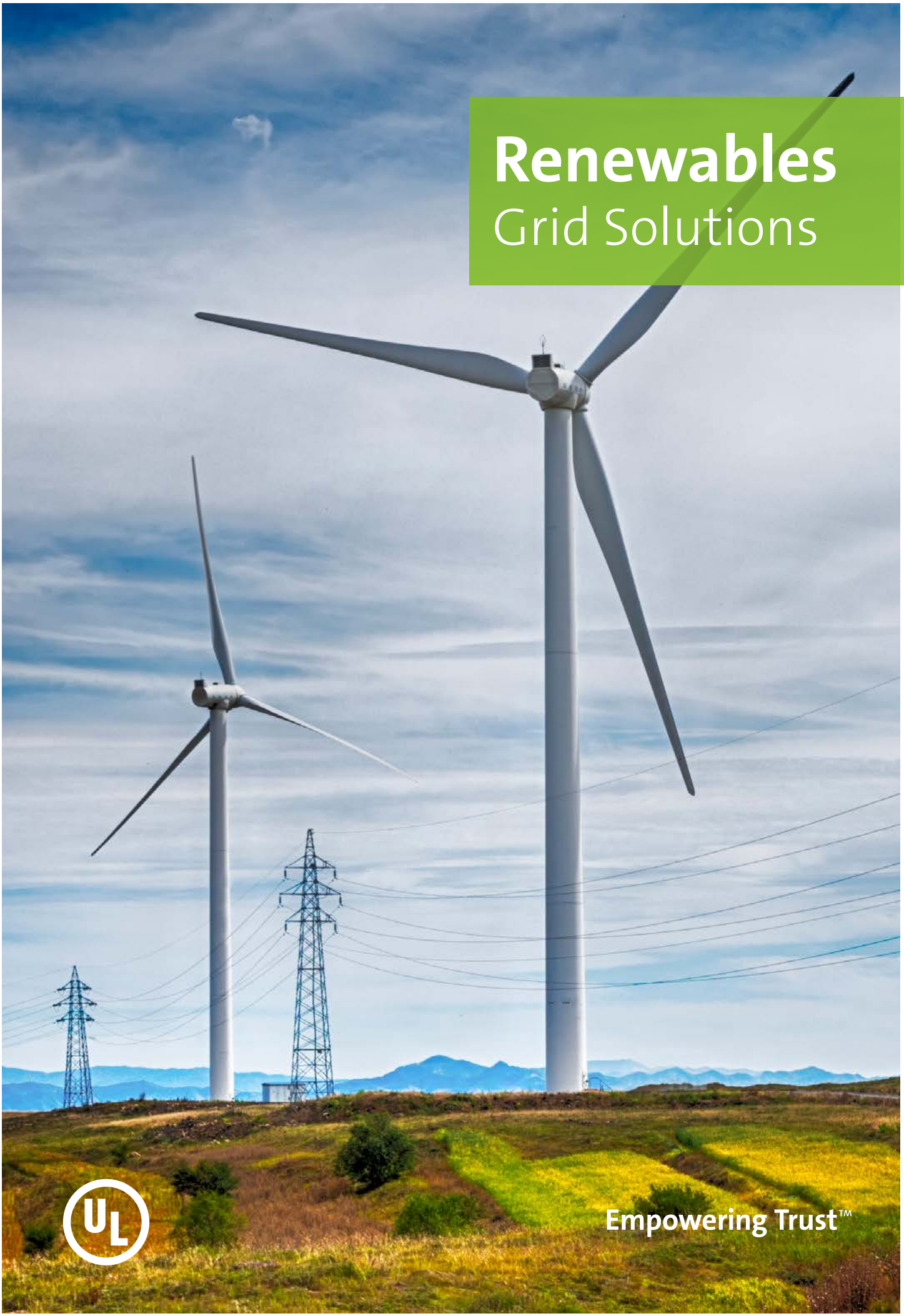
Renewables
Grid Solutions



Empowering Trust™

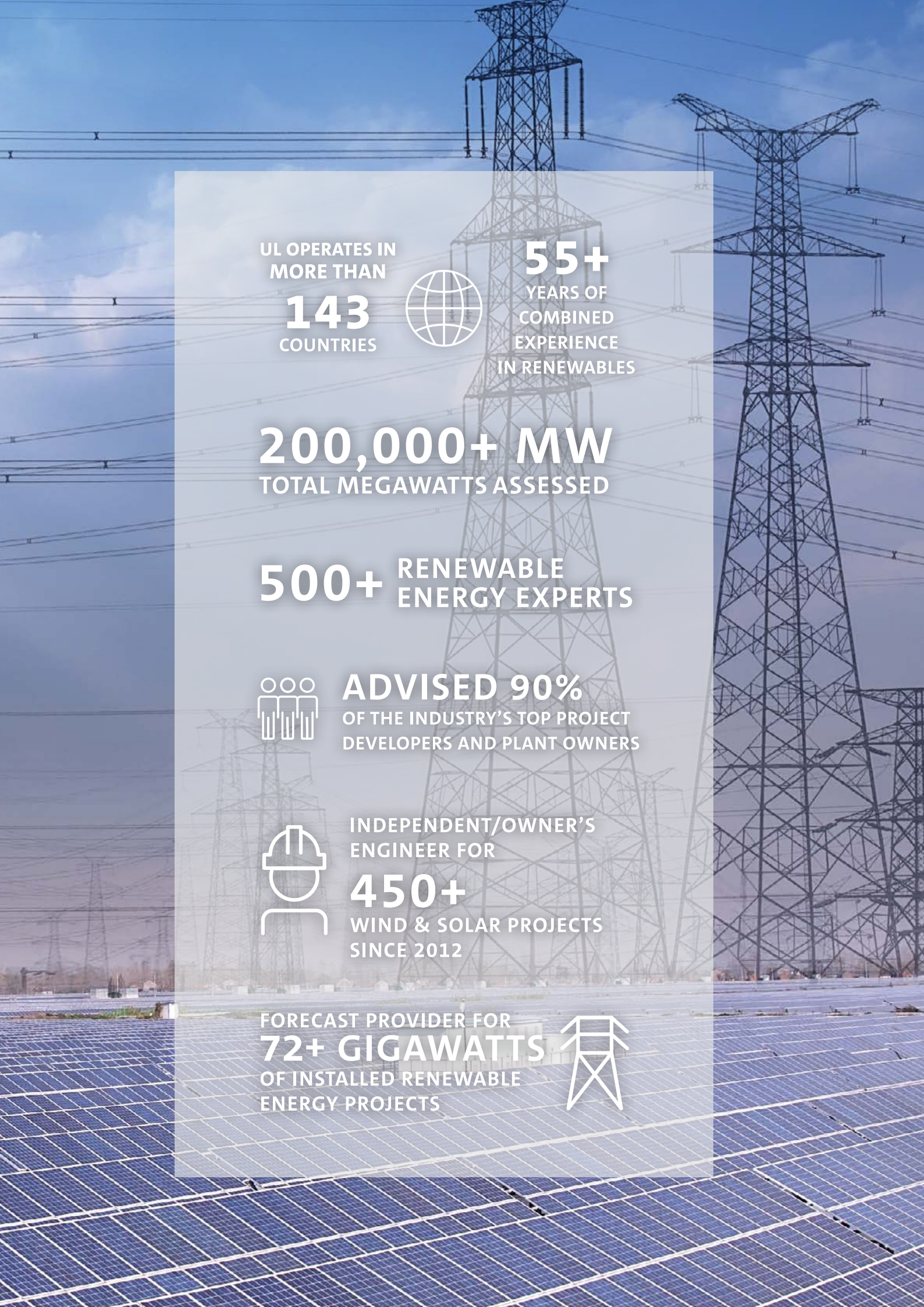
About us

Contents

Leaders in Global Services for Renewable Energy

UL works to help renewable energy manufacturers, developers, owners, investors, lenders, utilities and policy makers navigate the risk and complexity associated with renewable resources. We have become a trusted advisor by providing access to proven science and expert engineering, and by offering innovative solutions to meet the unique challenges of the renewable energy industry. We pride ourselves on being accessible, flexible and keenly responsive to the needs of our clients, helping them build projects that reduce humanity's global carbon footprint and generate healthy financial returns.

UL now delivers an even more extensive portfolio of renewable energy services, through the acquisition of AWS Truepower (2016). We advise on wind and solar projects, as well as battery and energy storage technologies, helping our clients make them safer, compliant, and perform to the highest standards. Our goal is to empower trust in renewable energy throughout the project lifecycle and across the supply chain.



