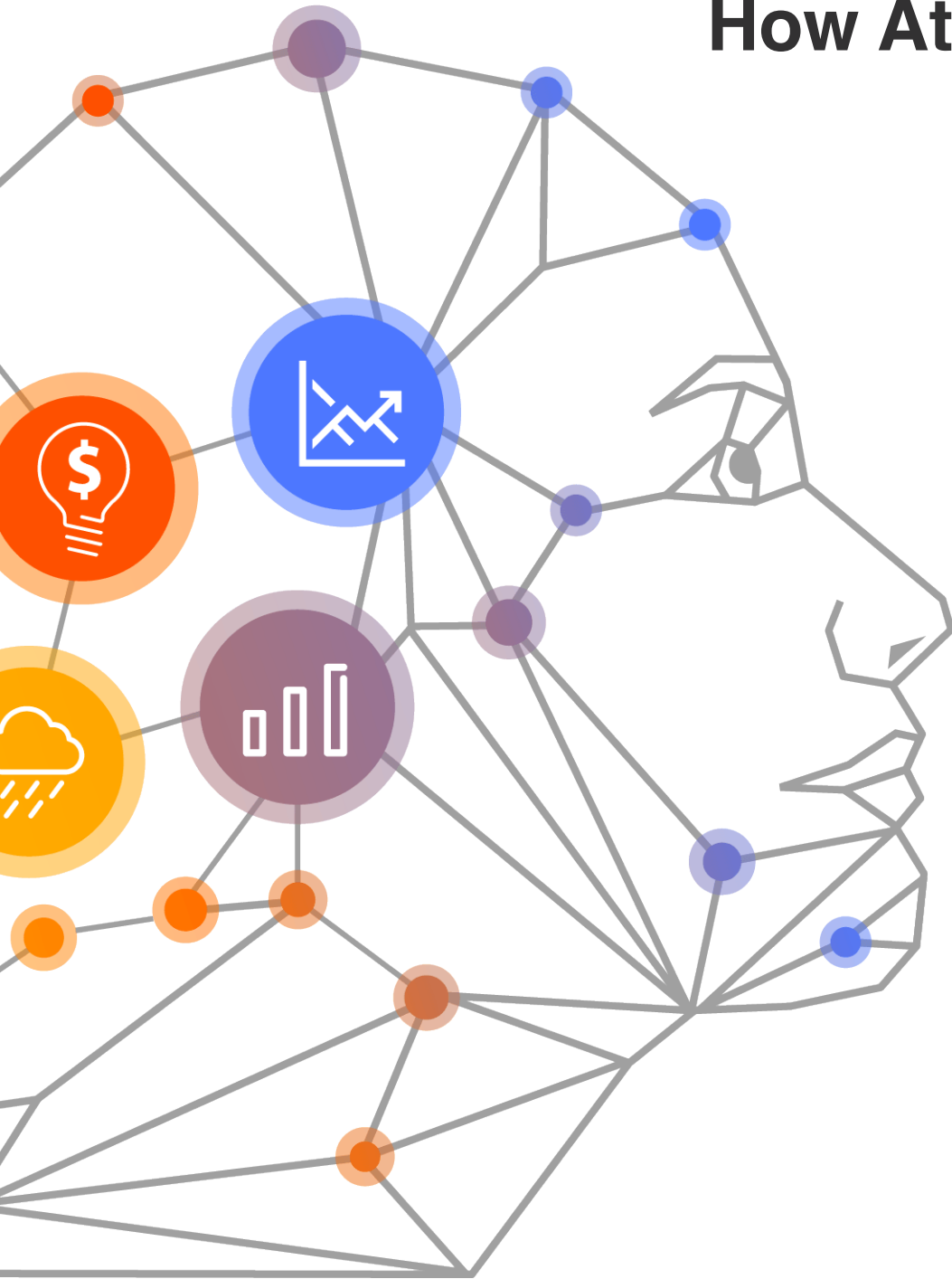


Artificial Intelligence for Energy Storage

How Athena Works



Executive Summary

Energy storage adoption is growing amongst businesses, consumers, developers, and utilities. Storage markets are expected to grow thirteenfold to 158 GWh by 2024; set to become a \$4.5 billion market by 2023.

