ENERGY SOLUTIONS

REPORT FOR

Scaled Deployment of Advanced Rooftop Unit (RTU) Controls in New York State (Interim Report)

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INTERIM REPORT

This interim report provides a summary of the scaled deployment of Transformative Wave's CATALYST Advanced Rooftop Controller that occurred between December 2015 and March 2018. It includes monitoring results for 130 units across 13 sites installed through April 2017. Project sites that were installed in late 2017 or early 2018 (32% of the 191 total deployment units) and have limited monitoring data have been excluded from the energy savings calculations in the interim report. Monitoring data from these more recent installations will be included in a comprehensive final report expected to be published in June 2019.

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ABOUT ENERGY SOLUTIONS

Energy Solutions is an employee-owned engineering services, demand management, and program design firm founded in 1995. Our mission is to create large-scale environmental impacts by providing market-based, cost-effective energy, carbon, and water management solutions. We seek to develop reliable, high-value partnerships with our clients through a strong commitment to innovation, collaboration and industry-leading quality.

ABOUT NYSERDA

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975. To learn more about NYSERDA's programs, visit nyserda.ny.gov or follow us on Twitter, Facebook, YouTube, or Instagram.

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1. EXECUTIVE SUMMARY

New York Governor Andrew M. Cuomo's Reforming the Energy Vision (REV) initiative includes a climate goal of 40% reduction in greenhouse gas emissions (GHGs) by 2030 from 1990 levels. In April 2018, Governor Cuomo announced an additional 40% increase in current energy efficiency targets, which would enable New York to achieve annual electric efficiency savings of 3 percent of invest-owned utility sales in 2025.[1]

Commercial heating, ventilation, and air conditioning (HVAC) makes up a substantial portion of New York's energy consumption. Rooftop Units (RTUs) provide HVAC services to a large portion of commercial and industrial buildings in New York and nationally, conditioning 46% of all commercial buildings and serving over 60% (39 billion square feet) of commercial building floor space in the United States (EIA 2003). Over 90% of RTUs utilize constant speed supply fans which run continually at full speed, meaning that the unit draws significantly more power than necessary the majority of the time to maintain occupancy comfort. Advanced Rooftop Controls (ARC), like Transformative Wave's CATALYST, are retrofit solutions for constant air-volume (CAV), single-zone packaged that can be installed onto existing RTUs and achieve significant energy savings by converting the RTU supply fan from single-speed to multi-speed without waiting until the unit needs to be replaced. The CATALYST and other ARC retrofit solutions are particularly important to meeting New York's aggressive efficiency goals by targeting the existing building stock that is not planning a major HVAC replacement in the near-term.

As part of NYSERDA's Emerging Technology and Accelerated Commercialization (ETAC) initiative, Energy Solutions managed a scaled deployment of the CATALYST in New York State from December 2015 through March 2018 to achieve the following objectives:

1) Validate energy savings claims at scale and across a wide variety of building types throughout New York State.
2) Build consumer and contractor awareness of the CATALYST and other Advanced RTU controls in general by providing trainings and informational sessions.
3) Increase the number of Affiliate contractors certified to sell and install the CATALYST through market outreach and new contractor partnerships with Transformative Wave.

During this time period, the CATALYST was installed on 191 HVAC units across 24 sites within New York State.[2] In addition to deployment and energy monitoring, Energy Solutions conducted workforce education and training to increase customer and contractor awareness of both the CATALYST and other intelligent controls, including:

- **5 "Contractor and Customer Engagement" webinars** which informed the targeted contractor network of the deployment opportunity and the benefits of the CATALYST. Across 5 webinars,102 attendees from different market sectors including HVAC contractors, commercial real estate partners, design engineers, and end use customer such as retail and restaurant chains.
- **6 "Intelligent Controls 101" webinar training sessions** which focused on communicating the energy, facility, human resources, and business value associated with advanced controls and how they're disrupting the market. Across these sessions

[1] "Governor Cuomo Announces New Energy Efficiency Target to Cut Greenhouse Gas Emissions and Combat Climate Change". April 20, 2018. https://www.nyserda.ny.gov/About/Newsroom/2018-Announcements/2018-04-20-Governor-Cuomo-Announces-New-Energy-Efficiency-Target-to-Cut-Greenhouse-Gas-Emmisons

[2] The unit count includes all units at sites that received deployment incentives regardless of whether all of the units were submitted for incentives. In total, 142 units across 24 sites received incentives.

between 72-83 attendees from the contractor market, end use customers, and utility stake holders benefited from the webinar series.

- **3 case studies** that communicated a different customer experience which highlighted energy and non-energy benefits. They focused on initial customer interest such as integration opportunities or customer comfort.

The deployment also conducted a comprehensive measurement and verification (M&V) plan to confirm Transformative Wave's claim that the CATALYST saves between 25% - 50% and to validate the data reported by the Catalyst eIQ platform. The M&V plan was based on the International Performance Measurement and Verification Protocol (IMPVP) -2012 framework and included 3 key activities:

1. Validation of Transformative Wave's energy savings claim by calculating the savings achieved by the sites in the pilot. CATALYST reported savings data was used to calculate the individual site savings. All units in the deployment was included in this validation step. values by using eIQ reported data. This component of the M&V plan was based on IMPVP Option A
2. Validation of savings data reported by eIQ using plan based on IMPVP Option B About 40% of the incentivized units in the deployment was included in this validation step.
3. Validation of data points collected by the sensors installed with the Catalyst using independent data loggers. 10% of the incentivized units in the deployment had loggers installed.

FINDINGS AND RECOMMENDATIONS

Finding #1- Sites participating in the deployment achieved an average of 42% electricity savings and 7% therms savings.

Across the 130 units from 13 project sites with monitoring data of twelve months or more, electricity savings ranged from 24% to 57% with an average of 42% electricity savings, and 75% of projects achieved at least 32% electricity savings. These interim results support Transformative Wave's claim that the CATALYST saves between 25%-50% RTU energy consumption. Complete results from the full 24-site, 191-unit deployment will be provided in an updated report in June 2019. These findings were validated through IMPVP Option A and IMPVP Option B.

Table 1. Therms and cost savings for sites reporting data for at least 12 months.

Building Type	Number of Sites	Total Units	Electricity Savings	Therms Savings	Cost Savings	Average Monitoring Duration (months)
Assembly	1	7	24%	10%	15%	16.0
Education	2	6	44%	3%	35%	12.0
Office	5	105	43%	6%	29%	15.6
Restaurant	1	3	45%	8%	30%	21.0
Retail	4	9	43%	7%	41%	14.2
Total	**13**	**130**	**42%**	**7%**	**33%**	**15.1**

Finding #2 The CATALYST is particularly well-suited to buildings with long operating hours, large capacity units, and/or sites with proportionally large HVAC loads and variable occupant loads, such as restaurants and retail.

Energy savings are affected by two primary drivers: total occupancy hours and fan size. Based on these drivers, the CATALYST is particularly well suited for restaurants, retail and other building types with increased annual occupancy hours. Restaurants also have proportionately high HVAC loads and therefore achieve strong total savings. Restaurants and retail spaces also have variable occupancy loads, making them strong candidates for the CATALYST since it is able to react to space changes and only provide the cooling or ventilation needed instead of operating based on the assumption that the space is fully occupied at all times.

Finding #3 – Successful deployment of CATALYST and other ARC technologies at scale requires a dedicated focus on workforce education and training.

Selling and installing ARC solutions (and intelligent controls more broadly) has an initial learning curve and requires dedicated training and experience to successfully integrate this into contractor core competencies. Of the four affiliates who participated in the deployment, 80% of affiliate sales came from the two affiliates who participated in sales training and had previous experience selling intelligent controls. Affiliates that attended sales strategy training in addition to the required installation training, were more equipped to identify new customer opportunities. 88% of total sales were either from experienced affiliates or national chain accounts. These affiliates were able to communicate the business value of ARC technologies to new customers and can use this new area of expertise to seek opportunities for business growth.

Recommendation #1 – Utility program measures should integrate the CATALYST into their program portfolios as standalone measures or large-scale pilots.

Savings results from this deployment and previous CATALYST studies, provide utility program managers with sufficient data to support the development of a measure for the CATALYST in their energy efficiency programs.

