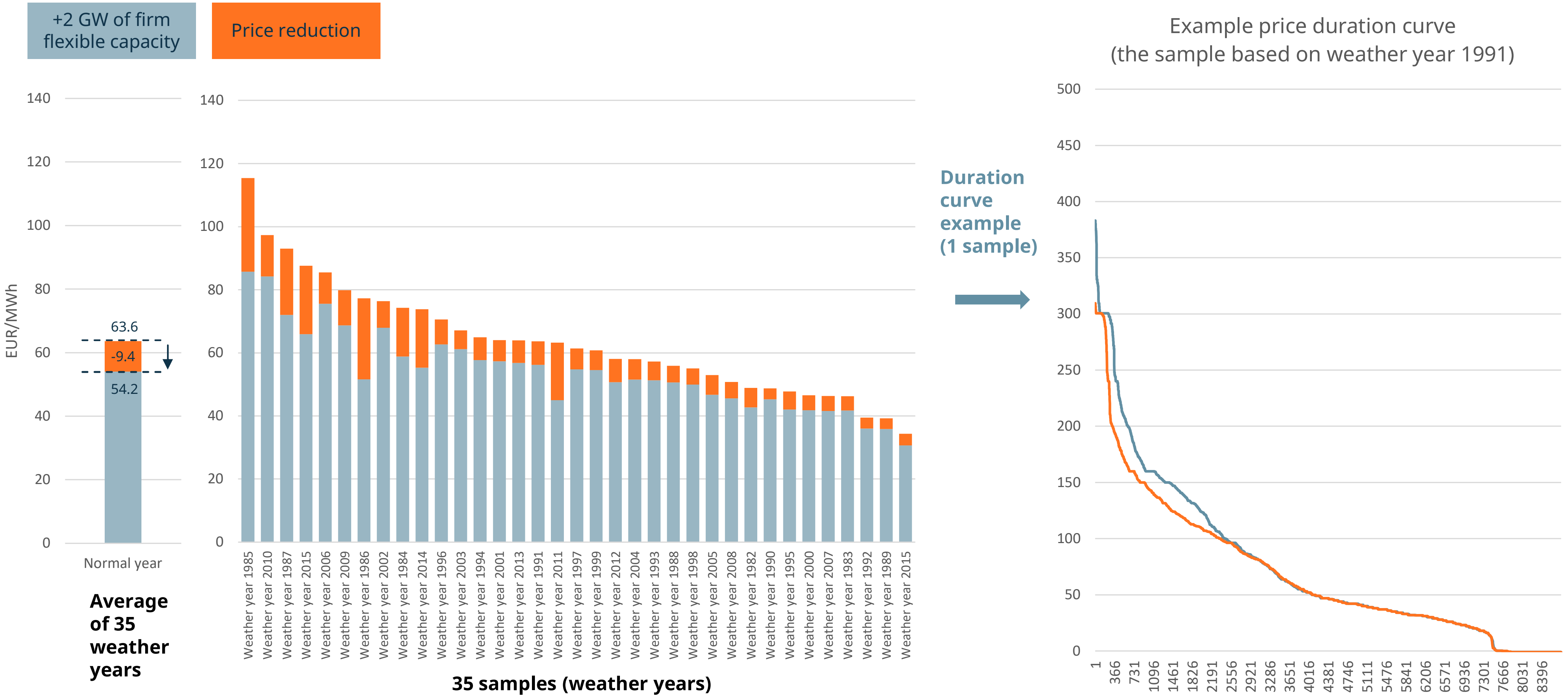
Finland area price in 2027 depends on the weather conditions

Yearly average price can be low or very high depending on wind and hydro conditions on the given year



Finland area price in 2030 depends on the weather conditions

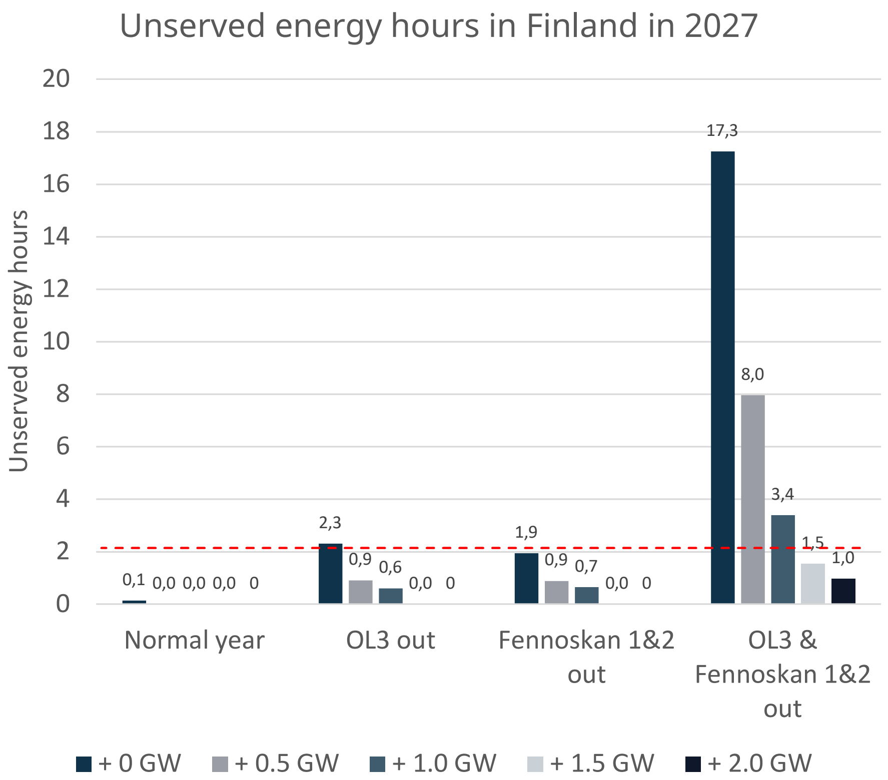
Yearly average price can be low or very high depending on wind and hydro conditions on the given year

