

The 5 Minute Wind Forecasting Challenge: Exelon and GE's Predix



At a Glance



Renewable Energy



Challenge

Exelon sought to optimize wind power forecasting by predicting wind ramp events, enabling the company to dispatch power that could not be monetized otherwise. The result is higher revenue for Exelon's large-scale wind farm operations.



Solution

GE and Exelon teams co-innovated to build a solution on Predix that increases wind forecasting accuracy by designing a new physical and statistical wind power forecast model that uses turbine data together with weather forecasting data. This model now represents the industry-leading forecasting solution (as measured by a substantial reduction in under-forecasting).



Results

Exelon's wind forecasting prediction accuracy grew significantly, enabling higher energy capture valued at \$2 million per year. The solution is being rolled out across 42 wind farms without changes to the underlying infrastructure. The success of the project contributed to Exelon's decision to sign a long-term enterprise agreement with GE.



Technologies

Predix Platform, including the following services:

Predix Machine (edge)

Database as a Service (Postgres)

Time Series

Key-Value Store (Redis)

Predix Analytics Framework

GE Digital's Data Science Services

A move toward digital industrial transformation

As a leading utility company with more than \$31 billion in global revenues in 2016 and over 32 gigawatts (GW) of total generation, Exelon knows the importance of taking a strategic view of digital transformation across its lines of business.

Exelon was developing strategies for managing its various generation assets across nuclear, fossil fuels, wind, hydro, and solar power as well as determining how it would leverage the enormous amount of data those assets would generate going forward.

In evaluating its strategies, the company reviewed its current on-premises OT/IT infrastructure across its entire energy portfolio. Business leaders looked at the system administration challenges and costs they would face to maintain the current infrastructure, let alone use it as a basis for driving new revenue across its business units. This assessment made digital transformation an even greater imperative, and inspired discussions about how Exelon could leverage a combination of edge and cloud technology rather than expanding or upgrading existing on-premises infrastructure.

Additionally, Exelon had amassed decades of operating and organizational data that it had been unable to leverage because it was either siloed or the technology, processes, and expertise to analyze it effectively were not available.

The company realized that they needed to bring data, people, and analytics together to improve business outcomes. Further, they needed to solve these challenges at the scale of a utility the size of Exelon.

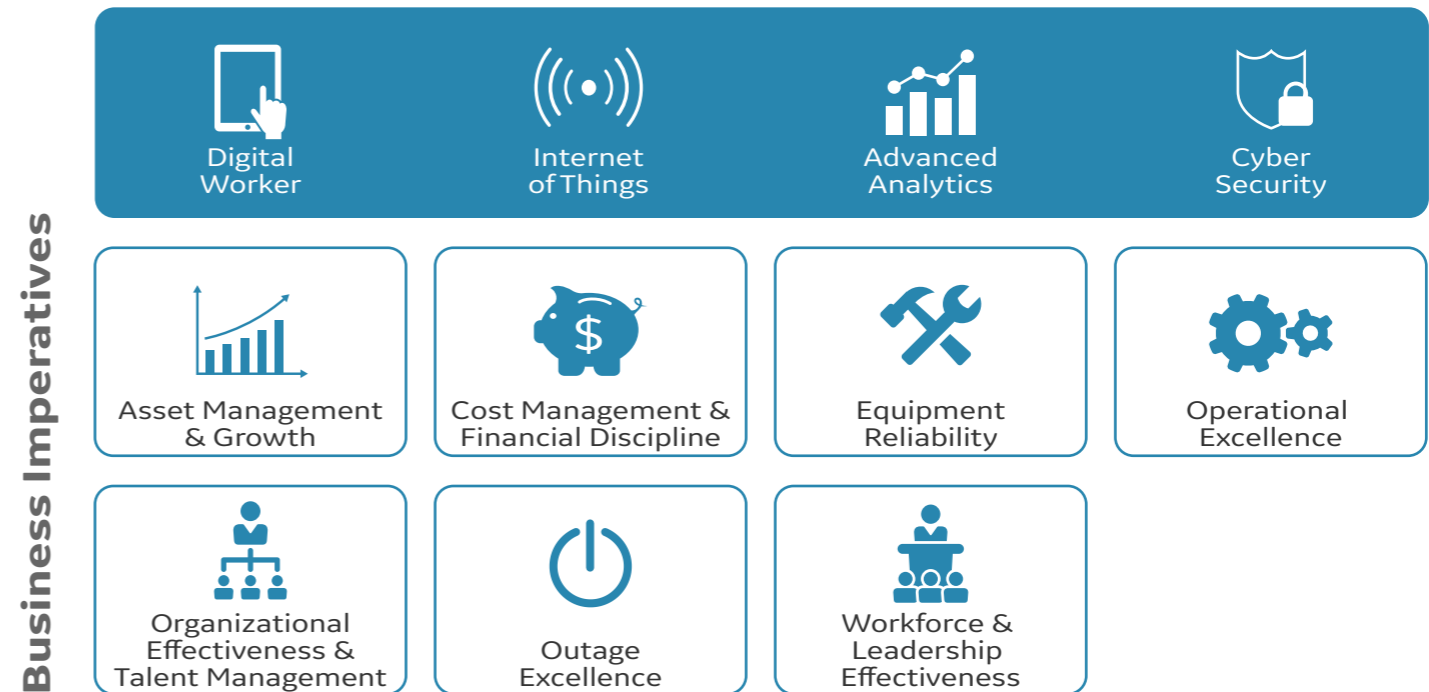
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Exelon knew they needed a shared, centralized approach to managing data, analytics, and solutions so that they could implement their strategy across the company. The individual power generation companies that are part of Exelon each have IT departments of their own, and the company had already experienced pain points from the mix of architectures and technology stacks in place at each generation company's data centers. Going forward, Exelon saw a need to centralize, standardize, and lower costs.

