AMI 360: Deeper Energy Efficiency via Advanced Regression Modeling

Efficiency Vermont R&D Project

December 2021

Abiodun Iwayemi
Jeff Hullstrung
Daniel Jordan
Chuck Clerici
Abigail Hotaling
Alexander Kloumann

Efficiency Vermont
20 Winooski Falls Way
Winooski, VT 05404

Contents

Executive Summary

High frequency interval electric meters provide a rich set of data that Efficiency Vermont can transform into actionable insights that describe customer facility operation. The Efficiency Vermont research team developed a report template for an electric utility data intelligence report (EUDIR) that demonstrates how advanced metering infrastructure (AMI) electric meter data analysis can be interpreted and presented to provide the following information for a customer facility:

- Electricity usage profile
- Energy bills and cost drivers
- Building operating schedule
- Energy model explanation
- Energy efficiency project savings summary

The team developed this report template using feedback from internal focus groups that included Efficiency Vermont staff from the engineering, partner and customer engagement, and marketing departments. The goals of the report are to:

- Increase customer confidence in the savings estimates Efficiency Vermont provides for energy efficiency measures
- Uncover changes in facility energy usage when they occur
- Provide deeper insight into drivers of facility energy consumption and energy cost
- Equip Efficiency Vermont account managers with automated reporting they can use for engaging their customers
- Lower energy savings acquisition costs by finding and quantifying savings without installing submeters at a customer facility

Feedback from Efficiency Vermont's internal stakeholders resulted in iterative improvements of the template. The final report will serve as a software proof of concept with actual customer data and will be tested with a handful of Efficiency Vermont's large commercial and industrial customers. Once Efficiency Vermont has external customer feedback, the organization plans to leverage its infrastructure such that staff can automatically generate these reports for their customers and drive additional energy savings for ratepayers across the state.

Introduction

The deployment of advanced metering infrastructure (AMI) for electric interval and water meters across Vermont via the federal Smart Grid Investment Grant (SGIG) program in 2009[1] promised many benefits to utilities and their customers. The benefits include more resilient infrastructure, remote / wireless data collection, and the ability to quickly detect faults and outages without customers needing to call their utility. Much of this promise has been achieved; Vermont utilities reported related operations savings of $27 million as of early 2016.[2]

A considerable gain with AMI data is the transition from monthly to hourly or even 15-minute electric interval meter data. Similar to the difference between standard definition and high-definition television, AMI provides significantly higher-resolution data, equipping users to detect equipment usage patterns, hourly trends, and the hours in which peak events occur.

Energy market transformation is continuing apace, and the low-hanging fruit of certain energy efficiency measures, such as lighting retrofits, is rapidly disappearing. This challenge has prompted the question of how Efficiency Vermont can use AMI data to provide actionable insights and uncover opportunities that would otherwise go unnoticed.

One of Efficiency Vermont's goals is to provide customers with targeted and specific recommendations that drive energy-efficient facility operation. This project aims to provide Efficiency Vermont account managers and energy consultants with tools to remotely identify energy efficiency opportunities via AMI data, track the performance of existing efficiency projects, and communicate this information to customers as simply and accessibly as possible.

Background

Many changes can occur in a customer facility that significantly affect its energy use, and detecting these changes in a timely way is challenging. It requires manual attention and scrutiny of energy data, which is difficult given the number of tasks facility managers juggle.

Separately, the COVID-19 pandemic highlighted the value of performing remote diagnostics and analysis, especially when site visits aren't possible for safety or logistical reasons. In late 2020, to keep staff and customers safe, Efficiency Vermont stopped site visits and limited its interactions with customers to teleconferencing and phone calls. The organization explored ways to serve customers remotely and provide insights into facility energy usage. Efficiency Vermont also wanted to help customers that had reduced their production levels check whether their facility energy usage had declined appropriately, or if they were leaving equipment on that they thought was off.