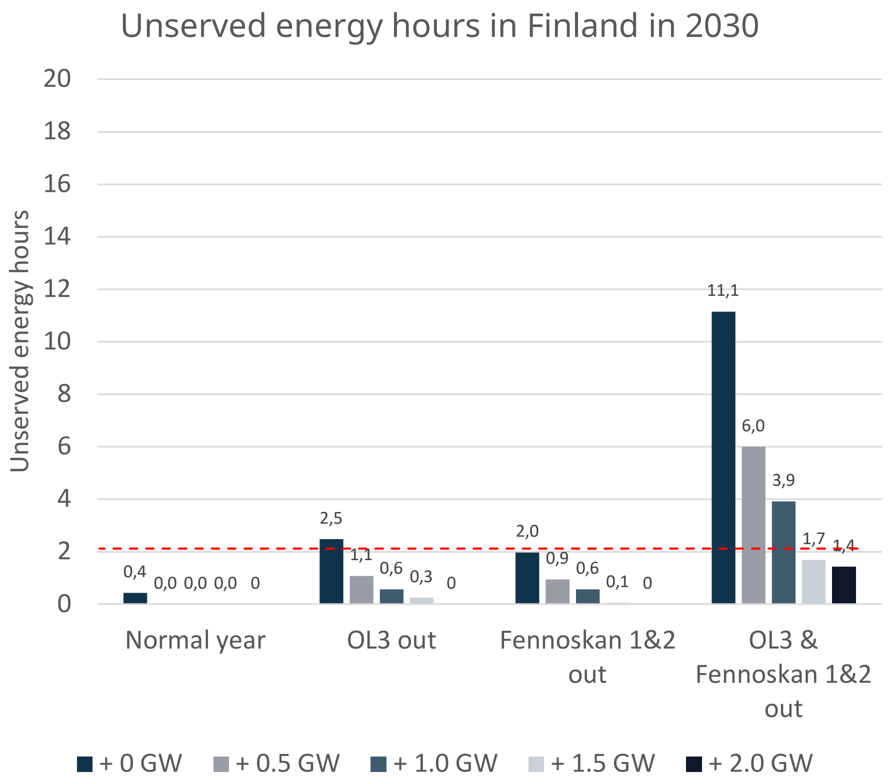


Additional firm flexible capacity increases system reliability

Unserved energy in the Finnish power system decreases significantly due to new firm flexible capacity especially during a crisis