In reviewing its challenges and goals, Exelon examined its alignment with GE's view of the Industrial Internet and found that GE offered tremendous synergy with Exelon's technology and business imperatives. Exelon's technology focus areas map one-to-one with capabilities of GE's Predix:

- Equipping the digital worker
- Leveraging the Industrial Internet of Things (IIoT)
- Using advanced analytics and data science
- Ensuring cyber security at all levels

Further, Exelon found that GE Renewables and Power Solutions built on Predix address the company's business imperatives in the areas of asset management, outage excellence, equipment reliability, and operational excellence.



Exelon's Technology Focus Areas and Business Imperatives

Exelon takes a comprehensive approach to power generation, with numerous generation facilities for renewable and conventional energy.

Beginning at the 2014 Minds+Machines conference in San Francisco, Exelon and GE began working together on ways to achieve the company's goals using Predix, holding a series of technical and visionary collaboration sessions that resulted in selecting 5 projects to quickly demonstrate the value of using Predix to leverage the right data to drive business outcomes.

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Key criteria for project selections included the following:

- **Technical feasibility**
The project must prove that Predix enables Exelon to address a specific business need.
- **Business value**
The project criteria included a well-understood, agreed upon, and measurable outcome.
- **Execution**
It must be possible to implement the necessary changes so that the new solution could be effective.

Defining architectural requirements

Given the long-term plan to centralize, standardize, and leverage its existing infrastructure, the conversation naturally turned to platforms to support its entire operation of its fleet of renewable and traditional energy generation facilities. As a result, platform decisions were made to meet this organization-wide need.

Build vs. buy decision making

Power generation facilities are critical to global infrastructure, so security and scale are of the utmost importance for selecting a platform with an architecture that supports both cloud and edge deployments.

Exelon knew it needed a platform with services purpose-built to handle the volume, velocity, and variety of industrial data, and to bridge its operational technology (OT) and information technology (IT) worlds. Security had to be baked in at a fundamental level.

Public clouds such as AWS and Azure offer infrastructure (Infrastructure-as-a-Service or IaaS) and platform (Platform-as-a-Service or PaaS) services that allow anyone to build and deploy apps with little governance. However, they are not purpose-built to support digital industrial use cases for many reasons:

- Public clouds lack the essential industrial services required (PaaS+) to take into account the unique requirements for modeling power generation assets, such as wind turbines, in addition to developing and deploying analytics that are required to increase the reliability and performance of individual wind turbines across an entire wind farm.
- Public cloud architectures do not have the ability to operate at the edge of the network where on-premises connections to assets occur. As a result, they cannot enable local operational intelligence.
- Public clouds do not have Industrial Internet platform capabilities, such as modeling industrial assets. Additionally, they lack the ability to deliver off-the-shelf applications (Software-as-a-Service) focused on increasing asset uptime and optimizing business operations, accelerating time-to-value.

