Capra Renewables

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The Renewables Market and Information Network
Teasers, Data Analytics, News, and Networking

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Capra's
Negative-Price Forecasting Model
Goes Live

Our neural-network based model is offered as a premium service to registered users.
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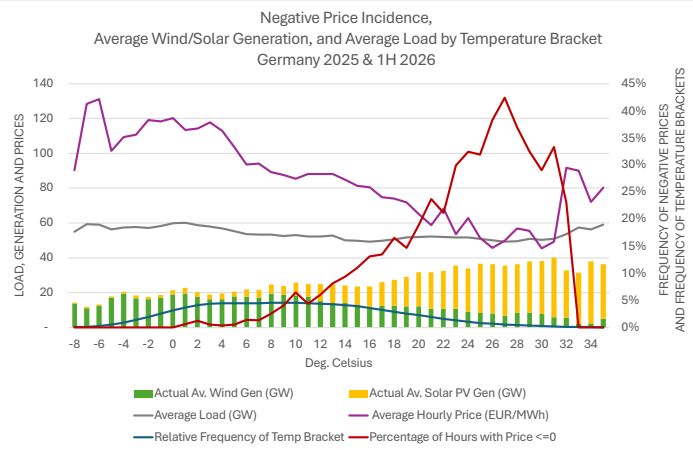
Never Let a Good Heatwave Go to Waste

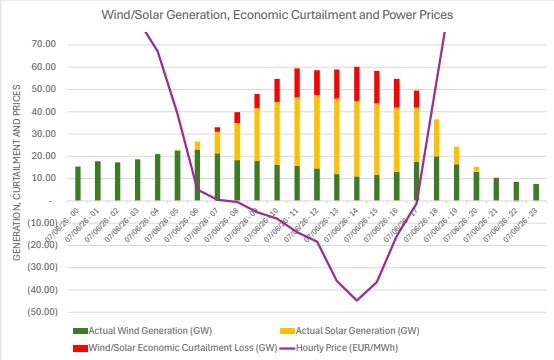
Solar radiation is as much the problem as it is a solution

Something curious happens as temperatures in Germany rise: people sweat and suffer in overheated buildings, while wholesale electricity prices fall and increasingly turn negative in line with sharply rising solar generation.

This observation should guide how we think about staying cool in hot temperatures. The right response is not a simple choice between active cooling, such as air conditioning, and passive measures, such as insulation, shading, vegetation, ventilation and better-adapted building design. Passive cooling is desirable and can be highly effective, but it is often expensive and difficult to implement across the existing building stock. It is also not the whole answer, particularly as Europe's electricity system moves towards a much higher share of renewable generation.



For decades, electricity was expensive and carbon-intensive. The sensible choice was therefore to consume less of it - always. Increasingly, the choices are more nuanced. At certain times, particularly during sunny summer hours, renewable electricity is abundant, cheap and, for the time being, too often economically unwanted, as indicated by negative wholesale prices.



Germany provides an example of what can be systematically expected as a consequence of the energy transition. The first graph above summarises this for 2025 and H1 2026. It shows solar and wind generation, demand (load) and the relative number of hours that traded at negative or zero prices in the spot market, all sorted and then averaged by temperature brackets. Temperature values are aggregated across Germany using a population-weighting.

A few observations are immediately obvious:

- Wind and solar generation are complementary. Wind decreases, solar increases with temperature. Overall, RES output increases on average with hourly temperature.
- Wholesale market negative-price incidence peaks during population-weighted average temperatures in Germany between 26°C and 27°C. 42% of hours in that temperature bracket traded at negative or zero prices in 2025/H1 2026.
- Load drops mostly with rising temperature but rises again for the hottest hours. The highest temperature hours are obviously in daylight (structurally higher demand) in summer (structurally lower demand). The lowest temperature hours tend to be in during night-hours (structurally lower demand) in winter (structurally higher demand). This offsetting effect is why the load curve looks relatively flat over the temperature spectrum.

The first graph shows actual wind and solar output after grid-induced curtailment and economic, price-induced curtailment. It does not show total RES production potential. Grid curtailment is noticeable, but it is increasingly economic curtailment, avoiding production during negative-price periods that now has a material impact on RES production vs production potential.

How significant this has become is illustrated in the second graph. It focuses on economic curtailment, i.e. voluntary output reductions as prices drop below zero. The graph depicts hourly actual wind and solar generation, generation lost through price-driven (economic) curtailment, and wholesale electricity prices for a representative day in June 2026 in Germany.