Finnish reliability standard for loss of load expectation (LOLE): < 2.1 hours/yr

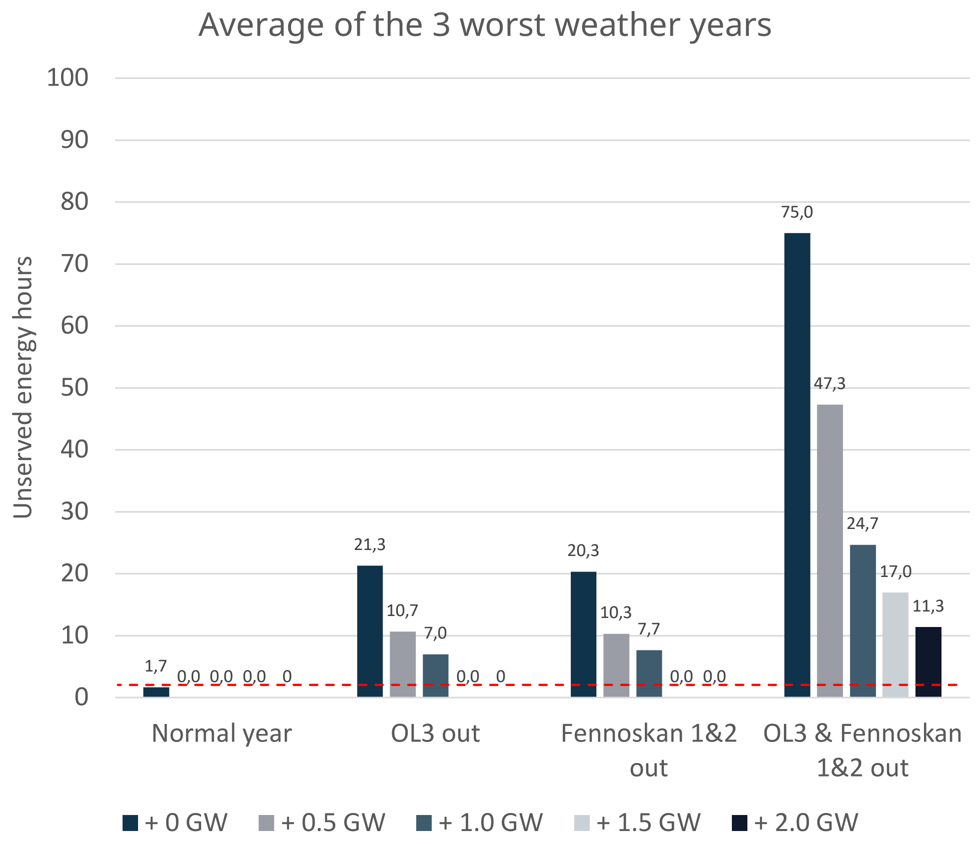


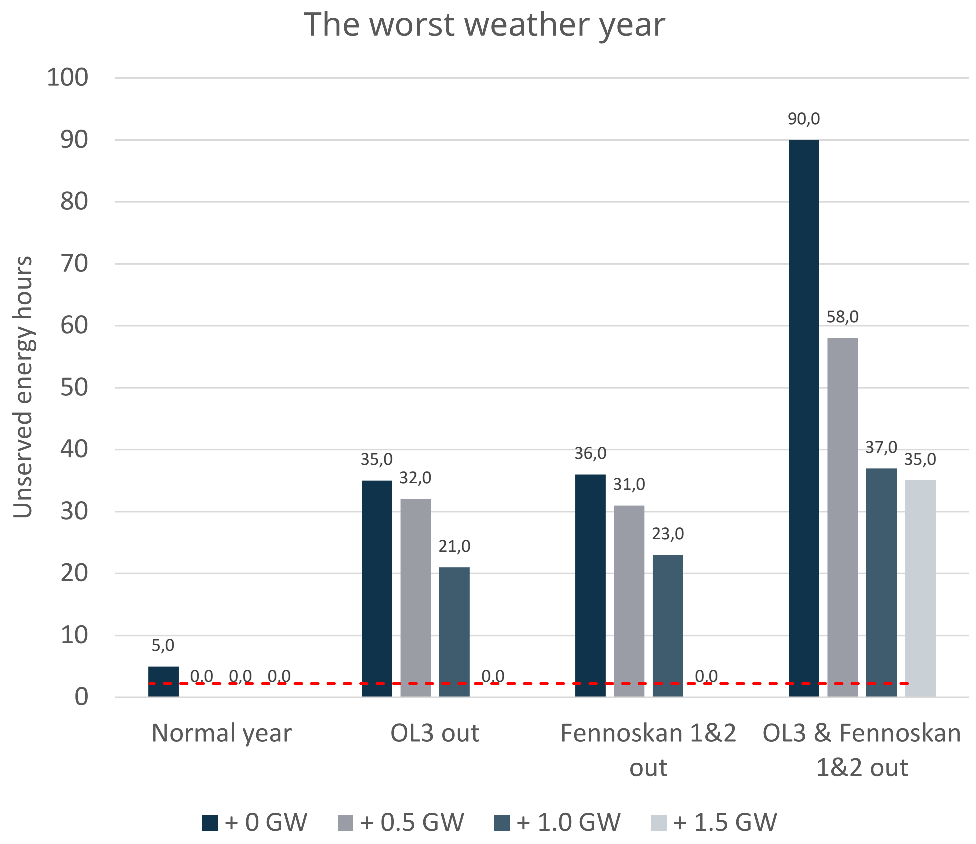


Average of 35 weather years

Unserved energy hours in 2027 during worst weather years

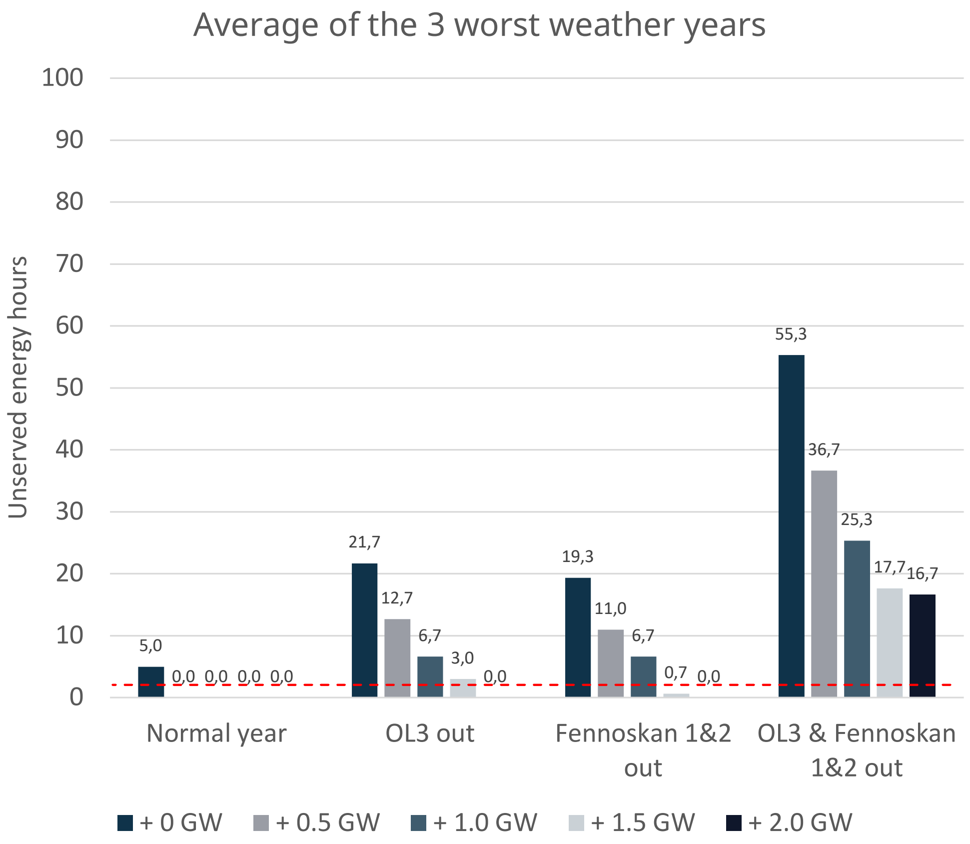
Additional firm flexible capacity is crucial to maintain system reliability when a bad weather year and a crisis takes place simultaneously