---

[1] Smart Grid, Department of Public Service, State of Vermont. https://publicservice.vermont.gov/electric/smart_grid.
[2] "Report on Savings Realized Through the Use of Smart Meters Pursuant to 30 V.S.A. §2811(c)." https://publicservice.vermont.gov/sites/dps/files/documents/Electric/Smart_Grid/2016%20Report%20on%20Savings%20Realized%20Through%20the%20Use%20of%20Smart%20Meters.pdf.

These opportunities led Efficiency Vermont to research harnessing AMI data to get a detailed view of customer facility usage in order to provide actionable insights to Efficiency Vermont's customers, and to drive greater energy efficiency. The ability to routinely detect and highlight facility energy usage changes in automatically generated monthly or quarterly reports could provide Efficiency Vermont's account managers with a powerful data-informed customer engagement tool. Such a report would highlight any changes to the facility since the last reporting period and would provide account managers with valuable information they could share with their customers to drive energy efficiency and detect hidden problems.

AMI DATA

The U.S. Department of Energy (DOE) defines AMI as "an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers."[3] The DOE provided SGIG funding across the country for the deployment of AMI infrastructure in 2009. These grants made $69 million of funding available to electric distribution utilities in Vermont to deploy smart grid infrastructure throughout the state.[4] These deployments, combined with the Vermont Public Utility Commission's Order in Docket No. 8316[5] authorizing distribution utilities to provide Efficiency Vermont with billing and AMI interval usage data, enable Efficiency Vermont to have access to AMI data from most Vermont utilities that collect it.

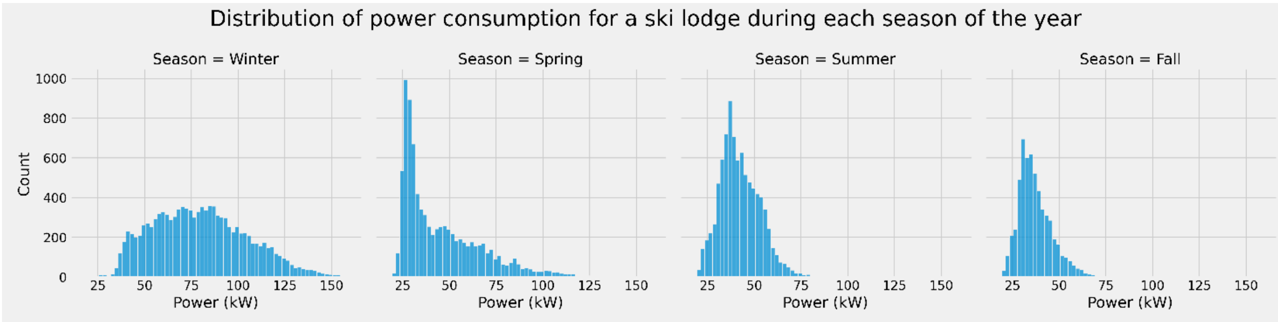
Monthly meter data provide 12 readings per year, whereas AMI smart meters generate 8,760 data points (for hourly data) or 35,040 readings (for 15-minute intervals) per year. Having such granular data equips Efficiency Vermont to answer the following questions about electrical energy consumption:

- What is the time of use of electricity?
- How much electricity is used at that time?
- What is the outdoor temperature at that time?

The first two questions are relevant for both grid peak loads and grid emissions. AMI data allow Efficiency Vermont to observe hourly and seasonal variations in usage, as shown in Figure 1. This figure illustrates the seasonal distribution of electric power demand at a ski lodge using 15-minute interval data. The granular interval data show that on average, winter usage is about 75 kW and peaks exceed 150 kW, whereas summer usage is about half of that.

[3] "Advanced Metering Infrastructure and Customer Systems: Results from the Smart Grid Investment Grant Program." https://www.energy.gov/sites/prod/files/2016/12/f34/AMI%20Summary%20Report_09-26-16.pdf.
[4] Smart Grid, Department of Public Service, State of Vermont. https://publicservice.vermont.gov/electric/smart_grid.
[5] Docket No. 8316, Vermont Public Utility Commission, *Order Re Use of Advanced Metering Infrastructure Data by Efficiency Vermont, October 30, 2018*. https://epsb.vermont.gov/?q=node/104/27082.