UL OPERATES IN MORE THAN

143

COUNTRIES

55+

YEARS OF COMBINED EXPERIENCE IN RENEWABLES

200,000+ MW

TOTAL MEGAWATTS ASSESSED

500+ RENEWABLE ENERGY EXPERTS

ADVISED 90%

OF THE INDUSTRY'S TOP PROJECT DEVELOPERS AND PLANT OWNERS

INDEPENDENT/OWNER'S ENGINEER FOR

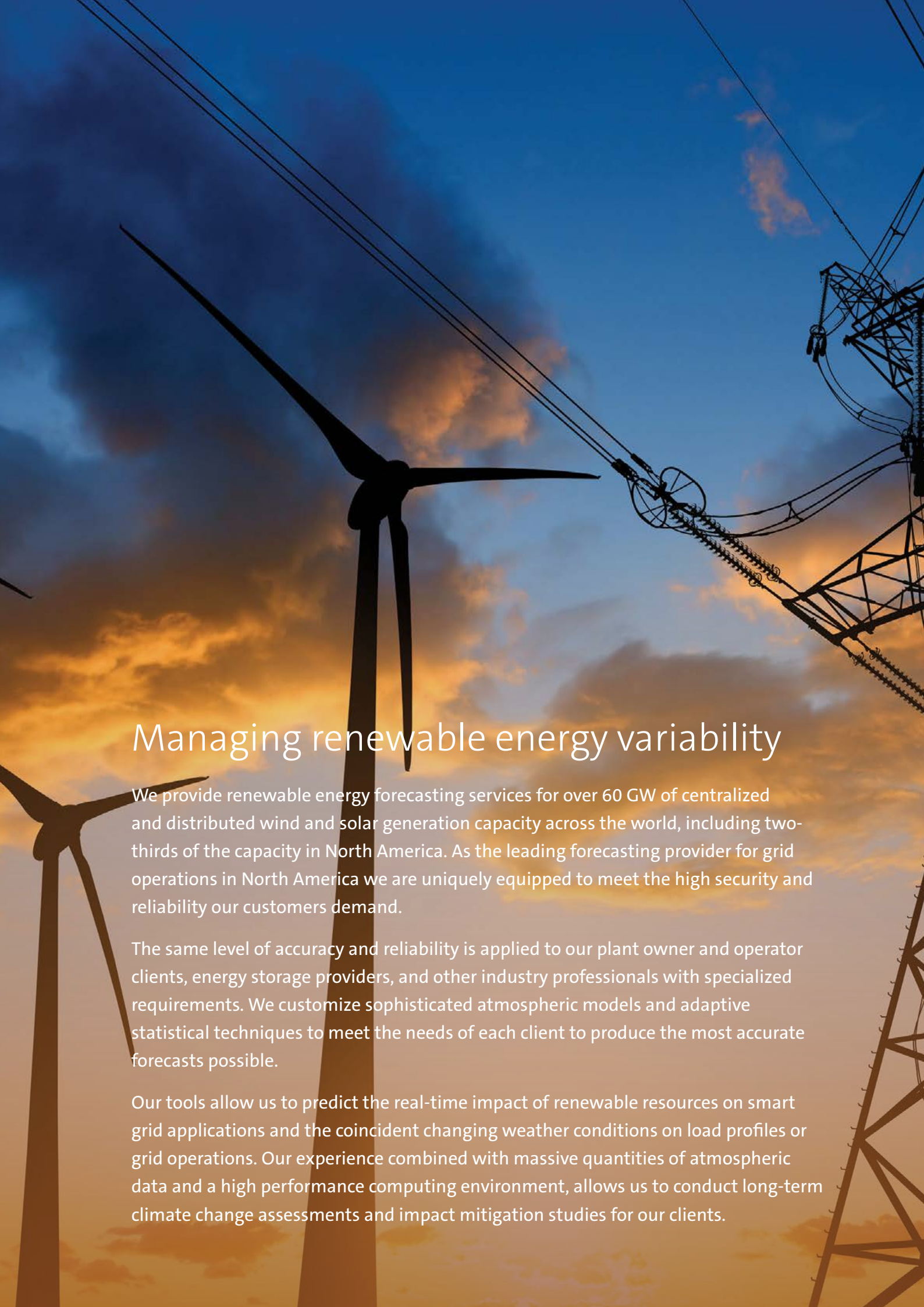
450+

WIND & SOLAR PROJECTS SINCE 2012

FORECAST PROVIDER FOR

72+ GIGAWATTS

OF INSTALLED RENEWABLE ENERGY PROJECTS



Managing renewable energy variability

We provide renewable energy forecasting services for over 60 GW of centralized and distributed wind and solar generation capacity across the world, including two-thirds of the capacity in North America. As the leading forecasting provider for grid operations in North America we are uniquely equipped to meet the high security and reliability our customers demand.

