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Finland: Scenarios for the impact of datacentres on electricity prices

Marketing communication

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This analysis examines the effects of datacentres on electricity prices, generation and imports under six scenarios. The results shows why steadily growing demand and the variable output of wind power need flexible balancing capacity alongside them.

Key findings

- Growth in electricity demand inevitably raises the price of electricity, because the current price is below the cost of generation for every form of production. The calculation assumes that the datacentres would use about 11 TWh of electricity a year, or 13% of Finland's electricity consumption. This could correspond roughly to the situation in 2030, which is in line with Fingrid's estimate that datacentre electricity consumption will grow to 7–16 TWh by 2030.
- In the most likely scenario, wind power is built as far as its profitability allows, and the average price of electricity then rises about 31% from today's level. For current households and businesses this means roughly €1.3 billion of additional cost a year. The electricity bill of an electrically heated house rises by about €390 a year.
- On an annual basis there is enough energy, and most of the additional electricity would be generated abroad. Imports do not remove price spikes, however, because during cold and calm hours the transmission links are already fully used.
- Wind power alone is not enough to keep prices in check. Even if wind capacity matching the datacentres' entire annual consumption were built, the average price would still rise 20%, because wind power is not available when electricity is scarcest.

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- Flexible consumption and generation are needed to ease the capacity shortage and to keep prices moderate. Gas turbines (+23%) and datacentre demand response (+24%) help considerably more than a two-hour battery (+29%).

Assumed datacentre capacity: 2.5 GW, average utilisation 50%

Data: Actual hourly data on electricity generation, consumption and prices, 9/2023–8/2026

Average electricity price over the past three years	**Most likely price increase**	**Additional cost to current electricity consumers**
48 €/MWh	**+31%**	**+€1.3bn**
about 4.8 c/kWh before taxes	to about €63/MWh	a year, at wholesale prices

1 Scenarios

The future capacity of the datacentres is estimated at 2.5 GW, and they are assumed to run at half power on average. Average load is therefore about 1,250 MW around the clock. The additional consumption is always covered in the cheapest way: by imports from Sweden and Estonia, or by Finland's own generation and demand response.

A - No new generation. The datacentres rely on the existing power system and on imports.

B - Commercially viable wind power, the most likely case. Wind power is built up to the point where the price a new farm receives reaches €35 per megawatt hour. About 2,460 MW of new wind power would be built, and the average utilisation of that capacity is 27.5%, so its output covers a good half of the datacentres' annual consumption.

C - Commercially viable wind power and batteries. As in scenario B, but with battery storage able to cover the datacentres' consumption for two hours (2,500 MWh).

D - Commercially viable wind power and gas turbines. As in scenario B, but with an additional 1,250 MW of gas turbine capacity. The gas plants are assumed to start only when the price of electricity rises above €200/MWh. They generate just enough to bring the price back to €200 per megawatt hour.

E - Commercially viable wind power and flexible datacentres. As in scenario B, but the utilisation of the datacentres varies between 40% and 60% according to the price. Annual consumption stays the same.

F - Full wind power match, for comparison. 4,553 MW of wind power is built, so that its annual output matches the datacentres' annual consumption. At the assumed return requirement the scenario is not commercially viable.

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Scenario	New wind power	Average price, €/MWh	Electrically heated house, €/yr	Flat, €/yr	Net imports, TWh/yr	Additional cost to current consumers, €m/yr
Today	9,521 MW, existing fleet	48.4	1,452	121	4.5	4,414
A · No new generation	—	73.8 (+53%)	+681 (+47%)	+64 (+53%)	12.6 (+8.0)	+2,233 (+51%)
B · Commercially viable wind power	2,460 MW	63.3 (+31%)	+387 (+27%)	+38 (+31%)	8.0 (+3.5)	+1,286 (+29%)
C · Wind power + batteries	2,460 MW	62.2 (+29%)	+362 (+25%)	+35 (+29%)	8.3 (+3.8)	+1,182 (+27%)
D · Wind power + gas turbines	2,460 MW	59.6 (+23%)	+272 (+19%)	+28 (+23%)	7.8 (+3.3)	+943 (+21%)
E · Wind power + flexible datacentres	2,460 MW	59.9 (+24%)	+278 (+19%)	+29 (+24%)	8.2 (+3.7)	+968 (+22%)
F · Full wind power match	4,553 MW	57.8 (+20%)	+234 (+16%)	+24 (+20%)	5.3 (+0.8)	+794 (+18%)

Today's figures are annual averages for September 2023 – August 2026. The wind column shows the installed fleet for today and, for the scenarios, the new wind power built on top of it. The household figures describe the energy component of a market-price contract including VAT. The last column shows the electricity costs of current households and businesses at wholesale prices; the datacentres' own purchases are not included. Today is shown as an annual level and the scenarios as changes from it.

