DemandCast: Global hourly electricity demand forecasting

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Tackling Climate Change Through Data-Driven Electricity Forecasting

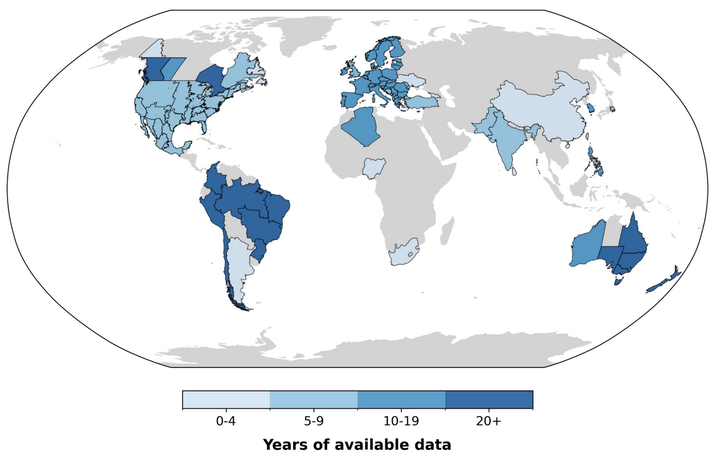
Human-induced climate change demands urgent decarbonization of the global electricity system, which currently contributes about one-third of CO_2 emissions. Electricity demand forecasting helps design reliable electricity systems that integrate clean generation and end-use consumption.

- Electrifying transport, heating, and industry can lower emissions if powered by clean energy.
- Future electricity demand remains uncertain due to population growth, economic change, and climate variability.
- Many developing regions lack access to reliable electricity systems.

Comprehensive Data Integration for Global Coverage

DemandCast brings together diverse public datasets spanning socioeconomics, climate, and electricity demand into a harmonized high-resolution dataset covering 2000–2025 and 56 countries, including subdivisions for large nations.

- Demand data: hourly and sub-hourly data, whose sources are collected in the Awesome Electricity Demand repository.
- Weather data: hourly temperature capturing climate-sensitive demand patterns.
- Socioeconomic drivers: population, GDP per capita, and annual electricity demand per capita.



Countries and subdivisions with publicly available electricity demand data

Machine Learning Model for Normalized Demand Patterns

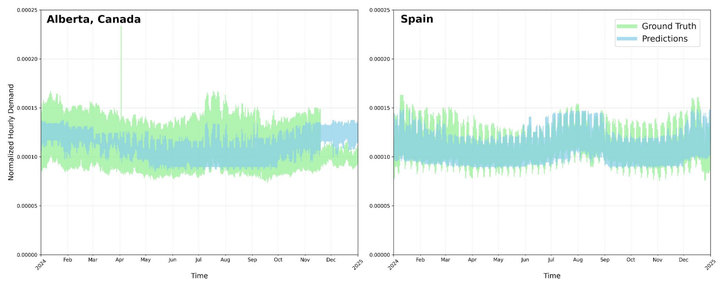
At the core of *DemandCast* is the XGBoost gradient boosting algorithm, trained on over six million hourly observations. It predicts normalized hourly demand and capture temporal patterns for any country in the world.

- Normalization enables learning daily, weekly, and seasonal variations across countries.
- Training design ensures comprehensive validation:
  - 81% training, 10% validation, 9% testing (latest full year reserved for test).
- Model outputs re-scaled by annual demand estimates to reconstruct absolute load values.

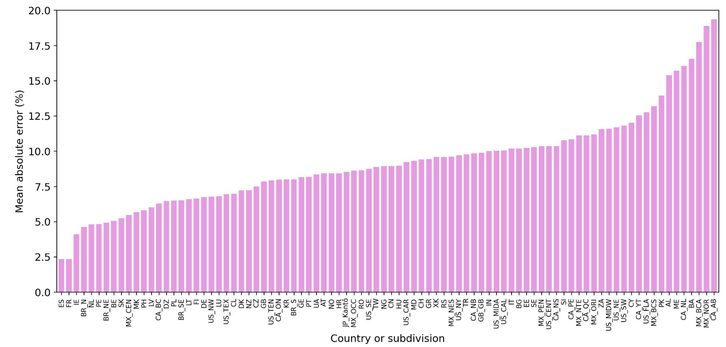
Accurate and Scalable Forecast Performance

The model achieves strong predictive skill across diverse regions with a mean absolute percentage error (MAPE) of 9.2% on out-of-sample data—comparable to prior studies using narrower datasets.

- 6 million+ training observations, 700k+ validation, 660k+ testing.
- Captures daily–seasonal demand variation effectively for heterogeneous systems.
- Regional variability in accuracy indicates data richness as a key performance factor.
- Supports operational and long-term planning through transparent and reproducible forecasts.



Comparison between historical and forecast electricity demand for the best and worst performing regions.



MAPE values resulting from the testing of DemandCast.

Looking Ahead: Probabilistic Forecasting and Data Expansion

DemandCast demonstrates the feasibility of open, large-scale electricity demand modeling for global decarbonization studies. Ongoing work explores predictive uncertainty, hyperparameter optimization, and clustering strategies for better generalization.

- Integrating uncertainty quantification for probabilistic demand forecasts.
- Expanding dataset coverage for underrepresented regions.
- Developing regionally tuned models with similar structural and climatic characteristics.
- Sustaining open data and model reproducibility for global energy transition research.

References

Kevin Steijn, Vamsi Priya Goli, and Enrico Antonini, “Awesome-electricity-demand: A curated collection of links to hourly or sub-hourly electricity demand data.”
https://github.com/open-energy-transition/Awesome-Electricity-Demand

Kevin Steijn, Vamsi Priya Goli, and Enrico Antonini, “Demandcast: Global hourly electricity demand forecasting.”
https://github.com/open-energy-transition/demandcast