The same level of accuracy and reliability is applied to our plant owner and operator clients, energy storage providers, and other industry professionals with specialized requirements. We customize sophisticated atmospheric models and adaptive statistical techniques to meet the needs of each client to produce the most accurate forecasts possible.

Our tools allow us to predict the real-time impact of renewable resources on smart grid applications and the coincident changing weather conditions on load profiles or grid operations. Our experience combined with massive quantities of atmospheric data and a high performance computing environment, allows us to conduct long-term climate change assessments and impact mitigation studies for our clients.

We Help Renewable Energy Customers With:

PROJECT DEVELOPMENT SUPPORT

Navigate project complexities in the earliest stages of development.

- Site Screening and Feasibility
- Turnkey Measurement Services (Met Masts and Remote Sensing)
- Resource Assessment
- Plant Designnd Energy Assessment
- Technology Selection and Suitability
- Infrastructure and Balance of Plant
- Permitting Support and Environmental Assessment

SOFTWARE AND DATA

Leverage the knowledge and expertise of our experts and enable your team to work independently.

- Windographer
- Openwind
- Windnavigator
- Wind Data Management
- Resource Maps
- Time Series Datasets
- Site Specific Reports

ASSET MANAGEMENT

Manage expectations of operational plants and improve performance, including safe and reliable operations of wind projects beyond the original design life.

- Operational Energy Assessments
- Performance Analysis
- Plant Performance Optimization
- Remote Sensing / Lidar for Turbine Diagnostics
- Turbine Inspections
- Root Cause Analysis
- Lifetime Extension / Remaining Useful Life
- Loads Simulations
- Components Evaluation

GRID SOLUTIONS

Understand renewable energy variability and the impact of weather-driven events:

- Real-Time Renewable Forecasting
- Grid Management and Planning Services
- Atmospheric Modeling and Applied Research

ENERGY STORAGE SOLUTIONS

Address safety concerns for large battery systems for wind and solar integrators and OEMS.

- Testing and Certification
- Performance Testing
- Custom Research

DUE DILIGENCE

Mitigate the risks associated with renewable energy project investment:

- Independent Engineering
- Technical Advisory
- Pre-Construction, Operational and Repowering Projects
- Custom Support for Investors, M&A, Tax Equity
- Turbine Technology, Civil and Electrical Design Review
- Contracts Review
- Environmental Permitting Review
- Financial Model Review
- Construction Monitoring
- Owner's Engineer

CERTIFICATION

Confirm compliance and provide assurance and confidence in wind technology.

- Certification of Turbines and Components
- Project Certification
- Grid Code Compliance
- Assessment of Construction and Foundations

TESTING AND INSPECTION

Verify the safety, reliability, performance and compliance of wind turbines and components.

- Validation and Type Testing
- Mechanical Loads
- Power Performance Testing
- Electrical Characteristics
- Low Voltage Ride Through Testing