The bill of an electrically heated house rises slightly less in percentage terms than that of a flat, because the house uses most of its electricity in winter, when wind power output is also higher on average.

2 Prices: the pressure falls on expensive hours

The average price hides the problem of capacity shortage and expensive hours. The datacentres use electricity also during cold and calm winter periods, when Finland is already short of electricity. It is precisely these expensive hours that become much more frequent.

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Scenario	Hours above €100	Hours above €200	Hours above €300	Price variation (standard deviation)
Today	1,354	187	45	65
A · No new generation	2,374	612	243	79
B · Commercially viable wind power	1,969	465	174	76
C · Wind power + batteries	1,930	433	152	73
D · Wind power + gas turbines	1,969	166	36	71
E · Wind power + flexible datacentres	1,846	371	116	70
F · Full wind power match	1,761	391	141	74

Hours per year above each price level, and the standard deviation of the hourly price (€/MWh), which describes the variation in prices.

In the commercially viable wind scenario, hours above €200/MWh increase from about 190 to 470 a year. Only in the gas turbine scenario does the number of the most expensive hours fall below today's level. Prices vary more in every scenario than they do today, including the full wind power match.

3 What eases the price increase and the capacity shortage

Gas turbines can generate electricity flexibly and thereby ease the capacity shortage and keep price spikes in check. The output in scenario D would mean about 470 operating hours a year, of which 170 at full power, and generating only 0.41 TWh would cut the price increase from 31% to 23%. In terms of emissions the use of gas matters little, as the turbines would produce about 0.5% of annual electricity generation. The turbines do not generate if the price of electricity is below their running costs (assumed €200/MWh). They generate only enough to bring the price back to €200 per megawatt hour, which is why the market price during their operating hours averages about €230/MWh. On these assumptions the gas turbines run so few hours a year that they may not be commercially viable.

Flexible datacentres. Varying utilisation between 40% and 60% reduces the price increase to 24% and saves the datacentres about €130 million a year on their electricity bill measured at market prices. Datacentres may have a financial incentive to be flexible, and the solution requires no new generation or storage capacity.

Batteries. A two-hour battery reduces the price increase only to 29%. Batteries empty within hours, whereas the most expensive periods are calm, freezing spells lasting days.

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4 Imports: a significant part of the energy solution, but not a solution to the capacity shortage

Without new generation, about 8 TWh of the datacentres' 11 TWh consumption would be covered through the transmission links: about 5 TWh from Sweden and 3 TWh from Estonia. Finland's net imports would grow from 4.5 to 12.6 terawatt hours a year. Commercially viable wind power would reduce the additional imports to about 4 terawatt hours a year.

Sweden supplies electricity above all during ordinary hours, when its hydropower-dominated system has room to manoeuvre. Estonia is usually more expensive than Finland and supplies electricity mainly during expensive hours. Precisely when the price matters most, that is during cold and calm periods, the links to Sweden are typically already fully used and the additional consumption falls on a tight regional market. Imports cannot solve the growing capacity shortage; it has to be covered either by demand response or by domestic balancing power. New transmission links could also ease the capacity shortage.

5 Wind power: why is too little of it built?

All wind farms generate during the same windy hours, so the more wind power there is, the less each farm receives for its electricity. At present Finnish wind power receives an average of €30/MWh, while the average price of electricity is €48/MWh. If a new farm needs €35/MWh to go ahead, the price level has to rise from today. In the market scenario about 2,460 MW of new wind power is built, which can generate about half of the datacentres' annual energy need. In the full match, where all the electricity consumed by the datacentres is generated by wind, the price received by new wind power would be only about €30/MWh.