We recommend that programs use the CATALYST energy monitoring capabilities to collect data on an ongoing basis to refine program assumptions over time. However, the technology is sufficiently well demonstrated that in most cases should not require further "field demonstrations" prior to integrating into a program. If a pilot is necessary, we recommend that it be at sufficient scale (at least 150 units) to ensure that all relevant information is collected and that the pilot activities warrant the time and investment required by the manufacturer. A large pilot scale is required to get new contractors on board and increase the number of installations in a given area. We recommend a subset of these installations go through an independent site-based measurement and verification protocol.

Recommendation #2 – Utility ARC programs should develop deemed estimates by leveraging real-time reporting capabilities of ARC technologies and consider adopting a standardized reporting format to facilitate program participation and streamline the process.

Deemed savings programs play a critical role in scaling new technologies since they simplify participation in utility incentive programs. A major barrier to deemed energy efficiency programs is a lack of a streamlined data collection method to develop and update deemed savings over time. While the CATALYST has over 12 thousand units in the field with real-time reporting capabilities, the largest published monitoring study is 130 units. Rather than complete additional small-scale demonstrations that are unlikely to substantially improve industry knowledge of ARC performance and improve deemed savings estimates, we recommend future demonstration efforts focus on standardizing energy monitoring data specifications for previously tested and verified ARC technologies so that deemed savings estimates can be based on a much larger scale and on an ongoing basis. In additional to ongoing performance validation, future pilot program should focus on scaling market adoption through new delivery mechanisms.

Recommendation #3 – Utility programs and other national entities should incorporate significant workforce education and training components into programs to ensure increased awareness and training for ARCs (and intelligent controls more broadly).

While controls can provide significant new business value to customers by reducing energy costs, improving insight into facility operations and ensuring occupant comfort, there is an important learning curve for both customers and contractors. In addition to providing financial incentives to reduce first cost, utility programs which target ARCs and other intelligent controls should provide a series of education and training programs that include introductions to the technologies, as well as more in-depth trainings to help contractors understand how to sell and install the technology and highlight the business value intelligent controls to customers.

Recommendation #4 - As the number of trained affiliate contractors familiar with the CATALYST and other ARC solutions grows, utilities should consider additional program mechanisms to focus on achieving scale.

As familiarity with ARC technologies and the number of trained contractors grows over time, utility programs should pilot new deployment mechanisms for the CATALYST and other ARC technologies such as midstream promotion through contractors to scale its adoption. Midstream approaches typically achieve far higher uptake than downstream programs but do require resolving important issues such as ensuring successful installation and operation.

2. MARKET AND TECHNOLOGY CHARACTERIZATION

MARKET CHARACTERIZATION

New York Governor Andrew M. Cuomo's Reforming the Energy Vision (REV) initiative includes a climate goal of 40% reduction in greenhouse gas emissions (GHGs) by 2030 from 1990 levels. Energy efficiency is expected to play a major role in meeting New York's aggressive GHG reduction goals. In April 2018, Governor Cuomo announced an additional 40% increase in current energy efficiency targets, which would enable New York to achieve annual electric efficiency savings of 3 percent of invest-owned utility sales in 2025.[3]

Commercial heating, ventilation, and air conditioning (HVAC) makes up a substantial portion of New York's energy consumption. Rooftop Units (RTUs) provide HVAC services to a large portion of commercial and industrial buildings in New York and nationally, conditioning 46% of all commercial buildings and serving over 60% (39 billion square feet) of commercial building floor space in the United States (EIA 2003). Building codes require that when a building is occupied RTU supply fans must operate continuously to meet ventilation needs, regardless of whether the RTU is providing heating or cooling to the conditioned space (PNNL 2013). Over 90% of RTUs utilize constant speed supply fans which run continually at full speed, meaning that the unit draws significantly more power than necessary the majority of the time to maintain occupancy comfort. Multi-speed supply fans can save significant energy by modulating fan speed to meet building demands as they change throughout the day and year.

A major challenge to meeting these aggressive energy efficiency targets are long equipment stock turnover lifetimes. Stock turnover refers to frequency and length of time it takes building owners to replace aging or faulty equipment. New York's Technical Reference Manual assumes that RTUs have an average lifetime of 15 years[4], and well-maintained units may operate for significantly longer than that[5]. Advanced Rooftop Controls (ARC), like Transformative Wave's CATALYST, are retrofit solutions for constant air-volume (CAV), single-zone packaged that can be installed onto existing RTUs and achieve significant energy savings by converting the RTU supply fan from single-speed to multi-speed without waiting until the unit needs to be replaced. Since most utility programs offer incentives for the purchase and installation of new HVAC units, even if 100% of buildings participated in utility programs, they are limited by stock turnover of HVAC equipment (roughly 5% of stock per year). There are very few technology solutions that currently exist that improve HVAC efficiency after installation, therefore the CATALYST and other ARC retrofit solutions are particularly important to meeting New York's aggressive efficiency goals by enabling efficiency measures that target existing building stock regardless of plans for major HVAC replacements.

The CATALYST can be installed on any age unit but is most cost-effective when installed on RTUs with at least 5 years of expected remaining useful life.

[3] NYSERDA, 2018
[4] New York State Department of Public Service. 2016
[5] Studies, including one conducted by the DOE in 2013 (https://www.regulations.gov/document?D=EERE-2013-BT-STD-0007-0105), shows HVAC lifetimes significantly greater than 15 years. However, energy efficiency programs around the country typically use 15 years as the useful life for HVAC units.

Advanced rooftop controllers can be installed on the vast majority of existing constant air volume RTUs and are particularly well suited for climates with extended shoulder seasons and buildings with long operating hours such as hotels, restaurants, retail, warehouses with small offices, industrial/manufacturing and educational facilities.

While this study reflects installations in New York State, ARC solutions are broadly applicable throughout North America. As of May 2018, the CATALYST has just under 12,000 installations throughout the U.S and Canada.[6] Of these installations, over 90% participated in an ARC incentive program. These utility programs offer both custom and deemed rebates for ARC technologies such as the CATALYST.

ADVANCED ROOFTOP CONTROLS (ARC) OVERVIEW

Technology Overview

Advanced Rooftop Controls are retrofit solutions for constant air-volume (CAV), single-zone packaged rooftop units (RTU)[7] that save energy by converting the RTU supply fan from single-speed to a multi-speed. While this conversion provides the majority of the ARC's energy savings, ARC technologies can also include additional energy savings measures unique to the specific product. While there are several different ARC technologies (Enerfit, Digi-RTU, and Schneider Electric Single Zone retrofit solution) available on the market each with a unique set of energy saving components, this deployment and report is based on Transformative Wave's CATALYST product, which includes the following capabilities[8]:

- Variable frequency drive (VFD) on the supply fan converts the supply fan from single-speed to multi-speed. The CATALYST logic chooses between 3 programmed speeds (40%, 75% and 90%) to run the fan at depending on the building occupancy level and mode the RTU is currently in (ventilation, heating or cooling[9]). This feature saves electricity because reducing fan speed reduces fan power consumption.
- Advanced Economizer Logic integrates outside air free cooling with mechanical cooling over a wider range of outdoor air temperatures. This logic provides electricity savings by decreasing the need for compressor energy.
- Demand Control Ventilation (DCV) senses return air carbon dioxide levels to determine the occupancy levels and adjust the outside air volume accordingly to provide only the ventilation needed at the given moment. This feature saves electricity because it allows the RTU to modulate the amount of air needed instead of providing the full design amount at all times.[10]
- Integration with Transformative Wave's online eIQ dashboard. The eIQ dashboard capabilities include visualization of RTU operation, a fault detection and diagnostics system, and internal graphing capabilities

[6] Transformative Wave website. http://transformativewave.com/
[7] CAV Single-Zone RTUs are small systems that serve a single thermal zone. A CAV unit operates the fan and compressor at full capacity until the zone space temperature reaches the specified setpoint. Once the setpoint is reached, the compressor turns off, but the fan continues to run at full capacity to provide the needed ventilation. CAV systems run the compressor and fan at full capacity regardless of the amount of cooling or ventilation needed.
[8] Transformative Wave also offers a "CATALYST Lite" version which includes only the multi-speed fan conversion component.
[9] For larger units, the fan speed varies with the stage of cooling – 75% for stage 1 cooling and 90% for stage 2 cooling.
[10] Additional information about the CATALYST functionalities can be found in reports previously published by the Pacific Northwest National Laboratory (PNNL 2013) and the National Renewable Energy Laboratory (NREL 2016).