CYBERSECURITY

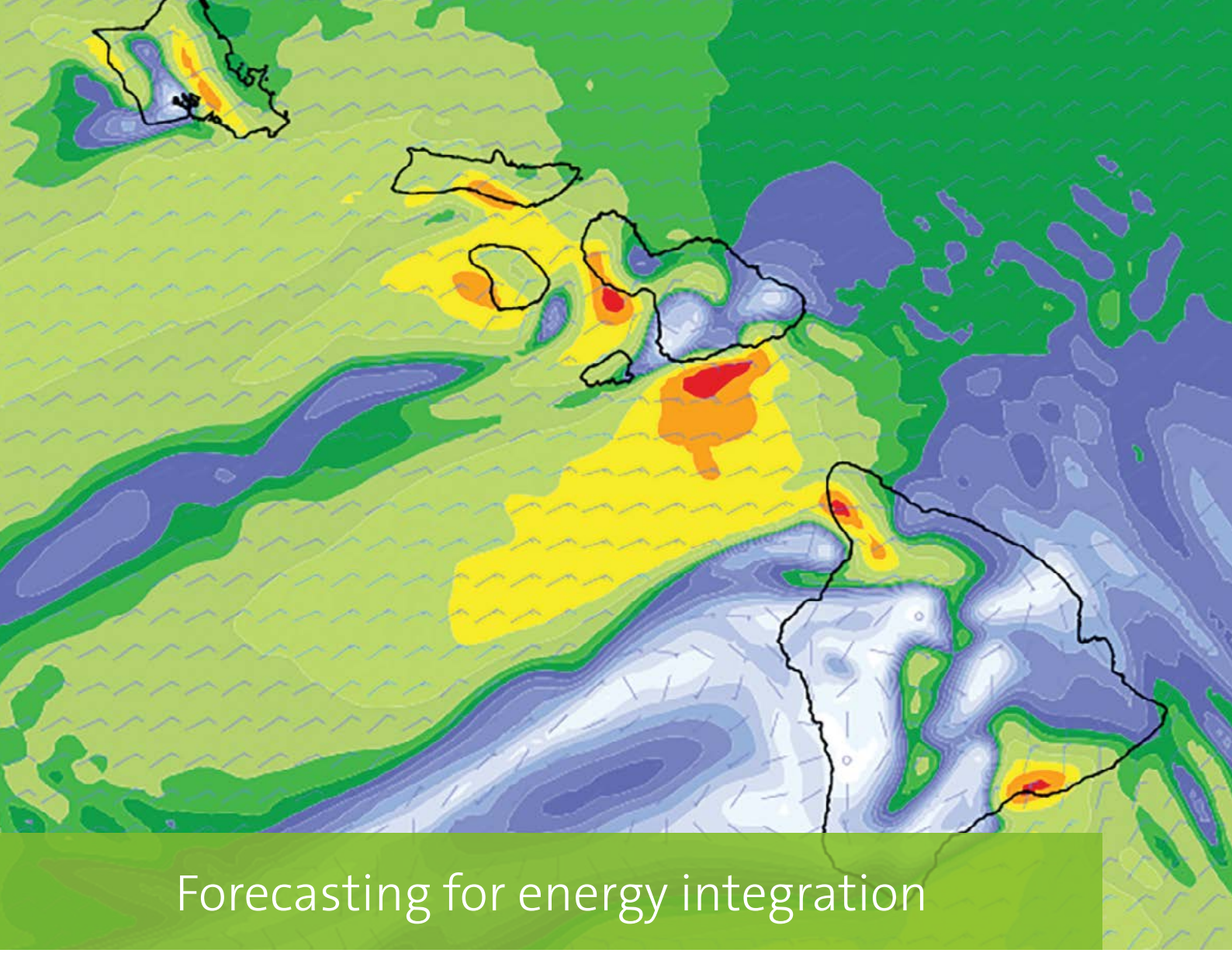
Help validate and substantiate security claims, meet regulatory requirements and mitigate risks of cyber incidents.

- Training
- Custom Security Testing
- Penetration Testing
- Code Review
- Risk Anaysis
- Gap Analysis

RESEARCH AND ADVANCED STUDIES

Research in electrical safety, renewable resource characterization, plant design, energy estimation and real-time forecasting.

- Custom Research
- Market Studies

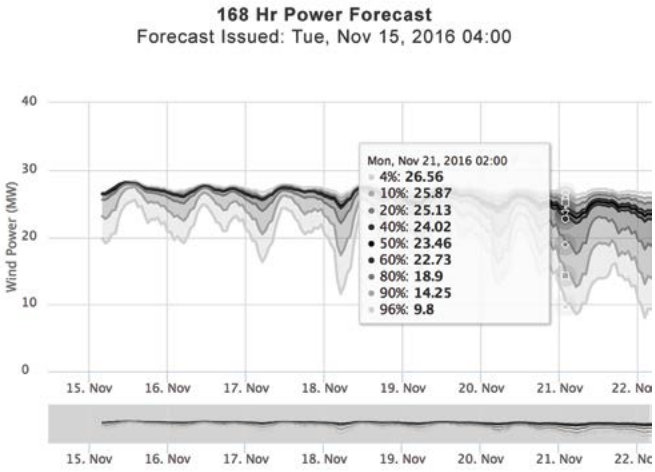


Forecasting for energy integration

As more grid-connected renewable energy projects are developed, power companies and grid operators/regulators increasingly recognize the need for accurate and timely renewable generation forecasts. These professionals also recognize the need for long-range analyses of how fluctuating power from renewables impact grid reliability, cost, and operation.

We are the preeminent renewable energy forecasting provider for Independent System Operators (ISOs) and balancing authorities in North America. As the renewable forecast service provider for 60% of the ISOs in North America, we create power forecasts for over 65% of the installed solar capacity and 47% of the installed wind capacity in the US and Canada.

These forecasts are customized for each individual wind and solar resource and are not simply control area aggregate predictions. We advance our forecasting techniques and implement cutting-edge strategies in our operational forecasting services through our client-driven solutions, 24/7 on-call support, and the determination to remain at the forefront of scientific research.