Figure 1: Distribution of 15-minute power draw for a ski lodge during each season of a year



With the 360-degree view that AMI data provide into how a customer facility is using energy, analysts can:

- Calculate savings for energy efficiency projects
- Provide recommendations on the most effective efficiency measures
- Track the performance of energy efficiency measures and verify the performance persistence of those measures
- Identify problems such as unexpected changes in facility usage patterns

MAKING DATA ACCESSIBLE

This project builds on three developments: 1) the findings of Efficiency Vermont's 2020 research and development project on advanced regression modeling,[6] 2) feedback from Efficiency Vermont's account management staff, and 3) lessons from Efficiency Vermont's customer interactions during the first six months of the COVID-19 pandemic. These inputs informed the creation of an electric utility data intelligence report (EUDIR) that presents the following information:

- Electric load breakdowns that show what portion of a customer's electric bill is driven by peak load and baseload
- Building usage schedule, or the hours of operation of a building inferred from how much electricity is used at each hour of the day
- Building energy models that capture baseline facility energy consumption, predict future usage, and highlight deviations from expected usage
- Changes to any of the above since the prior reporting period (for example, a quarter-over-quarter change)
- Insights based on the above, as well as customized recommendations and action items for the customer

[6] "What's going on in there? Interpretable machine learning for deeper energy savings." https://www.efficiencyvermont.com/news-blog/whitepapers/what-s-going-on-in-there-interpretable-machine-learning-for-deeper-energy-savings.

The EUDIR equips Efficiency Vermont to accurately perform remote energy audits for its commercial and industrial customers. The EUDIR also:

- Potentially helps customers achieve greater savings
- Increases customer confidence in the savings estimates Efficiency Vermont provides
- Provides deeper insight into drivers of facility energy consumption, including weather dependence, baseload consumption, and peak load consumption

Methodology

Internal cross-functional focus groups at Efficiency Vermont explored ways to visually represent AMI in the EUDIR report. The groups included subject matter experts from the following departments: partner and customer engagement, engineering, and marketing.

Efficiency Vermont chose these focus group members either because they had worked with the initial target market of large commercial and industrial customers or because they possessed valuable experience and perspectives that would inform the proposed report.

The project team processed AMI data stored in Efficiency Vermont's data warehouse using the modeling methods described in the 2020 report.[7] The team used open-source Python libraries and packages such as Streamlit,[8] Pandas,[9] Matplotlib,[10] and Altair[11] to create interactive data tools for visualizing the processed AMI data and generating the charts and analysis shown in this report. The team created several iterations of the report, soliciting focus group feedback with each iteration.

Visualizing AMI Data

The stakeholder-approved and customer-specific EUDIR report design includes the following sections:

- Electricity usage profile
- Energy bills and cost drivers
- Building operating schedule
- Energy model explanation
- Energy efficiency project savings summary
- Glossary

[7] "What's going on in there? Interpretable machine learning for deeper energy savings." https://www.efficiencyvermont.com/news-blog/whitepapers/what-s-going-on-in-there-interpretable-machine-learning-for-deeper-energy-savings.
[8] https://streamlit.io/.
[9] https://pandas.pydata.org/.
[10] https://matplotlib.org/.
[11] https://altair-viz.github.io/.

