energy toolbase

iEMS In-Depth Case Study

Using Energy Storage and Solar to Capture 71% of the Maximum Possible Demand Charge Savings for a Commercial Customer in Northern Canada

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Executive Summary

The Energy Toolbase Intelligent Energy Management System (iEMS) was installed alongside an Eguana Technologies storage system for an engineering and construction company in Alberta, Canada. The goal was to determine how efficiently the iEMS peak shaving algorithm could reduce demand for a facility with solar photovoltaic (PV) generation and electric vehicle chargers, located in a northern Canadian climate zone. The Energy Storage System (ESS) was commissioned in September of 2018. The iEMS was originally installed by Pason Power, who Energy Toolbase merged with in September of 2019.

Figure 1 - Customer's Building

The in-depth case study documents numerous challenges, learnings, and successes that occurred during the first year of operation. For example, we unpack two unanticipated operational issues that negatively affected the performance of the iEMS: (i) how snow cover materially impacted PV performance, which needed to be accounted for in the iEMS machine learning algorithm; and (ii) how significant changes to the customer's load profile, stemming from a change in electric vehicle (EV) charging, adversely affected demand savings.

The end results of the case study were overwhelmingly positive: solar PV was able to reduce 25% of the site's maximum demand and the addition of the iEMS-enabled storage system shaved an additional 24%. Over the course of the first year, the combined system captured 71% of the maximum demand savings possible. This includes two months of sub-par performance due to the unexpected issues mentioned above. The results section of the case study details specific instances where: (i) the iEMS reduced peak demand to compensate for days where there was no PV production; and (ii) the iEMS complimented PV system production to shave shoulder load and achieve elevated levels of demand reduction. Lastly, it is important to mention that the iEMS's peak shaving performance generally improved throughout the case study period, which demonstrated its ability to learn and improve over time.

Project Description

The Eguana Elevate energy storage system that was installed had a rated max power of 15 kW and energy capacity of 39 kWh. The project was sited at an engineering and construction company located near Edmonton, Alberta. The customer's building is approximately 10,000 square feet (930 square meters) and includes a mix of both office and warehouse space. The customer's load profile is representative of a typical office building, where the primary load occurs during business hours, from 8 am to 5 pm, Monday through Friday.

Figure 2 - Customer's location near Edmonton, Alberta

This customer had previously installed a 45 kW DC-rated solar PV system, as well as a level 2, 20 kW EV charger, at their site. During the case study period, the customer's maximum annual demand was 34 kW. Therefore, the PV power to peak demand ratio was roughly 1.3x. This is considered a high ratio, meaning the solar PV system was sized large relative to site load. Given that the customer's load profile generally overlapped with the solar PV production profile, and their PV system was generously oversized at 1.3x relative to site load, the host customer anticipated the solar PV system would provide meaningful demand charge savings. However, the most extensive study performed to date that explored demand charge savings from commercial solar[1] concluded that solar PV alone does not significantly or consistently reduce demand charges and does so with diminishing returns for large PV to site load ratios. Therefore, the site owner decided to employ energy storage to further maximize their ability to reduce demand charges.

One of the primary project goals was to determine how efficiently the iEMS enabled energy storage system could shave peaks and help firm-up demand reductions from PV. In the results section of the case study we quantify how much demand reduction was attributed to the solar and energy storage system independently. One other factor that made this project unique was having to contend with larger variances in solar production caused by snowfall. While the iEMS performs well in temperate climates, Edmonton has an annual average snowfall of 49 inches (124 cm), peaking in January at 9 inches (23 cm) for the month. This environment was expected to provide an untested real-world scenario for the iEMS.

[1] NREL/LBNL, Exploring Demand Charge Savings from Commercial Solar: https://emp.lbl.gov/publications/exploring-demand-charge-savings-0

Installation & Commissioning

The Eguana Elevate storage system was installed in September of 2018. The 15 kW, 39 kWh ESS, which utilizes LG Chem lithium batteries, fits on a standard size shipping pallet (see Figure 3). The Elevate unit comes equipped with an Energy Toolbase intelligent energy management system, which runs on a ruggedized, industrial computer. The iEMS comes standard with a performance guarantee and includes 10 years of software updates.

This Elevate system was installed indoors due to the cold Canadian winter being unsuitable for lithium battery technology. The unit is capable of being sited outdoors in climates where the temperatures range between 5 to 122 degrees Fahrenheit (-15 to 50 degrees Celsius). After the unit was placed onsite, the total installation and commissioning took less than half a day with a single journeyman electrician. The system was energized as soon as the electrical connections were hooked up and the iEMS controller was connected to the internet via ethernet cable.

Figure 3 - Eguana Elevate ESS at Customer's Site

Once the system went live, the site owner was able to use a web browser to log into Energy Toolbase's Energy DataHub software platform. Energy DataHub provides complete transparency into the real-time operational performance and savings of solar + storage systems operating in the field. End users can track and monitor all relevant system data analytics to comprehensively understand performance. Furthermore, Energy DataHub can remotely diagnose and fault correct issues before they become costly. Energy DataHub offers numerous data visualization screens, displaying energy usage, PV production, energy storage dispatch, and state of charge (SoC) (see Figure 4).

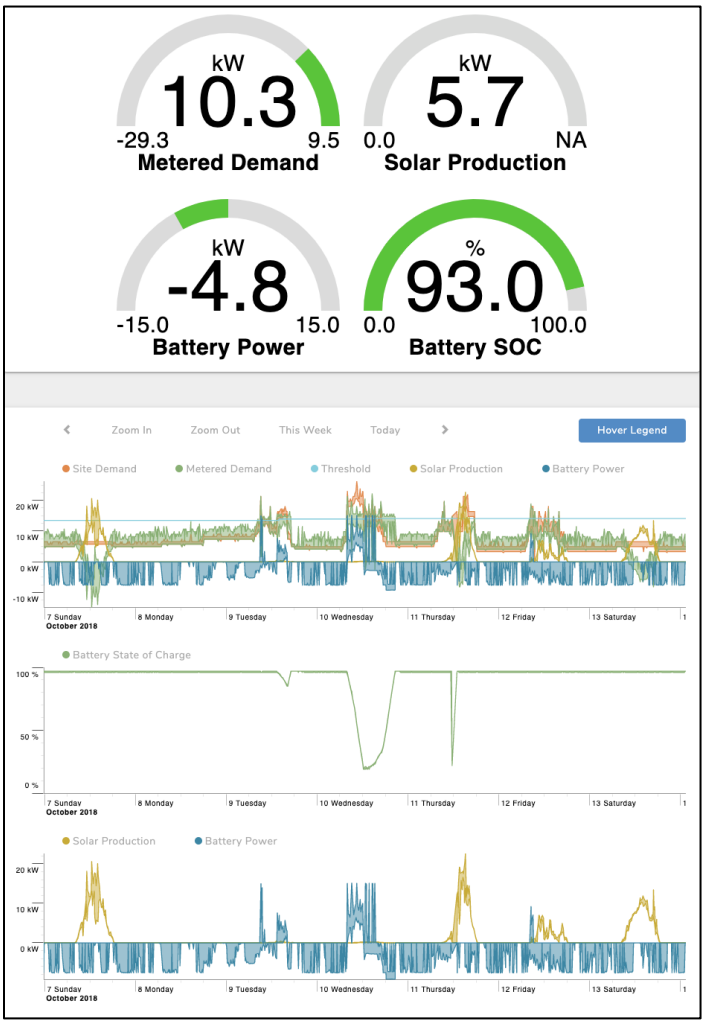
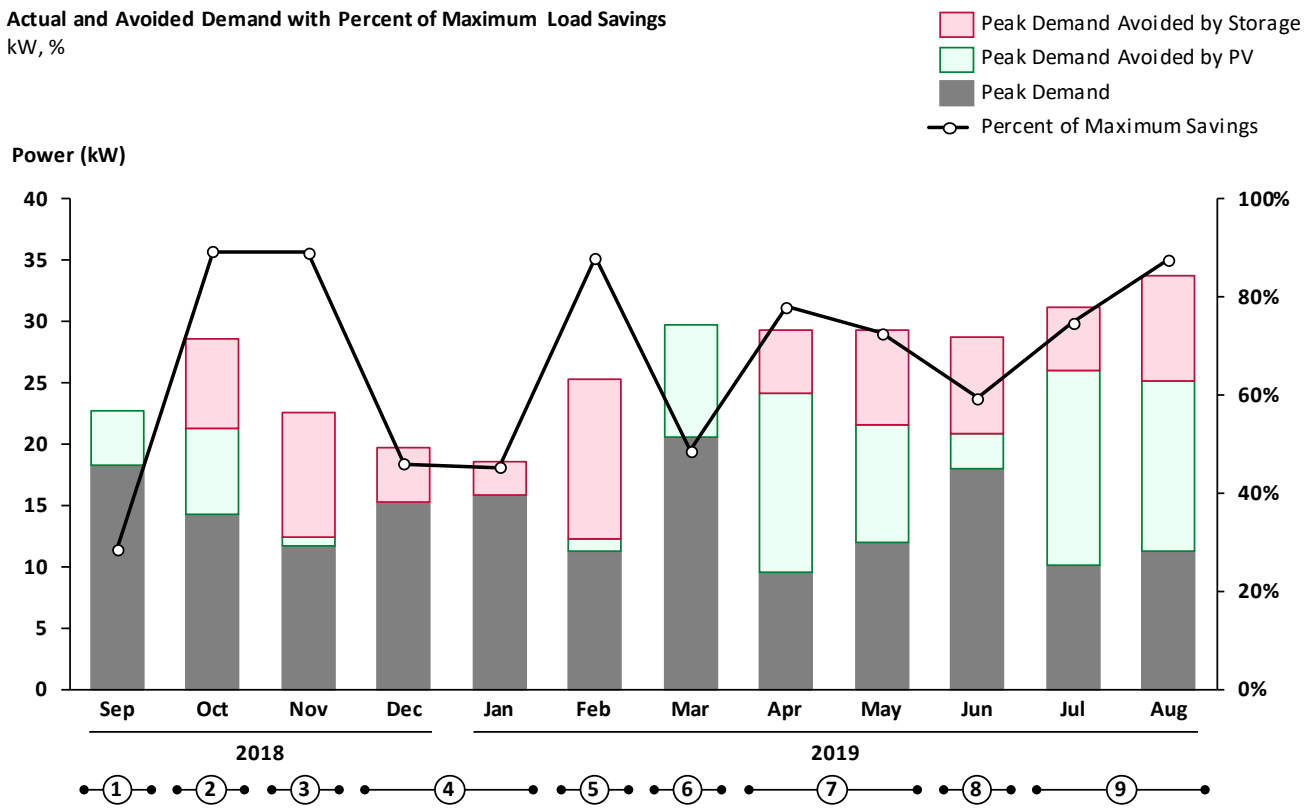