LOCATION: Hawaii, United States

Managing Utility-Scale Wind & Solar Generation

AWS Truepower, a UL company continues to work with Hawaiian Electric Industries (HEI) to design, develop, and deploy renewable energy tools. These tools facilitate the reliable and economic integration of a high penetration of renewables on Hawaii's island grids. One such tool is a customized wind and solar forecast system called the Solar and Wind Integrated Forecast Tool (SWIFT).

SWIFT provides forecasts every 15 minutes and up to 168 hours ahead for each island's utility-scale and distributed wind and solar generation. To accomplish this task, SWIFT uses a network of atmospheric sensors that have been specifically sited with observational targeting. This network is used to analyze forecast sensitivity to sensor-measured variables and location.

Along with modeled data and input from the SWIFT sensor network, the forecasts are configured to provide the best possible forecast accuracy in Hawaii's unique meteorological environment. A custom-designed website uses forecast graphics developed to meet operational staff needs. Flexible delivery options, such as web services, xml and ftp, provide a mechanism for easily importing forecast data into grid management tools.

LOCATION: New York, United States

Renewable Energy Forecasting Service for NYISO

In The New York Independent System Operator (NYISO) selected our company to provide generation forecasts for all existing and future wind plants in the New York Control Area. These forecasts allow NYISO to more effectively manage New York State's electricity market and grid operations.

The current suite of services for the NYISO includes forecasts with a 15-minute time interval extending out to eight hours delivered every 15 minutes, as well as a forecast for the next two calendar days delivered twice per day. As of Fall 2016, the NYISO wind forecasting service consists of over 1,900 MW installed capacity across 20 sites.

LOCATION: California, United States

Renewable Energy Forecasting Service for CAISO

The California Independent System Operator (CAISO) selected AWS Truepower, a UL company to provide five minute–ahead and hour-ahead generation forecasts for wind and solar plants in the CAISO balancing area and its adjacent markets. As of Fall 2016, the CAISO wind and solar forecasting service consists of over 13 GW of installed capacity.

Since 2014, AWS Truepower has provided CAISO with meteorological support for load forecasting by monitoring and advising on meteorological features that could have an impact on electrical load variations within the CAISO balancing area.

Grid management & planning

Photo Credit: NYISO

We understand the impact of centralized and distributed solar and wind technologies on the grid and the importance of reliable and economical operations. Our team has played an essential role in grid integration studies and the development of customized tools and datasets to support them. With simulated wind and solar resource data, we help planners, utility professionals, aggregators, and energy service providers manage and mitigate variability, including energy storage facilities.

Combining our advanced models with production data, we provide site-specific energy-generation profiles. The synthesized data characterizes critical seasonal and diurnal generation patterns, power ramp behavior, and resource variability with generation on time scales of seconds to years. Our advanced techniques allow us to create power and resource profiles for historical or future time periods to support a wide range of client needs.

LOCATION: Vietnam

High Resolution Wind Simulation Scenarios for Grid Reliability Model

Across the monsoon-dominated country of Vietnam, wind harnessed for energy could meet or exceed the country's energy demands. However, this plentiful wind resource experiences seasonal and diurnal variability. Depending on its correlation with load and transmission, this variability could have a substantial impact on developing wind projects' feasibility and costs.

To support grid simulations of high-penetration scenarios, AWS Truepower, a UL company worked with GE's Energy consulting business to identify 9 GW of potential onshore wind plants across Vietnam and achieve target capacities in the northern, central, and southern regions. We simulated wind resource and plant output at a 10-minute resolution using a combination of numerical weather prediction models and power conversion routines.

We also generated day-ahead hourly wind power simulations using transition probabilities, creating synthetic forecasts that imitated the statistical behavior of a real plant. The data was used to understand grid performance and the role of regional wind variability in grid reliability and development cost scenarios.

LOCATION: Latin and South America

Managing Utility-Scale Wind and Solar Generation

As commissioned by the Inter-American Development Bank, AWS Truepower, a UL company participated in a study that examined the net benefits of a low-carbon interconnected electricity system from Mexico to Argentina. Team members Energy Exemplar, Quantum (Argentina), and the Energy Center of Chile modeled capacity-expansion scenarios for 2015–2030. These scenarios evaluated cost-effective and technically feasible paths for variable renewable energy generation and inter-regional transmission projects.