Given its extensive requirements, Exelon had considered building its own solution. However, they realized that approach would necessitate significant funding and create risk. It would also consume considerable resources that would require working on non-differentiating tasks, possibly delaying the company's progress on strategic imperatives. Joint technical and visionary sessions with GE leaders led to a decision on Exelon's part to evaluate the capabilities of Predix.

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Evaluating Predix

During the evaluation process, Exelon realized that the GE vision for the Industrial Internet and the Predix roadmap were aligned with their long-term needs:

- **Ability to work with hardware from any manufacturer.** Exelon has GE wind turbines, but it also has equipment from other manufacturers. Exelon needed a solution that could work with all types of OEM equipment, GE and non-GE, today and in the future.
- **Ability to leave current systems intact.** Exelon needed a platform that interoperated effectively with existing on-premises systems. It did not want a cloud-only platform that would require “lifting and shifting” current systems to the cloud.
- **Cost-effective and scalable.** Exelon needed a solution that would enable the company and all its subsidiaries to realize the economies of scale, elasticity, global visibility, and re-use associated with the cloud.
- **Embrace new technologies.** Exelon needed to increase asset efficiency—as well as to maximize the life of an asset—by shifting from being reactive to proactive. This required the company to become a data-driven decision organization, using analytics to generate the insights they need.
- **Embedded security.** Exelon requires the highest level of security to protect critical infrastructure.
- **Industrial domain experience.** Building and operating machines requires a deep understanding of the physics involved to generate the insights required to support the wind forecasting requirement.

GE's co-innovation approach, sharing its own digital transformation journey experience and leveraging its vast experience working in industrial markets (one-third of the world's power comes from GE-powered machines), together with their commitment to work with Exelon across lines of business, encouraged Exelon to use Predix. As part of its decision-making process, Exelon vetted the GE solution map, verifying that it met the business needs of all of Exelon's power generation company verticals.

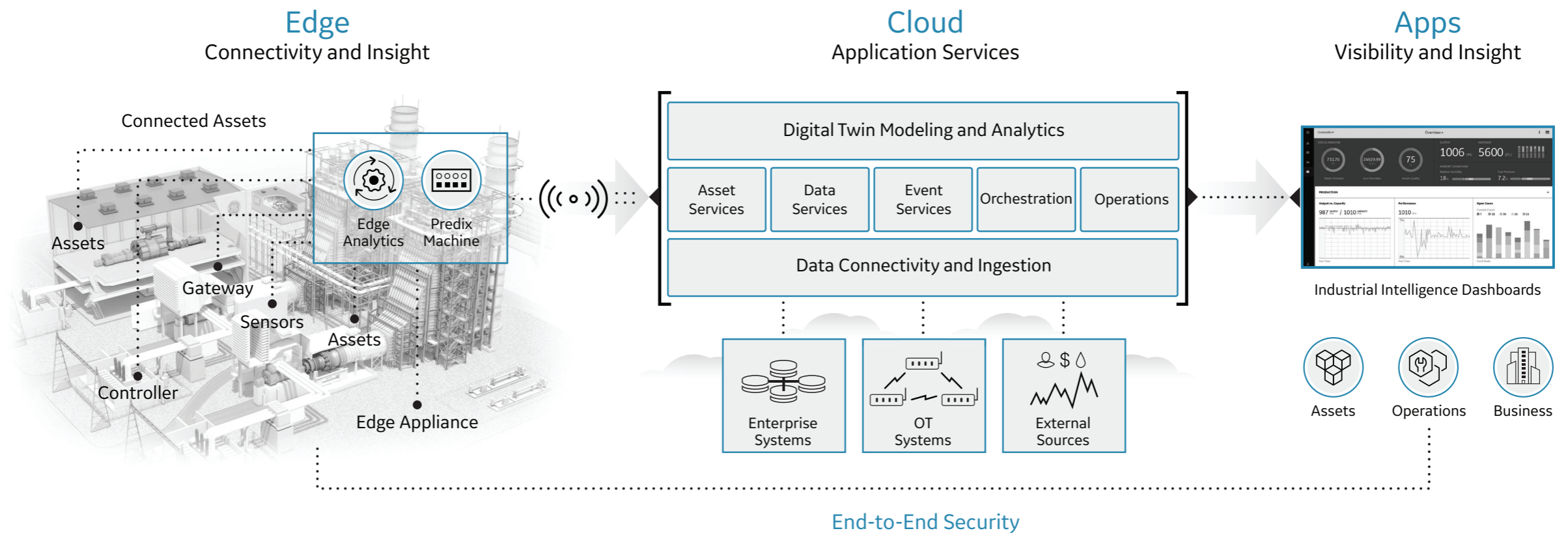
Predix is fundamentally different because it provides an edge-to-cloud solution with ready-built platform microservices that enable developers to rapidly write Industrial Internet applications.