Figure 4 - Screenshot of Energy DataHub

Results

This results section summarizes how the iEMS performed over the first year of operation. Following the results summary table, we provide a detailed analysis and commentary for nine distinct time periods identified in the summary. These deep dives are intended to provide additional context on the various factors that influenced the performance of the iEMS. The following terms are used throughout the summary and deep dives:

- **Maximum Site Demand**. This is the maximum demand within a given month, measured in kW. Assuming there was no PV or ESS, the Maximum Site Demand would be the power value the utility uses to calculate the customer's demand charges.
- **Peak Demand Avoided by PV**. This is the amount of demand reduced by PV generation. The value is calculated by subtracting the highest kW demand interval post-PV, from the site peak load. Given that PV is an intermittent resource and subject to changing weather conditions, Peak Demand Avoided by PV is an uncontrolled variable and can vary significantly from month to month.
- **Peak Demand Avoided by Storage**. This is the amount of kW demand reduced by the iEMS controlled ESS. The value is calculated by subtracting the highest kW demand interval post-PV&ESS, from the highest kW demand interval post-PV. The iEMS attempts to capture the highest Peak Demand Avoided by Storage possible by continuously re-forecasting weather data, PV production, and site load to determine the optimal times to dispatch the battery.
- **Maximum Potential Demand Avoided.** This is the highest kW demand reduction possible in each month given the size of the PV and ESS. This value is calculated by subtracting the highest Peak Demand Avoided by Storage that is mathematically possible (assuming the iEMS controlled ESS operated with perfect foresight), from the post-PV load profile; we then add back the actual, observed Peak Demand Avoided by PV.
- **Percent of Maximum Savings**. This is the percentage of kW demand savings achieved relative to the highest kW demand savings possible. The value is calculated by adding the Peak Demand Avoided by PV and the Peak Demand Avoided by ESS and dividing that by the Maximum Potential Demand Avoidance. It represents how efficiently the PV + iEMS reduced kW demand, compared to the maximum kW demand reduction possible, assuming the iEMS operated with perfect foresight.



PV and iEMS Performance Detail

		Maximum Site Demand (kW)	Peak load avoided by PV (kW)	Peak load avoided by storage (kW)	Maximum Potential Demand Avoided (kW)	Percent of maximum savings (%)	Performance explanation
1	Sep '18	23.0	4.4	0.0	15.5	28%	System installed Sept 11, 2018. Low efficiency expected due to the initial model training and only a half month contribution.
2	Oct '18	28.6	7.0	7.4	16.2	89%	Accurate prediction and discharge by iEMS provided 90% of total possible savings.
3	Nov '18	22.6	0.6	10.2	12.2	89%	Storage provided the vast majority of savings due to limited PV production.
4	Dec '18	19.7	0.0	4.4	9.5	46%	Excess snowfall curtailed PV which was not originally accounted for in the algorithm. Once the algorithm was updated to account for persistent snow coverage, higher levels of performance resumed.
	Jan '19	18.6	0.0	2.8	6.2	45%	
5	Feb '19	25.2	1.0	13.0	15.9	88%	With the PV generation forecast fixed (accounting for persistent snow coverage), the iEMS provided provided near-perfect savings.
6	Mar '19	29.3	9.1	0.0	18.7	49%	An unexpected and material change in the load profile impacted performance as the algorithm began learning the new loads.
7	Apr '19	29.7	14.7	5.1	25.4	78%	Algorithm was effective in forecasting the changed load profile, and higher levels of performance resumed.
	May '19	29.4	9.5	7.7	23.8	72%	
8	Jun '19	28.7	2.9	7.8	18.0	59%	Inaccurate third-party weather data impacted efficiency.
9	Jul '19	31.4	15.9	5.1	28.0	75%	While PV provided the bulk of the savings, storage contributed another 5 - 8kW of avoided peaks. With the algorithm having learned for nearly a year, we see increasing stabilization of the savings achieved.
	Aug '19	33.5	13.9	8.6	25.7	88%	
	Average	*27.0*	*6.8*	*6.6*		*71%*	**excludes Sep '18*

Figure 5 – Summarized Results from First Year of Operation

1 Sep 2018: Low demand reductions due to half month contribution

The energy storage system was initially energized on September 11th of 2018. Given that the site peak load was set during the first week of September, the ESS did not contribute any demand reduction for the month. The solar PV system reduced 4.7 kW of demand, resulting in a combined PV + ESS reduction of only 30% of the total possible demand charges in the month. Because the storage system was turned on mid-month and made no demand reduction contributions, the September percentage of maximum savings number was not used in the annual average.

An important issue, unrelated to demand charge reductions, was discovered shortly after the ESS was energized, which we detail below.

Energy DataHub's high resolution data sampling discovered a transformer voltage fault issue

When the ESS was brought online and Energy DataHub began reporting data an unexpected issue with the utility transformer was discovered. The AC phases of the poly-phase transformer, which should align closely with one another, were discovered to be out of sync (see Figure 6).

After the local utility company, Fortis, was provided with graphical data that clearly depicted the issue, the utility moved quickly to replace the transformer. On 10/11, Fortis installed a new transformer, and the voltages can been see going back into sync with one another starting on 10/12.

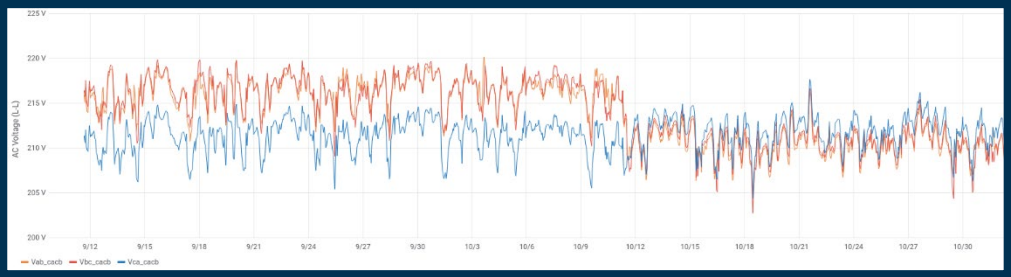


Figure 6 – Energy DataHub screen showing AC line voltage

2 Oct 2018: iEMS Provided Near-Perfect Savings

During the month of October, the site's maximum demand peaked out at 28.6 kW. The PV reduced 7 kW of demand and the iEMS enabled ESS reduced an additional 7.4 kW. The combined demand reduction of 14.2 kW equated to exactly 50% of the site load for the month. Relative to the percentage of maximum savings possible the iEMS performed very efficiently. The maximum load that could have been avoided from solar and storage was 16.2 kW. Therefore, the combined system captured 89% (14.4 kW/16.2 kW) of the maximum demand savings possible in the month. As illustrated in the top portion of Figure 7, the iEMS achieved a high demand savings efficiency with a relatively low amount of ESS cycling throughput.

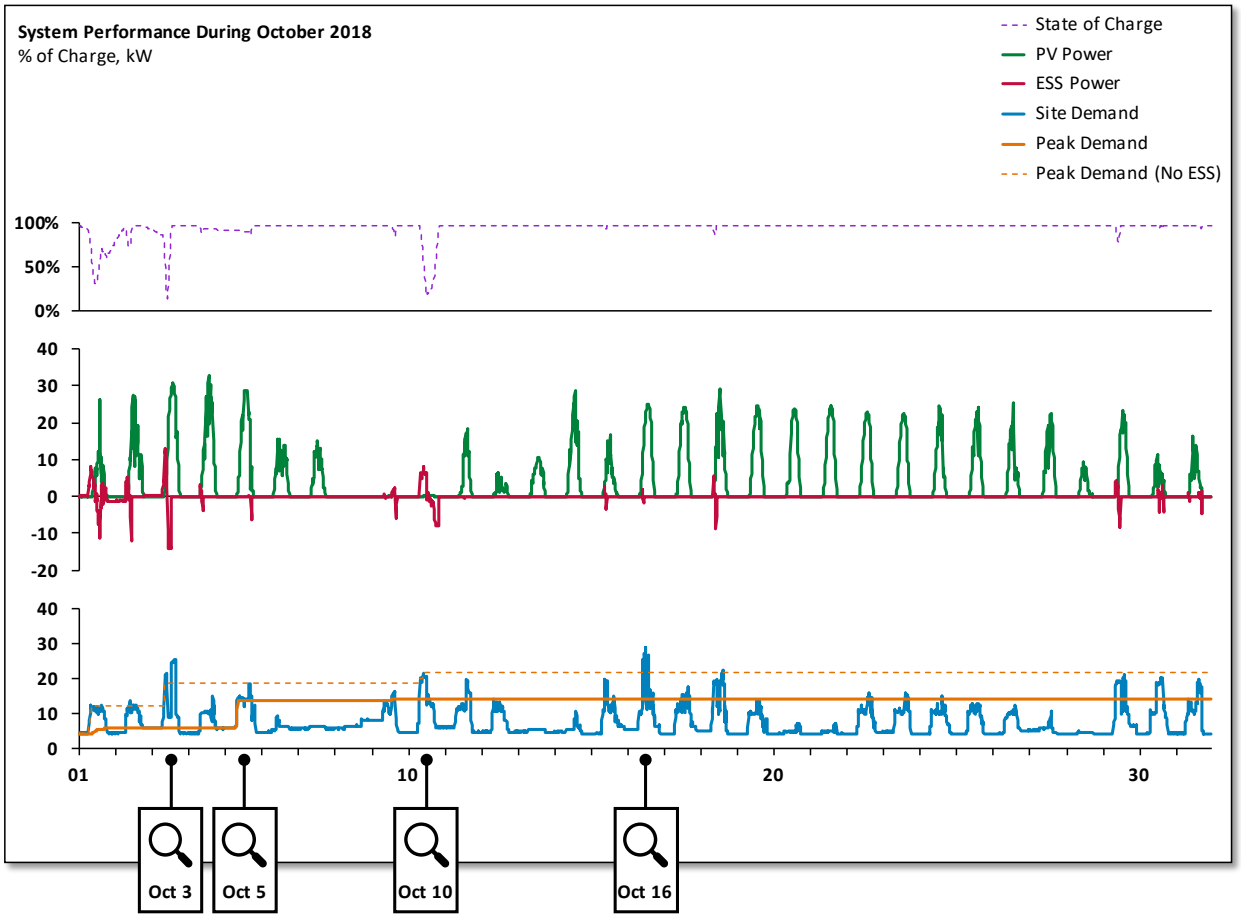


Figure 7 - Energy Storage System Behavior in October

When looking at the energy storage system performance throughout the month of October, four dates of consequence are detailed below.