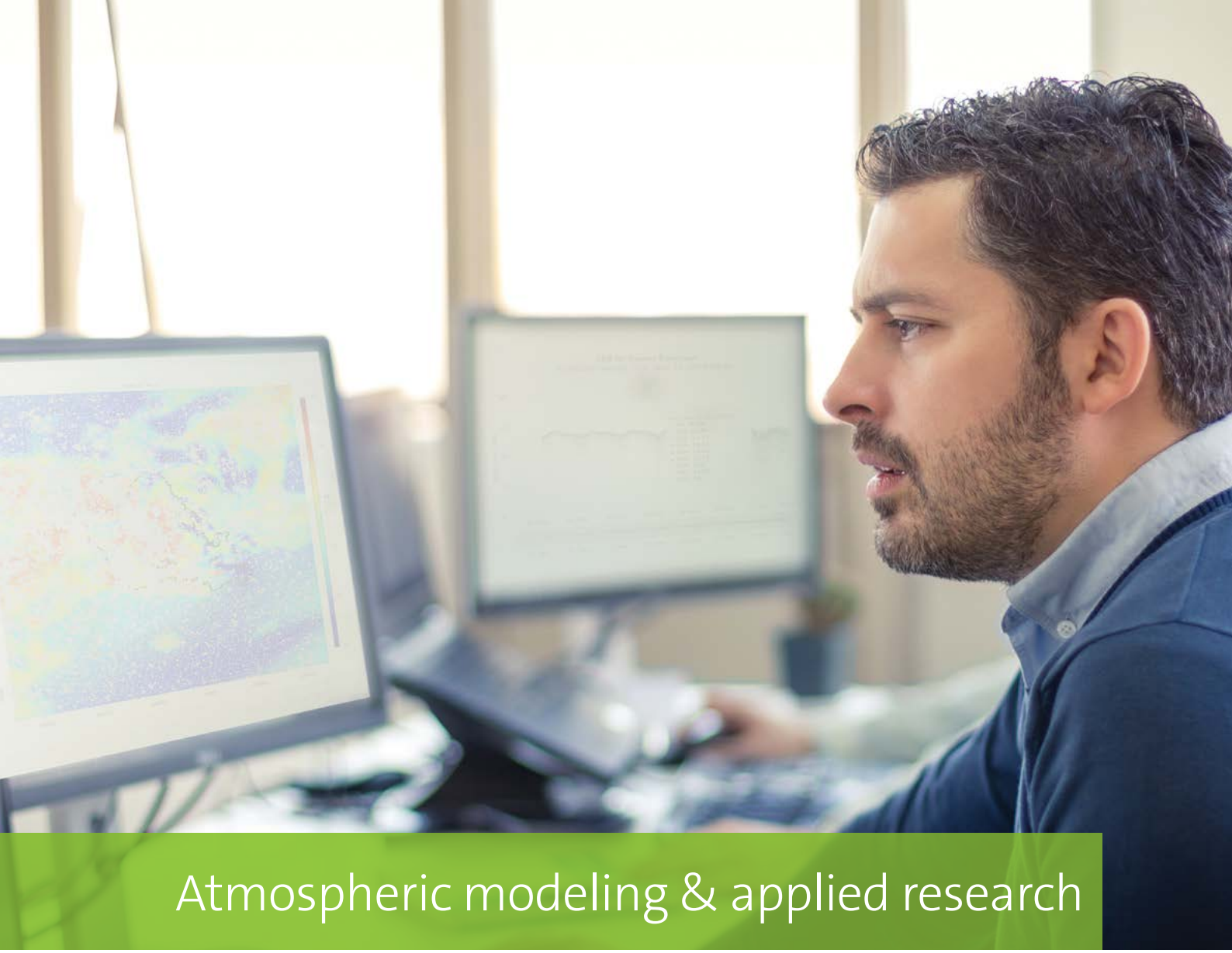
We conducted a systematic assessment of potential capacity using a GIS-based approach, a 200 m wind speed map, and a satellite-based solar resource map to estimate wind and solar MW capacity by country and resource zones. These estimates provided the upper boundary for the transmission expansion model. Over 500 hourly power generation profiles covering a 15 year period were created using atmospheric variables simulated from a 27 km Weather Research and Forecasting (WRF) model run. The model output was adjusted using high-quality measured data and then run through AWS Truepower's power conversion models to simulate generation patterns by zone.

LOCATION: Hawaii

Integrating Real-Time and Forecasted Solar Information for Edge-of-Network Application

AWS Truepower, a UL company operates Hawaii's Solar and Wind Integrated Forecast Tool that uses real-time weather, power generation, and plant operational data to provide a forecast of potential power on various timescales for decision-making purposes. This system also provides an estimate of behind-the-meter solar production at the distributed level by substation.