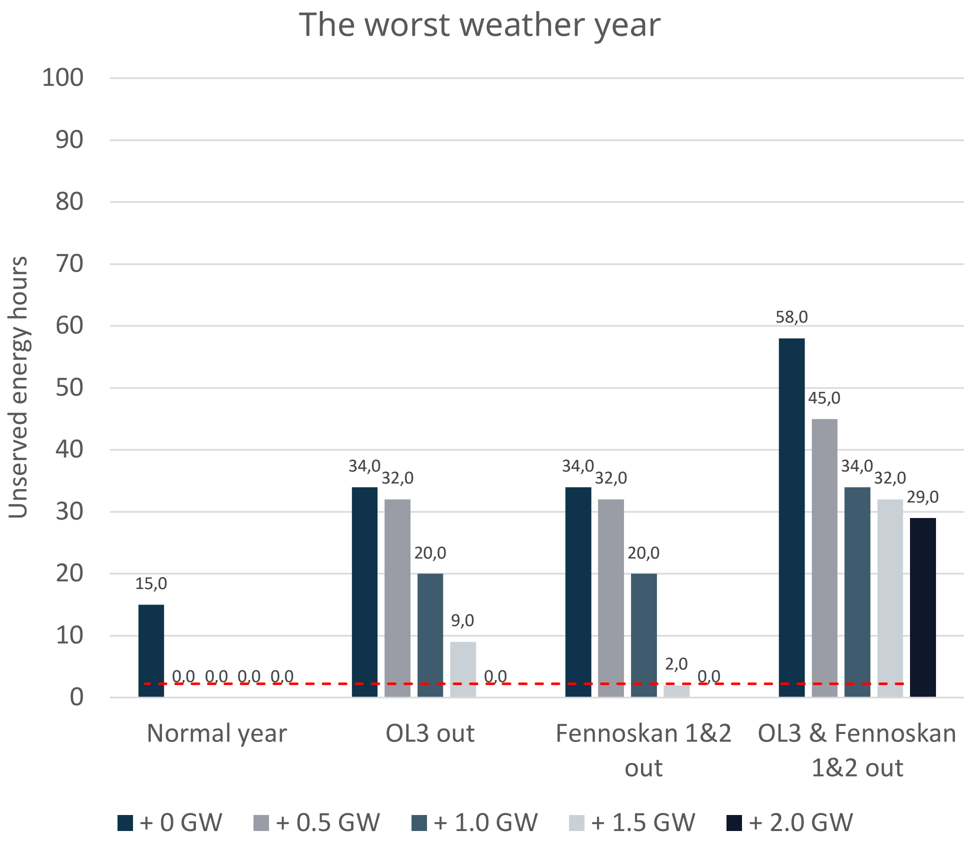




Unserved energy hours in 2030 during worst weather years

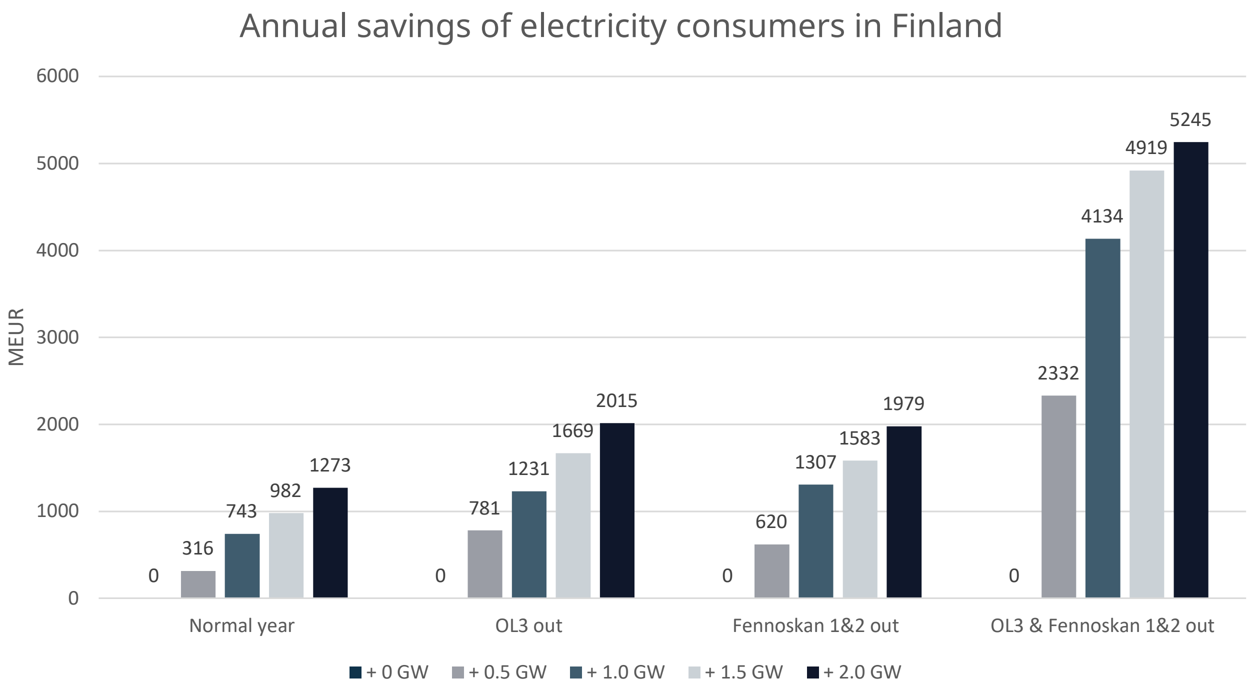
Additional firm flexible capacity is crucial to maintain system reliability when a bad weather year and a crisis takes place simultaneously