One-third of the world's power comes from GE-powered machines.

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PREDIX



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The 5 minute wind forecasting challenge

A key challenge with monetizing wind power is that it is difficult to forecast times where you will have excess capacity, referred to as ramp events, in time to sell the power that will be generated. Forecasts are used by dispatchers, traders, and operations and maintenance planners in regulated and deregulated markets. An accurate forecast is key for all of these stakeholders.

Forecasts with different time ranges are required depending on the use case:

- Real-time forecasting for dispatching. Selling wind power requires forecasts in 5 minute intervals, for the next hour, updated every minute.
- Forecasts, in one hour intervals, for day-ahead volume and price bidding.
- Week-ahead forecasts, in one hour intervals, for scheduling operations and maintenance when there is little to no wind.

Furthermore, accurate forecasting requires the use of detailed meteorological data. Such data can be expensive if it comes from private data providers. Along with accurate forecasts, leveraging free data sources such as NOAA in the US can increase the profitability of wind farms.

In their current state, Exelon's wind forecasts were not responsive enough to predict wind ramp events. When wind farms had more capacity, they couldn't dispatch the additional power in the Midwest Independent System Operator (MISO) market because they could not anticipate quickly enough that the power was going to be available.

Requirements for the new wind forecasting solution

Exelon had the following requirements for its new wind forecasting solution:

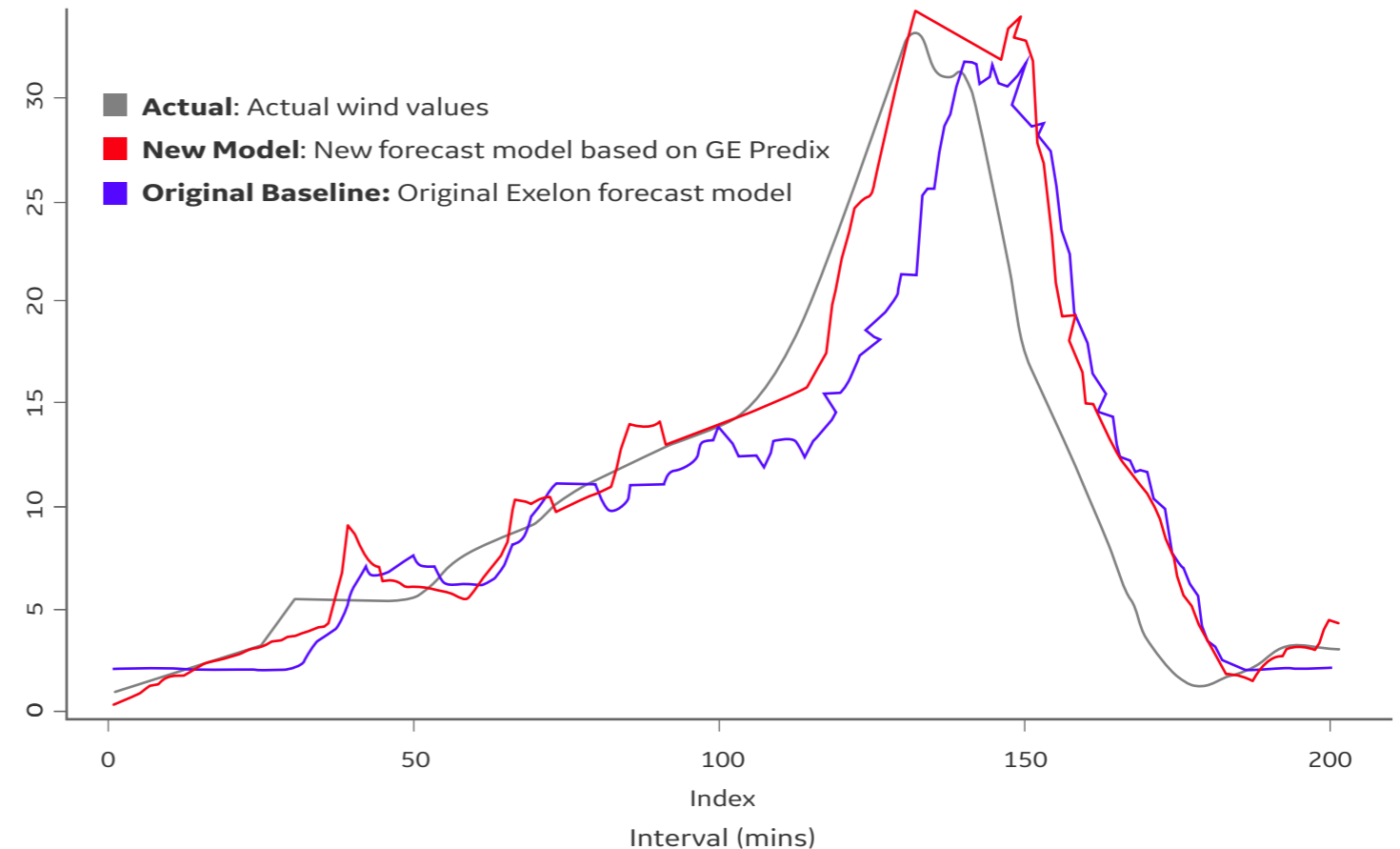
- **Reduce under-forecasting.** The solution needed to demonstrate increased accuracy compared with existing in-house and third-party forecasts, especially for ramp events.
- **Use existing infrastructure and fit in with existing processes.** The solution had to leverage data from Exelon's existing OT infrastructure, and in particular, its data historians, which collected data at the wind farm level. The solution must incorporate all relevant data, perform all required analytics, and write multi-level forecast results back to the data historian to feed downstream business systems.
- **Meet SLA requirements.** To meet expectations, the solution had to gather data, run analytics, and write results back in less than one minute in order to dispatch power every 5 minutes in support of real-time forecasting.
- **Scale well when rolled out widely.** The solution needed to quickly and cost-effectively scale from a pilot of 4 wind farms to 42 wind farms, with 1.5 GW total generation capability.
- **Work seamlessly with any wind turbine.** The solution needed to be OEM-agnostic and able to work for all Exelon wind farms regardless of the wind turbine manufacturer.
- **Use cutting edge data science techniques to gain insights** from Exelon's rich trove of wind forecasting data and measurably improve Exelon's existing forecasting models.

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Creating a wind forecasting solution on Predix

Exelon and GE took a co-innovation approach to creating the solution. Exelon had access to GE resources for data science, architecture, and software engineering as part of the solution development process.

Exelon provided GE with a year of historical data, enabling the data scientists to understand any diurnal and seasonal effects that would impact the forecasts, as well as specific operating characteristics for the 4 initial wind farms. With that information, the data scientists were tasked with reducing under-forecasting. The graph shows how the model built using Predix closely tracks the actual values, as compared with the baseline model that Exelon had created previously.



