

Driving Deeper Operational Savings in SMB Facilities through Virtual Commissioning Using Real-Time, 1-Minute Interval Data

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ABSTRACT

In 2016, ComEd, a large Midwestern electric utility, and Power TakeOff launched its pioneering Virtual Commissioning™ (VCx™) program. Trends in energy usage profiles of small and medium-sized business and public sector customers are analyzed to identify operational savings opportunities. Customers with high savings potential are then contacted and provided with remote technical support to implement improvements. An M&V 2.0 approach is used to verify savings. The program has proven very successful, growing from 2 GWh savings in its first year to over 23 GWh in 2021.

In late 2020, a pilot with Chicago Public Schools (CPS) was launched in which access to one-minute interval usage data was collected in real time, vs. the day-old 30-minute data used by the existing program. The goal was to find out if the market for VCx could be expanded to include more complicated buildings, and to determine if deeper savings could be identified at facilities which had previously undergone VCx.

Over 50 locations covering a range of building and equipment types and ages were selected for the pilot, including many in economically distressed locations. Onsite CPS staff and program analysts were provided with real-time energy dashboards, enabling them to see the impacts of operational adjustments as they were performed and allowing them to troubleshoot in situations where equipment-level energy usage was not clear from the AMI data. Preliminary results are very positive; deeper savings were found at previous VCx sites, and substantial savings were identified at sites that were not previously addressable by the program.

Introduction

VCx Overview

In the mid-2010s, ComEd, which provides electric delivery services to over 4 million customers in northern Illinois, was in the midst of a ten-year, \$2.6 billion plan to upgrade and modernize the electric grid in its footprint. As part of that effort, Advanced Metering Infrastructure (AMI) meters would be provided to all ComEd customers. In a pioneering effort to take advantage of this newly available data, ComEd and its partner Power TakeOff launched the Virtual Commissioning (VCx) program for commercial and public sector customers.

The goal of the VCx program is to identify those businesses and public sector customers with the highest potential to save energy by improving the ways in which they operated their facilities. Power TakeOff receives a daily feed of 30-minute AMI data for all ComEd business and public sector customers, providing vastly improved insight into customer usage patterns. Their suite of analytical tools sifts through thousands of electric usage profiles to identify facilities with high potential for operational savings through equipment scheduling, changing of setpoints, and other operational improvements. Power TakeOff also receives firmographic

information and customer contact data, enabling them to perform targeted, one-on-one phone and e-mail outreach to high-potential-savings customers.

Selected businesses with high potential energy savings are contacted directly to provide custom recommendations for operational improvements to building systems. These recommendations can range from very simple control measures such as setting of time clocks to turn equipment on and off on an optimal schedule to sophisticated programming of the building automation system. In every case, technical assistance is provided to ensure that the customer is able to successfully complete the implementation. Example energy usage profiles from a VCx pre- and post-engagement are shown respectively in Figures 1 and 2 below.