Product Installation and Contractor Training

To facilitate installation, the CATALYST is sold as a retrofit kit with all parts coming in a single package including the VFD, the economizer controller, an eIQ central hub, temperature sensors (if the project includes the optional BMS), and cell tower to facilitate communication between the eIQ central access point and the eIQ cloud server[11]. Figure 1 shows how the individual units communicate with the Transformative Wave cloud server. shows how the individual units communicate with the Transformative Wave cloud server.

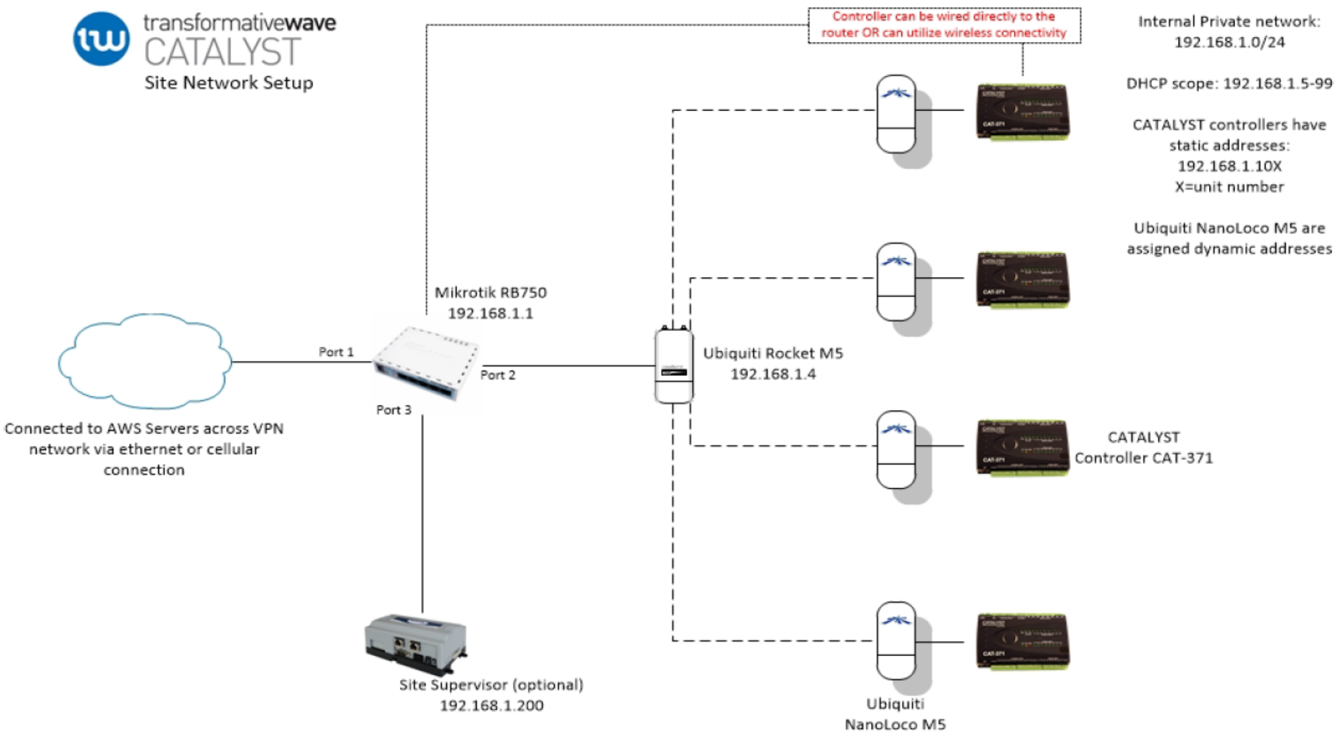

Figure 1: Catalyst/eIQ Communication Architecture. The signals from the individual CATALYST units are either grouped together and communicate with the cloud server via a central point (Ubiquiti Rocket) or each individual unit can be hardwired directly into a modem to communicate directly with the cloud server. The optional site supervisor is used for very large sites which require a more robust communication option for all the data coming in from the units.

For each site, the economizer controller is pre-wired and pre-programmed at Transformative Wave's headquarters, which simplifies on-site installation for contractors. The wiring is color coded to ensure that the they are connected to the correct terminal[12]. Once at the site, the economizer controller is bolted to the RTU and wired to the economizer, the VFD is installed on the fan, and the eIQ hub is installed on the roof to receive signals from each economizer controller box. Once the hardware is fully installed, eIQ begins receiving unit operation information and determines the general health of the unit at the time of installation. Any faults identified are then followed up upon by the contractor as they would for any fault identified during the CATALYST operation.

Contractors installing the CATALYST are required to complete specific Transformative Wave training sessions at their headquarters in Kent, Washington to ensure that installation is completed correctly. The 3-day technical training includes both classroom and hands-on training segments. Classroom training includes sessions on the purposes and applications of the

[11] Cell tower is not required if eIQ access point can tie directly into facilities existing network.
[12] The CATALYST specification document clearly notes the final terminal for each color-coded wire.

various CATALYST options, and installation best practices. Participants apply the knowledge they learned in the classroom in hands-on trainings by learning how to install, commission and trouble shoot CATALYST units in Transformative Wave's training lab.[13]

eIQ Platform

The eIQ platform provides a web-based visualization of RTU efficiency, system performance, fault detection, and energy accountability tools which can either be integrated with an existing building management system (BMS) or it can be installed along with the eIQ Tridium BMS. The CATALYST controllers communicate either over Wi-Fi or physical wiring to the central eIQ communication hub (one per site), which then communicates with the eIQ cloud server via a cellular connection. The eIQ online interface streams information from all units within a site together into a single online interface that can be used to remotely adjust setpoints, visualize the current operation of a given unit, provide fault detection and diagnostics and real-time energy monitoring and reporting. eIQ can integrate multiple sites into a single portfolio view so that building portfolio managers can control them from a single access point.

eIQ's fault detection and diagnostics feature functions by tracking the operation of a unit and alerting the building owner if the unit appears to be experiencing a fault of some kind. The CATALYST's series of sensors locate where the fault is occurring, and the location and suggested causes are displayed within eIQ. eIQ's home view has a series of indicators that are lit either green, orange or red depending on whether the unit is operating well, or has a potential fault, meaning that a building operator can quickly identify any units with potential issues.

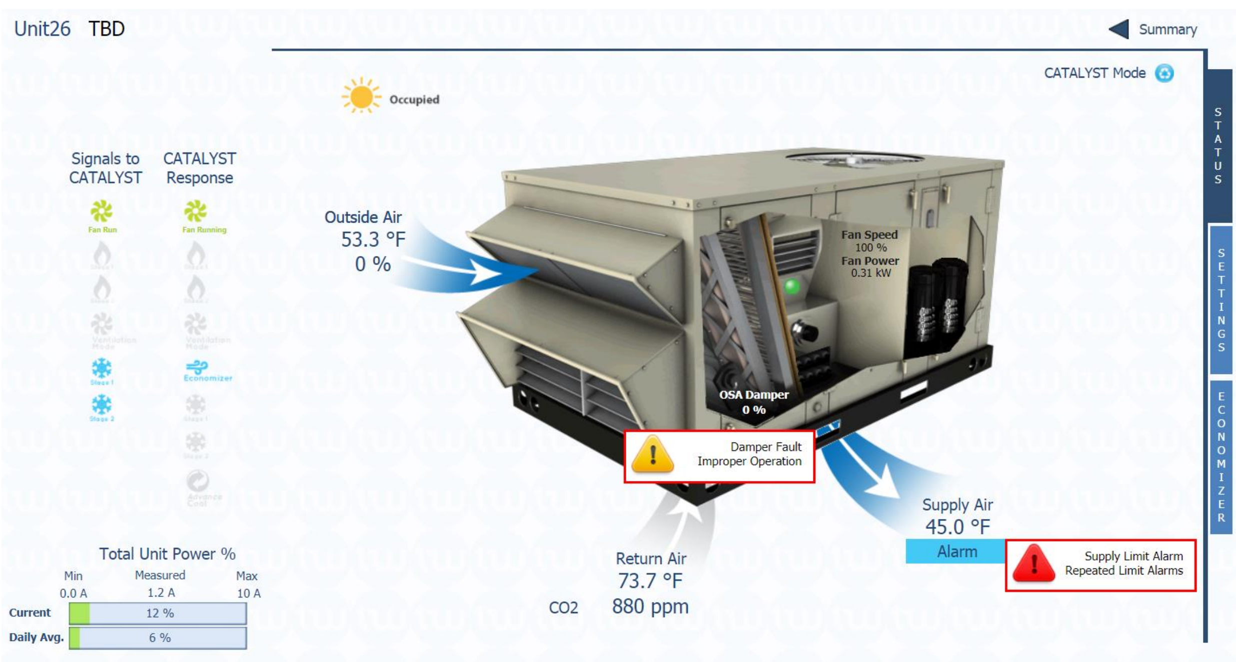

Figure 2. View of a unit operating with a fault identified through the eIQ portal (Credit: Transformative Wave)

The eIQ automated fault detection and diagnostics feature has additional energy benefits as it decreases the amount of time an inefficient unit is running due to an undiagnosed fault.