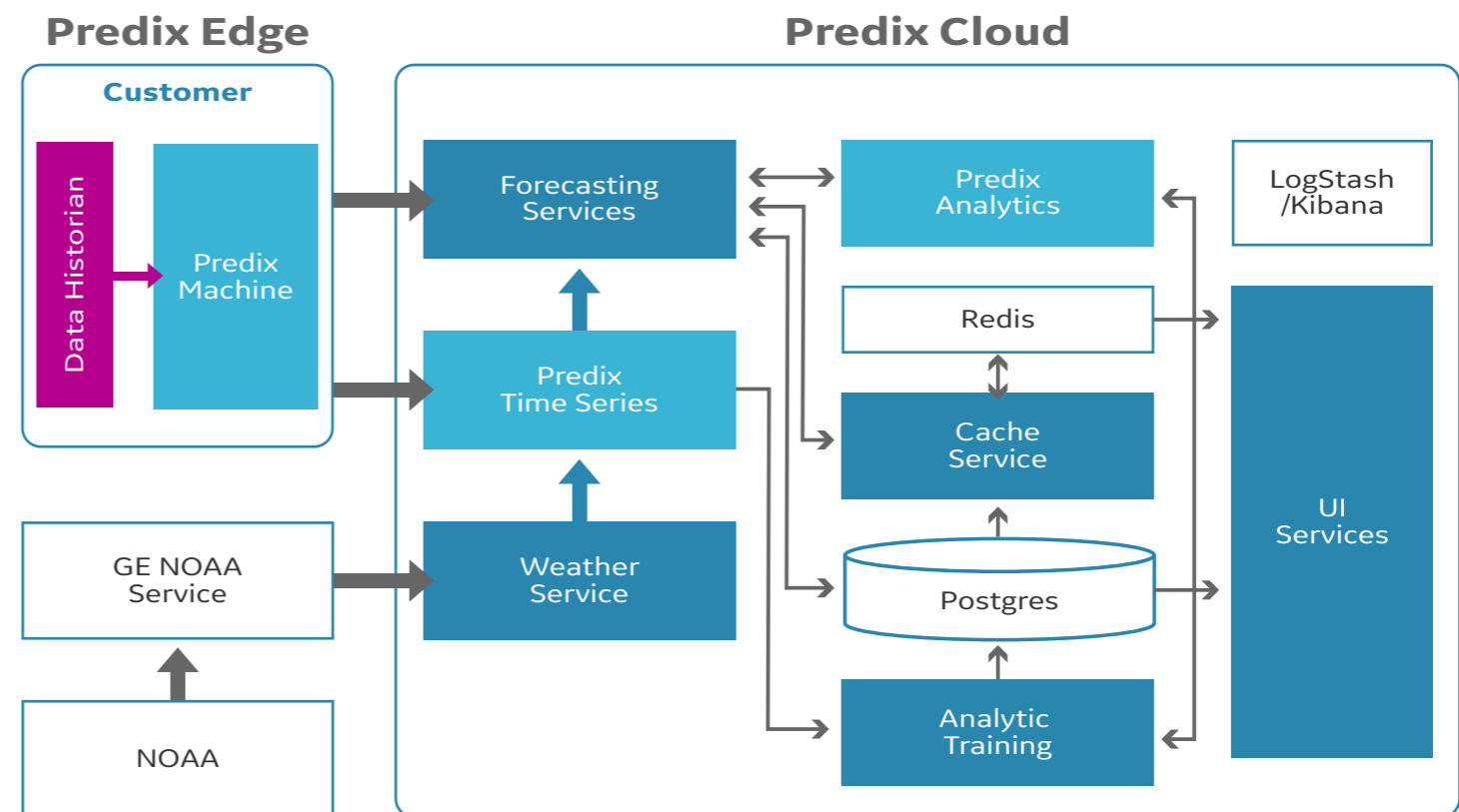
GE model forecast compared with actual generation and original baseline forecast

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The solution architecture in Predix

In the wind farm's current data architecture, information is aggregated at the wind farm level by a data historian. The data historian records and retrieves production and process data from all the wind farm assets over time, consuming data via OT protocols. Predix microservices transmit data from systems on the edge to the cloud. The Predix machine, running on an IoT gateway at the edge, connects to Exelon's data historian and reads data that it sends to the Predix cloud. In Predix cloud, data is ingested using Predix Time Series and analytics are performed (see diagram). The results of the analytics are, in this use case, written back to the data historian via Predix machine.