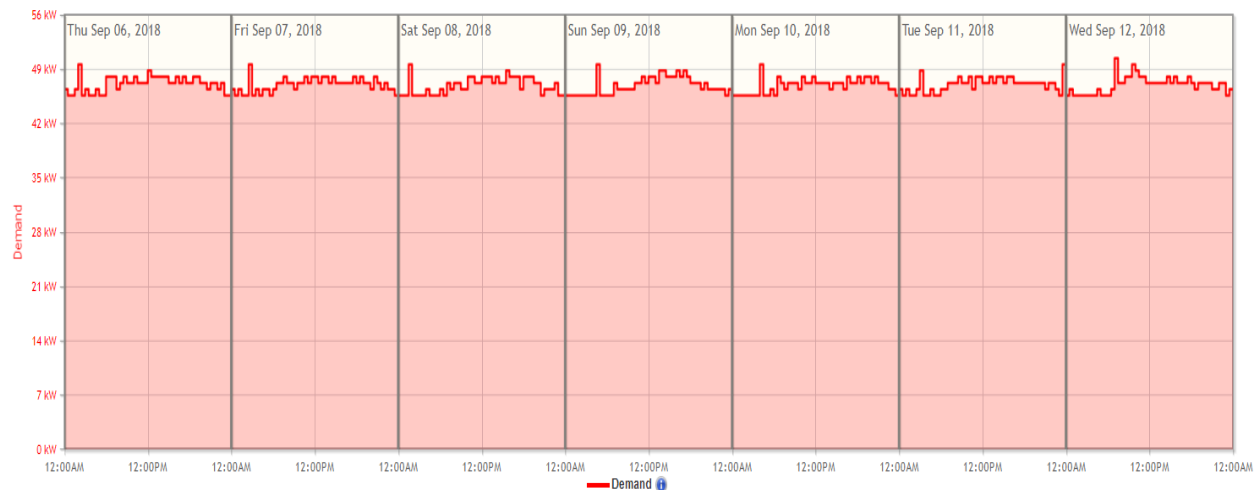


Figure 1. VCx example of retail store energy usage profile. Energy usage was constant, 24/7/365.

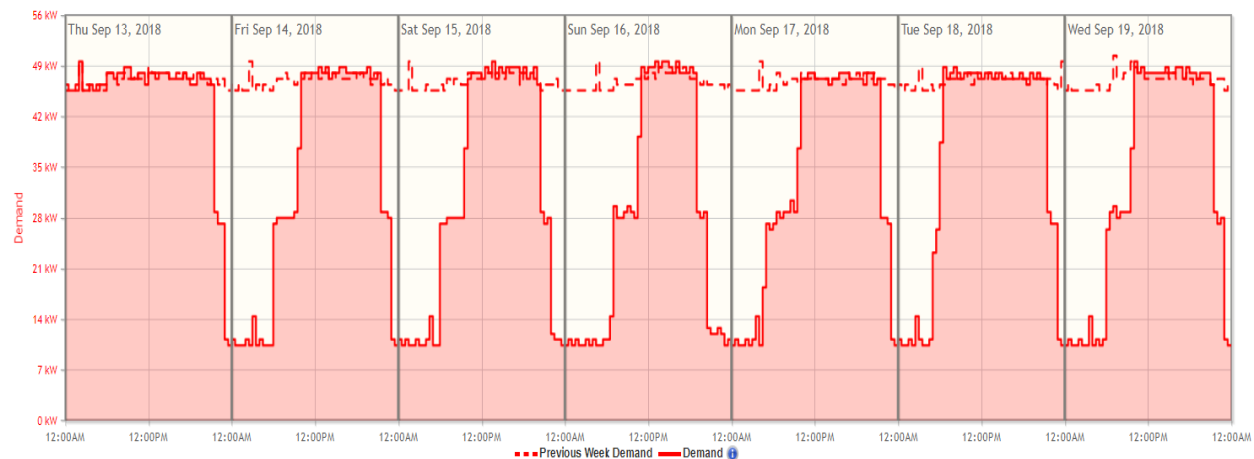


Figure 2. Energy usage profile after VCx engagement for the same participant. Lighting and HVAC schedules were put in place along with operational hours of 10 am to 9 pm.

Like identification of operational improvements, all measurement and verification (M&V) is performed remotely. Since VCx was the first utility program in Illinois to rely entirely on using whole-facility interval-level meter data to validate and claim program savings using individualized customer-by-customer modeling, ComEd and Power TakeOff worked closely with the program's third-party evaluator, Navigant (now Guidehouse) to corroborate saving

methodologies. Power TakeOff's M&V team used modeling compliant with IPMVP Option C and utilized linear regression techniques to normalize baseline and reporting period consumption independently. Typically, three to nine months of post-implementation interval usage data, along with 12 months of 30-minute interval meter pre-change data and variables such as type and date of change implemented, hourly TMY3 weather data, day of week, and explanation of non-routine events (NREs) were required to complete M&V for a given measure.

Program Results

From the start, the VCx program was designed to be easy for its target market – small and midsize commercial and public sector customers with non-24/7 operations - to participate. There is no program application or other paperwork, no in-person meetings, and ComEd pays for the VCx service as the program incentive. The customer pays only for implementation of operational improvements, which are usually very low-cost and typically yield simple paybacks of a year or less. As monitoring of energy data is done remotely, customers can also be notified if an anomaly in usage is found post-VCx, supporting persistence of energy savings.