Allowing wind power to be built in eastern Finland as well could increase the amount of commercially viable wind power, because wind conditions vary across Finland. New plants would then weaken the price received by existing plants less than plants built close to them, in similar wind conditions.

6 Conclusions: steady consumption meets variable generation

The heart of the problem is timing. Datacentres use roughly the same amount of electricity every hour of the year. Wind power generates abundantly in some hours and almost nothing in others.

- There are many calm hours. Over the past three years wind power generated less than 10% of its capacity in about a quarter of all hours. There were about 12 calm spells of at least two days a year, and the longest lasted seven days.
- It is precisely these hours that determine the electricity bill. During calm hours the average price is already €85/MWh today, while during windy hours it is €14/MWh. With the datacentres and commercially viable wind power, the average price of low-wind hours rises to about €122 per megawatt hour.
- Additional wind power mainly makes windy hours cheaper. The full wind power match pushes the price of windy hours down to about €11 per megawatt hour. It nevertheless covers less than a quarter of the datacentres' consumption in 17% of hours. The surplus is exported or sold cheaply, while the shortfall is bought expensively. An annual energy match is not the same as an hour-by-hour match.

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- Imports and short-duration storage run out at the wrong moment. During calm winter periods the links to Sweden are already fully used and the electricity markets of neighbouring countries are tight too. A two-hour battery covers the evening consumption peak, but not a week-long calm spell.
- A rise in the price of electricity weakens the purchasing power of households and the competitiveness of industry, so it is worth limiting as far as possible. Higher electricity prices, on the other hand, increase the income of domestic electricity producers.

7 What should be done so that the price increase stays moderate and no capacity shortage arises

- Last year the price of electricity in Finland was the second lowest in the EU. Prices probably cannot stay at today's level, because the average price wind power currently receives is below the assumed cost level of new generation. The price level therefore has to rise somewhat.
- Alongside wind power, balancing power and demand response are needed. Demand response can involve both current electricity users and future datacentres, on which obligations concerning demand response could also be imposed. Industrial electricity users have recently been offered new electricity contracts with better incentives for demand response than before. Industrial demand response can therefore be expected to grow from its current level. This has not, however, been taken into account in these calculations.
- The need for balancing power does not appear to be solved entirely by the market, at least not very quickly. Some gas plant projects are currently under way, and some datacentres are planning gas plants as backup power. In addition, some battery storage is being built in Finland, but its capacity is not sufficient during long freezing periods. Pumped storage plants would be a useful addition to the flexibility of the power system: they would raise the price of electricity during cheap periods, which would improve the profitability of wind power, and they would add supply when electricity is scarce. No pumped storage projects have been launched so far, however. The transmission system operator Fingrid has estimated that Finland needs 1,000 MW of balancing power by 2030. The projects currently under way do not meet this need.
- To get balancing power investments started, datacentres could be given an obligation or an incentive to build their backup plants so that they can take part in balancing power generation. Alternatively, datacentres could conclude an agreement with an electricity supplier under which the balancing power they need is built. For example, the conditions for connecting to the transmission grid could require datacentres to provide either balancing power or demand response.

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8 Limitations of the analysis

- The analysis is based on the current power system, in which power plants, transmission links and consumption are held at the 2023–2026 level. Higher prices would in time attract other generation investments, so the long-term effect is probably smaller than presented here.
- The reaction of neighbouring countries is an assumption. Prices in Sweden and Estonia may react more weakly or more strongly than assumed.
- Frequency, not timing. The model tells how often price spikes occur, but not in which hours they occur.
- Idealised operation. Gas turbines, batteries and flexible datacentres are assumed to respond perfectly to prices. Construction costs and emissions are not included.

Annexes · data, method and detailed results

A Data

All data is public and hourly. The model is estimated for the period September 2023 – early September 2026 (26,463 hours). The results are annual averages for September 2023 – August 2026.

Time series	Source	Used for
Day-ahead electricity price, Finland	Nord Pool, via the Sähkötin service	The price being explained
Consumption and generation (wind, nuclear, CHP, hydro)	Fingrid open data	Demand and supply
Installed wind capacity	Fingrid open data	Output per megawatt; sizing of new wind power
Cross-border flows and transmission capacities	Fingrid open data	Spare import and export capacity
Prices in Sweden (SE1, SE3) and Estonia	elprisetjustnu.se, Elering	Which links are fully used; the price of imported electricity
Helsinki temperature	Open-Meteo (ERA5)	Household heating; datacentre cooling

Earlier data has been left outside the analysis: in 2022 prices reacted about three times more strongly to demand, and in January–August 2023 prices were clearly higher than demand and supply explain.