Global cumulative deployment capacity, 2013-2024E (GWh)

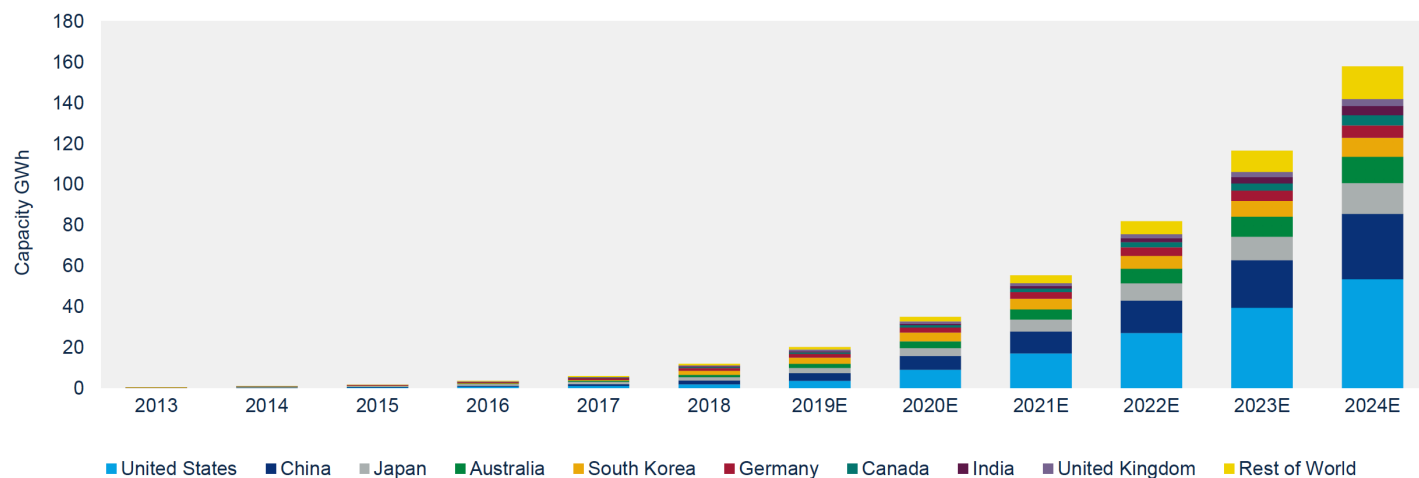


Figure 1 Source: Wood Mackenzie.

The growth of storage is changing the way we produce, manage, and consume energy. As regulators, lawmakers, and the private sector seek to address climate change and pursue renewable energy, they are looking to energy storage as the critical lynchpin. By delivering the flexibility to adjust the timing of electricity consumption and delivery, energy storage smooths the transition to a clean energy future.

The flexibility that energy storage provides is valued by numerous stakeholders, and enables a variety of value streams such as utility bill optimization, solar charging and solar self-consumption, backup power, incentive optimization, and wholesale market participation. Enterprises capitalize on these value streams to support their expense management and sustainability strategies, developers use them to enhance project economics, and utilities are able to integrate more clean generation, reduce system peak loads, and defer transmission & distribution investments.

Optimizing energy storage systems for multiple value streams and maximizing the value of storage assets depends on intelligent operating systems that analyze large datasets and make real-time decisions, automatically responding to changing conditions. Stem's operating system is Athena, the industry-leading artificial intelligence (AI) platform available in the energy storage market.

This whitepaper gives businesses, developers, and utilities an understanding of how artificial intelligence for energy storage works. It dives into Athena's features and Stem's principles that drive product development, and discusses how that supports our customers and partners. It includes real-world examples that demonstrate Athena's capabilities in the field.

Why AI for energy storage?