[13] Installation training takes about 24 hours over 3 days to complete. Transformative Wave also offers sales training one-on-one and through formal training events at their Kent Headquarters.

Although this brings additional energy savings, it is generally difficult to quantify as the amount of time and energy saved is often site specific.

eIQ can also create trend analyses for any of the data points collected by the series of CATALYST sensors for a specified timescale. Images of the eIQ interfaces and reporting capabilities is included in Appendix B - eIQ Screenshots.

Product Cost

Transformative Wave provides contractors with pricing and specification tool that enables them to estimate project economics for a given building based on building type, estimated run hours, RTU capacity and fan horsepower. While individual sites may vary, the CATALYST's pricing can be generally broken down into three primary components:

- **Site materials**: This includes the VFD, the economizer controller, the eIQ central hub, and optional temperature sensors. There is a single eIQ central hub per location, and one VFD and economizer controller for each unit. The eIQ central hub and economizer controllers are both fixed costs, whereas the VFD cost varies with the size of the unit.
- **Contractor/in-house labor:** Labor costs include in-house work done by Transformative Wave at their factory and on-site work completed by the installing contractor. The wiring and programming is all done in house by Transformative Wave to leverage economies of scale and simplify on-site installation. The cost of the in-house labor is a one-time cost that varies with both the number of controllers being installed and the complexity of the logic being programmed. On-site labor includes installing the VFDs and bolting the economizer controller to the RTU. Additional labor may be needed to include the temperature sensors and to repair any faults identified by the CATALYST once fully installed.
- **eIQ cloud server subscription**: An ongoing subscription to the cloud server is required for the user to be able to view the information being collected by individual controllers that are sent to the cloud via the eIQ central hub.

The cost of the CATALYST is primarily driven by the size of the VFD required for each RTU, and therefore CATALYST units installed on units with larger cooling capacity and fan horsepower will cost more because of the increased VFD cost. However, because energy savings also scale with fan size, project economics are typically more favorable for larger units. Other CATALYST unit materials, including sensors and wiring are fixed and therefore do not change with RTU size.

Transformative Wave includes a 2-year warranty for the VFD and a 1-year warranty for the remainder of the CATALYST components. The warranty covers any unexpected mechanical failures. Transformative Wave quotes the replacement VFD at about $500 - $800. Transformative Wave finds that the VFD is very reliable with failures occurring typically due to installer error or water damage.

ADOPTION BARRIERS

While the CATALYST has been successful in its demonstrations and has received awards from organizations for its energy savings capabilities, it still faces a number of common adoption barriers for technologies in the commercialization process:

CUSTOMER AND SUPPLY CHAIN BARRIERS

- **Low consumer awareness –** While it has been successfully demonstrated in multiple previous third-party validations [14], the CATALYST and other ARCs are relatively new technologies and are fundamentally different than simply installing new, more efficient equipment that facility managers may be used to. This information barrier requires additional customer education and awareness.
- **Underdeveloped supply chain and lower contractor awareness–** Because the CATALYST and other ARC technologies are retrofit solutions and are different than selling new equipment, contractors have an initial learning curve to successfully sell and install them. Since HVAC contractors and design/build engineering firms have traditionally focused on selling and installing new equipment in replacement of existing units, they may not be aware of retrofit opportunities and how controls can support new business models moving towards a more ongoing, service-based customer relationship.
- **First cost investment–** Customers are often concerned with up-front capital investments, and the common use of performance metrics such as simple payback does not accurately characterize performance of longer-term investments and critical infrastructure such as HVAC. Metrics such as savings to investment ratio (SIR) or life cycle cost (LCC) analysis better reflect the total value of energy savings. Identifying non-energy benefits (through reduced maintenance and downtime, improved occupant comfort, etc.) also identifies additional business value that ARCs provide. Since the landlord owns the building's HVAC units but the tenants receive the main benefits from the energy savings, it is difficult to decide who should invest in and commit to the cost. The benefits are often split between the two parties in an unknown amount making the decision difficult.

REGULATORY BARRIERS

- **Limited utility support and ongoing need for pilot demonstrations–** Although the CATALYST has roughly 12,000 units installed nationally and numerous previous published 3rd party validations, utilities often require their own pilots to validate energy savings claims for technologies prior to incorporating them as a measure in their portfolio. This requires technology companies to conduct many time-intensive pilots across multiple utility territories, limiting their ability to achieve scale following successful demonstration.

TECHNICAL BARRIERS

- **Existing Equipment Issues –** Technology like ARCs which dependent on the condition of existing building equipment is less likely to be successful if it is installed on aging and poorly maintained units. Older equipment may be in bad enough shape to preclude installations from moving forward or require significant work to bring the unit up to baseline working order.
- **IT Coordination –** Facility and IT managers may be concerned with networked controls which tap into the building's network, limiting or delaying access which extends deployment timelines. The CATALYST circumvents this issue by establishing its own separate network and not tapping into the building IT infrastructure.

[14] Third party validations include NREL 2016, E Source 2016, PNNL 2013, SMUD 2014, and UC Davis 2014.

3. ETAC DEPLOYMENT OBJECTIVES

SUMMARY OF PROJECT GOALS

NYSERDA's Emerging Technology Accelerated Commercialization (ETAC) initiative supports market adoption of commercially available yet under-used energy saving and load-reduction strategies or technologies in commercial, institutional, and non-process industrial settings through large-scale and high-impact demonstrations of these strategies and technologies. This large-scale deployment of Transformative Wave's CATALYST focused on showcasing solutions that address barriers to broad market acceptance of the CATALYST and ARCs more broadly through three key goals:

1. **Demonstrate performance at scale and support integration into utility programs:** Increase confidence of building owners and utility program managers by installing a large number of units across a wide variety of building types, providing sufficient performance data to increase consumer and utility confidence in ARC technologies and integrate the technology into New York utility programs. To ensure accurate measurement and validation of energy savings claims, NYSERDA's Technical Consultant, LaBella Associates, provided M&V planning and oversight.

2. **Develop the supply chain and market awareness:** Increase the number of affiliate contractors who are trained to sell and install the CATALYST (and ARCs more generally) through marketing and outreach efforts, ensuring that there is a robust supply chain that can support and meet the needs of New York building owners and operators. In addition, provide more general training to contractors, building engineers, and design/build engineering firms on the role that intelligent and networked controls in savings energy and optimizing building operations.

3. **Build consumer awareness and confidence through transparent project reporting:** Publish case studies, project reports, and an online public dashboard to communicate project energy savings and non-energy benefits over time, highlighting customer experience with the technology across different building types. Because of the CATALYST's energy monitoring capabilities, ongoing performance reporting can be conducted and reviewed through the dashboard on an ongoing basis to review the product's performance and financial performance over time.

DEPLOYMENT OVERVIEW

Project eligibility and incentive structure

The ETAC initiative offered a $2,400 per unit incentive to certified Transformative Wave "Affiliate"[15] contractors for selling and installing each CATALYST unit, which contractors provided as a pass-through incentive to customers to reduce project first cost. This flat-per unit incentive approach was used to improve the project economics for smaller units and encourage installations across all building types and unit sizes, since large units typically have better

[15] In order to become a certified Affiliate, contractors must attend Transformative Wave's multi-day training on selling and installing the CATALYST, which is described in more detail in the Product Installation and Contractor Training section.

financial returns. The ETAC initiative for the CATALYST accepted project applications from November 2015 to December 2017. All commercial buildings within New York State who paid the System Benefits Charge were eligible for incentives. Upon completion of installations, Energy Solutions verified installation through the eIQ interface to ensure that the controls were installed, and that the HVAC unit was performing properly. For a detailed overview of the project process, see Appendix A.