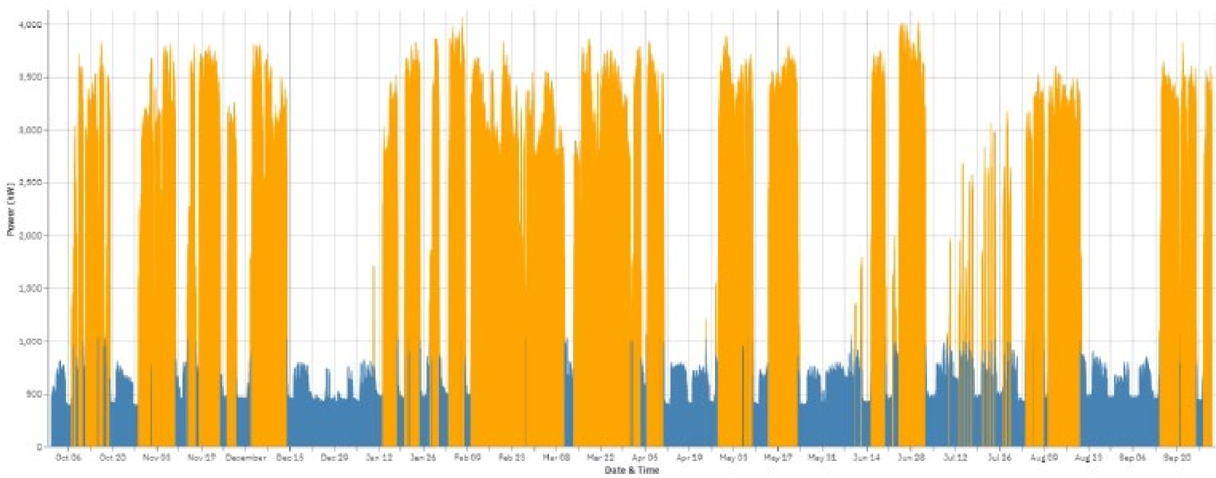
Each report section, covered in more detail below, presents a chart followed by a table summarizing key insights and recommendations based on the specific findings in the chart to support the customer in interpreting the data and identifying opportunities for improvement. The glossary defines the technical terms used in the report.

REPORT SECTIONS

Electricity Usage Profile

The electricity load profile, as displayed in Figure 2, consists of a color-coded time series chart showing the peaks (in yellow) and "resting" load (in blue) of a customer facility over 12 months from October year 1 through September year 2. It depicts when and how frequently the peaks and troughs occur.

Figure 2: Electricity load profile chart

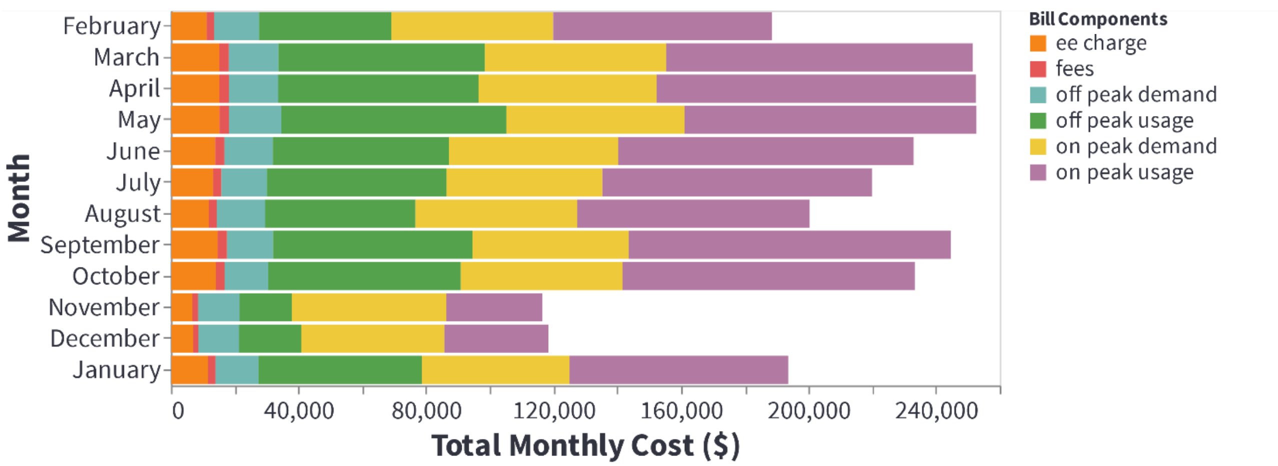


KEY INSIGHTS	SUGGESTIONS
Your facility spends **50%** of its time in **base load state**	• Reducing the base load, peak load, and/or number of peak events would reduce energy cost
Your power demand **never falls below 300kW**	• There may be opportunities to turn off additional loads during non-productive times • An Energy Treasure Hunt may identify opportunities to reduce costs

Energy Bills and Cost Drivers

As shown in Figure 3, the report provides an estimated bill breakdown with an accuracy of +/- 5% for February year 1 through January year 2. Illustrating the bill components in this way offers customers insights into what's driving their costs (for example, peak load charges) and enables Efficiency Vermont staff to identify and recommend measures for reducing costs.