This approach has proven both effective and scalable over the last several years, with program savings growing from 2 GWh in 2017 to over 23 GWh in 2021. VCx has proven to be especially suitable for customers with large numbers of similar locations, such as banks, national retailers and public schools. A customer's locations can be ranked according to savings potential, allowing energy managers to prioritize spending across their building portfolio. In addition, the same improvements can often be applied at many locations. As such organizations frequently have a single point of contact with many locations under management, a single customer engagement can be very impactful.

Introduction of Real-Time Data

As one of the largest public school systems in the United States, the Chicago Public Schools (CPS) are an ideal example of such an organization. CPS operated 636 schools serving over 340,000 students during the 2020-2021 school year (www.cps.edu). An early and frequent participant in VCx, CPS had saved over 7 GWh of electricity through the program by the end of 2020. Those projects had been performed using the 30-minute interval data from CPS's AMI meters, usually provided by ComEd to the Power TakeOff analytical team a day or two after it was generated.

However, as was the case for the VCx program in general, there were buildings for which analysis of the meter data was not sufficient to identify and verify operational savings opportunities. In addition, ad hoc collection of data- for example, turning on and off equipment that was connected to a meter for which the energy usage curve was very complex- was difficult and time-consuming due to the need for the analyst to wait a day or more to see the impact.

Access to interval data in smaller increments, and access in real time, offered the potential to overcome these challenges. In 2020, ComEd and Power TakeOff began to consider the following questions:

- Can sites that were previously unable to participate in the VCx program due to inconsistent or difficult to assess 30-minute interval data become successful participants if 1-minute interval data were available?

- Can sites which have already completed VCx projects achieve deeper energy savings with the addition of real-time interval data in smaller increments?
- Does providing access to real-time usage data provide additional customer benefits beyond the operational improvements targeted by VCx?
- In what scenarios is real-time monitoring equipment best utilized? What sites could be best and most cost-effectively served?

To maximize the usefulness of a pilot that would address these questions, the ideal participant would have:

- A wide range of buildings in terms of age of equipment and dates of construction/renovation
- Sites which had building automation systems (controlled both centrally and on an individual facility basis) and sites that did not have a BAS
- Sites which had previously completed VCx and sites which had not
- Facilities with a range of building envelope materials, heating and cooling systems and controls, and single sites that exhibit a wide variety of these variables

The vast diversity of CPS facilities met all these criteria, and they agreed to participate in a pilot starting in late 2020.

Introduction of Real-Time Data

The CPS team (sustainability director, chief engineer, facilities managers) developed a list of over 50 CPS locations which featured the desired wide range of building ages, equipment, and controls capabilities. As a first step, the ComEd account manager for CPS, along with the ComEd/Power TakeOff pilot team, worked with ComEd's meter provisioning department to install pulse outputs on the meters of the CPS pilot sites to provide a real-time energy usage output. That pulse output is captured and recorded by cellular-based real-time monitoring equipment (see Figure 3 below), which logs the data in 1-minute intervals and transmits it to Power TakeOff's centralized Energy Management and Information System (EMIS) once a minute. The cellular technology used with the real-time equipment allows for more flexible and fast deployment, without the need to install Ethernet or be provided access to the local network, and proved to be incredibly reliable in hard to deploy circumstances, including numerous sub-basements with no standard cellular coverage.



Figure 3. Cellular real-time monitoring equipment used for the pilot. A complete real-time kit is shown on the left prior to installation, and a picture of a completed installation is shown on the right.

As an additional customer service, battery-backup equipment was installed at four CPS locations which were acting as early vaccination sites as part of the City of Chicago's COVID-19 response activity. If a site were to lose power, the battery backup provided over 48 hours of continuous data monitoring and would trigger alerts to immediately inform CPS building engineers and facility personnel of the power outage and also when power was restored.

Once a site was up and running, CPS personnel would have access to a real-time energy dashboard (Figure 4) which provided a view of energy usage at the meter level for each participating site, along with hourly weather data and additional alerting and reporting capabilities.