Energy storage is a game-changer for businesses, residences, developers, and utilities alike. Anyone that consumes, manages, or distributes energy directly benefits from the flexibility that energy storage delivers - whether that's the flexibility to buy energy at the cheapest times, to use more renewable energy, to sell energy at the best price, or to switch to backup power during a grid outage. Energy storage gives businesses an innovative way to manage expenses and become more sustainable, while allowing developers and utilities to increase the variety of services their projects can deliver.

But there is a grand misconception about the technology behind energy storage. Whether we are speaking to operations managers, energy managers, or developers, we find that many focus their evaluation on the battery hardware itself. While the quality of batteries and power converters is important for reliability, longevity and safety reasons, our customers find they have multiple choices of battery hardware providers.

However, the value of energy storage is not derived exclusively from batteries - the largest single value differentiator between energy storage systems is the software controls operating the system. Unlike passive energy technologies, such as solar PV or energy efficiency upgrades, energy storage is a dynamic, flexible asset that needs to be precisely scheduled to deliver the most value. Energy storage can be operated in a variety of ways to deliver customized services based on a customer's unique needs. For instance, a commercial customer may want to reduce peak demand charges while reserving power in the battery for backup during an outage, while a project developer may want to store power from a solar PV system and shift energy output to maximize revenue through participation in wholesale energy markets. In most cases, energy storage customers are capturing value from multiple different applications of the product, often four or more. But in order to deliver that value, battery operating systems have to make complex, real-time decisions about when to store or deploy power.

Savvy software controls are required in order to:

- Digest large and complex datasets such as rate structures, weather forecasts, price signals, and market participation rules
- Forecast energy demand onsite and on the grid
- Predict responses to changing signals in real-time
- Optimize battery flexibility to deliver value from multiple applications

Meet Athena

Stem's technology is built on state-of-the-art data and machine learning frameworks. Raw data is streamed from our fleet of connected batteries, solar panels and meters. This is married to critical data retrieved from utilities, markets and other data providers. When the data is ingested and prepared for use, the real fun begins. Let's examine where some of that data comes from.

Athena at the Edge

Athena's Edge Platform serves as the control hub of each customer or project site. The Edge Platform continuously collects extensive data from meters, breakers, energy storage and solar generation systems and conducts local, real-time control. At the site, Athena ensures safe and reliable battery operation. Athena resides on Stem's state-of-the-art industrial internet-of-things platform which allows us to constantly roll out new software to customers, while ensuring safety, security, and quality of service.

Athena in the Cloud

The Athena Cloud Platform is at the center of a network of Stem's edge devices, utilities, markets, and third-party data providers. This network streams huge volumes of data that is ingested by the Athena Cloud Platform, then processed and cleaned to ensure data is complete and accurate and any anomalies are detected. This Athena-engineered data is then published for Athena applications that include forecasting, optimization, performance reporting, incentive compliance, program and asset management, and other uses. Athena not only absorbs data, but also offers an extensive set of secure APIs that provide data access to multiple stakeholders. Athena's gateway services provide real-time integration endpoints that tie into utility and market control systems.