Performance Monitoring Requirements: As part of the customer program agreement, all customers agreed to anonymized energy reporting through the eIQ system for up to three years to collect performance monitoring data across all sites and ensure persistence of energy savings over time. A full description of the performance monitoring process is detailed in the Measurement and Verification Plan Details section."

Contractor engagement and education

The project team and NYSERDA conducted two types of contractor and industry outreach:

- Five introductory webinar sessions on the CATALYST for HVAC contractors, facility managers, building owners, and specific customer verticals in the New York market that demonstrate its benefits to customers.
- Offering a 3-part series of webinars to contractors and end use customers highlighting the value proposition of intelligent controls and how to use the newfound insights from the advanced data analysis to inform their decisions and take action. This series focused on distinct technologies and emerging market trends and was provided to 60 attendees from utilities, design engineering firms, and contractor companies.

Project performance dashboard

The dashboard was built to be fully interactive and enables potential customers, utility program managers, and/or potential contractors view anonymized project reporting that best addresses their interests and needs. The dashboard provides both a portfolio-level summary of the deployment to understand general project trends, as well as drill-down capability to see detailed information on a project by project basis, including:

Portfolio level:

- Average savings across entire deployment (in both therms and kWh)
- Average portfolio savings per month
- Financial performance (Savings to Investment Ratio) with an adjustable discount rate

Project level:

- General geographic location[16]
- Number of units
- Number of months of data collection
- Building type
- Building square footage
- Project cost

[16] To preserve project site anonymity, each site is represented as a point on the map without any other identifying characteristics such as zip code.

The Tableau-based dashboard integrates updated energy monitoring data from the Transformative Wave Server every 15 minutes, enabling ongoing monitoring of energy and financial performance over time at both a portfolio and individual project level.

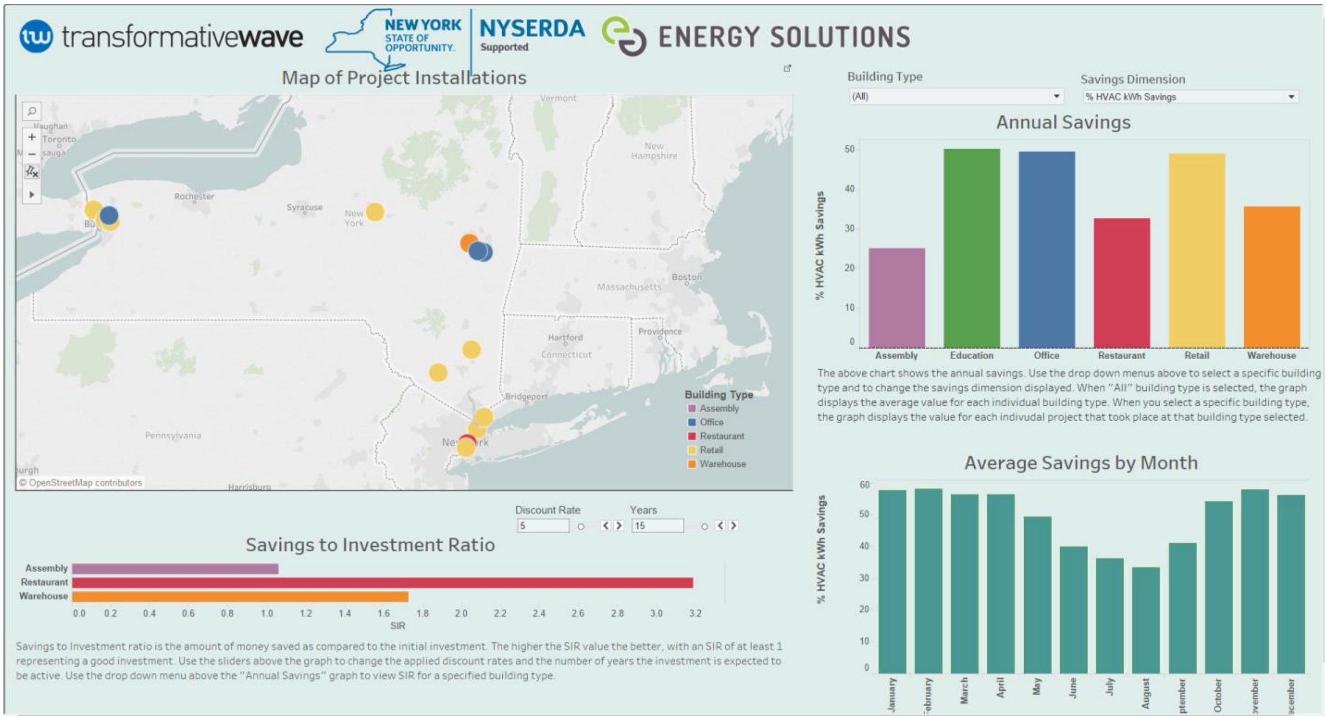

Figure 3. Interactive Performance Monitoring Dashboard. All information is streamed from the eIQ database and updated on a 15-minute basis.

The viewer can hover over the points in the map to see project specific information. The building type and savings dimension can be toggled to show a single building type and to change the savings type shown. The discount rate and years of investment assumptions in the “Savings to Investment Ratio” chart can be adjusted to meet user preferences. Additional dashboard images can be found in Appenidix D: Additional Dashboard Screenshots.

MEASUREMENT AND VERIFICATION (M&V)

The project conducted measurement and verification to determine the energy and cost savings realized at each site in the deployment, and to assess the accuracy of the eIQ predicted savings and the data points reported by eIQ. The M&V and was based on the International Performance Measurement and Verification Protocol (IMPVP) -2012 framework.[17] The energy savings calculation methods are listed below, along with how they were applied in this deployment’s specific M&V plan, and how many units went through each step of the plan.

Energy Savings Calculation Methods

There are two primary methods to quantify energy and cost savings, which are listed below in order of relative accuracy. Both methods use data reported in the eIQ, which is based on usage measurements taken by installed current transductors, heating and cooling calls made by the

[17] Efficiency Valuation Organization. January 2012,” *International Performance Measurement and Verification Protocol”*

site's BMS, and site occupancy levels determined by the carbon dioxide sensors in the HVAC return air ducts.

RETROFIT ISOLATION / CALIBRATED SIMULATION APPROACH (IPMVP OPTION B)

The retrofit isolation/calibrated simulation approach uses CATALYST'S ability to run in Energy Savings Mode (ESM), which is the full CATALYST energy savings operation, and Standard Operating mode (SOM), which is an emulation of the pre-retrofit conditions. Switching between these modes runs on a prescribed schedule during the first year after installation to build a temperature regression model that is used to on given timescales to estimate savings. This method is based on IPMVP Option B, Retrofit Isolation and was used in this study to determine the accuracy of the eIQ predicted savings.

Energy use in both ESM and SOM are reported by the CATALYST. The savings is then calculated as:

$$Savings = (Annualized\ SOM\ Energy\ Use - Annualized\ ESM\ Energy\ Use) \frac{+}{-} Adjustments$$

This method provides the savings to the highest degree of accuracy of the options above because the CATALYST is according true energy use in both modes and calculating the difference. The annualized baseline and post-retrofit energy use calculations can be found in Appendix C: Savings Calculation Details.

CALCULATED SAVINGS APPROACH (IPMVP OPTION A):

Power measurements and other data collected during CATALYST operation from sub-meters and controllers can be used to calculate the estimated savings achieved by CATALYST operation. The pre-retrofit consumption is estimated by adding the avoided energy consumption back to the actual energy use. The pre-retrofit conditions are based on a series of measurements taken prior to installation. This option is based on IPMVP Option A, where key parameters are measured, and then additional information of baseline is approximated and was used to calculate the savings realized at each site participating in the deployment.

The power measurements and other data collected during CATALYST operation by the eIQ Platform from each of the RTU's full unit sub-meters and CATALYST controllers can be used to calculate the estimated savings achieved by CATALYST operation. The Pre-retrofit consumption is estimated by taking the measured CATALYST energy use and adding back the calculated avoided energy consumption associated with each conservation measure implemented by CATALYST control.