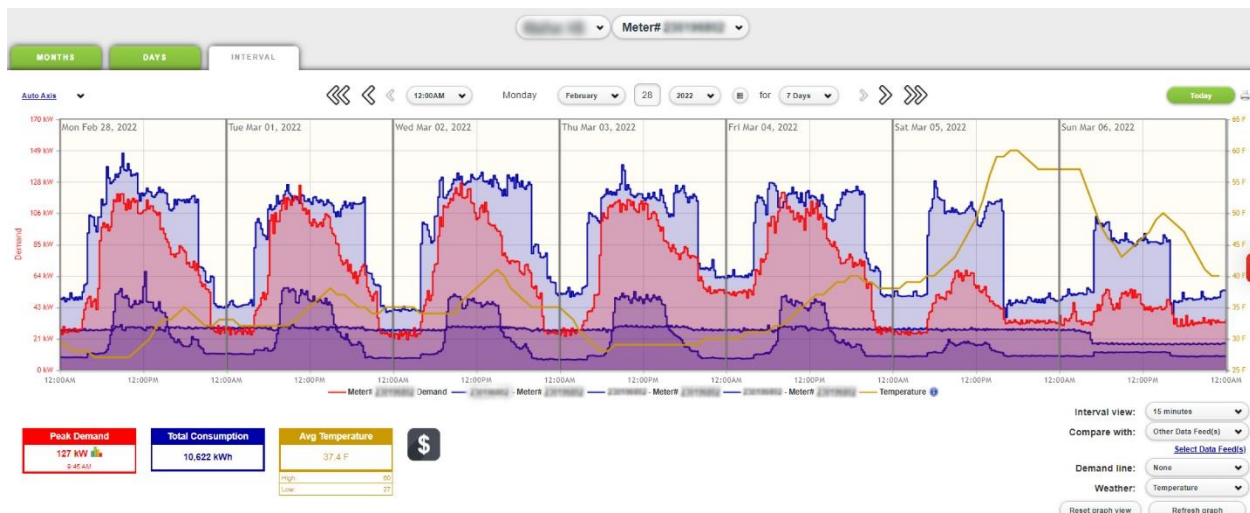


Figure 4. An example screenshot from the real-time energy dashboard. This screenshot shows 15-minute data over a one-week period for four separate utility meters (red and blue lines) from a single school site, along with hourly weather data (yellow line).

The higher resolution one-minute usage data not only enables 30x the level of granularity compared to the typically available 30-minute interval data to more accurately identify loads and energy saving opportunities, but the one-minute frequency of data provides near instantaneous feedback from on-site activities to troubleshoot and identify the right on-site corrections for improved energy management.

Example Site Engagements Using Real-Time Monitoring (RTM)

Elementary School A

The participating site labeled Elementary School A is a 55,000 square foot site which did not have a functional automated controls system at the time of initial engagement. In addition, COVID-19 disruptions made it difficult to model for savings. Through their participation in the pilot, the building engineer and program analyst were able to utilize the access to real-time data to pair much of the HVAC equipment, kitchen equipment, most of the lighting, and specific locations in the building to their corresponding electrical meters to assist with more accurate energy usage modeling.

One of the anomalies in the electrical data that was identified during this process was a malfunction in the compressor for a walk-in freezer. The cycling, or slight surge pattern in the data was indiscernible using the normal 30-minute interval data; however, it was very apparent in the 5-minute data and obviously even more so in the 1-minute data (see Figure 5). Once the kitchen usage was isolated to a specific meter, various pieces of equipment were turned on and off in a process of elimination until the source of the anomaly in the data was exposed. This allowed the compressor to be repaired (a much cheaper solution than having it eventually fail due to the frequent cycling and require replacement) and energy to be saved from the time of repair going forward.



Figure 5. Early morning energy usage at Elementary School A showing difference in resolution of normal 30-minute interval data vs. 1-minute real-time data. The higher resolution real-time data enabled the identification of a malfunctioning freezer compressor.

This same trial-and-error process was used to make comparisons between the various air handling systems at the site and discern when supply fans were continuing to run outside of their command, allowing corrective strategies to be implemented.

Elementary School B

This 152,000 square foot elementary school with functional automated controls is a site of previous engagement with VCx, and features a BAS accessible on the enterprise server for the district. Although the interval data showed that savings opportunities were likely available for specific periods (such as weekends), changes in scheduling and weekday demand spikes made it impossible to adequately model for and claim those savings following the initial VCx engagement.