Athena Analytics

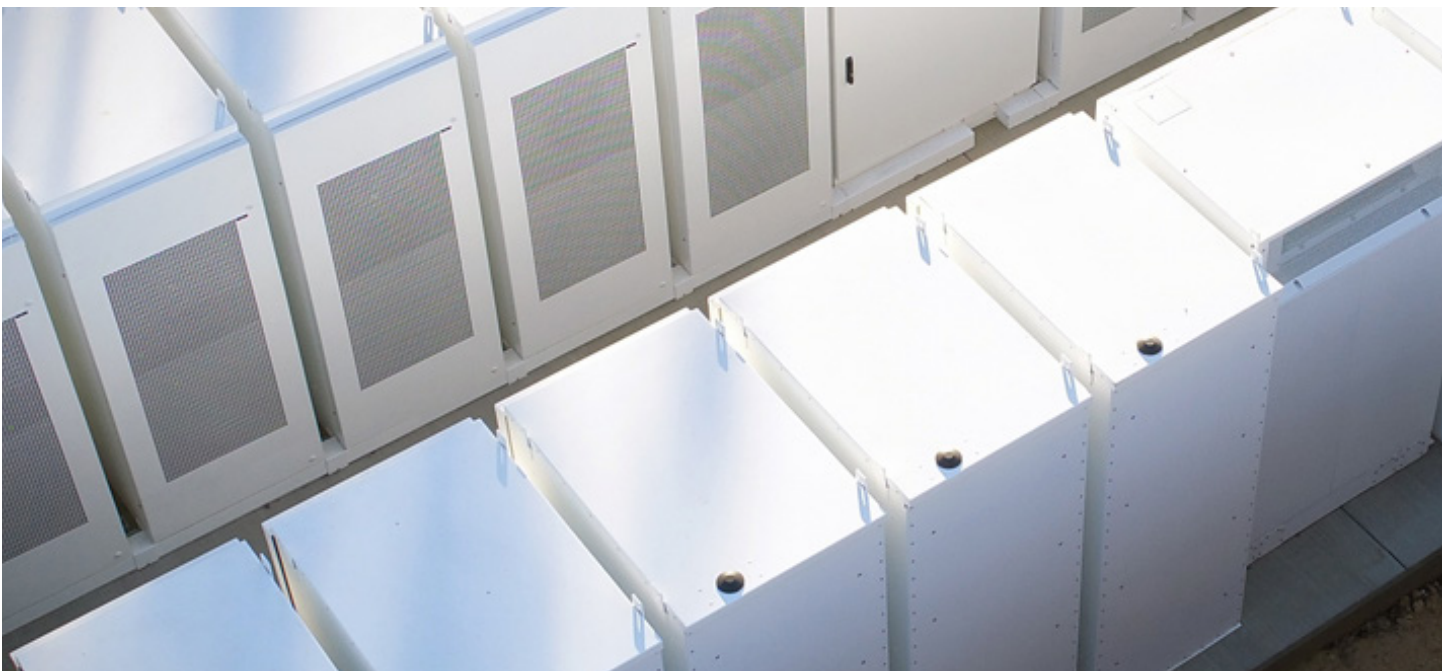
Athena's machine learning sees the future - forecasting the electricity demand of individual buildings and of wholesale markets, as well as distributed solar production. These machine learning models improve as they are given more data. With 3.5 TB of data used every year for forecasting, our models are getting pretty smart!

Athena's optimization engine uses these forecasts and a host of other data to maximize the value delivered by our networked energy storage. Energy and demand prices, whether from a customer's tariff or a wholesale electricity market, are critical inputs. Our optimization merges these price inputs with load forecasts, solar production forecasts, greenhouse gas (GHG) emissions data, value of backup, and other data as needed. Each site within Stem's network operates according to a uniquely optimized solution.

Managing a fleet of hundreds of sites with complex equipment configurations is not a job for human operators, but Athena's streaming data processing and anomaly detection algorithms support the Stem network operations team, alerting them to issues that require human intervention and automatically responding to others. Athena's heuristics include training to optimize battery life to extract maximum value from these consumable assets.

Customer and Partner Portals

After all that hard work, Athena wants to show off. The partner portals allow partners to simulate savings for new potential customers, and the customer portal allows partners and end users to see how Athena is operating their sites. The portal delivers savings data and gives customers insights into energy use trends at their site, empowering facility teams to take action. Athena's APIs allow Partners to pull data directly if desired.



Features and Advantages of Athena

Figure 2 depicts the foundations of Athena, including the Athena Edge Platform, Athena Cloud Platform, and Athena Analytics. Those foundational components of Athena deliver forecasting, monitoring, optimization, and automated controls capabilities. With those capabilities in hand, Athena is able to manage multiple applications such as bill savings, solar + storage optimization, market participation, and backup power. Athena's secure APIs and web portal provide critical data and transparency to partners, utilities, and grid operators.