Savings from each measure component (VFD, demand control ventilation, and advanced economizer) are calculated separately are added together to calculate the full system savings. The full calculations for each measure component can be found in Appendix C: Savings Calculation Details.

The savings due to the VFD are calculated to a high degree of accuracy because they are based on two known quantities: the peak fan kW (which is measured at the time of installation), and the instantaneous fan power draw (which is measured by the CATALYST sensors). The savings from demand control ventilation and the advanced economizer sequence have a lower degree of accuracy because there is a series of assumptions made about how the unit would have been operating in the pre-retrofit condition.

Measurement and Verification Plan Details

The plan included the following features and parameters for all sites in the deployment:

- **Recording of Pre-Installation Conditions**: Existing conditions were collected during installation to establish the baseline condition and verify the accuracy of the data reported by the CATALYST system. Data collected included economizer changeover setpoint, economizer control type, space setpoints and occupancy schedules, baseline fan power, and outside air damper position.
- **Savings Calculated via the Calculated Savings Approach:** eIQ calculates the savings at each site internally and reports the data daily. The savings calculated were processed to determine average deployment savings, and savings for subsets of the deployment. The reported savings values were also combined with site details collected during the project process to determine what site and equipment characteristics drives energy and cost savings.

In addition to the features above, about 40% of the 142 incentivized units went through additional M&V activities, including:

- **Data Validation through Mode Switching:** The CATALYST was programmed to switch between pre- and post-retrofit conditions, or Standard Operating Mode (SOM) and Energy Savings Mode (ESM), respectively. Switching occurred daily for the first 2 weeks of every other month. Mode switching started on the 1st day of the month immediately following CATALYST installation. It was estimated that this schedule would result in the loss of only 5% of the first-year energy saving. The site savings calculated via mode switching was compared to the site savings reported by eIQ to determine the accuracy of eIQ reported savings. Figure 4 details how each component of the M&V plan was applied to the sites participating in the deployment.

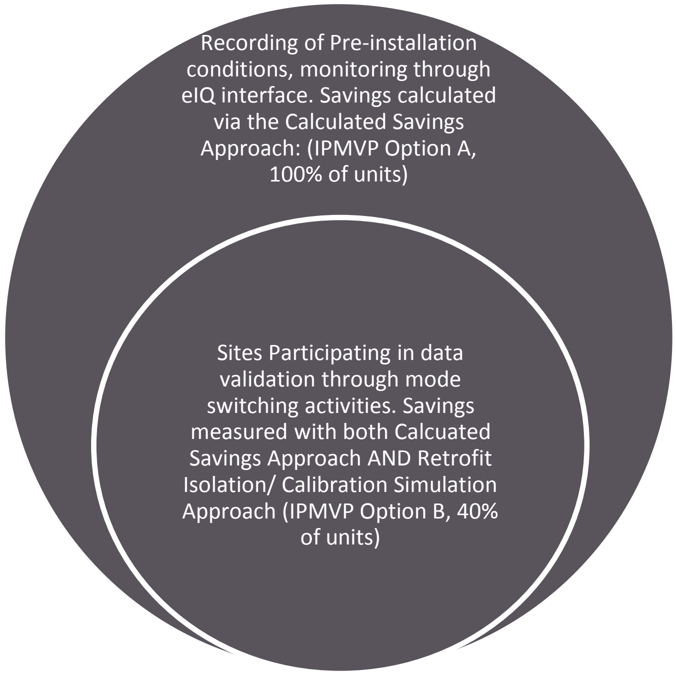

Figure 4: Overview of M&V methods across projects within the ETAC deployment

Data recording began the first day of the month immediately following installation completion. The data recording proceeded for 1 full year, meaning at the completion there will be 12 weeks of recorded data for each site: 6 weeks of SOM and 6 weeks of ESM runtime.

Table 2. Overview of M&V strategies by building type.

	Monitored Through eIQ and savings calculated via calculated savings approach[18]		Sites participating in data validation through mode switching. Savings calculated via Retrofit Isolation/Calibration Simulation Approach	
Building Type	Total Sites	Total Units	Total Sites	Total Units
Retail	9	38	9	35
Education	3	9	0	0
Office	6	112	2	9
Restaurant	5	25	5	15
Assembly	1	7	0	0
Total	24	191	16	59

60 out of the 142 units that were incentivized participated in the data validation through mode switching protocol outlined detailed above. The original implementation of the data validation protocol was delayed due to continuous Measurement and Verification plan revisions which impacted the execution schedule and collateral development. Not all incentivized units were required to participate in switching as this condition was not included in the original customer agreement form since the plan was not finalized at the time of collateral distribution. All

[18] The units monitored through eIQ was greater than the number of units incentivized because 2 sites had units that had the CATALYST installed, but were not eligible for the incentive. In one case, the units did not qualify because they served multiple zones while the program limited eligibility to units with single zone control. In the other case, the units were not eligible because there was a cap on the number of units an individual customer could submit for incentives. These units were still able to be monitored for savings validations because eIQ groups all of the units on an individual site together.

customers who submitted applications using the updated customer agreement beginning in September 2017 were required to participate in the data validation protocol along with a sampling of the customers who submitted applications prior to September 2017 and also agreed to participate.

In addition to the plan components detailed above, LaBella Associates installed on 5% of all RTUs in the deployment to confirm that measurements reported through the eIQ interface accurately reflected independent measurements in the field. Data collected included full unit power draw, fan power draw and compressor status. The data collected was compared to data output by the CATALYST to confirm the accuracy. Discrepancies of 5% or less were ignored, and the CATALYST data was used. Larger discrepancies resulted in the adjusting of reported data.

4. RESULTS

DEPLOYMENT SUMMARY

Deployment marketing and outreach efforts began in October 2015, applications submission opened in December 2015 and project installation and commissioning took place between June 2016 to March 2018, with participation from the following Affiliate contractors: Atlantic Westchester; EMCOR Betlem; American Energy Care and SureTemp. In addition to Affiliate contractors, projects were also completed through Transformative Wave's National Accounts arm.

Table 3. Summary of Key Deployment Results Statistics

Building Type	Total Sites	Total Units[19]
Assembly	1	7
Retail	9	35
Restaurant	5	15
Office	6	76
Education	3	9
Total	24	142

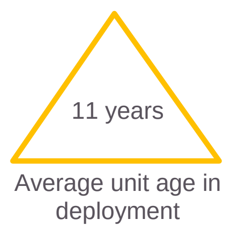

Figure 5: Average Project Timeline

The average installation timeline from start to finish was 1.1 months and ranged from 1 to 3 months depending on the number of units and the specific customer needs. The site installation began after the project team approves the project and the customer ordered the CATALYST

[19] The unit count includes all units at sites that received NYSERDA incentives. In a few cases, not all units within a project site were applied for and/or received NYSERDA incentives. In total, 142 units across 24 sites received NYSERDA incentives.

equipment. Site installation was considered completed after all units were online and visible in the eIQ platform. After installation was completed, the commissioning and quality assurance period averaged about 1.4 months across all units. The commissioning and verification concluded when the project team received all unit startup documentation and when the eIQ platform indicated that all units and controls were fully functioning. On average, the final incentive payment was issued one week after a site was commissioned and verified by the project team.

Some sites had a longer installation timeline if they had extensive site specifications such as stringent occupant requirements, integration with other advanced systems, and installing a BMS that controlled several sites. In cases where the project did not move forward with installation, this was rarely due to technical barriers and more so attributed to customer acquisition hurdles.

The average age of RTUs across the deployment was 11 years, ranging from 1 year and 19 years. Since the CATALYST has an expected lifetime of at least 8 years, this suggests that many building owners are operating their RTUs well beyond New York's assumed measure life of 15 years. This has important implications for utility program trying to comprehensively address HVAC in existing buildings by targeting existing units that are still in good working condition and will not be replaced with more efficient units in the near future.

The sites in the deployment were spread across the state as can be seen in Figure 6.