Note that the architecture is designed to utilize free weather data from sources such as the US National Oceanic and Atmospheric Administration (NOAA), avoiding the costs associated with paid weather data services.



Reference Architecture

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Role of analytics

The GE Renewables Data Science team created a net new model, a physical and statistical wind power forecast model based on historical data provided by Exelon. They incorporated diverse data sources and took into account seasonal or time-of-day effects. The result is an industry-leading forecasting solution as measured by a substantial reduction in under-forecasting.

The team was able to increase their time-to-market by using the powerful analytics capabilities (streaming, batch analytics) and higher level analytics languages (Python, MATLAB, Java) available in Predix. For wind forecasting, the analytics were coded in Python, including all the forecasts and data quality analytics. Data quality is essential for forecasting applications, and so the application needed to clean and validate the data prior to use, particularly because upstream systems such as data historians do not typically address data quality.

Forecasts being served by this application include:

- Real-time forecasting analytics: Useful for dispatching in real-time markets, this model forecasts wind power generation in 5-minute intervals for the next hour (it is updated every minute).
- Day-ahead forecasting analytics: This model predicts wind power generation in 1-hour intervals for volume/price bidding in day-ahead markets as well as reducing imbalance penalties.
- Week-ahead forecasting analytics: This model forecasts wind power generation in 1-hour intervals up to 7 days ahead for improved operations and maintenance planning, which enables maintenance to be scheduled during times that minimize impact on wind production and market commitments.

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Results

The wind forecasting application built on Predix was scalable to support wider rollout. The microservice architecture enables horizontal scalability. Additional wind farms are supported by creating additional instances of the analytics runtime for those wind farms.

The application performance is substantially better than Exelon's stated SLA (which was set at 60 seconds). The initial rollout of the application, which supports forecasts for four wind farms, consumed the data from the data historian, ran the analytics in Predix Cloud, and wrote back the results in just 18 seconds a (70% performance increase).

The model is tuned specifically to reduce under-forecasting, enabling Exelon to sell power generated by short-term ramp events. The results are impressive: the model increased the accuracy of predicting events significantly over the company's existing algorithm. This reduction in under-forecasting delivers a 1-3% annual energy production (AEP) gain through software alone, which is the equivalent of about 70 MW of new capacity, valued at about \$2 million per year fleet-wide.

While the model is tuned to reduce under-forecasting in real time, it also improved the other forecasts as well. Day-ahead generation relative forecast accuracy improved by 9%. The Week-ahead forecast enables outage planning so that maintenance can be deliberately scheduled when there is little to no wind, thereby minimizing revenue loss.

When characterizing this project, John Mostek, Operations Center Manager at Exelon, stated, "Working with GE and Predix has really accelerated the time-to-implementation beyond anything you could get just going out to the marketplace. The solution was designed to fit our exact needs right from the start."

The wind forecasting project was one of five initial projects across Exelon power generation verticals, including gas, nuclear, and wind. The success of these projects resulted in Exelon signing a long-term enterprise agreement with GE so that they can continue to develop Industrial IoT applications on Predix.

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John Mostek, Operations Center Manager, Exelon

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Next steps

Exelon plans to roll out the solution from the pilot of 4 wind farms to 42 wind farms.

From a Predix standpoint, the wind forecasting solution is being offered to Renewables customers as part of GE's Digital Wind Farm.

GE is building a value tracker that calculates the value of this application to Exelon as compared with the original baseline forecast. Data scientists plan to monitor accuracy of forecasts and continue to refine and improve the models. They are monitoring KPIs such as normalized root mean square error (nRMSE) and normalized mean absolute error (NMAE). If there is substantial variance, data scientists are notified so that the model can be retrained. Furthermore, data scientists plan to monitor by site, by type of forecast (real-time, day-ahead, and week-ahead), by seasonality, and by wind volume (low, medium, and high). Using this data, data scientists can support ongoing improvements to forecasts and further increase the accuracy of the models.

To Learn More

[Digital Wind Farm](#)

[GE Power and Utilities](#)

[“GE Renewable Energy Introduces New Suite of Digital Wind Farm Apps” \(press release\)](#)

[Minds and Machines: Electricity Reimagined \(video\)](#)

[Predix](#)