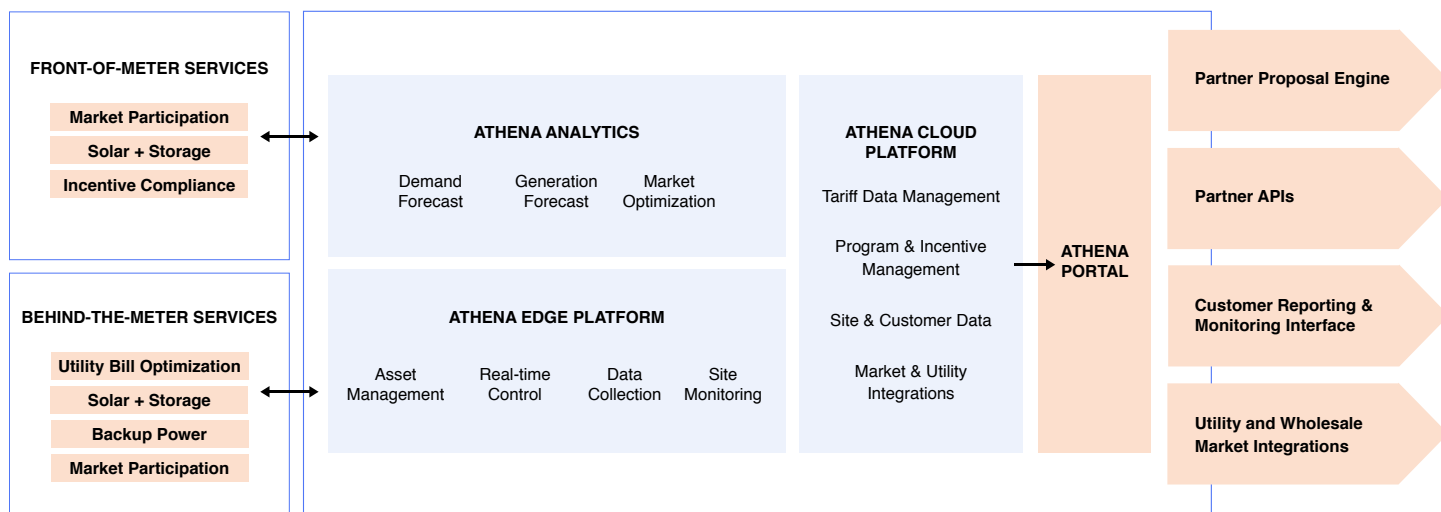


Figure 2 Athena's AI and Platform Capabilities Unlock a Broad Range of Value for Energy Storage

Component	Benefit	The Athena Difference
Athena Edge Platform	Precise, safe, and secure operation of energy storage at each customer site.	10 million runtime hours have hardened and constantly improved Athena's ability to optimally operate energy storage systems.
Athena Cloud Platform	Organization and cleaning of data from diverse sources, APIs and service endpoints for multiple stakeholder integrations.	Stem ingests and cleans approximately 1 terabyte of data every day, which allows us to efficiently deliver value across our growing network.
Athena Analytics	Accurately predict energy demand and market conditions, and optimize operation to deliver value while optimizing the use of the storage assets.	Athena has more and diverse data to make accurate forecasts. Breadth of experience in geographies, utilities, and markets allows us to deliver more value.
Customer and Partner Portals	User interface for customers to learn about their facility and for partners to generate proposals.	Over a decade of refinement of our customer-facing tools including rich and easy to integrate APIs.

Stem's Technology Principles

Stem helped create the energy storage industry. As a creator of this market, we have learned a lot over time, often from the early mistakes we made! This learning informs everything we do, from the way we monitor battery health to the way we forecast market demand. Breadth of experience in geographies, utilities, and markets allows us to deliver more value.

Accurate

Data is the foundation of AI and “data engineering” often comprises 80 percent of the job of a data scientist. Athena automates these data engineering processes to ensure our algorithms train on rich and accurate data.