Electricity cost savings in 2030

Additional firm flexible capacity decreases electricity prices significantly

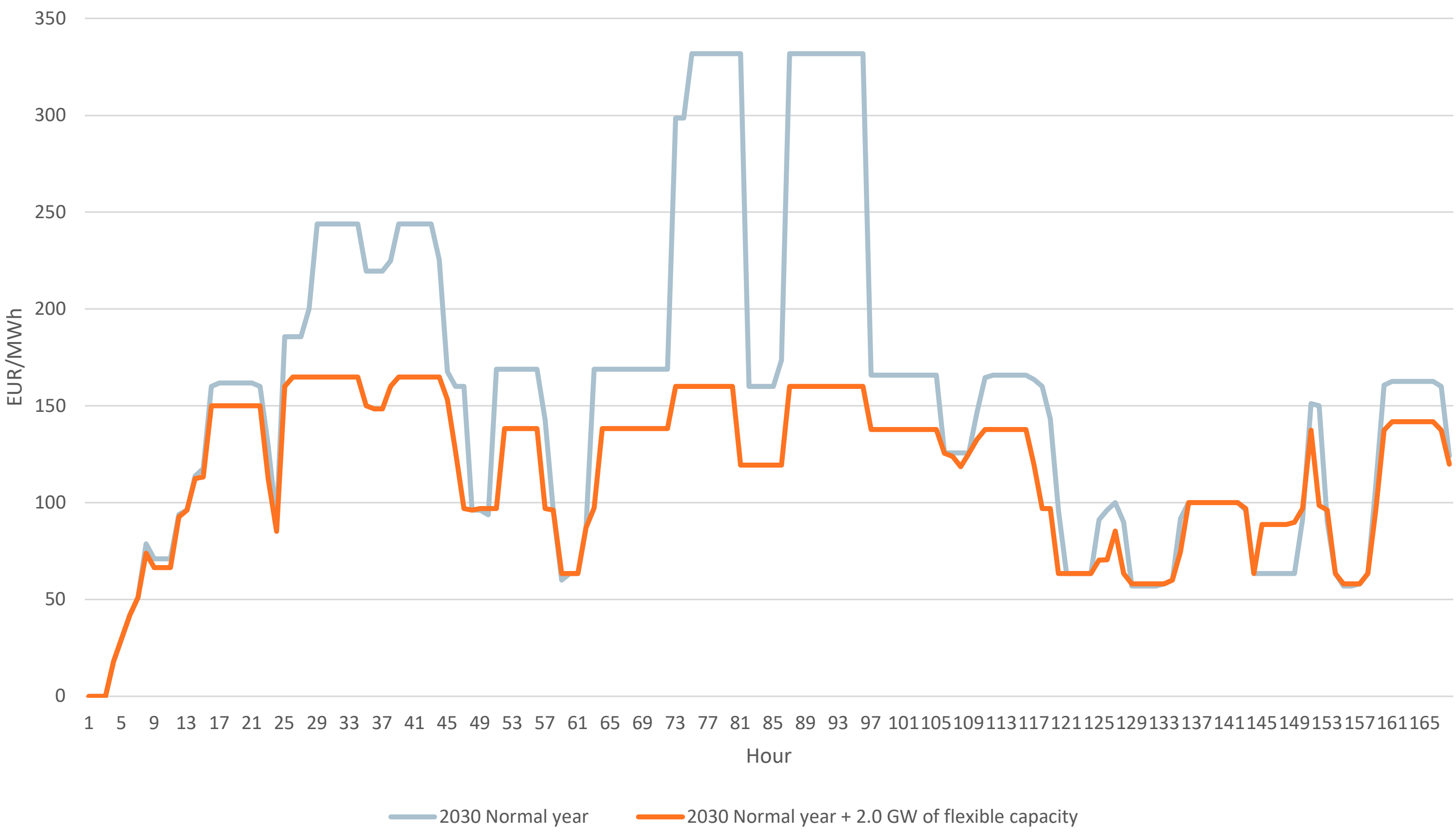


- On a normal year, additional 1.0 GW or 2.0 GW of firm flexible capacity would lower the cost of electricity by 743 MEUR or 1273 MEUR, respectively, in 2030
- From electricity consumers’ perspective, the simple payback time for an investment into firm flexible capacity is less than two years