Oct 3

On October 3rd, ESS discharged to shave the early morning peak. The iEMS detected an early-morning demand spike before PV production came online. The ESS discharged accordingly and shaved the peak. By 10:30 am, PV production began ramping up, which was able to cover site load on its own for the balance of the day. The iEMS transitioned to charging mode later in the day when it knew it would not set a higher high. The ESS efficiently complimented PV on this day, and the post PV/ESS max demand stayed at 6 kW.

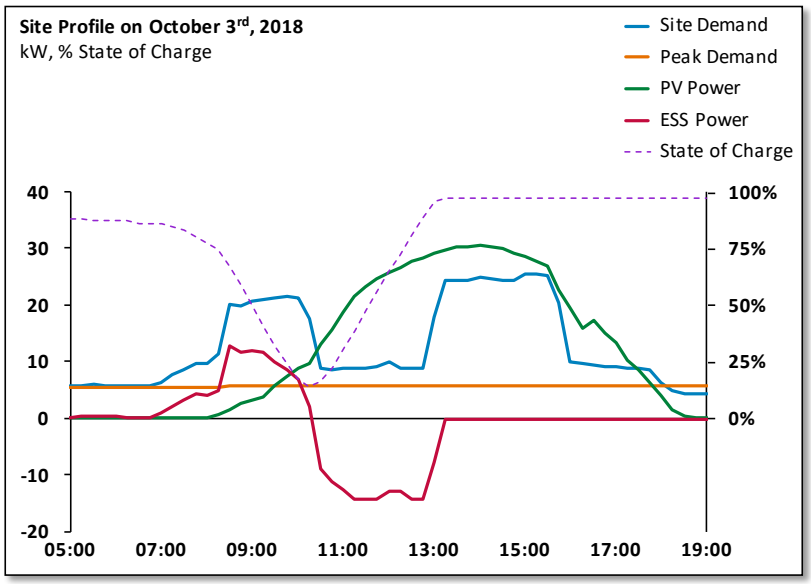


Figure 8 - Site profile on Oct 3

Oct 5

On October 5th, ESS was taken offline, causing a higher high. Power was temporarily shut off and the iEMS was taken offline after it was discovered that the utility had a fault in one of their transformers supplying the site. As a result, there was no ability for the ESS to dispatch to mitigate the early morning demand spike, which led to a new higher high. All indications show that had the iEMS been online, that spike in site load would have been shaved.

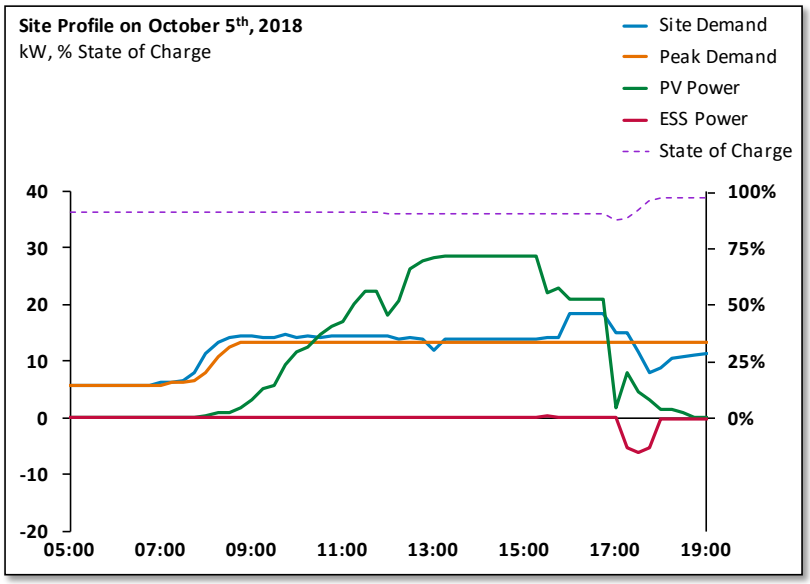


Figure 9 - Site profile on Oct 5

Oct 10

On October 10th, ESS did all the peak-shaving; iEMS predicted no PV. There was no PV production on this bad weather day, which required the ESS to do all the work. Fortunately, the iEMS anticipated no PV production via its updated weather forecast and discharged throughout the morning and early afternoon. The ESS was able to effectively shave site demand down to the set point, or peak demand level that it entered the day at.

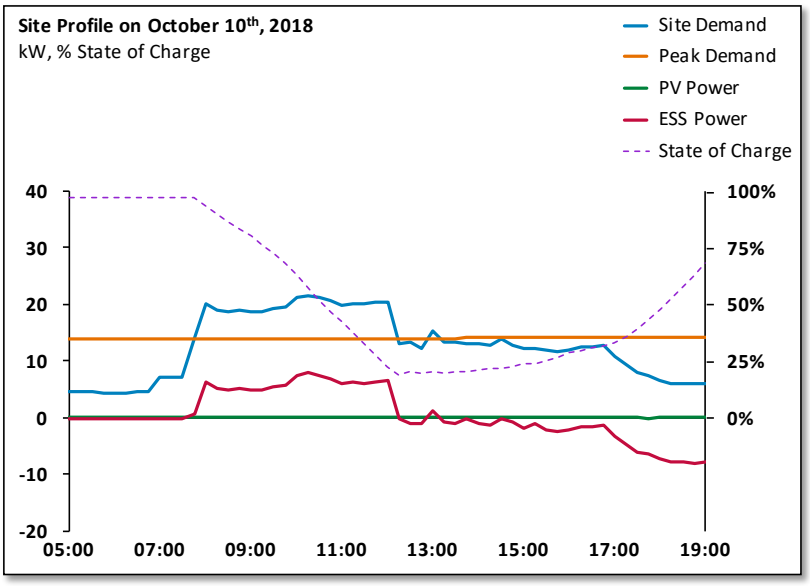


Figure 10 - Site profile on Oct 10

Oct 16

On October 16th, ESS avoided unnecessary cycling. The site load hit its maximum demand for the month at 29 kW. However, PV production overlapped well against site load. Given that the post PV/ESS peak demand did not exceed a peak earlier in the month, the system determined that there would be no economic value in dispatching any further than the small early morning discharge. Instead the ESS maintained its full SoC, preserving capacity, and limiting unnecessary cycling.

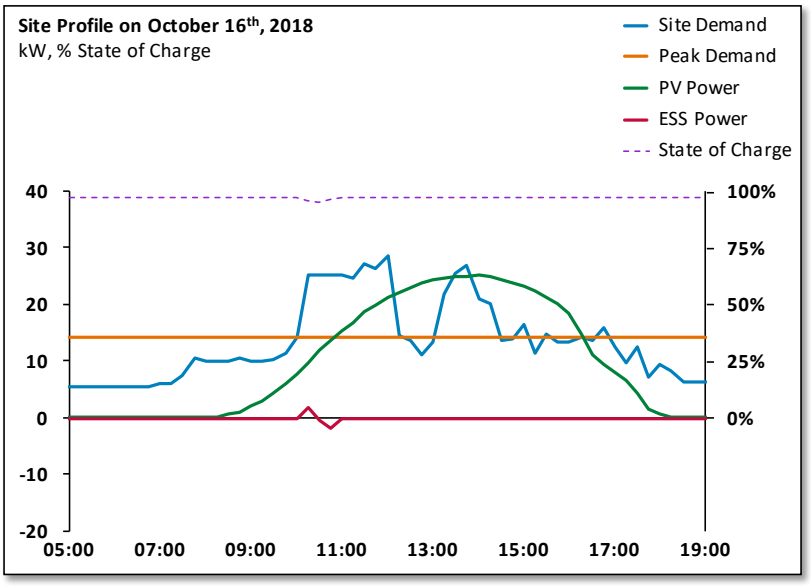


Figure 11 - Site profile on Oct 16

3 Nov 2018: Storage Provided the Vast Majority of Savings

During the month of November, the site peak load of 22.6 kW occurred on November 23rd (see Figure 12). Similar to October, the iEMS performed highly efficiently in November, capturing 89% of the maximum demand savings possible. But the strong result was achieved in a much different fashion. In November, there was limited PV production on several days early in the month, resulting in PV only contributing 0.6 kW of demand reduction. The ESS provided the vast majority of demand savings, reducing 10.2 kW of site load.