Cloud-native

Stem is putting finishing touches on its 4th generation of software. Nearly every line of code has been re-written to improve the value we deliver. Our software is cloud-native and leverages a microservices architecture enabling us to release new software every day, so the hits keep coming!

Reliable

With over 10 million hours of total system run-time, Stem has learned a lot about how to keep systems healthy, available, safe, and secure. Our network operations center monitors the status of all sites, 24/7. Real-time alerting and diagnostic tools keep uptime at a maximum. We work closely with leading energy storage system suppliers to ensure that we operate systems in a manner that is safe, and prolongs the life of the battery.

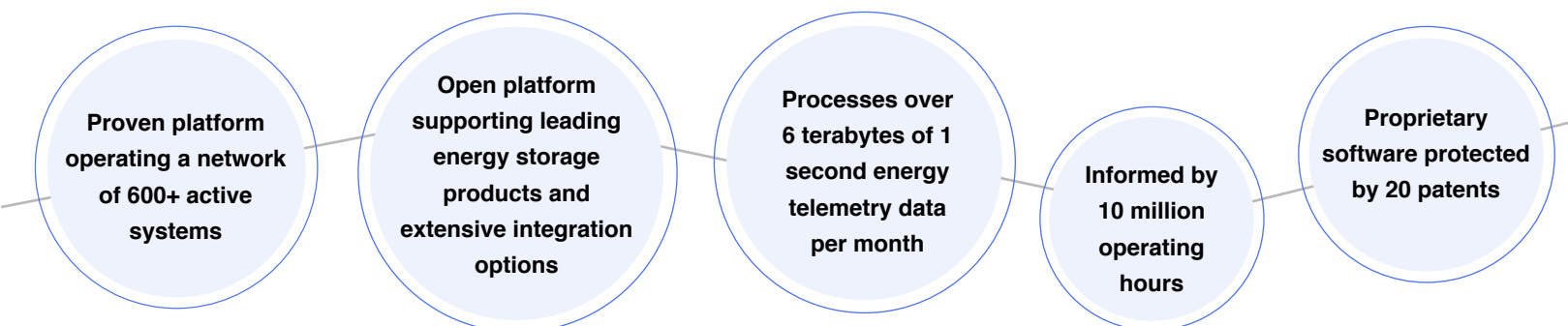
As a major operator of grid-connected systems, Stem is serious about cybersecurity. Both on customer sites and in the cloud, Stem utilizes multiple layers of security to ensure that our network is hardened against any malicious attack.

Flexible

Stem is determined to build the world's largest network of energy storage. This means preparing for and managing complexity. We navigate the shifting landscape of utility tariffs, constantly re-optimizing to ensure our customers receive the greatest benefit possible from storage. We handle compliance with incentives, and we integrate with utility programs and wholesale markets. Above all, we co-optimize these value streams, so that one battery can do the work of several. This ambition has caused us to build our software so it is ready to leap into the next market and provide the next application.

Open

We believe in the value of a partner ecosystem and that open platforms win. Our standards-based APIs and service endpoints mirror industry momentum behind newer standards such as REST, IEEE 2030.5, Sunspec as well as tried and true approaches like DNP3, Modbus and others. We our provide our partners access to data and services so they can build their own unique value leveraging Athena and the Stem network.



Athena Use Cases

Athena optimizes battery control for more than a dozen value streams, such as:

- Wholesale Market Participation
- Coincident Peak Management
- Solar Charging and Self-Consumption
- Grid Services
- Incentive Optimization (e.g. New York VDER, California SGIP, Investment Tax Credit)
- Demand Charge Management
- Global Adjustment Management
- Backup Power

A single battery asset can deliver value from multiple applications, but only with the help of an AI like Athena that can determine the value of different applications in real-time and prioritize accordingly. Three use cases are highlighted below.

USE CASE: SOLAR CHARGING

Athena forecasts on-site solar production and site loads to ensure energy storage system operations are in compliance with the solar Incentive Tax Credit, while co-optimizing other available value streams. In real-time, Athena captures solar production data and adjusts the system operations as needed to account for variances in solar production throughout the day.