Figure 3: Customer bill cost by component chart

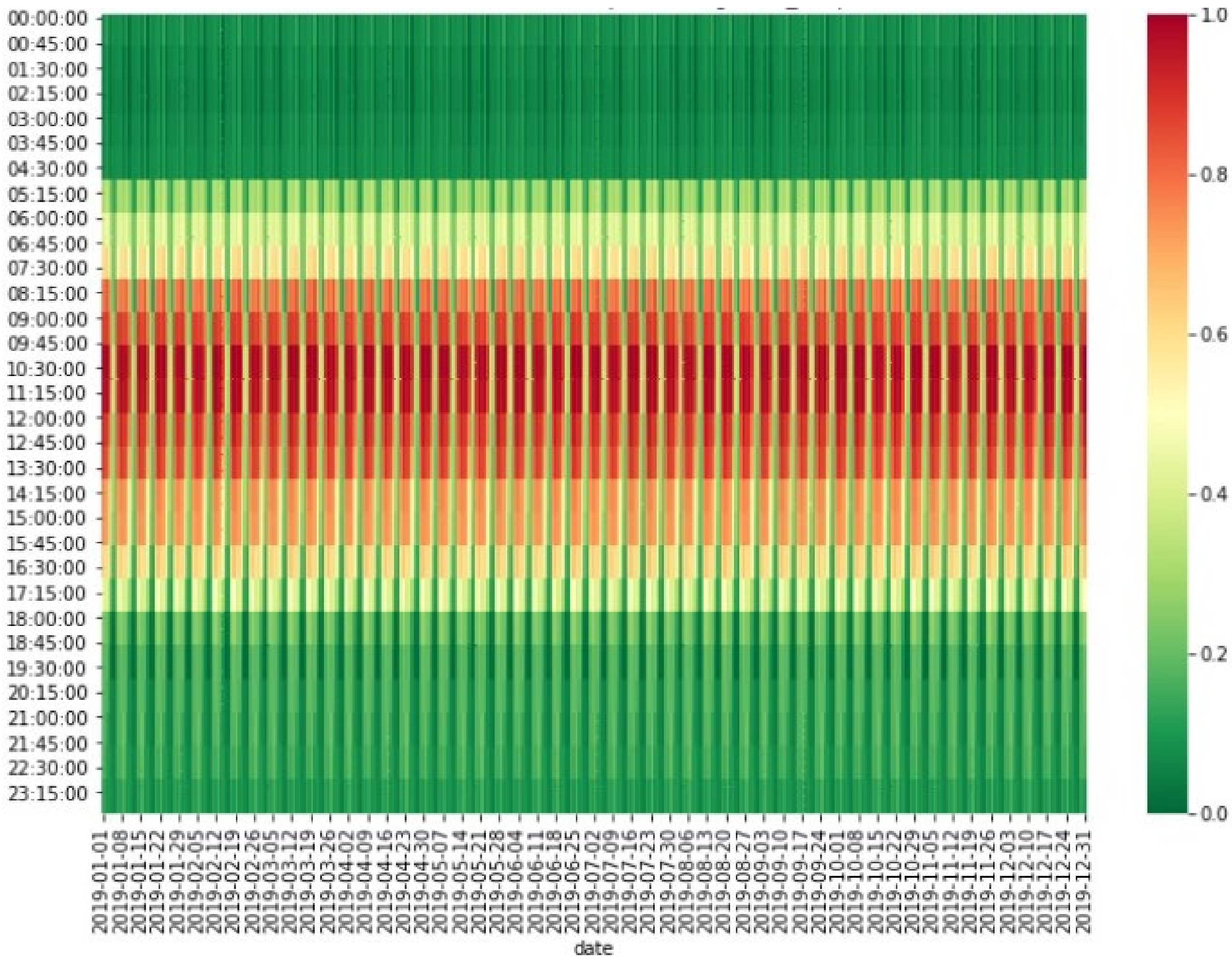


KEY INSIGHTS	SUGGESTIONS
Your **total electric costs** for this period are about **$2,400,000**	• This represents a 5% increase over last period
On-peak energy and **on-peak demand** are the largest components of the bills	• Shifting loads to off-peak periods would lower costs • A flexible load analysis may be a worthwhile means to explore cost reduction opportunities