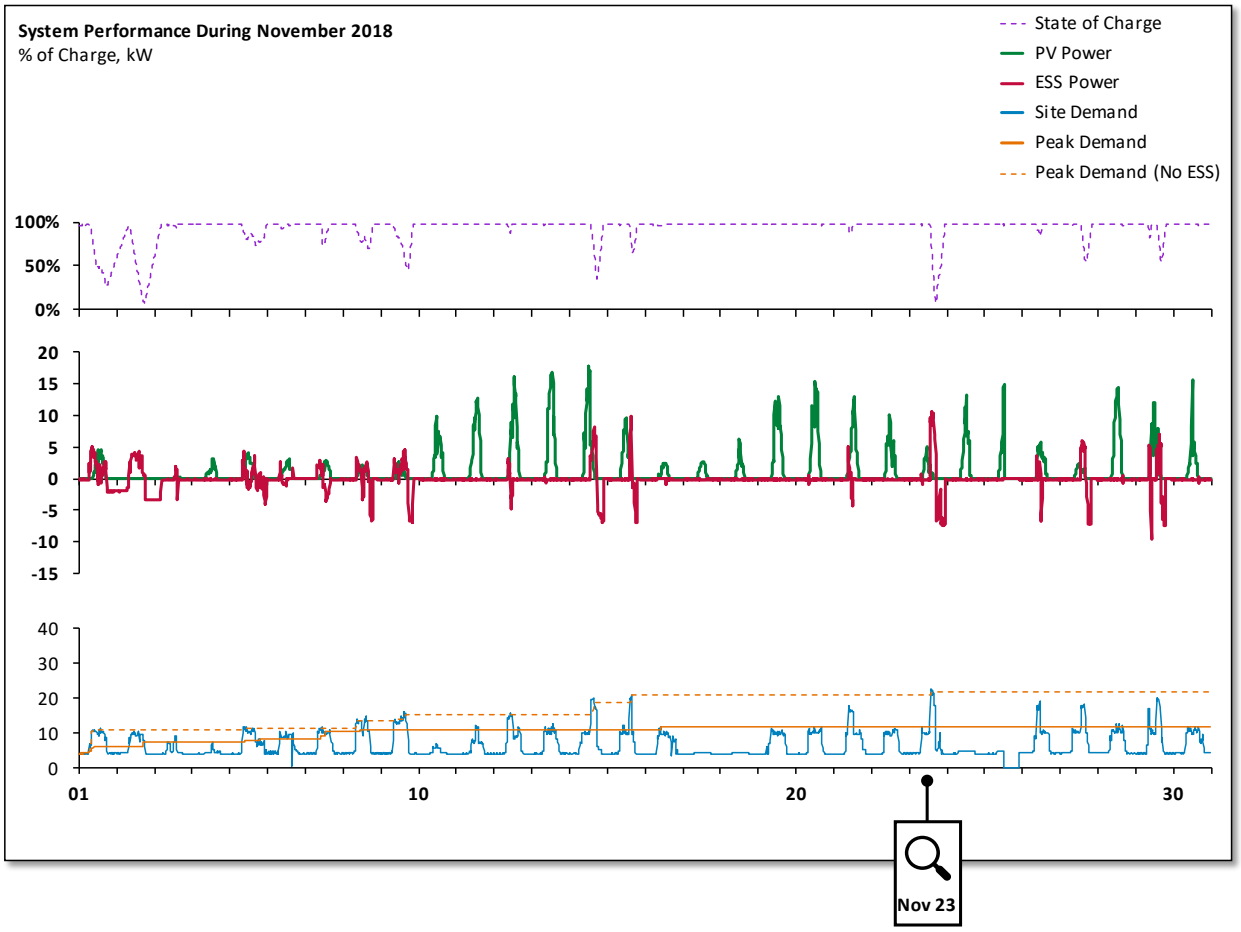


Figure 12 – ESS Dispatch and Site Load in November

Nov 23

On November 23rd, ESS peak shaves a wide shoulder in the afternoon. The site experienced a spike in demand, from roughly 2 pm to 6 pm (see Figure 13), and there was limited PV production throughout the day. The iEMS detected the demand spike and discharged accordingly, fully shaving the 4-hour peak shoulder and maintaining the set point it entered the day with. This day illustrates one of the many scenarios where an iEMS enabled storage system complements the PV to help firm-up a customer's demand reduction.

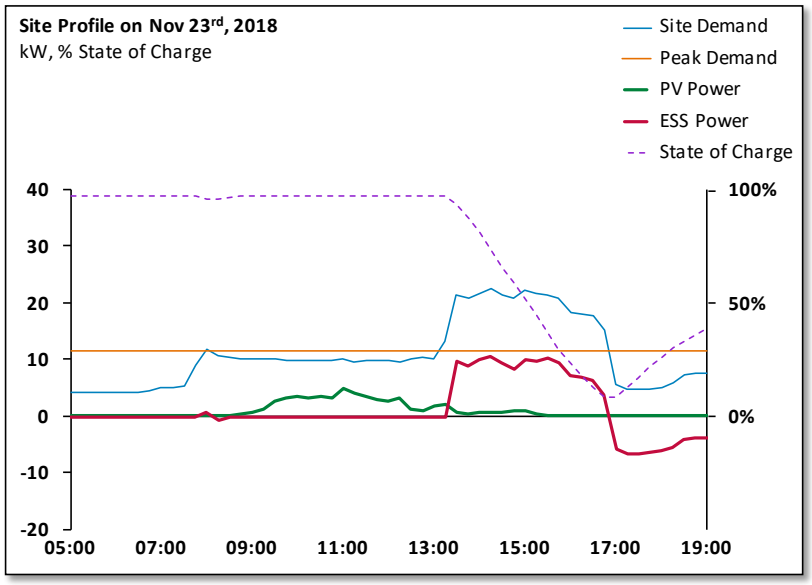


Figure 13 - Site profile on Nov 23

4 Dec 2018 - Jan 2019: Snowfall Accumulation Prevented PV Output

In late November and early December excessive snowfall accumulated on the solar panels, causing PV generation to be severely reduced. While the iEMS continually downloads new weather data and cloud cover forecasts every hour to re-estimate solar PV output, it did not account for snowfall accumulation effect on the panels. This was the first site the iEMS had to contend with this accumulation phenomena. Effectively, the machine learning model was managing ESS dispatch anticipating solar PV production, but no production materialized because of snow on the panels (see example in Figure 14). Consequently, the iEMS underperformed, only achieving 46% and 45% of maximum savings in December and January, respectively.

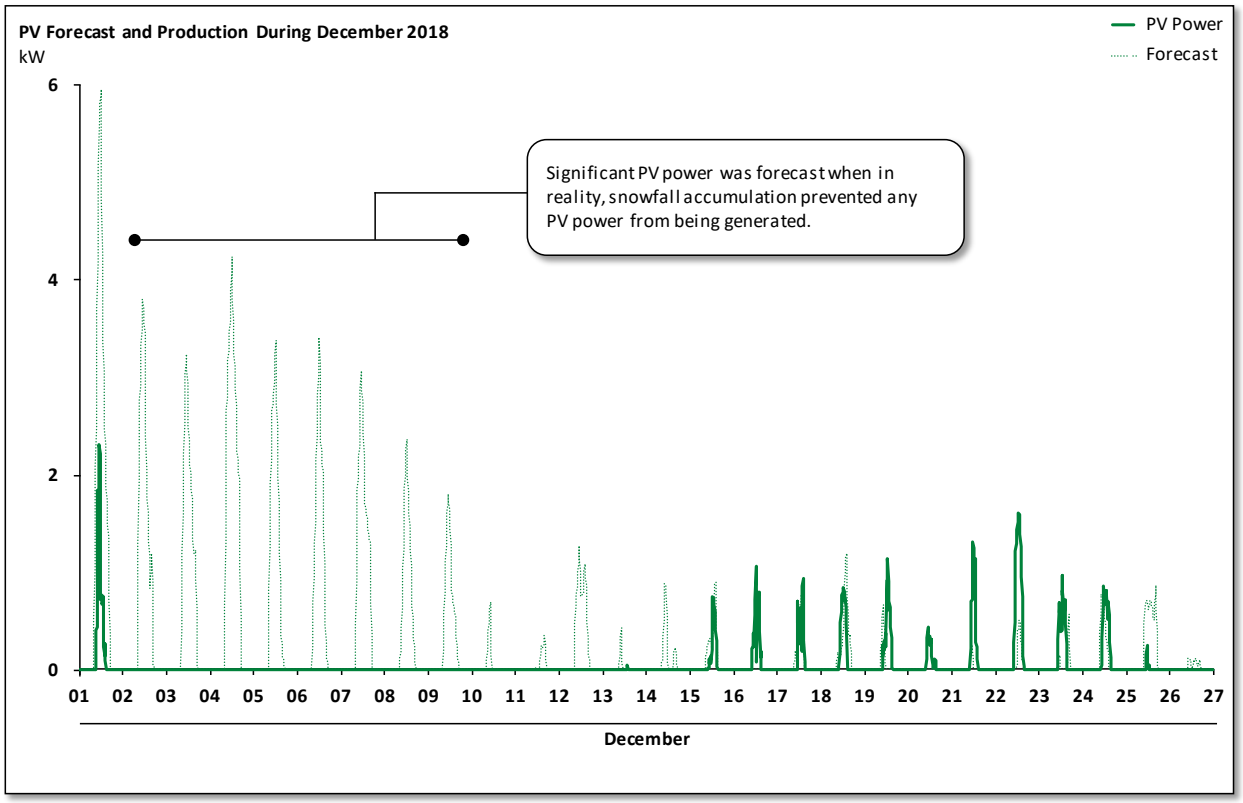


Figure 14 - Snowfall Accumulation Causing Disparity between PV Forecast and Reality

In January, Energy Toolbase released an update to the iEMS algorithms to account for snowfall accumulation effect. Once the update was implemented, the iEMS performed significantly better in the month of February, delivering 87% of maximum possible demand savings.

5 Feb 2019: PV Forecast Improved, iEMS Provided Near-Perfect Savings

After the update to the PV forecasting algorithm was implemented, the iEMS began successfully predicting the absence of PV in February (see Figure 15). PV production during February was so negligible that it was barely seen in the data. The iEMS operated accordingly, performing dispatch assuming there would be no PV contribution. As a result, the combined system captured 87% of the maximum demand savings possible. In the detail section below, we further unpack two days of particular interest.

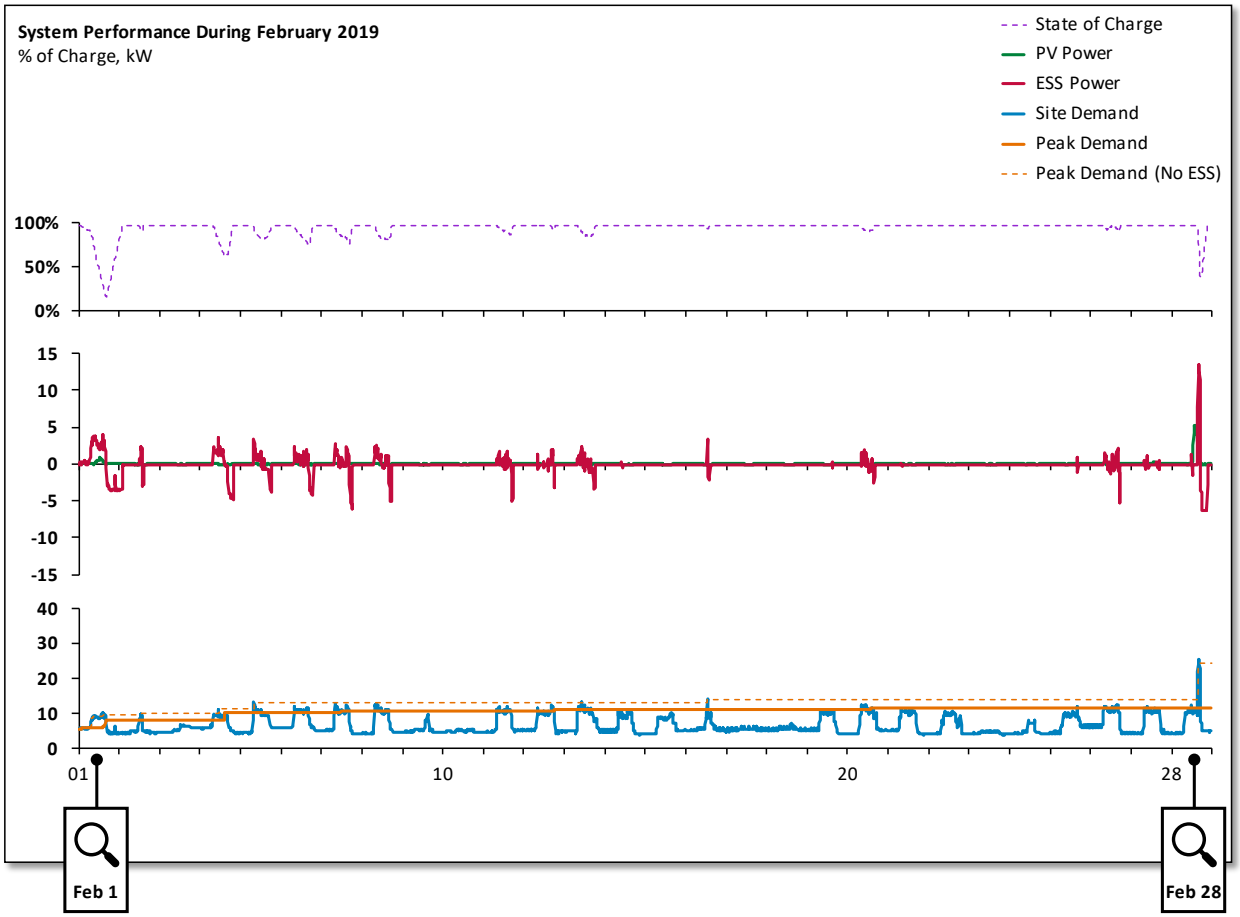


Figure 15 - ESS Dispatch and Site Load in February

Feb 1

On February 1st, ESS discharges over a 10-hour period. The iEMS accurately predicted the lack of PV and discharged throughout most of the day. While a higher high peak demand was set by the end of the day, the iEMS peak shaved as effectively as possible. Note: the iEMS did not discharge beyond 10% SoC to ensure compliance with the manufacturer's warranty.