Figure 3 shows a customer site in a given day. The solar production curve is in yellow, the metered site load is in green, the energy storage system discharge curve is in orange, and the energy storage charge curve is in light green. In this example, the energy storage system is lowering demand peaks that occur in the early morning and evening when solar production is low.

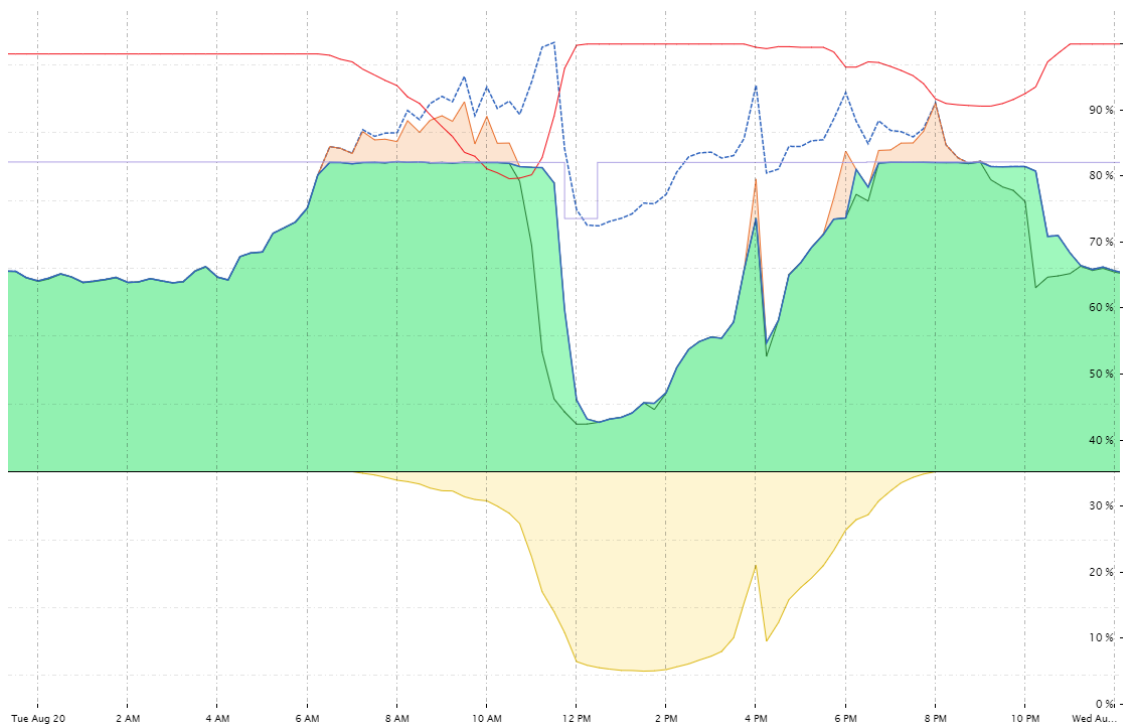


Figure 3

USE CASE: WHOLESALE MARKET PARTICIPATION IN CALIFORNIA

Athena automatically bids energy storage capacity into real-time and day-ahead electricity markets managed by independent system operators. As a result, project developers and customers earn revenue without any disruption to their facility.

Figure 4 represents a customer load that is supported by a 1 MWh Stem energy storage system. Of the 1 MWh capacity, 500 kWh participated in the Demand Response Auction Mechanism (DRAM), a wholesale market program in California that generated added value to this customer, on top of savings generated from demand charge management, the Investment Tax Credit (ITC), and solar firming.