Building Operating Schedule

This section, shown in Figure 4, uses a heatmap of the AMI data to visualize the facility's operating schedule. The heatmap equips Efficiency Vermont's customers to determine whether their power consumption matches their expectations and helps them detect unexpected usage patterns based on time of day and day of week. For example, it will highlight electricity usage that occurs outside expected operating hours.

Figure 4: Building operating schedule heatmap

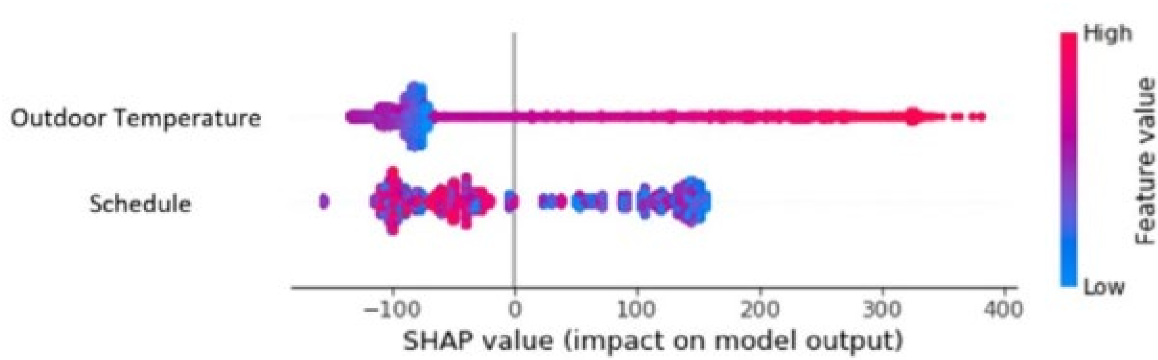


KEY INSIGHTS	SUGGESTIONS
Building operations **ramp up at 6:00 AM** and **ramp down at 6:00 PM**	• If this differs from your expected schedule, optimization can be considered
Demand tends to **peak between 10:00 AM and 12:00 PM**	• It may be worthwhile exploring if loads can be shifted earlier or later
Weekend loads are **considerably lower** than weekday loads	• The facility appears to be unoccupied and may benefit from a weekend Energy Treasure Hunt

Energy Model Explanation

The energy model explanation provides a visualization of the relationships learned by the energy model from the customers' AMI data. This model baselines the customer's electricity usage and allows Efficiency Vermont to predict future usage with inputs such as outdoor air temperature and the building schedule. For example, in Figure 5 the higher outdoor air temperatures (red values) are correlated with higher energy consumption.