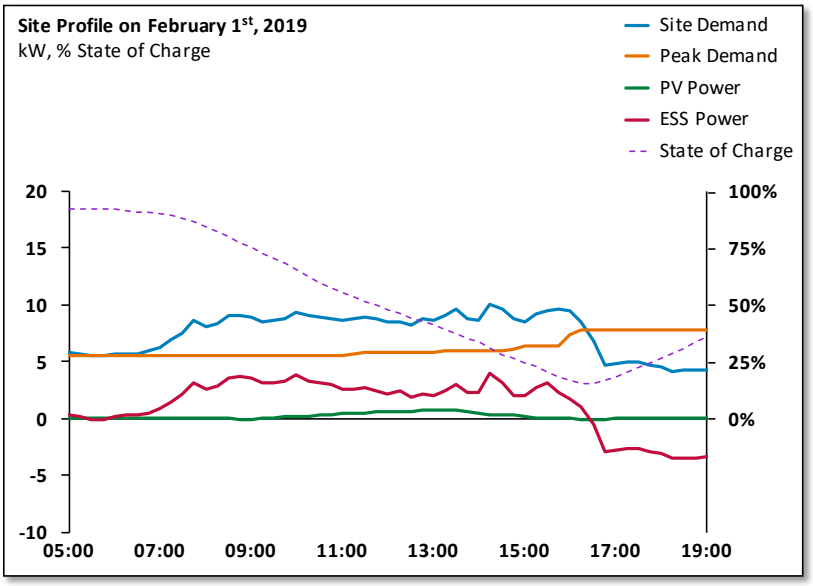


Figure 16 - Site profile on Feb 1

Feb 28

On February 28th, ESS peak shaved EV charging load. The iEMS maintained a 100% SoC throughout the day, which enabled it to efficiently discharge to mitigate a late afternoon EV charging demand spike. Even though the site demand more than doubled from 12 kW to 25 kW, the iEMS was able to prevent a higher high from being established on the last day in the billing cycle.

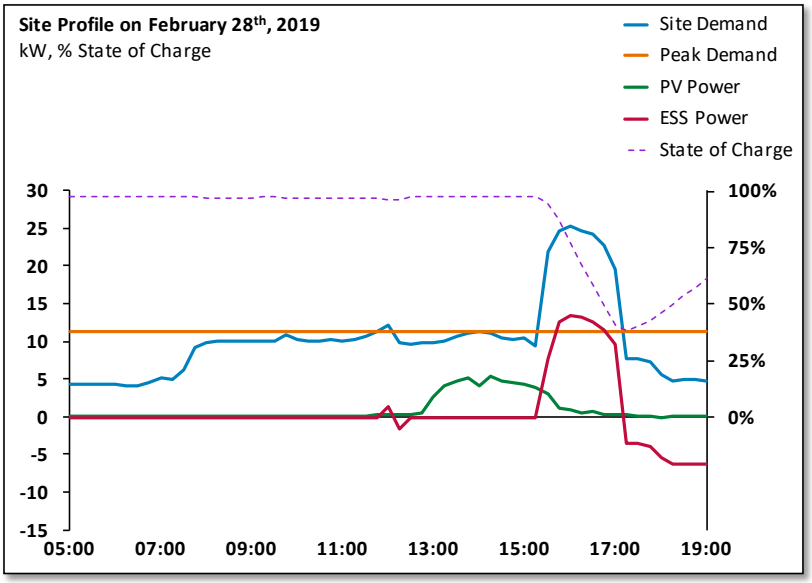


Figure 17 - Site profile on Feb 28

6 Mar 2019: Major Change in the Customer's Load Profile Impacted the iEMS's Peak-Shaving Performance

In March, the staff on site significantly changed the way they charged their EVs, which led to a reduction in system performance (see Figure 18). Prior to the installation of the energy storage system, staff did not charge their EVs during peak hours, and charging events were typically no more than two hours. But excitement around how the new ESS solution would offset EV charging demand led to a behavior change on when and for how long the staff charged their EVs. The change in the load profile pattern challenged the iEMS's ability to forecast site load.

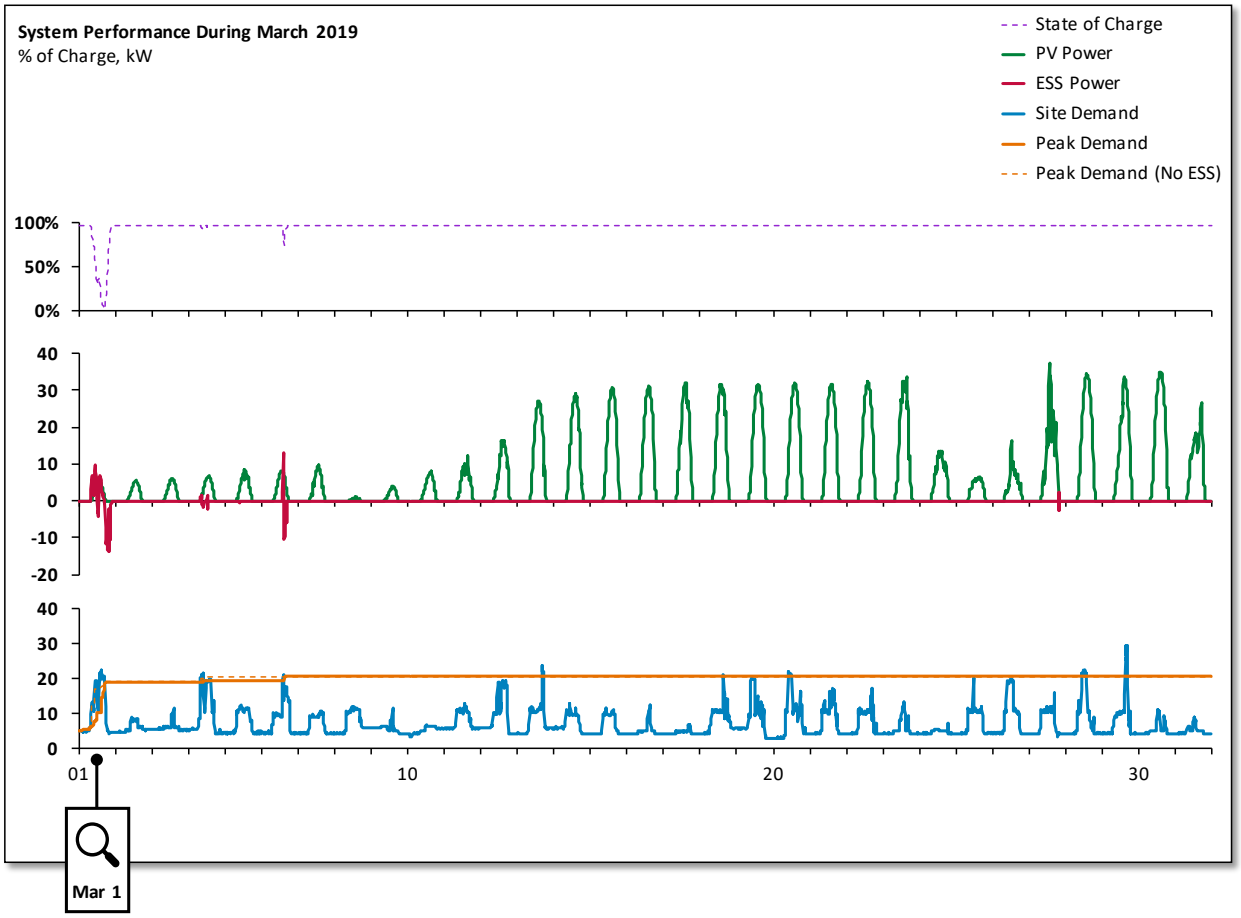


Figure 18 - ESS Dispatch and Site Load in March

Mar 1

On March 1st, new charging pattern emerged. The site's normal EV charging periods typically lasted roughly two hours, which can be seen on February 29th from roughly 3:00 pm to 5:00 pm (see Figure 19). However, starting on March 1st, the site's EV charging activity lasted roughly six hours, which was 3 times longer than typical. Accordingly, the iEMS was expecting a 2-hour charging demand spike, and rapidly dispatched the battery to reduce site load, predicting that the shoulder would not last well beyond 2-hours. As a result, the battery did not maintain sufficient capacity to peak shave a six-hour shoulder and was effectively caught flat-footed by the unexpected second charging event from roughly 1:00 pm to 5:00 pm. Consequently, the monthly site demand jumped to 20 kW in March, which was substantially higher than the 11 kW peak demand seen in February.