- Negative prices have been set to zero, because electric boilers now absorb surplus electricity and negative prices have become rare and shallow.

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- Swedish transmission capacity after October 2024 has been estimated from actual flows, because Fingrid stopped publishing it. Whether a link is fully used is inferred from price differences between areas.

B How the estimates were made

- Each hour is described by two numbers: remaining demand (consumption less wind, nuclear and combined heat and power) and spare capacity (unused hydropower and import capacity).
- The distribution of possible prices is learned from the data. For each hour the model estimates the probability that the price exceeds each of 24 price levels between -50 and 1,300 €/MWh. Rare price spikes are thus also taken into account.
- The additional consumption is covered in the cheapest way. After the output of new wind power, the remaining net consumption of the datacentres is covered simultaneously by Finland's own flexibility and by the transmission links, at the price at which these together suffice. Finland's own flexibility, that is additional supply and consumption that drops out as the price rises, has been measured from Nord Pool's actual Finnish bid curves: about 120 MW when the price rises by €20/MWh and 300 MW when it rises by €100/MWh. A link brings more electricity to Finland only when the Finnish price exceeds the price in the neighbouring country, so electricity always flows towards the more expensive side. In the model the price increase is limited by the response of supply and demand estimated from Finland's actual data. The neighbouring country's own price rises as it supplies more electricity: in Sweden by 0.2 times the effect in Finland, but the factor rises to 1.0 when the Swedish price is €100–200/MWh. In Estonia the factor is 1.0, but it falls to 0.3 at high prices, when the country's oil shale and gas plants can increase their output.
- Scenario assumptions. The load of the datacentres averages 1,250 MW and is slightly higher in summer because of cooling. New wind power follows the hourly profile of the existing fleet and generates on average 27.5% of its capacity. Commercially viable wind power is sized so that a new farm receives €35/MWh. The battery storage has an energy capacity of 2,500 MWh, a power of 1,250 MW, an efficiency of 85% and one cycle a day. The gas turbine capacity is 1,250 MW. In each hour the turbines generate just enough to bring the price back to €200 per megawatt hour; the price exceeds €200 only when all of the capacity is in use. It makes no difference to the calculation whether the turbines belong to the datacentres or are separate plants, as the market effect is the same. The utilisation of flexible datacentres varies between 40% and 60%, annual consumption stays the same and use is timed so that the electricity bill is minimised. Battery use and demand response are solved iteratively until prices settle.

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Accuracy of the model

The model matches the three-year average price (48.4 vs. 48.35 €/MWh) and the number of expensive hours (186 hours above €200/MWh in the model and 187 actual; 44 hours above €300/MWh in the model and 45 actual). It explains about 28% of the price variation between hours and 36% of the variation between days. The model tells how often price spikes occur, but not when they occur. The reactions of neighbouring countries are assumptions; the most likely price increase settles at 28–32% and, without new generation, at 45–56%.