We currently forecasts across five islands, delivering a consistent dataset that estimates the invisible generation, providing situational awareness, and therefore opportunities, for managing grid resources. This project expands the use of forecasted data for distributed sources with possible applications for smart inverters, battery operations, line voltage regulation, and other load offset programs.



Atmospheric modeling & applied research

Our demonstrated ability to accurately model the atmosphere and its impact on the local, regional, or global energy industry sets us apart from the competition. We perform big data analytics using high-performance computing which allows us to quantify the uncertainty of scheduling real-time renewable energy and utility electric loads. We can predict this uncertainty minutes, hours, days, seasons, and even years in advance.

If a client needs to estimate the potential generation from a planned solar or wind plant, our team can accurately simulate the plant's generation and variability on multiple time scales, spanning monthly generation to second-by-second generation. This expertise also extends to tasks like planning optimal power scheduling approaches, creating power forecasts to calculate a renewable plant's forecastability, determining expected coincident generation from other centralized or distributed resources, and even predicting the impact of new efficiency technologies (e.g. storage, smart appliances, electric vehicles, etc.) on power system load profiles.

Reliable Solar Energy Integration

With funding support from the US Department of Energy's SunShot program, AWS Truepower, a UL company led a project with several partners to help support CAISO efforts to more reliably incorporate solar energy into its system. Along with team members Pacific Northwest National Laboratory (PNNL), CAISO, and Siemens, we developed an integrated grid management toolset to incorporate solar energy while removing system reliability concerns and potential impacts to energy prices. Application of the tool lowered the reserves required to balance the system thereby reducing the overall cost of bulk power system integration for solar generation. The integration tool included advanced probabilistic solar power forecasts, new methods to quantify uncertainty, and flexible ramping algorithms to support unit commitment and dispatch processes. When tested, our approach was shown to remove system reliability issues in multiple historical scenarios where solar generation had contributed to system reliability problems.

Hydro-Québec Historical Simulations

Across the service area of Hydro-Québec, understanding wind plant behavior in various weather regimes is critical, and our client was seeking a wind power time series that mimicked operational wind farms' behavior. An hourly wind power and loss time series was produced for 1979–2015 at 39 existing and planned wind farms in Québec, Canada. We started by modifying our wind farm design software Openwind and implemented a time series energy estimation model calibrated using SCADA data from 18 operational wind farms. These advances allowed us to quantify time-varying plant losses from wakes, availability, environmental (including icing), and electrical systems. The simulated historical wind power production and plant losses were created using the Weather Research and Forecasting (WRF) model, where the time series from the atmospheric model were adjusted and converted into hourly generation. All turbine level plant losses were tracked separately allowing for detailed comparisons with actual operation. Results illustrated a high correlation between hourly modeled generation with actual power that also aligned with monthly/seasonal trends, providing valuable insight into plant operations as affected by site weather conditions and technical constraints.

Stochastic-Kinematic Irradiance Estimation System

For this project, we developed a novel approach to modeling clouds and their impact on high-frequency (~1 second) synthetic irradiance and power data for proposed solar PV. The approach combines a mesoscale Numerical Weather Prediction (NWP) model with a microscale model called the stochastic-kinematic irradiance estimation system (SKIES). The model simulates cloud movement and evolution that accounts for rapid ramps in solar irradiance and power generation. It also creates one-second solar irradiance and power production data at utility-scale and distributed PV sites. The model was validated against high-frequency observations at 25 locations in Hawaii and is able to simulate solar irradiance fluctuations. In the Hawaii study, the modeled ramp distributions on time intervals ranging from ~1 second to 1 hour agreed with observed ramp distributions. The modeled power spectral density (PSD) also had a shape and features similar to the observed PSD. SKIES can be used to support high PV penetration scenarios and grid operations under different market conditions, electrical system reliability studies and the application of storage to reduce cloud-induced ramps.

Key Office Locations

AFRICA
Johannesburg, SOUTH AFRICA

ASIA PACIFIC
Beijing, CHINA
Suzhou, CHINA
Bangalore, INDIA
Ise, JAPAN
Tokyo, JAPAN
Seoul, KOREA

EUROPE
Lyon, FRANCE
Bremen, GERMANY
Cuxhaven, GERMANY
Hamburg, GERMANY
Oldenburg, GERMANY
Wilhelmshaven, GERMANY
Milan, ITALY
Ansoain (Navarra), SPAIN
Barcelona, SPAIN
Izmir, TURKEY
London, UNITED KINGDOM

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Buenos Aires, ARGENTINA
São José dos Campos, BRAZIL
Rio de Janeiro, BRAZIL
Bogotá, COLUMBIA
Mexico City, MEXICO

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