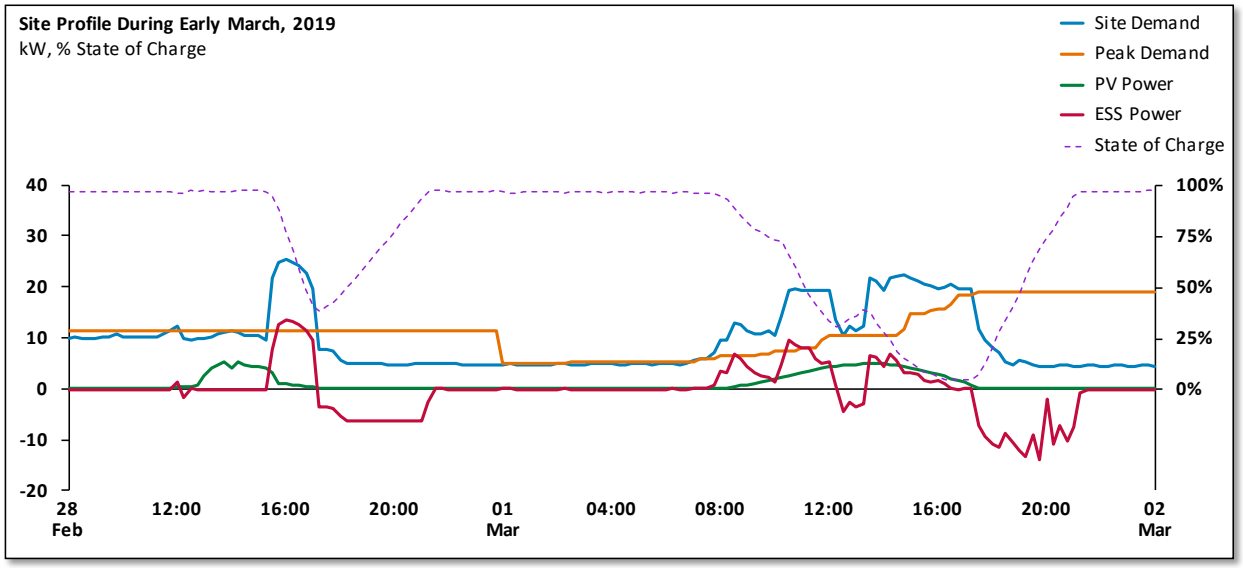


Figure 19 - ESS Dispatch and Site Load in Early March

For the month of March, the PV+ESS system only achieved 49% of the maximum demand reduction possible, which was one of its worst months of the year. However, after the iEMS experienced this anomaly, it learned to predict the pattern of longer duration EV charging. This example illustrates a real-world challenge of dealing with unpredictable changes in site load. The following month demonstrates the iEMS's ability to autonomously learn and adapt.

7 Apr - May 2019: Algorithm was Effective in Forecasting Changed Demand

The effectiveness of the new learning was evident in both April and May's performance where the system achieved 79% and 72% of maximum savings, respectively. For the month of April, the iEMS was able to maintain a consistent peak demand set point throughout the entire month (see Figure 20).

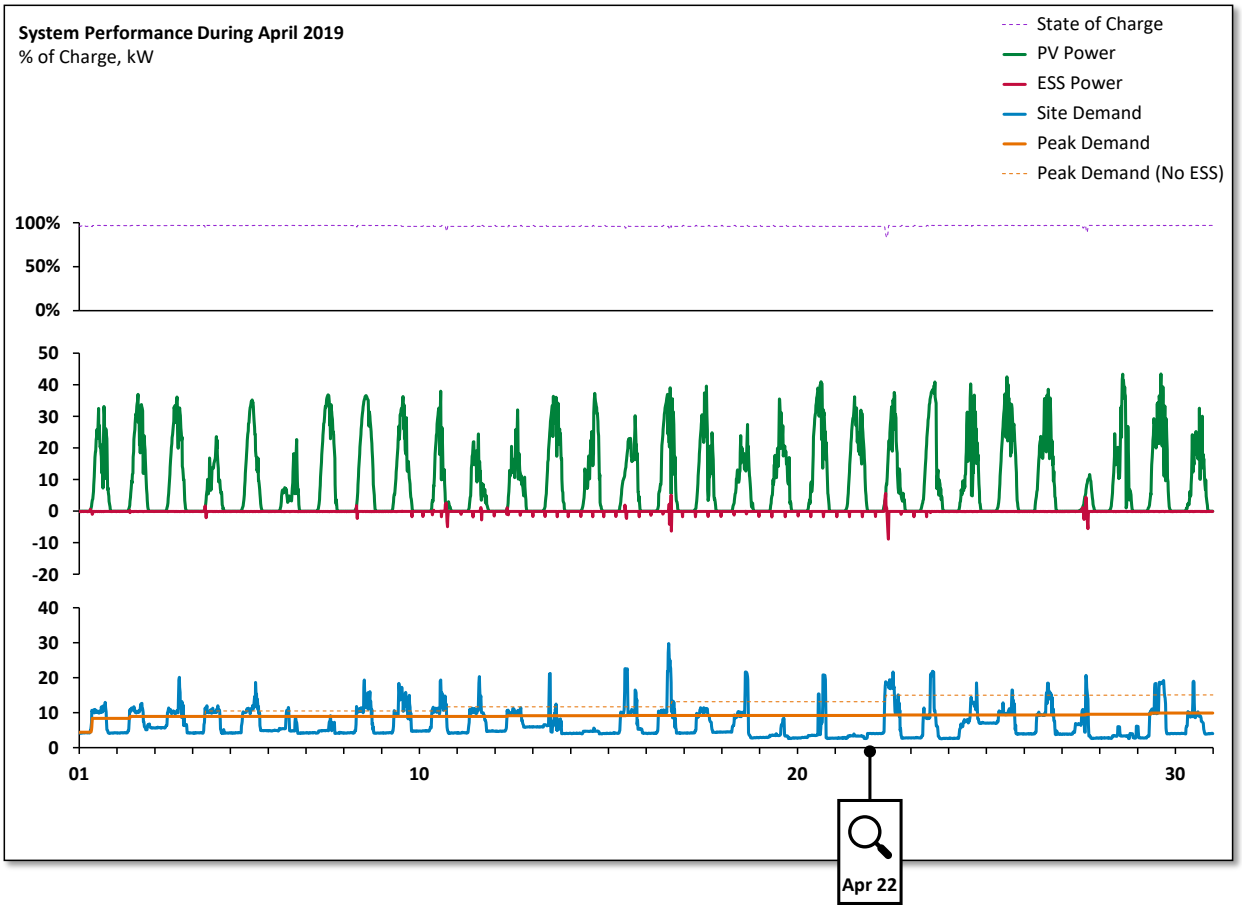


Figure 20 - ESS Dispatch and Site Load in April

Apr 22

On April 22nd, ESS complimented PV to shave a six-hour wide shoulder. The site experienced another six-hour duration EV charging event, lasting from roughly 7:30 am to 1:30 pm. The ESS discharged early in the morning to shave site demand before the PV system came online for the day. And then PV reduced the late morning and early afternoon demand on its own. Collectively, the PV+ESS system was able to maintain the same set point throughout the day.

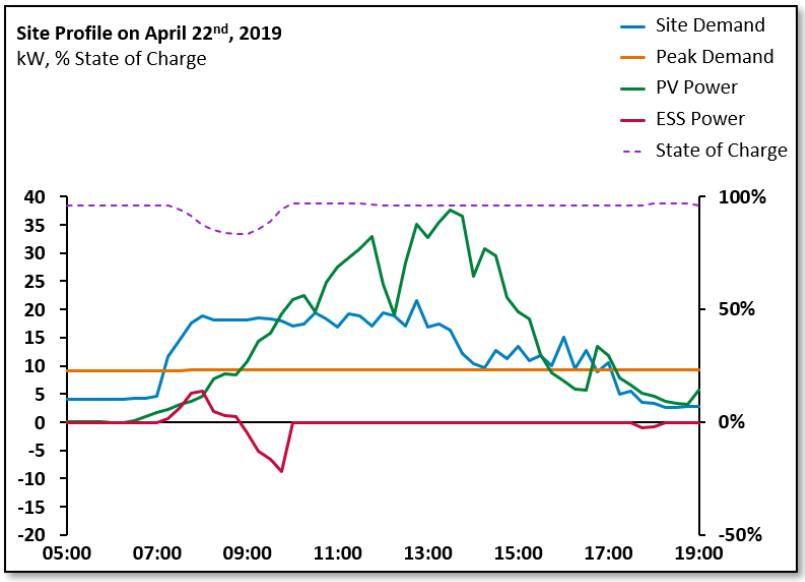


Figure 21 - Site profile on Apr 22

May 30

On May 30th, ESS firmed-up demand reductions, during a midday PV production dip. The site experienced a roughly four-hour duration spike in site load, from 11 am to 3 pm, which coincided with a dip in PV production. ESS dispatched to shave the peak down to the set point, this time discharging over an approximately three-hour period, from 11 am to 2 pm. iEMS was prepared to discharge longer and continue firming-up demand, but PV production ramped back up at 2 pm.

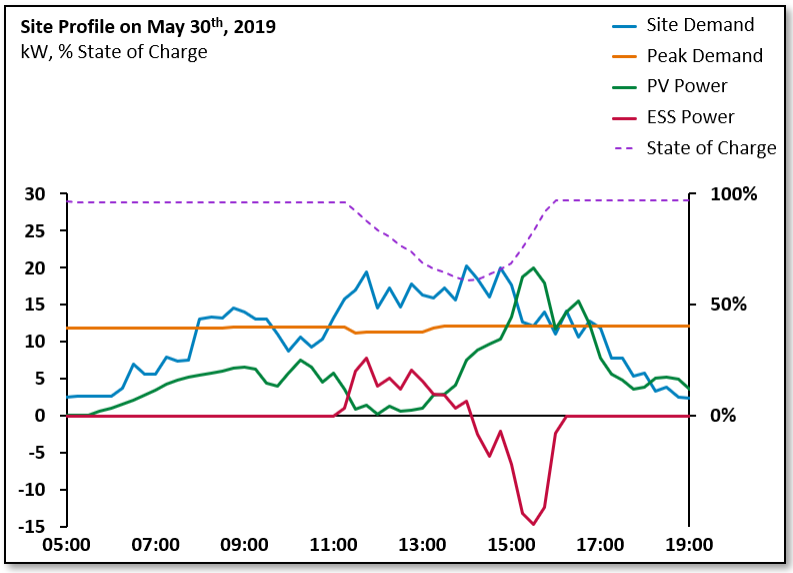


Figure 22 - Site profile on May 30

8 Jun 2019: Inaccurate Third-Party Weather Data Impacted Efficiency

During the month of June, the combined demand reduction of 10.7 kW only equated to 59% of total possible demand savings. The PV system only reduced 2.9 kW of demand, while the ESS contributed 7.8 kW in reductions. The subpar performance for the month was largely the result of one bad day, which occurred on June 4th (see Figure 23).

On June 4th, the actual PV generation significantly departed from the PV production forecast, over a three-hour period in the afternoon. On June 4th, the data iEMS received predicted the probability of precipitation at nearly 0% (see Figure 24). As a result, the system forecasted a relatively normal bell-shaped curve of PV generation for the day. However, severe rain and cloud cover materialized around 2 pm to 5 pm in the afternoon, which resulted in PV production being nearly zero for two hours. Unfortunately, the PV production dip happened to perfectly coincide with a spike in site usage (see Figure 25). This led to a higher site peak getting set that evening (increasing from around 9 kW to 16 kW).