We estimate production potential (production without economic curtailment) using 120m wind speeds / shortwave solar radiation with capacity weighting to aggregate across Germany and apply standard conversion efficiency curves to derive production potential. Economic curtailment is the difference between potential and actual production. The graph shows as much as 15 GW, or 25% of potential

production, being shed during negative-price hours. This is common by now, and it is mainly wind, but increasingly also solar, as generators try to avoid negative pricing. Solar is somewhat less sensitive as the large share of rooftop solar doesn't react as much to wholesale price signals – for now.

Coming back to air-conditioning load, this points to a potentially important system benefit. Cooling demand is naturally correlated with periods of high solar output. If consumers face short-term price signals, directly through hourly or 15-minute tariffs, or indirectly through optimisation by suppliers or third-party providers, significant cooling demand can be shifted into periods when renewable electricity is abundant and wholesale prices are low or negative.

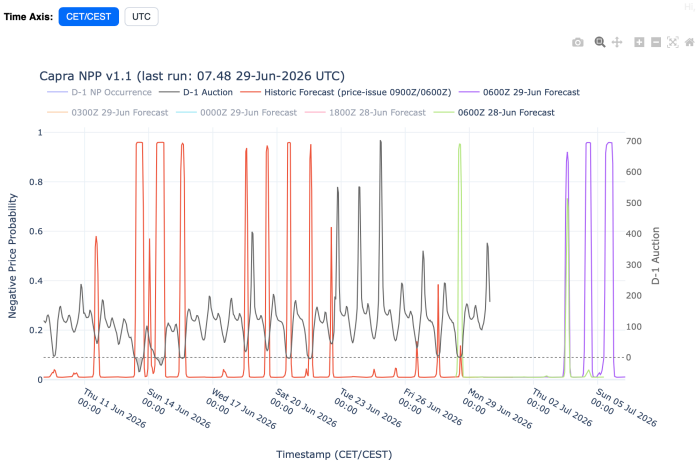
This does not mean that air conditioning is automatically free for consumers. Retail tariffs include network charges, taxes and supplier margins, and the benefit depends on smart-meter rollout and tariff design. But at the system level, flexible cooling demand can help absorb electricity that might otherwise be curtailed or sold at negative prices. Batteries and pre-cooling can further help shift demand into the periods of ample RES supply and reduce the risk of creating a bigger evening peak.

A back-of-the-envelope model illustrates the scale. Adding 15% AC penetration across German households and assuming one actively cooled zone per dwelling would add a peak of roughly 7 GW in the hottest time brackets. A move to 50% penetration would add around 19 GW in the same central case, while a high case with multi-zone or whole-home cooling would be higher.

Those are meaningful numbers. But they are not out of scale with today's economic curtailment of wind and solar, and certainly not out of scale with ongoing investments in solar PV and wind capacity. Germany's solar capacity has doubled over 2020-2025, and government plans show that it is likely to almost double again by 2030. This investment is necessary to get greater RES coverage in low wind/solar periods and enable increasing cheap and low-carbon electrification. Timing and management of load and investment in applications, such as ACs or EVs, that can naturally consume energy in sync with production help make sensible use of increasingly overbuilt RES capacity in times of peak production. This will only become more important as the energy transition progresses.

Neural-Network-Based Negative Power Price Forecasting

Production Version Goes Live on Capra



Capra's machine-learning model to forecast the probability of negative power prices is now live and available on Caprarenewables.com. It is offered

as a premium service to registered users. We have made several improvements to the pre-production neural network which was introduced in the last newsletter. Most notably we strengthened the modelling of the German market within the wider European system to better capture the impact of cross-border trade flows.

What's on the Graph

Negative-Price Probability Forecast

The chart displays the output of ***Capra NPP***, our neural network model for forecasting negative electricity price probabilities over a rolling 168-hours horizon (one week). Forecasted probabilities are shown alongside historical outcome data and D-1 auction prices. The model estimates the probability that German electricity spot market prices will be zero or negative for a particular delivery hour.

Forecast Schedules

The model is updated eight times per day using the latest available weather forecasts.

The chart allows users to switch between four past forecast runs. This allows users to compare how the outlook has changed as new weather data becomes available.

Other inputs, such as capacities, are updated weekly.

Historical Forecast Performance

Historical data is based on the forecast issued closest to the day-ahead market gate closure, using the 09:00 UTC model run. This provides a consistent benchmark for comparing forecast probabilities against realised market outcomes and analysing model performance over time.

Market Coverage

The current version covers the German electricity market only. Additional markets will be introduced in future releases.