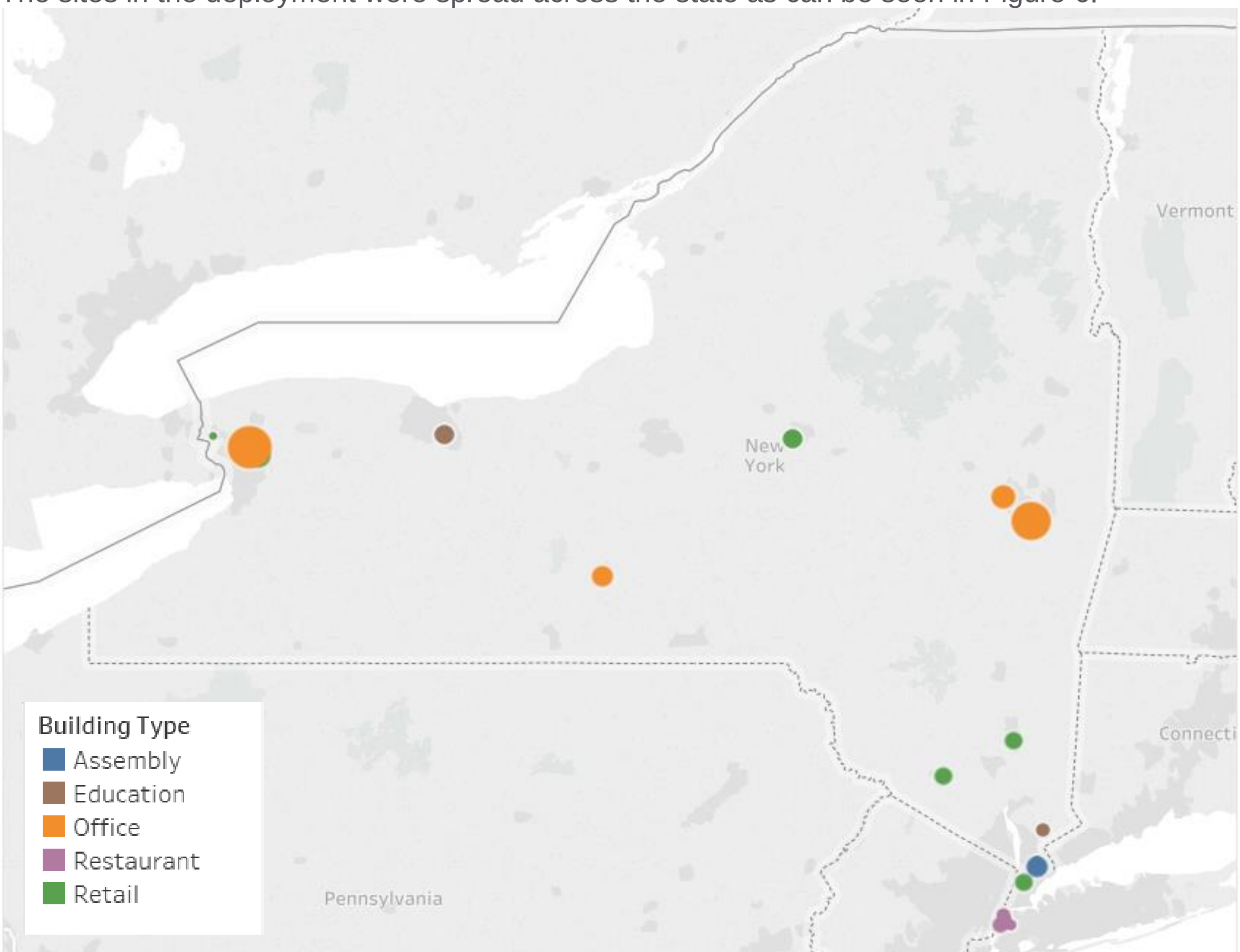

Figure 6: Map of Project Installations. The size of the point indicates the relative number of units installed at the location (Of the 191 units installed at 24 sites, the smallest installation size was 1 unit, the largest 30 units). Not all projects are visible due to close geographic proximity causing overlapping points.

ENERGY SAVINGS

eIQ Monitoring Results

Overall, the CATALYST achieved 42% electricity savings, 7% therms savings, and 33% operating cost savings over an average monitoring duration of 15 months. Table 4 shows the average energy and cost savings as a percentage of the baseline usage.

Table 4. Energy and Cost Savings (%) for sites with 1 years' worth of data. The total savings are a weighted average based on the number of sites within each building type. Data for this report was collected through March 2018

Building Type	Number of Sites	Total Units	Electricity Savings	Therms Savings	Cost Savings	Average Monitoring Duration (months)
Assembly	1	7	24%	10%	15%	16.0
Education	2	6	44%	3%	35%	12.0
Office	5	105	43%	6%	29%	15.6
Restaurant	1	3	45%	8%	30%	21.0
Retail	4	9	43%	7%	41%	14.2
Total	**13**	**130**	**42%**	**7%**	**33%**	**15.1**

Cost savings were calculated by multiplying the kWh and therms saved by a flat kWh and therms rate respectively and adding together. The kWh and therm rates are blended rates calculated by Transformative Wave based on the specific customer's rate schedule.

Office and retail building types had the greatest number of total projects, which were analyzed to identify the primary drivers of differences in energy savings outcomes (Table 5).

Table 5. Electricity Savings statistics for office and retail spaces

Building Type	Average	Range	Std. Deviation
Office	45%	31% - 57%	10%
Retail	40%	30% - 45%	6%
Total	43%	30% - 57%	8%

The range in energy savings was primarily due to differences in annual operating hours. The maximum office savings (57%) was from a facility that operated for about 7,600 hours[20] during the year while the minimum savings (30%) was from a facility that operated closer to 3,200 hours during the year. The impact of hours of operation on percent savings is discussed in more detail below.

SEASONAL IMPACT ON ENERGY SAVINGS

Figure 7 shows the electrical savings percentage per month for each building type.

[20] These operating hours are atypical for this building type.

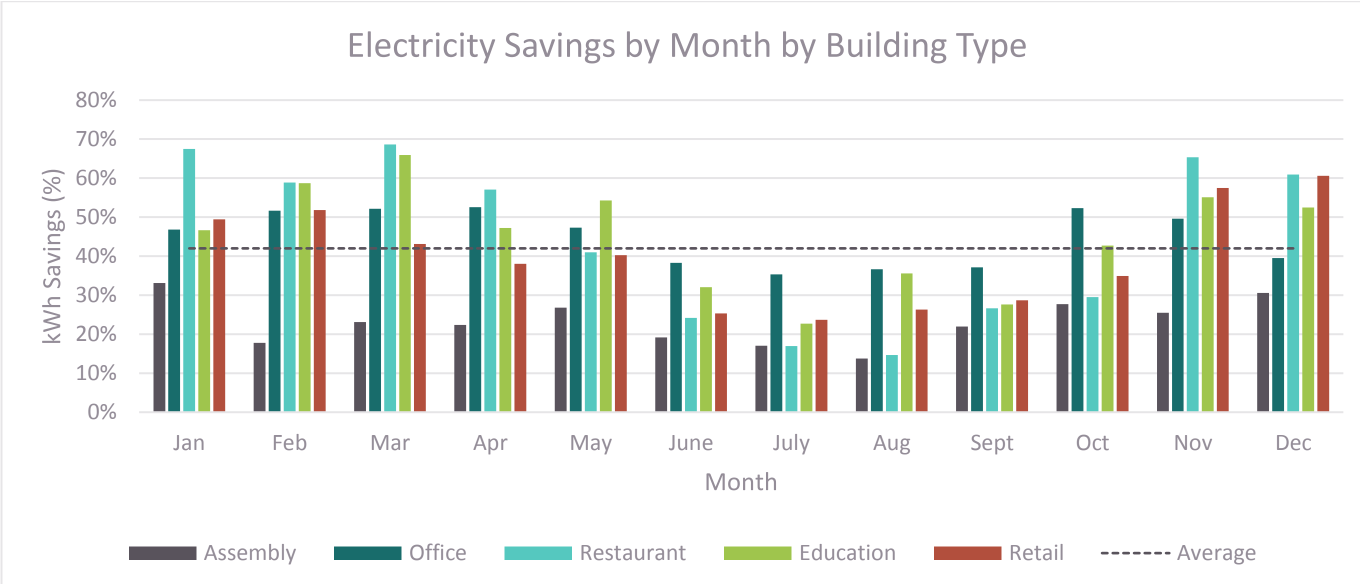

Figure 7. Electrical (kWh) Savings as Percentage of the Baseline kWh per building Type. The value for each building type is the average across all sites for the specific building type and the chart also includes a line showing the average across all sites.