Average of 35 weather years

Hourly price during an example week

Finland's marginal price on a Febryary week in 2030, weather year 2011

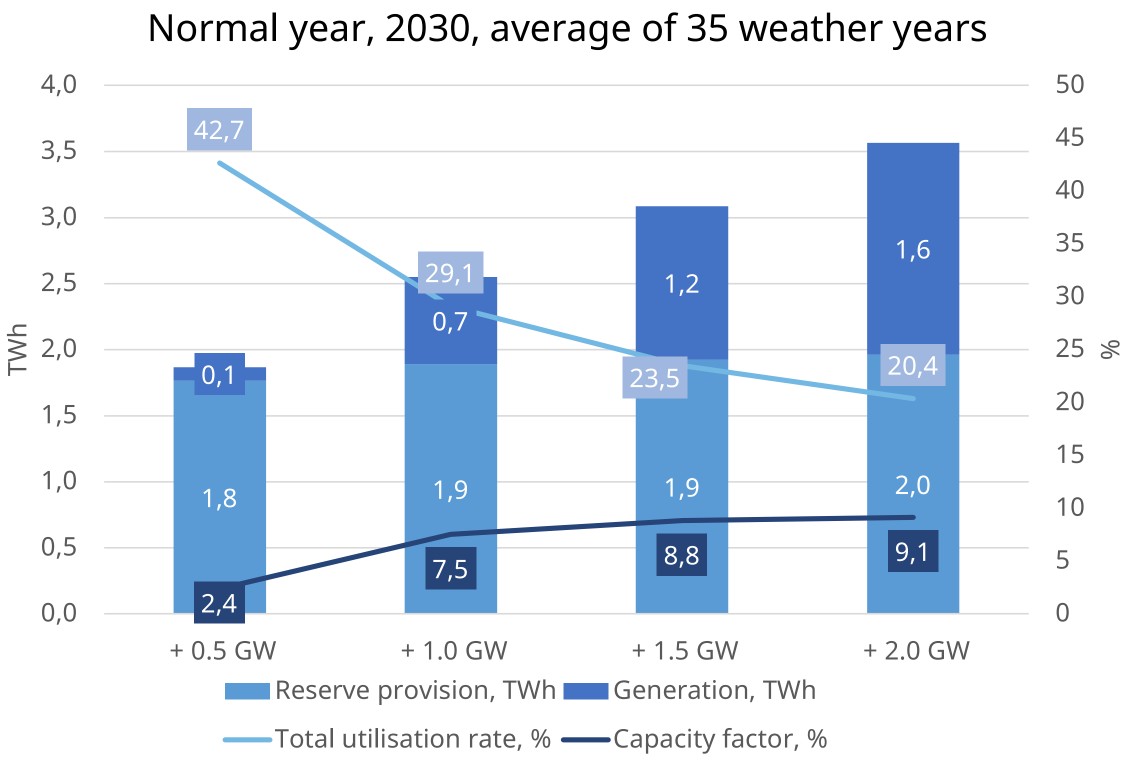


Average marginal price for the studied week in February

- Normal year: 155 €/MWh
- Normal year + 2.0 GW of firm flexible capacity: 116 €/MWh

Capacity factor and utilisation factor of additional firm flexible capacity

Additional firm flexible capacity provides value to the system during half of the year

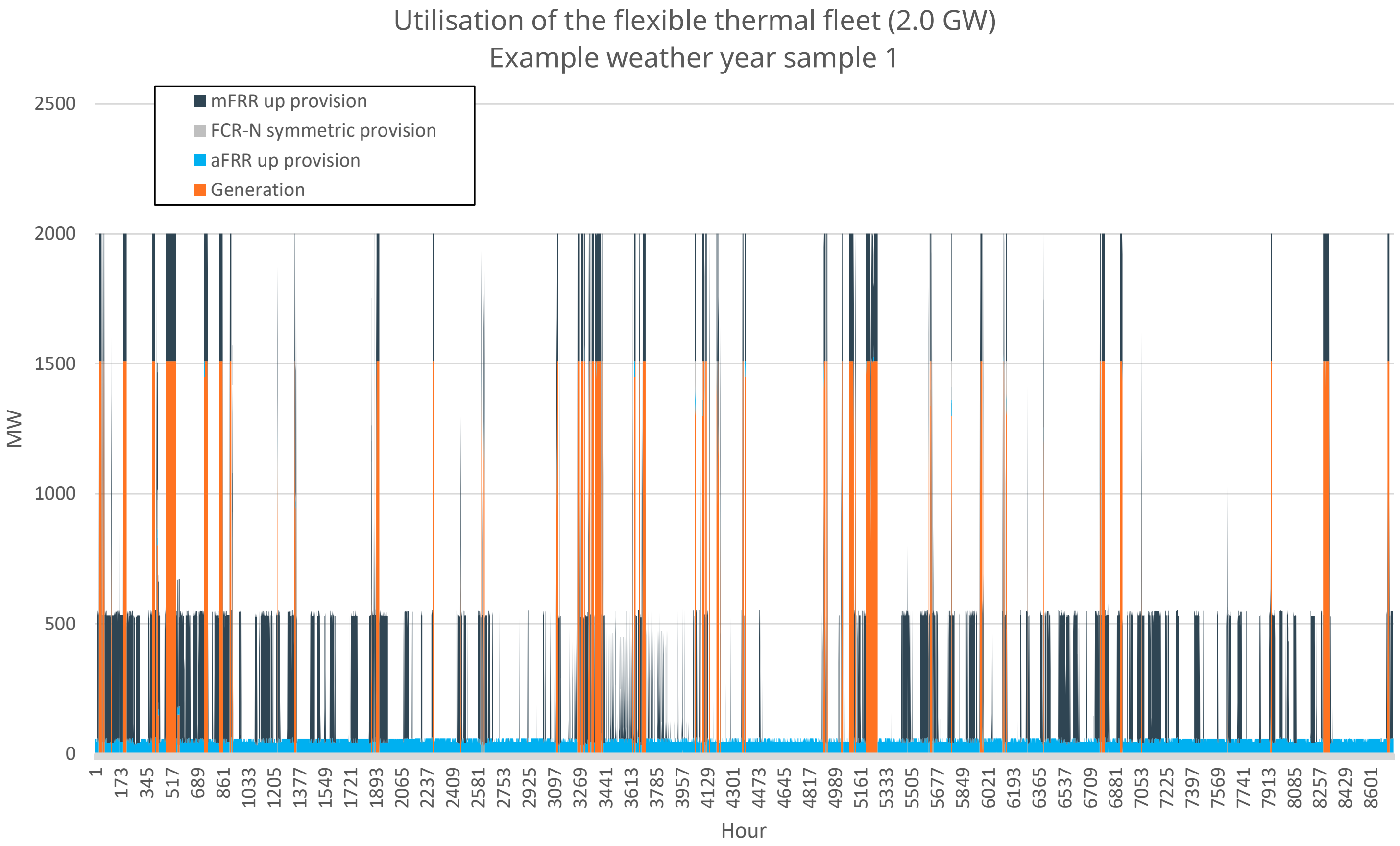


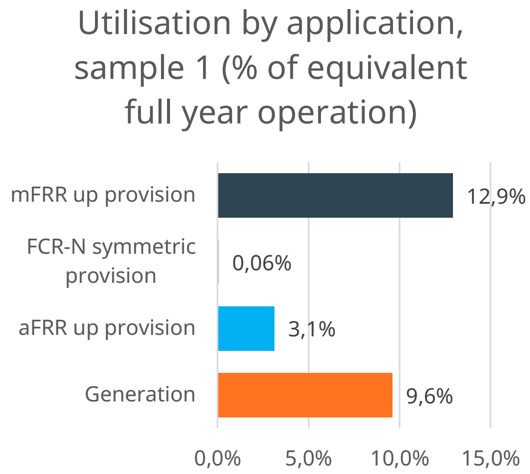
- In 2030, firm flexible capacity operates at a low capacity factor, 2-10%
- System value is not limited to electricity generation: total utilisation rate (generation + reserve provision) is 20%-43%