Figure 5: Energy model interpretation chart



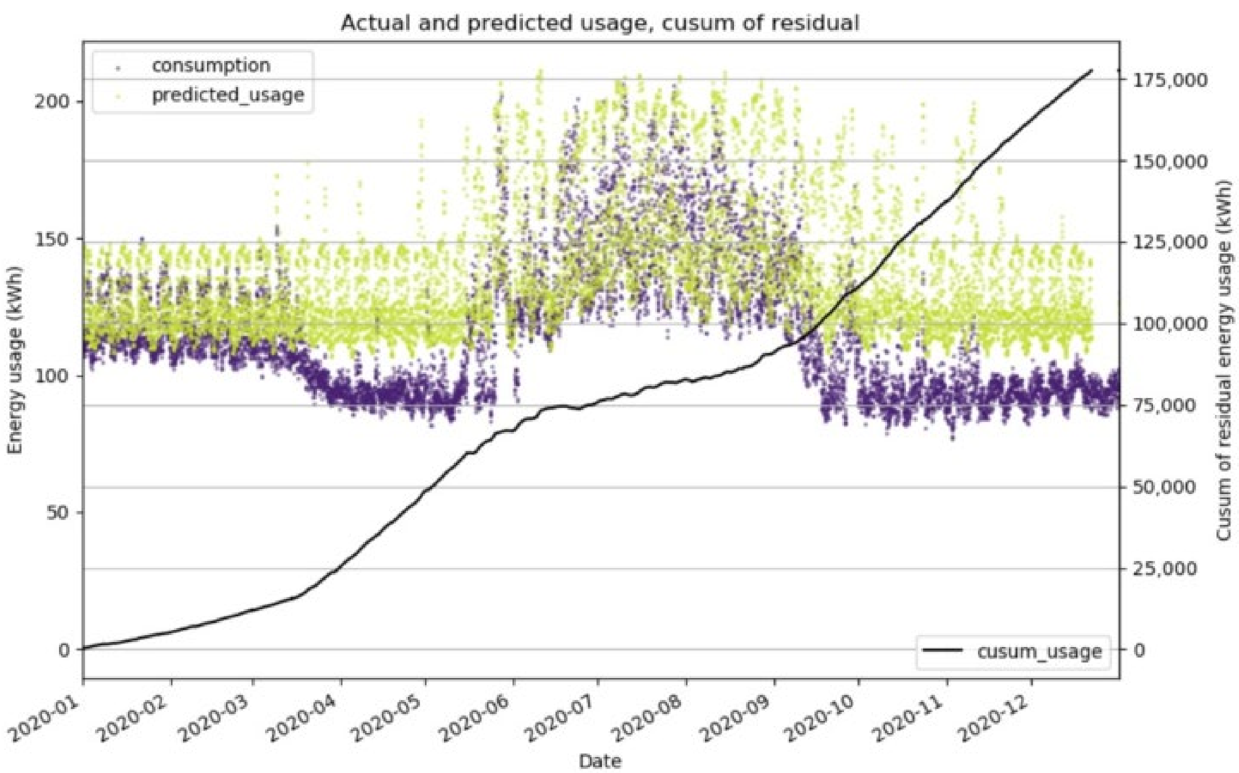
KEY INSIGHTS	SUGGESTIONS
Outdoor air temperature is **strongly correlated** with power demand	• Electric cooling loads appear to be more impactful than electric heating loads • Retrocommissioning the cooling system may reduce energy costs
Time of day and **day of week** are less important but still show a large range of demand values	• Shifting loads from times of high demand to times of low demand may result in cost savings

Energy Efficiency Project Savings Summary

If a customer has completed an energy efficiency project with Efficiency Vermont, this section includes a cumulative sum (CUSUM) chart showing the accumulated savings of that project over time. This visualization allows Efficiency Vermont to celebrate efficiency wins or, conversely, investigate if the expected savings have not materialized.

For example, the chilled water system improvement project shown in Figure 6 is saving energy in the shoulder season and December, and the total energy savings are in line with the modeled predictions, verifying the value of the energy efficiency investment, which is a win for the customer.

Figure 6: Energy efficiency project savings summary chart



KEY INSIGHTS	SUGGESTIONS
The **energy savings of 18%** are **in line** with the estimate that we developed	• This represents an annual energy cost savings of $42,000
The system performance **improved** after **September 2020**	• Optimizing the controls was worthwhile

Conclusion

Efficiency Vermont's internal testing indicated that using AMI data to create a summary of building operating patterns would equip Efficiency Vermont staff with a tool for rapidly detecting, summarizing, and highlighting patterns and changes in energy usage at a customer facility. It can also provide an effective tool for engaging customers on energy usage in their facility, identifying energy efficiency opportunities, and tracking the performance of prior projects with customers.

Going forward, Efficiency Vermont will use the EUDIR to create a software proof of concept with actual customer data. Efficiency Vermont will test this proof of concept with a handful of its large commercial and industrial customers. Once the team has external customer feedback, it plans to leverage the organization's infrastructure to allow staff to automatically generate these reports for their customers, thereby driving additional energy efficiency savings for ratepayers across the state.