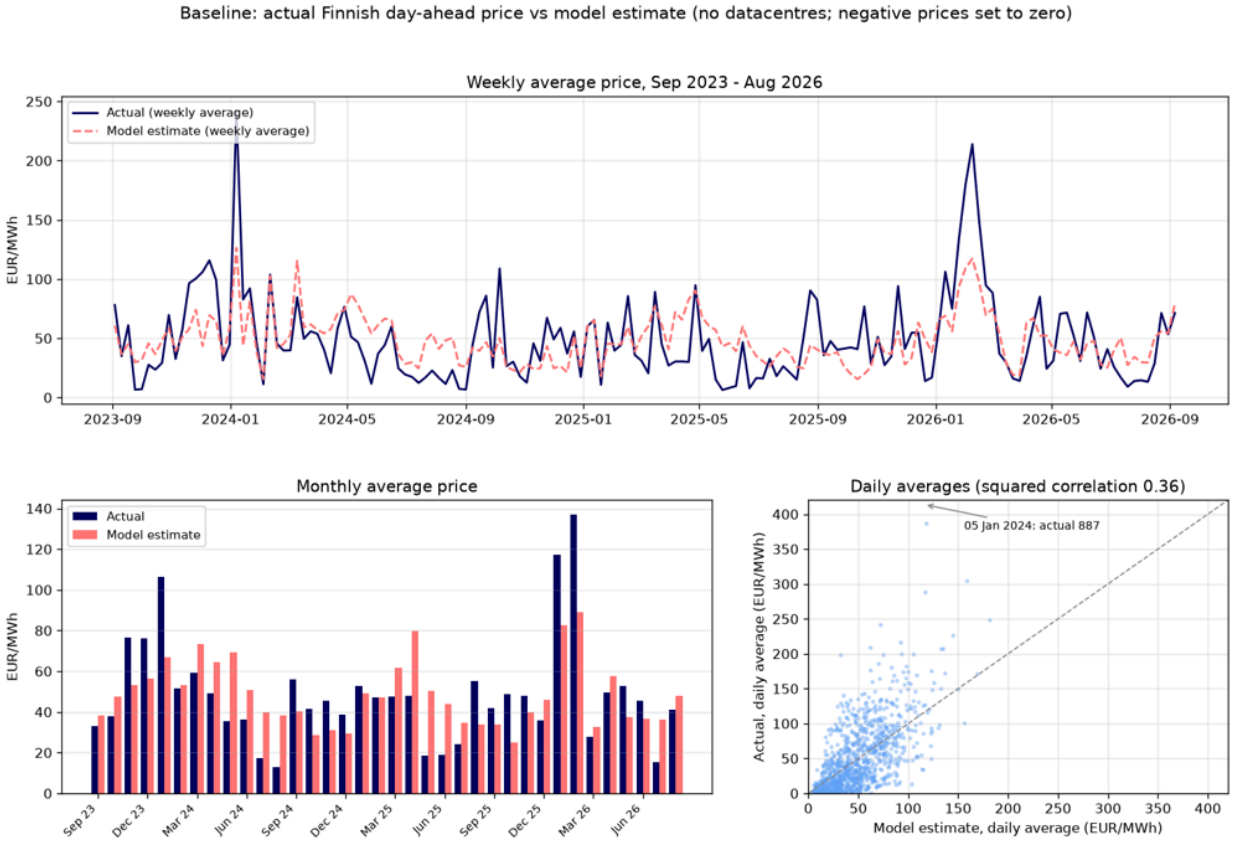


Figure: Actual price and the model's estimate without datacentres. The model follows the seasons and the price peaks of cold spells, but smooths the sharpest spikes.

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C Detailed results

Measure	Actual	Model, today	A	B	C	D	E	F
New wind power, MW	—	—	0	2,460	2,460	2,460	2,460	4,553
Average price, €/MWh	48.35	—	73.78	63.30	62.16	59.58	59.86	57.81
Change	—	—	+52.6%	+30.9%	+28.6%	+23.2%	+23.8%	+19.6%
Hours above €100/MWh	1,354	1,346	2,374	1,969	1,930	1,969	1,846	1,761
Hours above €150/MWh	463	460	1,114	881	842	881	762	762
Hours above €200/MWh	187	186	612	465	433	166	371	391
Hours above €300/MWh	45	44	243	174	152	36	116	141
Electrically heated house, additional cost €/yr	—	—	+681	+387	+362	+272	+278	+234
Flat, additional cost €/yr	—	—	+64	+38	+35	+28	+29	+24

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Change in net imports, TWh/yr	—	—	+8.05	+3.54	+3.81	+3.32	+3.71	+0.77
Additional imports	—	—	8.05	3.74	4.04	3.53	3.83	2.27
Additional exports	—	—	0.00	0.21	0.23	0.21	0.12	1.50
Northern Sweden (SE1)	—	—	+3.46	+1.15	+1.43	+1.12	+1.57	-0.42
Southern Sweden (SE3)	—	—	+1.95	+0.73	+0.78	+0.69	+0.75	+0.06
Estonia	—	—	+2.64	+1.66	+1.60	+1.52	+1.39	+1.13
Covered within Finland, TWh/yr	—	—	2.90	1.72	1.61	1.53	1.45	1.15

Annual averages for September 2023 – August 2026. "Model, today" is the model's own estimate for the actual system. The import figures are changes from today, when net imports are 4.51 TWh. A positive figure for a link means more imports or less exports.