Average of 35 weather years

Example: Operating profile of firm flexible capacity in 2030

Utilisation of the different assets, including firm flexible capacity, is dynamically optimised in the model, based on cost-minimisation



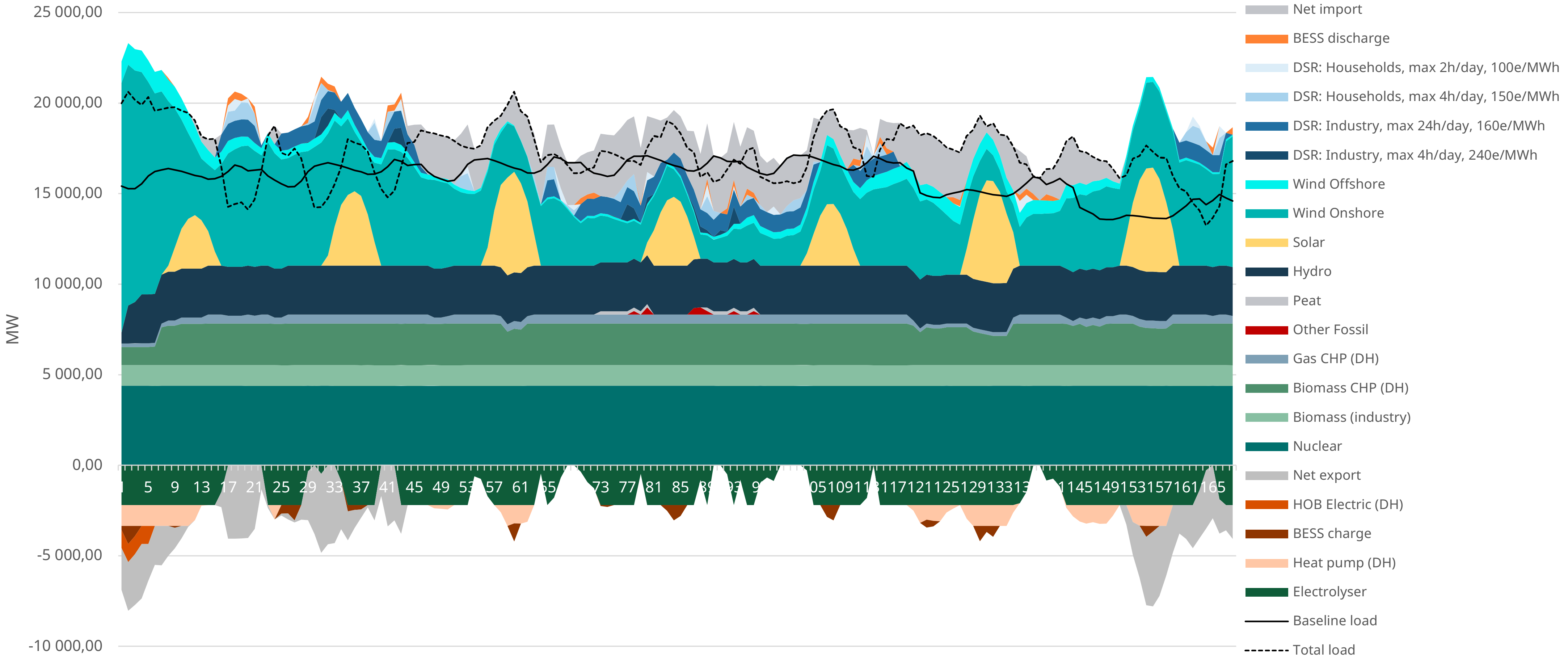


System value of firm flexible capacity in Finland

- Higher reliability
- Hedge against high DA prices in normal and extreme situations
- Provision of different reserve products