When real time engagement began, a loss of data was experienced, presumably as a result of a power loss to the box. However, it was only happening during overnight periods during the week, weekends, and holidays when the building was expected to be unoccupied. The program analyst and building engineer worked to track down the source of the outage by using the one- and five-minute interval data and a trial-and-error method of elimination. The engineer had limited the issue to a series of potential culprits: 14 breaker switches and 3 toggle switches throughout the building. Through a process of elimination, the team found that a single breaker was responsible for the outage to the real time box. It was determined that one of the custodial staff used this breaker to turn off all the lights in a specific hallway of the building. Unbeknownst to the custodian, turning off this breaker also cut power to a few of the secondary

heat sources in the rooms at the end of that hallway. The engineer, not knowing the breaker was being turned off at night, thought the difficulty in recovering occupied room temps in those spaces was due to a malfunction with the equipment serving those spaces and had been troubleshooting the issue for some time when the issue of the breaker being turned off came to light. The issue was corrected with the custodial staff and, even during extreme weather events this past winter, the issue of morning recovery in the affected classrooms was eliminated.

In addressing the demand spikes during the weekdays, it was discovered that outside doors were being blocked open for deliveries in the morning and again during some recess periods. Without understanding the underlying cause, the building was attempting to compensate for these periods with the doors left open for deliveries by setting excessive space temperature set points as well as extending equipment schedules outside of occupancy windows. The 5-minute interval data was instrumental in pinpointing and identifying the underlying cause of the excessive heating and cooling with a more exact timeframe for when the HVAC was attempting to recover/maintain temps because of the open doors for deliveries. With the identification and correction of this behavior, the building could be returned to a more efficient operational level. These changes can be seen in Figure 6 below showing energy usage profiles before engagement vs. after these changes were made.



Figure 6. A 7-day energy usage profile comparing the real-time data prior to VCx engagement (dashed line), including high weekday demand, compared to mid-engagement progress (solid red line with fill).

Using a similar process of investigation using the real time data, the building engineer and program analyst are using the real-time data to better understand and eliminate the source of higher than expected usage between 5 pm and 10 pm during the week and expect to be able to achieve additional deeper savings at the site.

High School A

High School A is located in a 410,000 square foot building which also hosts several other entities. Each entity has its own requirements for space conditioning. To complicate things, zones of control for building systems do not overlap neatly with the different spaces, making it very difficult to create equipment scheduling that provides the desired conditions for each entity. The building team and program analyst are working to troubleshoot using the more granular interval data to define the overlap in the zones.

The site had a previous VCx engagement just prior to COVID which encountered modeling challenges, and savings could not be claimed at that time. VCx has been reimplemented at this site with the aid of real time monitoring. One anomaly under investigation is specific to a single meter with sporadic weekend consumption. Figure 7 below shows sample

notes provided to the building engineer, specifically showing a breakdown of usage from the previous Saturday with 1-minute interval data, which the engineer is using to isolate the cause of the problem.



Figure 7. An image showing notes from investigating high weekend energy usage at High School a with the building engineer.

High School B

The main building at this high school is a 433,000 square foot, eight story, mostly glass structure that has passenger and freight elevators, a pair of escalators on every floor from the lower level through the seventh floor, multiple chillers for cooling, and a variety of electric heating options, most specifically for the classrooms which are on the perimeter of seven of the eight floors in this building. There are also four full kitchens throughout the building, those on upper levels being referred to as “detail” kitchens, all having expected kitchen equipment such as exhaust and refrigeration.

The building does not have a working BAS (although one is planned), so building engineers largely run the building manually and many processes are set to a 24/7 mode as a result. Program activity to date has involved utilizing the real time monitoring to isolate specific spaces in the building, as well as specific equipment, to one of the three designated electrical meters at the main building. This includes the escalators, lighting at each level, kitchen equipment for three of the four kitchens, the cooling system, and some of the electric heating components. By mapping equipment to meters and improving understanding of the connectivity of building systems, much of the data needed to perform VCx is being gathered, and the search for savings will be able to commence immediately once a BAS is installed.