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Earnings level of wind power

Scenario	New wind power receives, €/MWh	Existing wind power receives, €/MWh	Income of the existing fleet
Today	—	29.55	€580m/yr
A · No new generation	—	45.88	€900m/yr
B · Commercially viable wind power	35.00	34.87	€684m/yr
C · Wind power + batteries	35.01	34.87	€684m/yr
D · Wind power + gas turbines	33.99	33.88	€665m/yr
E · Wind power + flexible datacentres	34.28	34.16	€670m/yr
F · Full wind power match	30.25	30.15	€592m/yr

Average price per megawatt hour generated. The existing wind fleet is 9,521 MW.

Flexible datacentres

Case	Average price	Change	Hours above €300	Electrically heated house	Price paid by the datacentres	Saving for the datacentres
No new generation, steady (A)	73.78	+52.6%	243	+681	73.45	—
No new generation, flexible	70.21	+45.2%	162	+555	60.96	€137m/yr
Commercially viable wind power, steady (B)	63.30	+30.9%	174	+387	63.03	—
Commercially viable wind power, flexible (E)	59.86	+23.8%	116	+278	50.79	€134m/yr

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The price paid by the datacentres is the average market price of the electricity they buy.

Gas turbines at different running costs

Switch-on price	Operating hours per year	Of which at full power	Output	Average price	Change vs today	Hours above €300	Price during operating hours	Net imports, TWh
200 €/MWh	465	166	0.41 TWh	59.58	+23.2%	36	230	+3.3
130 €/MWh	1,223	678	1.20 TWh	56.26	+16.4%	36	162	+2.9
90 €/MWh	2,318	1,540	2.39 TWh	53.25	+10.1%	36	125	+2.1
No turbines	—	—	—	63.30	+30.9%	174	—	+3.5

The results have been calculated on top of the commercially viable wind power scenario B. The turbines generate just enough to bring the price back to the switch-on level. Full power is used only if the price stays above that level even then. The price during operating hours means the average market price during the turbines' operating hours.

The full price distribution

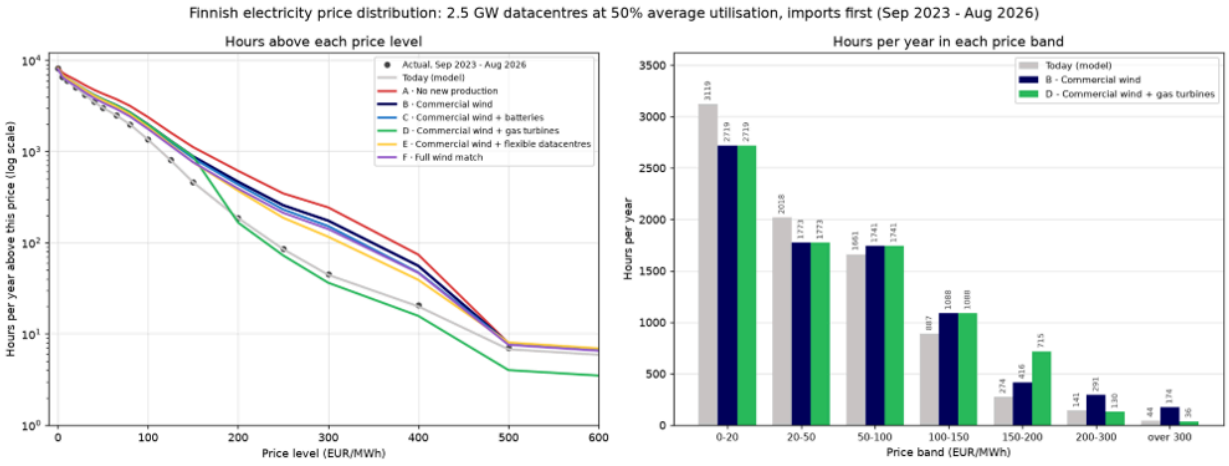


Figure: On the left, hours per year above each price level in all scenarios (logarithmic scale). On the right, hours per year by price band. For clarity, only today, the most likely case B and the gas turbine scenario D are included.

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