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Advanced Forecasting for Energy Systems

Saving Money & Cutting Emissions

RAL scientists developed improved energy forecasting systems that address the weather dependence of the energy system, including renewable energy.

These forecasts improve grid reliability, minimize operating costs for utility companies, and save customers money. Accurate forecasts are becoming increasingly critical as wind and solar power account for growing shares of the energy portfolio because they help system operators plan conventional fossil-fuel-based generation and maintain the balance between electricity supply and demand.

Utilities Depend on Accurate Forecasts

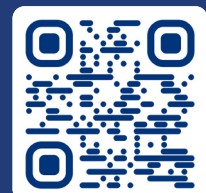
Electric utilities and independent system operators (ISOs) need to make critical decisions daily regarding energy generation, distribution, demand, storage, and integration. Accurate knowledge of the current and future state of the atmosphere is essential for supporting these decisions. Wind speed and solar irradiance are among the most challenging weather variables to forecast and are the primary meteorological drivers of wind and solar power generation. Additionally, topography, surface roughness, ground cover/vegetation, atmospheric stability, wake flow around obstacles, low-level jets, clouds, and aerosols including dust and smoke, all affect wind and solar energy production and need to be included in forecast models.

Benefits & Impacts

- Integrate wind & solar power onto the grid
- Effective utility participation in energy markets
- Better forecasts save utilities & customers money
- By maximizing wind & solar use, emissions are minimized

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As wind and solar energy portfolios continue to expand, and adding storage to the mix as we move toward larger amounts of carbon-free energy generation, the need to address these forecast challenges is taking on new urgency. Wind and solar energy forecast inaccuracies lead to substantial economic losses in energy markets, while accurate forecasts save utilities and their customers millions of dollars annually and also minimize carbon and other pollutant emissions from fossil-fuel power plants.

Forecasting Solutions

RAL scientists and software engineers have integrated weather forecasting models and machine learning (ML) algorithms into renewable energy prediction systems. WRF-Solar® is a version of the NSF NCAR-developed Weather Research and Forecasting (WRF) model with a set of enhancements specially designed to improve solar forecast accuracy for both intra-day and day-ahead time horizons. The MAD-WRF model combines the improved physics in WRF-Solar with assimilation of satellite and surface observations to start the model with clouds in the right places, which further reduces solar forecasting errors in the first few hours. RAL scientists have also partnered with other national labs to better couple mesoscale and microscale phenomena to improve wind forecasts in complex terrain where many wind farms are located.

DI-Cast® has long been at the core of RAL forecasting systems, including for renewable energy, and statistically optimizes forecast model output based on recent performance. More recent ML-based techniques like StatCast-Wind and StatCast-Solar deliver further improvements by synthesizing long histories of forecasts and observations from wind

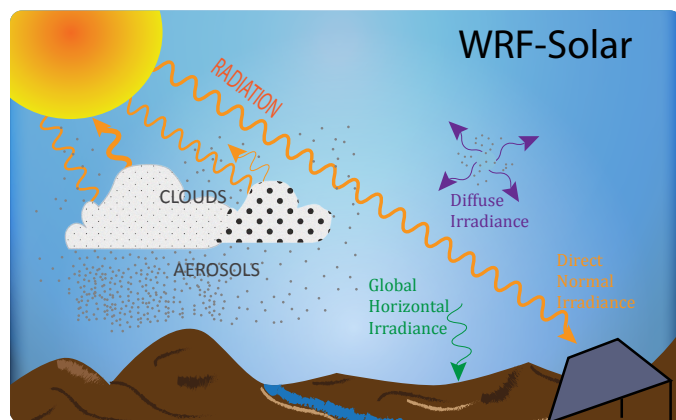


Diagram of WRF-Solar physics improvements

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Shagaya Renewable Energy Park in Kuwait

and solar power plants to learn relationships among variables, and by using real-time observations to correct near-term forecasts. Additionally, the analog ensemble (AnEn) has proven to be a powerful tool for reducing forecast errors and delivering reliable probabilistic forecasts without the significant computational expense of running a full ensemble of weather prediction models. Variations of these solutions have been developed for and used by clients ranging from Xcel Energy, the U.S. Department of Energy, the New York State Energy Research and Development Authority, the Kuwait Institute for Scientific Research, and more.

Advancing renewable energy prediction through weather modeling and machine learning.

New Opportunities

Improved weather prediction and precise spatial analysis of small-scale weather events are crucial for energy management, as is the need to further develop and implement advanced technologies. This is particularly true as distributed (rooftop) energy generation proliferates and the deployment of large-scale storage and electric vehicles increases. Energy system planners also need to be aware of our changing climate and how wind and solar energy resources and their variability may be affected regionally in the coming decades. Understanding and forecasting wind and solar droughts is becoming more important. RAL scientists are actively engaged with industry decision-makers, both domestically and internationally, on how best to anticipate and respond to short- and long-term changes in atmospheric conditions to mitigate weather-related risks, particularly in wind and solar energy prediction.



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