The greatest benefit of real time monitoring to date at High School B also involves an auxiliary building across the street from the main building, which houses gyms, auditorium, pool, and other areas that are often used by community groups. The site was one of the first CPS locations to house and distribute COVID vaccines. In the beginning, the vaccine was housed in

the main building, while the vaccine distribution occurred in the auxiliary building (primarily for logistical reasons). The real time monitoring allowed for alerts and alarms to be placed on the two buildings for almost immediate notification in the case of a power outage, which would have put the vaccine in jeopardy.

Elementary School C

Elementary School C is a 150,000 square foot elementary school that, similar to High School C, had in a previous VCx engagement encountered challenges with modeling due to COVID, making it impossible to claim savings. This site also had a change in hands-on personnel during COVID, so the real time engagement was with a very different building team than the original VCx engagement. When students returned on August 31, 2021, the program analyst and new engineer walked through the existing energy action plan from the previous VCx engagement and re-implemented all recommendations. At the onset of the heating season, the engineer notified the energy advisor of challenges with bringing the building to temperature. The real time data was used to isolate a few of the anomalies seen in the data; most specifically, a strong cycling beginning just before midnight and going through to startup was evident in the 1-minute interval data (Figure 8). Initially, the engineer and program analyst believed it could be due to an alarm on one of the boilers, a flame failure, which the engineer was resetting upon arrival to the building each morning. However, resolution of the flame failure issue did not resolve the cycling in the data during the overnight period. As a second attempt at resolution, the engineer and program analyst are planning to schedule an early morning evaluation at the beginning of the next heating season to troubleshoot the potential cause of the anonymous energy usage while using the 1-minute data feed to coordinate their activities and find the source of the higher than expected energy usage.



Figure 8. Strong overnight and early morning cycling is evident in the 5-minute data shown below for Elementary School C.

Initial Results

As mentioned above, M&V for energy savings generated by the VCx program is performed using pre-and post-implementation energy usage trends over extended periods of time, using 12 months of pre-engagement data and three to nine months of post-engagement data, depending on the measure implemented. The disruption of usual building occupancy and operations due to the COVID-19 pandemic has also added to the amount of time needed to complete M&V according to program standards. The real time VCx program engagements follow the same M&V process as the normal VCx program; however, the more granular real time data provides greater insights into activities on-site that can be used as an additional tool to

help overcome modeling challenges due to Non Routine Events (NREs) and to help create appropriate Non Routine Adjustments (NRAs) based on a deeper understanding of site operations from the real time data.

As of the time of this writing, thirteen sites had completed their real time VCx engagement, including six sites that had prior traditional VCx program engagements, and seven sites that had not previously participated in VCx. Energy consumption models were created for each of the sites to produce an annual estimate of the energy saved through the VCx program. Table 1 displays preliminary results of real time projects occurring at sites that had prior traditional VCx projects.

Table 1. Real Time Meter projects with prior traditional VCx program engagement

CPS Site Number	Traditional VCx Year	Traditional VCx Savings	Real Time Project Year	Real Time Additional Project Savings	Deeper savings from Real Time
Elementary School E	2018	527,209	2022	626,304	119%
Elementary School F	2020	196,931	2021	191,728	97%
Elementary School G	2021	453,376	2022	169,321	37%
Elementary School D	2019	175,214	2022	40,153	23%
High School C	2020	918,503	2022	102,546	11%
Elementary School B	2020	401,035	2022	28,415	7%

The initial analysis of these first pilot sites shows how real time data has helped CPS achieve a total of 1.16 GWh of additional, deeper savings that were not achieved during the first time VCx engagements. These sites achieved additional, new savings that were on average 49% of the savings from their original VCx program participation. Table 2 displays preliminary results for first-time VCx sites with their savings, and those savings as a percent of the site's typical annual usage (before the energy efficiency measures occurred).

Table 2. CPS sites with first time engagement real time projects

First Time RTM Sites	Real Time Project Savings (kWh)	Savings % of Baseline
Elementary School H	274,726	24%
High School E	198,191	17%
High School F	165,098	9%
High School D	209,932	6%
Elementary School I	39,940	2%
Elementary School J	168,942	17%
Elementary School K	123,418	9%

Another 1.18 GWh in savings were achieved from participants in the real time VCx program who had not previously participated in VCx, specifically because they were not good candidates for traditional VCx. Utilizing real time data enabled them to become effective VCx participants and average savings per participant were 12% of their baseline consumption. The mean savings were 168,607 kWh.