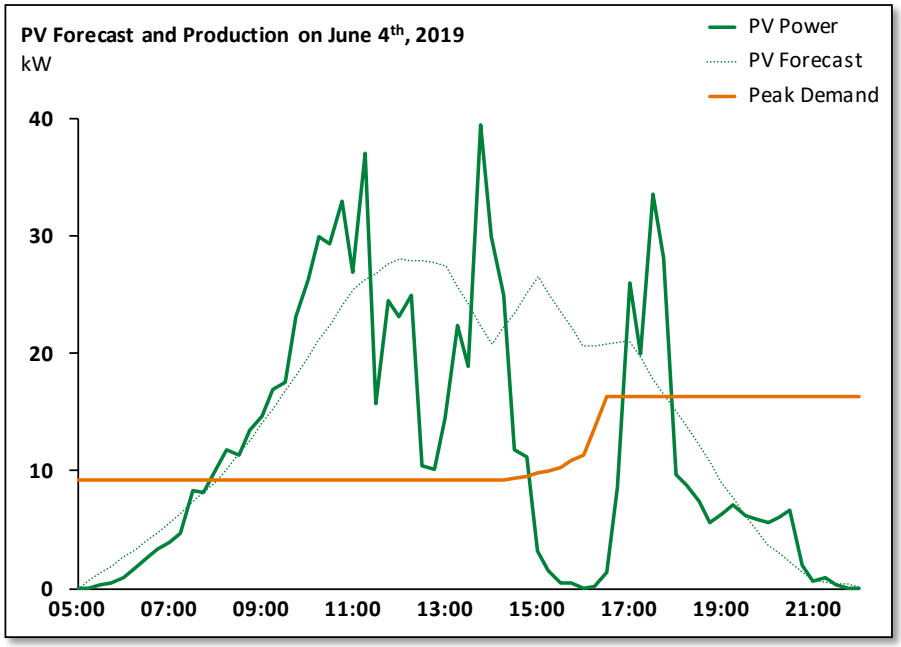


Figure 23 - PV Forecast and Production on June 4th

Jun 4

On June 4th, probability of precipitation forecast showed a very low chance of rain. The short-term weather forecast predicted a very low possibility of precipitation throughout most of the day on June 4th. During the peak sunlight hours of 8 am to 6 pm, the weather model projected a less than 10% chance of rain (see Figure 24).

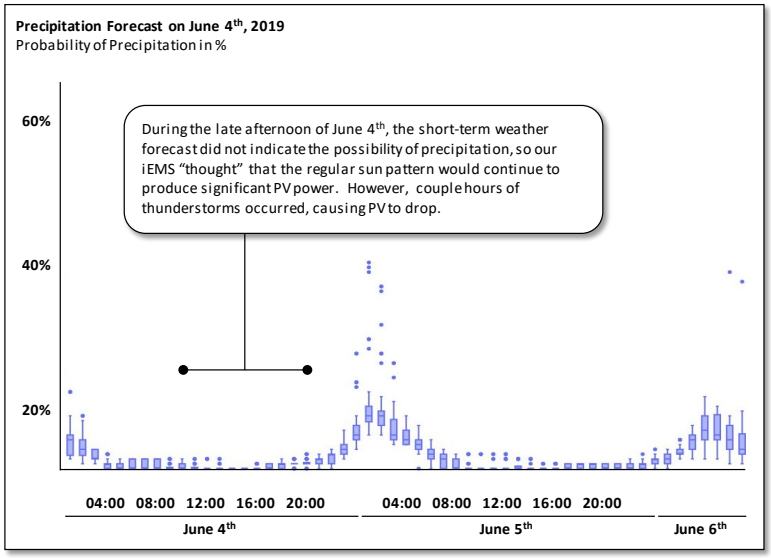


Figure 24 – Precipitation forecast on Jun 4

Jun 4

On June 4th, PV production went to zero, which coincided with a spike in site load. Starting around 3 pm, PV production fell to zero as an unexpected thunderstorm materialized. Unfortunately, this happened to coincide with a spike in site usage (see Figure 25). The iEMS began rapidly discharging to shave the peak but did not have confident foresight on how PV or site load would finish the day. The erroneous forecast caused the iEMS to stop discharging, setting a higher high, which we can now see in hindsight was premature.

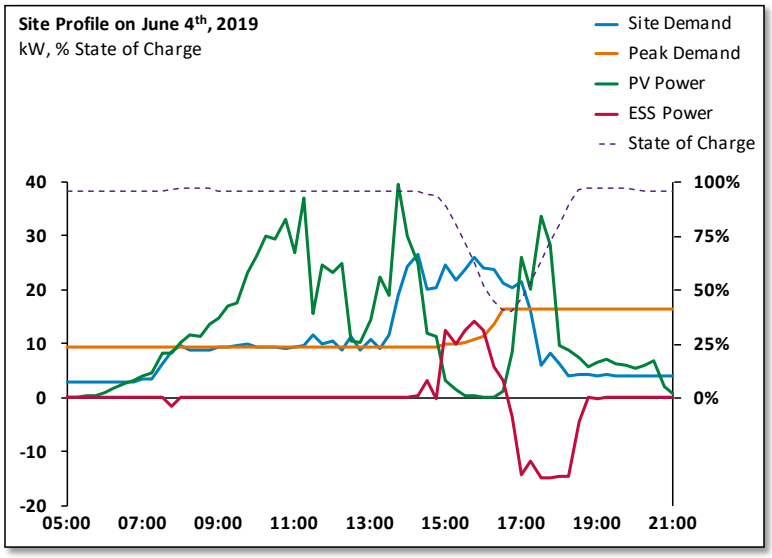


Figure 25 - Site profile on Jun 4

9 Jul - Aug 2019: PV Provided the Bulk of the Savings

In July and August, PV provided the bulk of the demand savings. Both summer months, when PV peak power is at its highest, provide a good illustration of the benefit and limitations of having a high PV to site load ratio. The PV system is rated 45 kW DC and the site's max annual demand is 34 kW, hence the PV to site load ratio of 1.3x. In the month of July, PV generation peaked at nearly 43 kW, far exceeding the highest site demand of 31 kW (see Figure 26). Out of the 21 kW in total demand reductions for the month, PV accounted for 16 kW or 76%. The detail day of July 26th (see Figure 27) illustrates the limitation of a high PV to site load ratio, and the need to pair ESS with PV to achieve higher aggregated demand reductions.

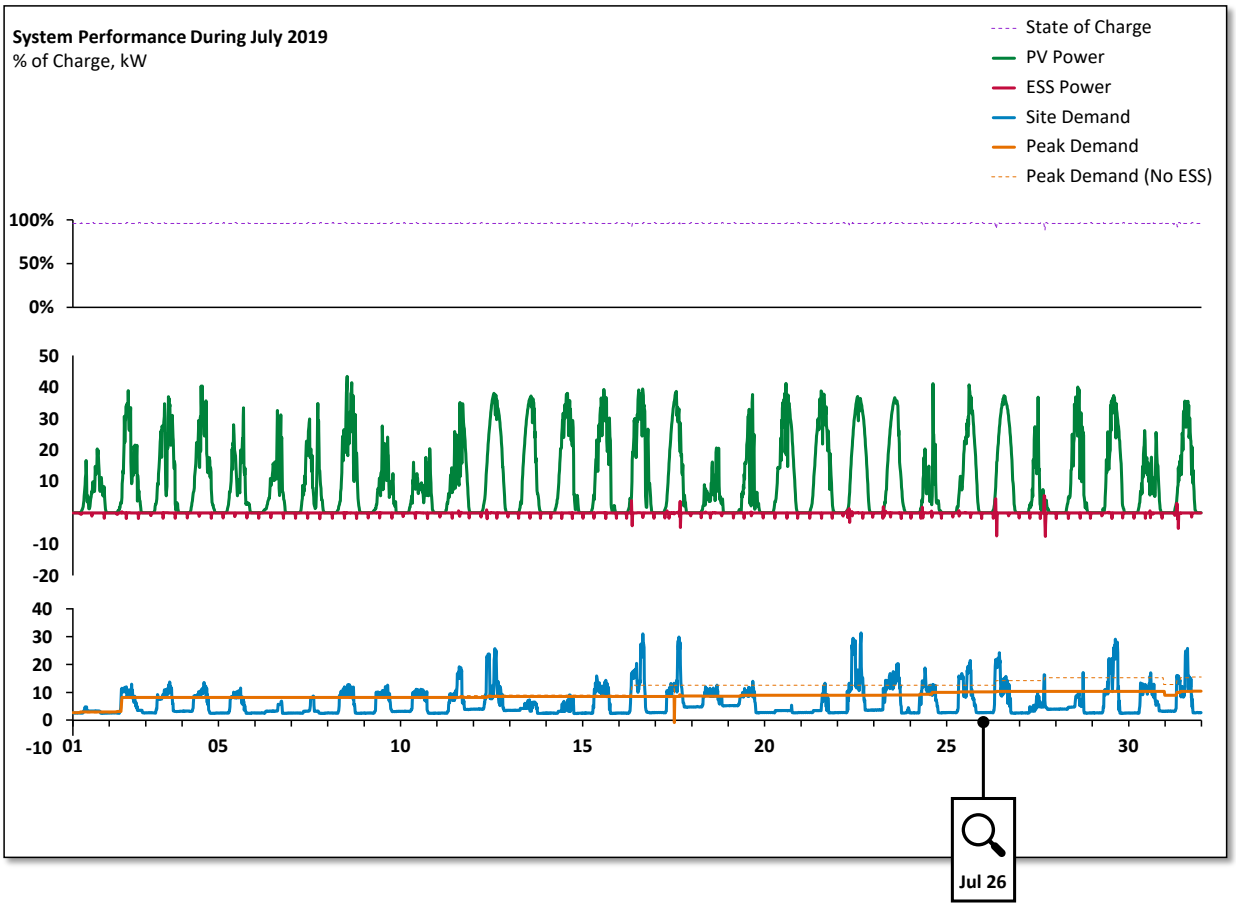


Figure 26 – July 2019 PV Provided the Bulk of the Savings

Jul 26

On July 26th, ESS compliments PV to reduce demand. Peak PV generation (36 kW) far exceeded peak site load (25 kW) on this day. However, the morning site load spike around 8 am, before PV came online, illustrates the need for pairing ESS to help firm-up demand reductions. The ESS intelligently dispatched to mitigate site load in the morning; the combined system was able to prevent a higher peak demand getting set on this day.