Wholesale Market Participation in California

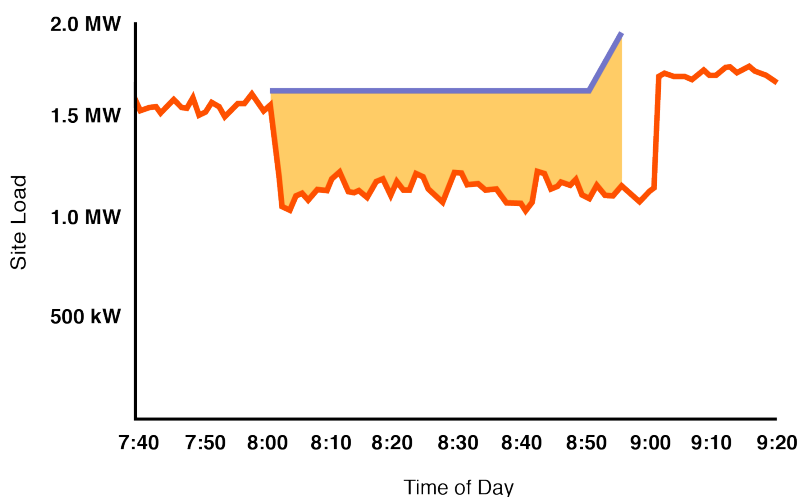


Figure 4

USE CASE: GLOBAL ADJUSTMENT MANAGEMENT IN ONTARIO

Commercial electricity rates in Ontario are largely based on facilities' contribution to systemwide peak demand. The Global Adjustment is the fee that commercial customers are charged based on their contribution to the system peak. Athena accurately predicts the timing of these system peaks and dispatches stored energy so organizations can dramatically lower their energy usage during peak times without disrupting their operations.

The Independent Electricity System Operator (IESO) in Ontario publicly shares its system forecasts, but their predictions are often not 100% accurate. Since everyone has access to this public forecast, many customers use the information to curtail their load, which often has a direct impact on systemwide demand,

changing the timing of when the peaks occur. Due to Athena's forecasting and real-time monitoring capabilities, Athena can accurately predict peaks, even catching some that the IESO does not accurately predict. Figure 5 depicts a day in July 2019 where Athena accurately predicted a peak that the market prediction did not catch.

Ontario Demand: Predicted and Actual

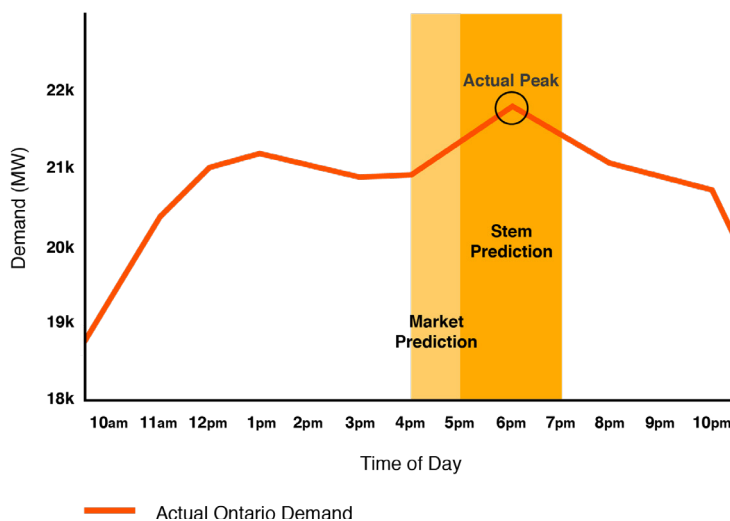


Figure 5

Summary and Key Takeaways

Energy storage is only as valuable as the software that operates it. An intelligent operating system is the key driver that enables energy storage to deliver value to businesses, residences, developers, and utilities.

Athena is the brains behind Stem's energy storage network. With more than 10 million operating hours and nearly 1,000 systems operating, Athena has ingested and analyzed far more data, and has more operating experience than any other energy storage software in the market. No other platform has the same track record, sophistication, and range of capabilities.

Stem's technology principles - accurate, cloud-native, reliable, flexible and open - ensure that Athena will be the market leader in energy storage intelligence for years to come.



**To learn more about Athena,
request a demo at stem.com/demo
or contact us at stem.com/contact.**