These real time VCx results data are early and a small sample size. With only thirteen completed real time sites to work with at this time, a determination of whether there were statistically significant differences in savings levels between first-time traditional VCx and first-time VCx real time sites is not yet possible. Additional post-implementation data and a larger sample size will provide an opportunity for a more conclusive answer with statistical power.

Addition of Plug Load Control Devices

Very few of CPS's locations have central air conditioning. Over 30,000 window AC units are used in schools and administrative buildings, along with other plug load equipment such as air purifiers, smart boards, and vending machines. At the beginning of the pilot, the electric load from all these devices was out of reach from existing building control systems, representing a huge additional opportunity for savings.

Beyond the potential energy savings from adding window AC units and other plug loads to the equipment controllable in an automated fashion, auxiliary benefits are clear as well. CPS reports significant issues with needing to replace AC unit coils that freeze when the units run during the winter, and air purifier filters last only half as long as predicted due to the units running 24/7 instead of only when needed. These problems could be reduced or eliminated with better controls. The initial estimated project ROI for adding controls to a small set of test locations is estimated at 12 months, even without factoring in the auxiliary benefits.

To test this idea, four schools were selected with diverse characteristics and high impact for CPS. A total of 175 AC units, 62 air purifiers, 7 smart boards, and 5 vending machines were targeted. Wi-Fi enabled plug load controllers were either plugged into wall sockets or hardwired by CPS electricians where higher currents are demanded.

CPS is working with its BAS provider, KMC, to make the equipment controllable by the BAS. KMC has written a driver and created dashboards to allow CPS personnel to control the devices. Building engineers will have a license to control the devices and will be responsible for scheduling changes and investigating automated changes. A diagram showing the overall solution is in Figure 9 below.



Figure 9. Plug load control device diagram and information flows.

Training will be provided for teachers, administrators, and other building personnel. In addition, VCx program staff will be provided with view-only access to the KMC dashboards. By fall 2022, VCx analysts will be able to include that data in their search for operational improvement strategies at these CPS sites.

It is expected that, even with training, some building users will occasionally override the schedules; for example, a teacher may wish to work after hours in a classroom when the window AC would be programmed to be off. As a result, KMC is programming redundant commands to shut off the units every two hours to make sure that overrides don't persist and the equipment does not run longer than is needed. Additionally, for those controllers that are not hardwired but plugged into outlets, a security harness was installed that locks the power cord into the controller, so the controller cannot be easily removed from the load it is managing.

While this addition of automated controls for plug loads was not part of the real-time project, it offers tremendous potential for the VCx program in general. A successful demonstration of generating energy savings in this way would be applicable to other buildings without central AC or with large non-24/7 plug loads. CPS plans to expand deployment to more and more buildings as cost permits, pending successful verification of savings.

Next Steps

The original savings objective of the pilot was to achieve 4.2 GWh of savings across 50 sites. Promising preliminary results led to expansion of the scope in multiple ways with the enthusiastic support of the customer; analysis to date indicates a total of 2.3 GWh verified savings across 13 sites with completed projects, a trend that suggests the original savings estimate for the pilot will be exceeded by a significant amount. For those 13 locations, sites that had already completed traditional VCx engagements were able to increase their total savings by 49% through the addition of real-time data, and sites which were previously not accessible through VCx were able to achieve an average of 12% of whole-building usage, which is similar to that achieved at other sites through traditional VCx.

The successful use of real-time interval usage data in small increments to expand the target market for VCx and to drive deeper savings in buildings offers strong growth potential to ComEd's existing VCx program. Based on results to date, 50 more sites have been added to the work with CPS, and a number of projects at other school districts and private businesses are also planned.

Going forward, consideration will be given to offering a real time option to a wider range of customers and to making it available as an option on all VCx engagements. In addition, if CPS is able to achieve significant energy savings through the use of plug load devices addressable by a BAS, ComEd can consider offering incentives for those devices and/or have them as an option in future VCx projects where building controls are limited.