Who Benefits from the Model

Anyone who has exposure to the electricity spot market like RES, BESS, or conventional asset operators, traders, large consumers, but also policy makers and advisors:

- **Positioning ahead of negative-price events**
- **Optimisation of RES, BESS, and hybrid or conventional assets**
- **Improved intraday and balancing strategies**
- **See real-time the market impact of a rapidly changing generation mix.**

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In case you have missed our Market News Feed in May, June and July…

All newsfeeds available to members on CapraRenewables.com

Capra Market Review – May–June 2026
Market Policy & Auctions
May and June were characterised by projects awarded under recent support mechanisms progressing into execution. Romania's first CfD-backed developments advanced significantly, with Scatec reaching financial close on its 190 MW Dobrun and Sadova solar portfolio and CIP achieving financial close on the 396 MW Pestera II wind project. The first projects supported through Italy's MACSE storage framework began progressing beyond auction awards, with financing and development milestones announced for several large-scale BESS projects, while Poland approved reforms to accelerate onshore wind repowering. Together these developments demonstrated that recent auction and policy frameworks are increasingly

translating into financed projects and construction activity.
Companies mentioned: Scatec, Copenhagen Infrastructure Partners, European Investment Bank, Qualitas Energy, Octopus Energy Generation, ZE Energy

Corporate PPAs

Corporate renewable procurement remained active, with agreements increasingly supporting AI infrastructure, industrial decarbonisation and hybrid renewable portfolios. Amazon signed one of Europe's largest renewable PPAs with Skyborn for 600 MW from the Gennaker offshore wind project, while Vattenfall agreed long-term renewable supply for Nscale's AI data centre in Norway. Hybrid structures gained momentum through agreements involving Hyperion and Repsol, while EDF, Drax, Shell, Statkraft and UrbanChain expanded their route-to-market and optimisation activities. The period highlighted how long-term commercial contracts continue to underpin investment across both generation and storage assets.
Companies mentioned: Amazon, Skyborn Renewables, Vattenfall, Nscale, Hyperion Renewables, Repsol, EDF, Drax, Statkraft, Shell, UrbanChain, Ampyr Distributed Energy, Fortum, EcoDataCenter

Wind

Wind activity spanned every stage of the project lifecycle, from planning approvals and financial close through to offshore installation, commissioning and portfolio transactions. Key milestones included offshore construction at Baltica 2, first turbine installation at Ecowende's Hollandse Kust West VI project, planning consent for Dogger Bank South, and financial close for major projects including Pestera II, Twyn Hywel and Wałcz. Commissioning milestones in Austria, Finland and Germany, together with portfolio acquisitions and turbine supply agreements, demonstrated continued investor confidence across European wind markets.
Companies mentioned: Ørsted, PGE, Ecowende, Shell, Eneco, Chubu Electric Power, RWE, Masdar, Copenhagen Infrastructure Partners, Bute Energy, RP Global, Enercon, Nordex, Vestas, Ocean Winds

Solar

Solar investment remained geographically diverse, with activity spanning utility-scale developments, agrivoltaic schemes, EPC awards and portfolio acquisitions. European Energy began construction of Italy's largest agrivoltaic project, Blue Elephant Energy commenced work on a 268 MW solar park supplying Deutsche Bahn, and Plenitude completed its flagship 330 MW Renopool development in Spain. Additional progress across Poland, Romania, Bulgaria, Germany and the UK demonstrated that utility-scale solar deployment continues at pace, increasingly alongside co-located storage.
Companies mentioned: European Energy, Blue Elephant Energy, Deutsche Bahn, Plenitude, OX2, Matrix Renewables, Scatec, Rezolv Energy, Voltalia, BELECTRIC, Metlen, Schroders Greencoat, ib vogt

Energy Storage

Battery storage remained one of the most dynamic areas of the market, characterised by larger projects, increasingly sophisticated commercial structures and continued investment in long-duration technologies. Major announcements included Trianel's 900 MW Waltrop project, the proposed 1.4 GW Grohnde development, NatPower's 25 GWh agreement with Tesla, ECO STOR's financing for Germany's largest BESS under development and Zenobē's financial close at Coalburn. Alongside rapid growth in conventional lithium-ion systems, the period also saw commercial progress for iron-air storage, CO2 Battery technology and vanadium flow batteries. Collectively these developments illustrate a market evolving towards portfolio-scale deployment supported by financing, optimisation agreements and increasingly diverse storage technologies.
Companies mentioned: Trianel, Luxcara, BKW, Tesla, NatPower, Zenobē, ECO STOR, Next Kraftwerke, ContourGlobal, Greenvolt, Sungrow, ENGIE, R.Power, Fidra Energy, Gresham House, Sumitomo, Google, Energy Dome, Ore Energy

And Finally...

One of the clearest themes running through the May and June news flow was the growing influence of AI and digital infrastructure on renewable energy markets. Long-term electricity supply agreements for data centres featured repeatedly, while investment in flexible generation, battery storage and hybrid renewable projects increasingly reflected the need to support rapidly growing computational demand. Rather than representing isolated announcements, these stories collectively suggest that AI-driven electricity consumption is becoming an increasingly important source of long-term demand for renewable generation across Europe.