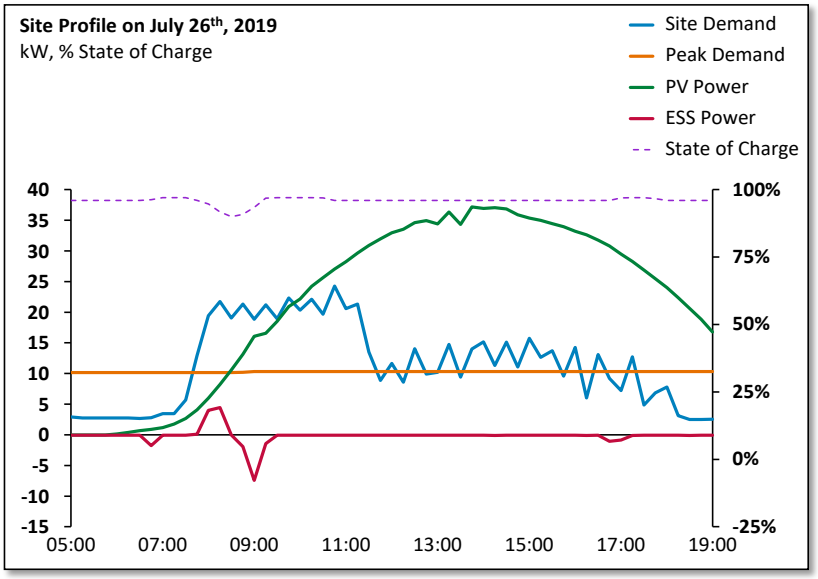


Figure 27 - Site profile on Jul 26

Conclusion

The iEMS enabled Energy Storage System efficiently complimented the solar PV system to capture 71% of the maximum possible demand charges savings for the customer

Over the first year of operation, the solar PV system reduced the customer's demand charges 22% on average, while the iEMS enabled ESS provided an additional 24% reduction. The solar and storage demand charge savings can be seen broken out by month in the chart below (see Figure 28). Outside of March, which is the month where the iEMS's performance was negatively impacted because of the customer's altered EV charging activity, the ESS reduced demand more consistently than PV from month-to-month. Note: the reason that the demand charge savings numbers differ slightly from the earlier reported kilowatt demand reduction number of 25% and 24% for PV and ESS respectively, is because the Fortis utility rate schedule the customer was on featured a demand tier billing mechanism.

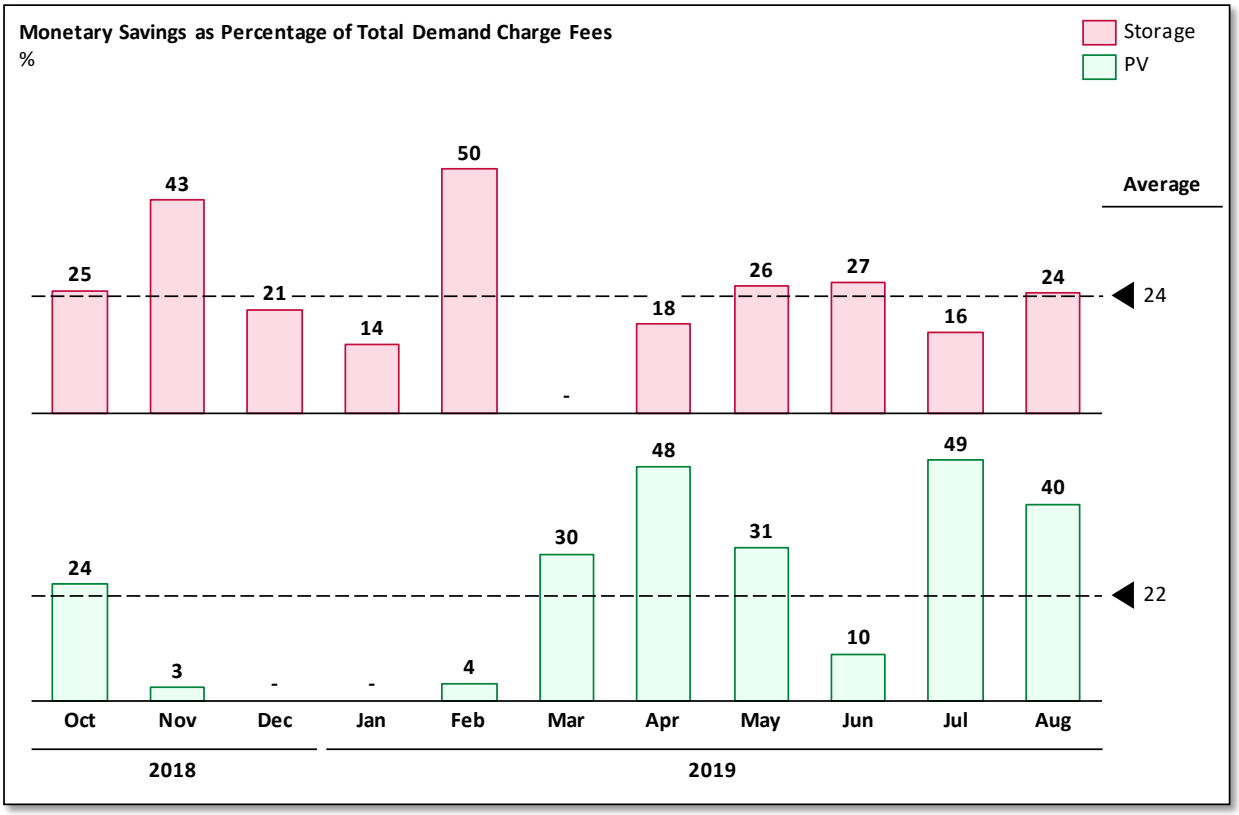


Figure 28 - Solar + Storage Savings as a Percentage of Total Demand Charge

It's important to highlight that the combined demand reductions from PV and ESS, as seen in the blue area in Figure 29, generally improved throughout the first year of operation. This is partly attributable to the iEMS's ability to better forecast site load and PV production as the year went on, and its machine learning model became more efficient at predicting load and making optimal dispatch decisions.

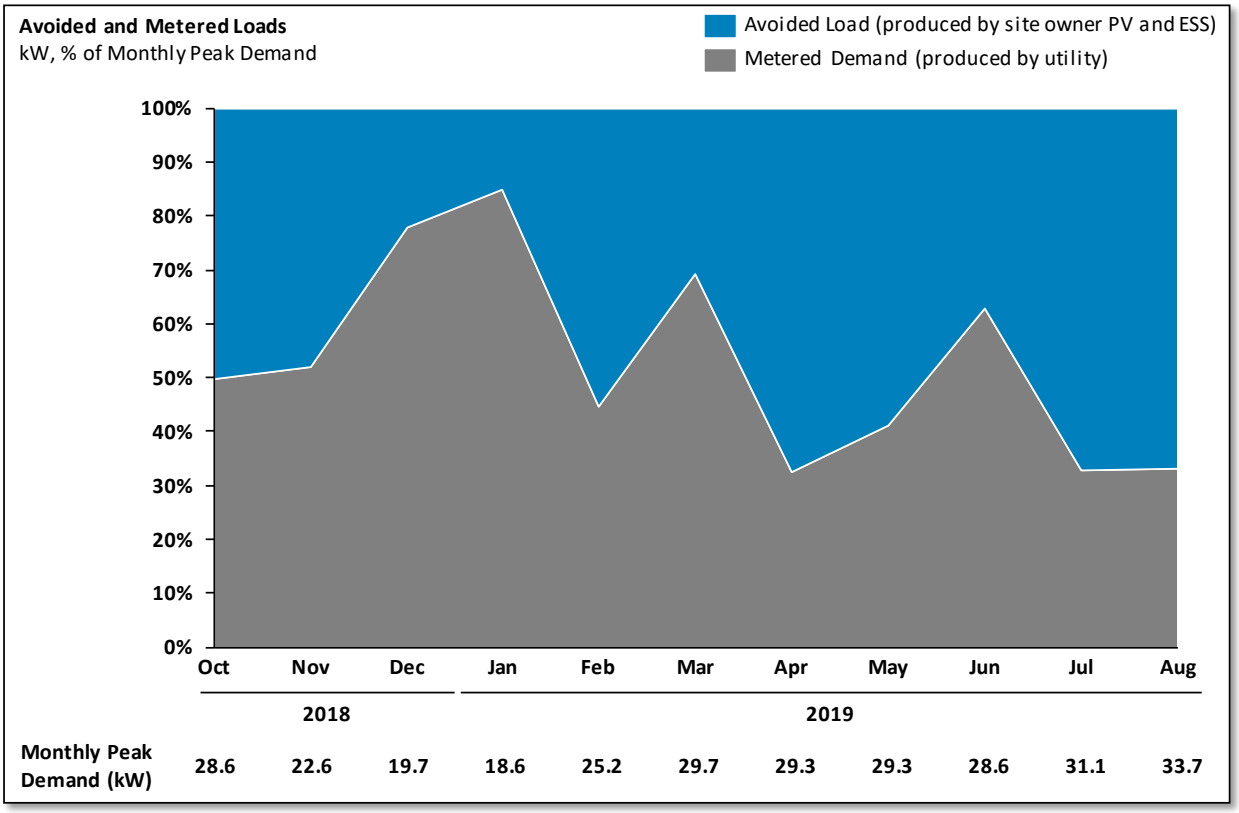


Figure 29 – Avoided Load by Month

iEMS's Continual Improvement

Energy Toolbase's engineering team is continually iterating and improving the iEMS control algorithms. Several software updates have been released since this case study, which enable the iEMS to ingest additional data inputs and make better forecasts. Based on this project's improving demand reduction trendline (see Figure 29) and the continued algorithm improvements, we anticipate that the percentage of max demand savings will continue to improve.

Acknowledgements & References

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References:

NREL/LBNL, Exploring Demand Charge Savings from Commercial Solar,
https://emp.lbl.gov/publications/exploring-demand-charge-savings-0

Energy Toolbase blog, Demand Charge Savings from Solar PV - The Definitive Guide,
https://www.energytoolbase.com/newsroom/blog/DemandChargeSavingsFromSolarPVTheDefinitiveGuide

Energy Toolbase, iEMS Datasheet,
https://www.energytoolbase.com/MarketingDocs/iEMSDatasheet.pdf

Energy Toolbase, Energy DataHub Brochure,
https://www.energytoolbase.com/MarketingDocs/EnergyDataHubBrochure.pdf

Eguana Technologies, Elevate ESS Datasheet,
http://www.eguanatech.com/_resources/Installer_Resources/Elevate/59125%20Elevate%20datasheet.pdf

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