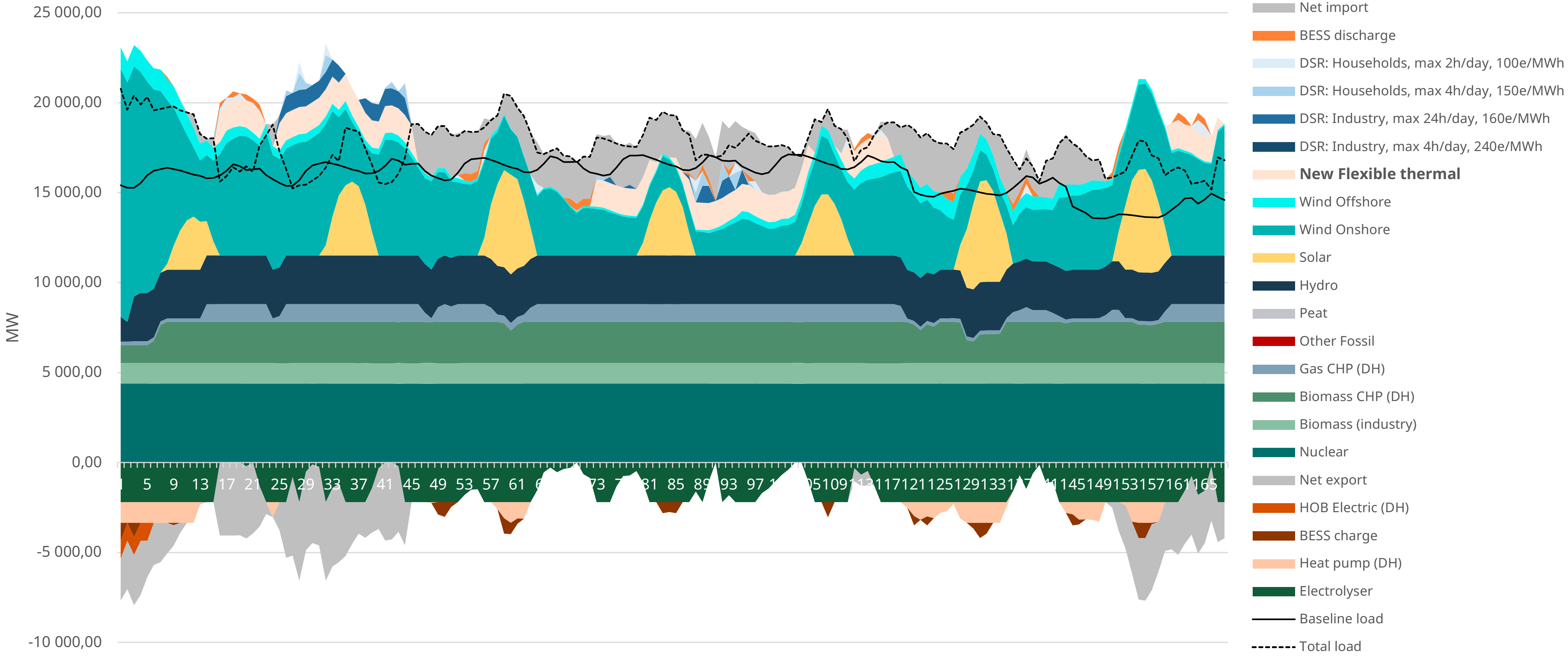
Example week from the model

High demand & low wind week in February (12.-18.2.2030), weather year 2011

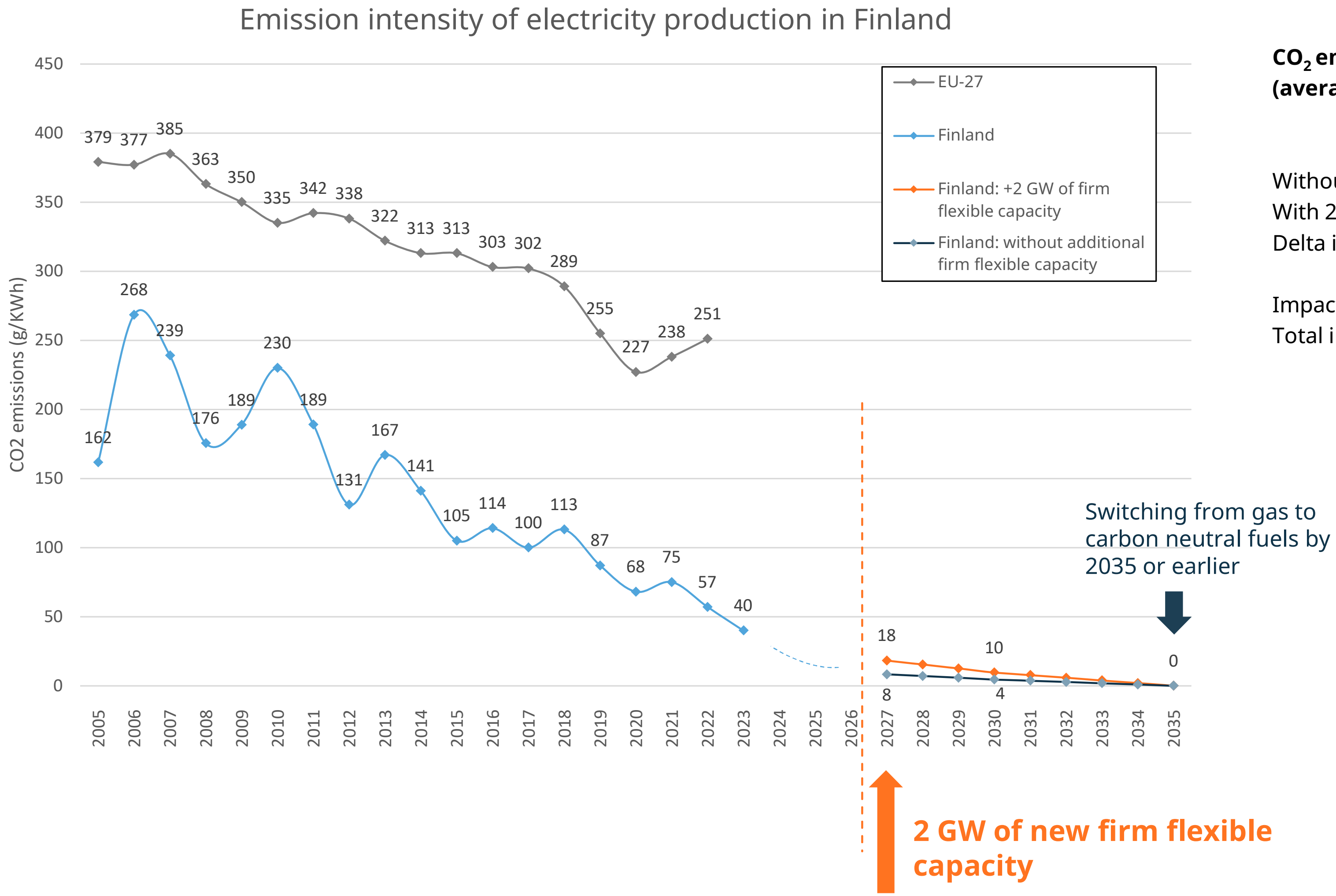


Example week from the model

High demand & low wind week in February (12.-18.2.2030), weather year 2011, **+2.0 GW of additional flexible thermal capacity**



Finland is on the path to a zero-carbon system



CO_2 emissions, Finland (average of 35 weather years)

	2027	2030
Without flexible thermal	1.60	1.09 Mton
With 2 GW of flexible thermal	2.83	1.91 Mton
Delta in Finland	1.23	0.82 Mton
Impact outside Finland	-1.87	-0.93 Mton
Total impact	-0.64	-0.11 Mton

WÄRTSILÄ