Energy savings were highest in shoulder seasons, when the CATALYST takes advantage of outside air for cooling, and lowest in summer when compressors are needed for a higher percentage of facility runtime and RTUs operate at full load much of the day. Savings are high during winter because the units have a lower overall electricity use because there is no compressor input needed (the units all used gas heating). Therefore, because the units only use electricity to run the fans in the winter, they realized a higher overall percent savings since the fan savings provide most of the overall unit electricity savings.

The restaurant building type (1 site) had the biggest range of savings month to month. This is consistent with expectations because restaurants have a higher internal heat load due to the cooking equipment. The higher internal heat load increases the need for compressor energy during the summer and decreases the need for heating (and thus fan energy) input during the winter months. The assembly had the smallest range. However, this is likely due either to the overall lower savings as compared to the other building types, or the small sample size for this building type.

ELECTRICAL SAVINGS BY MEASURE

Electrical savings are a sum of the savings due to the VFD, the advanced economizer sequencing and the use of demand control ventilation.

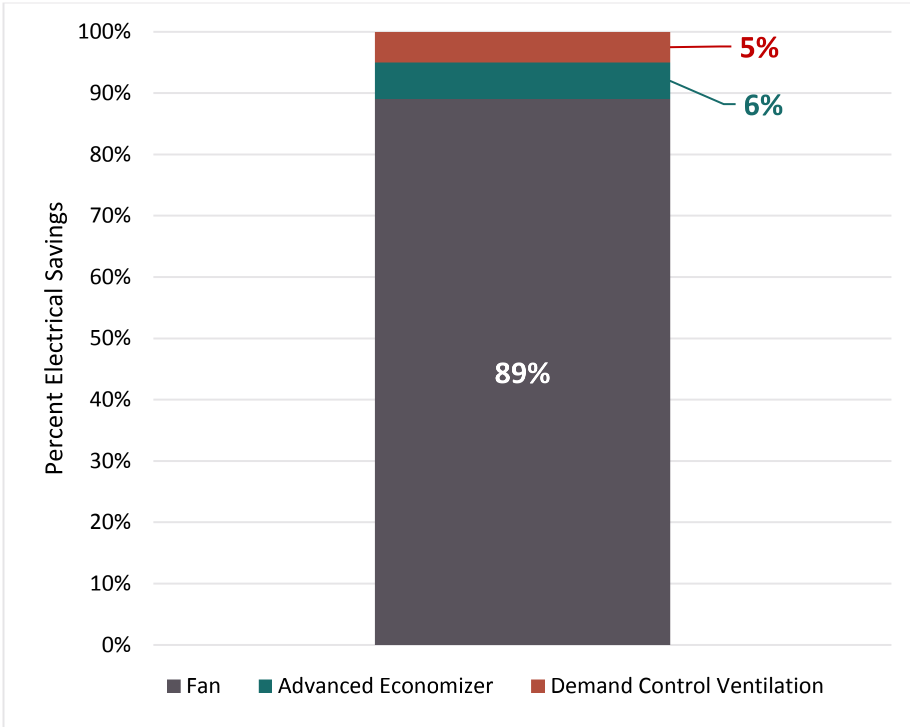

Figure 8. Breakdown of electrical savings by measure averaged across all units, based on reported data from eIQ interface which reports savings from the three measures separately

The chart shows that the VFD provides most of the savings. The fan speed reduction provides the majority of the savings because fan power decreases at the same rate as the cube of the speed reduction. The CATALYST VFD controls the fan to run at 40%, 75%, or 90% speed depending on what is needed. These represent an 88%, 58%, and 27% reduction in power consumption respectively.

In addition, as noted In Figure 8, the fan savings are calculated to a high degree of accuracy because the calculations are only based on two inputs- fan power at 100% speed and instantaneously measured fan speed. Therefore, because the fan savings constitutes almost 90% of the total system savings, it can be inferred that the total system savings are also calculated to a high degree of accuracy as well.

IMPACT OF OCCUPANCY HOURS ON PERCENT ENERGY SAVINGS

The CATALYST uses a carbon dioxide sensor installed in the return air duct to sense the carbon dioxide levels in the return air to infer building occupancy status. The CATALYST reports that a space is occupied based on CO_2 thresholds. The standard setpoint for the CATALYST is 1000 PPM- above this point the CATALYST adjusts operations to open up the dampers to bring in more outside air. Occupancy hours is one of the data points in eIQ and is reported as a percentage of the hour the CATALYST sensed that the space was occupied. For example, if the CATALYST sensed that the space is occupied for 15 minutes out of the hour, the data point would be reported as 25% occupied for the hour. The annual occupancy hours for each site was compared to the percent electrical (kWh) savings to determine whether occupancy is a driver for energy savings. The chart below shows the relationship:

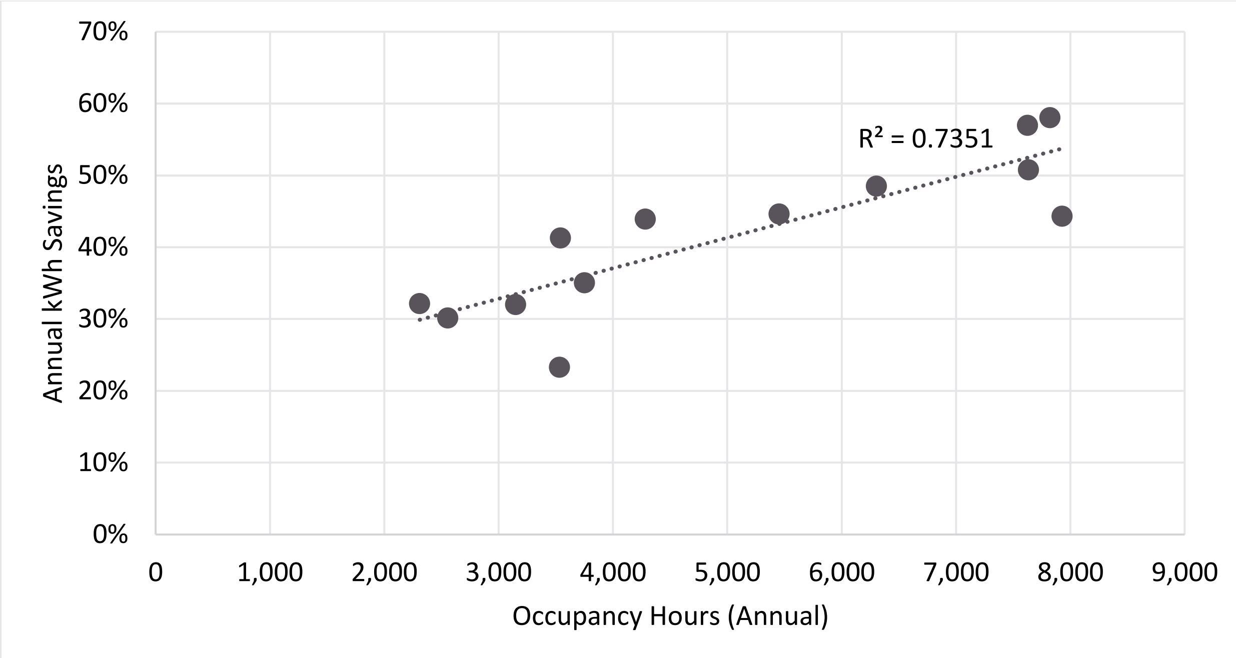

Figure 9. Impact of annual occupancy hours in percent kWh savings.

Based on the occupancy data across projects sites, there is site saves a higher percentage of electricity over their baseline usage if the site is occupied for a higher total number of hours. This trend is even stronger for the retail and office building types, which had R^2 value of 0.76 and 0.95, respectively. The sites that fell into the retail building types were clothing retail locations, whereas the office building type had sites that ranged from a traditional 8 AM – 6 PM runtime office to a call center that operated 24 hours a day. There are increased savings for sites with longer occupancy hours because these sites have more opportunity to be operating in part load conditions for a higher percentage of the total operating hours, which is when the CATALYST can provide more savings over the baseline.

Contractors who participated in the deployment agreed with this finding that sites with longer run times represent an ideal use case for the CATALYST. One contractor noted that a site that has 10-ton units running for at least 2-shifts per day was a perfect site to install the CATALYST at.

Results of Mode Switching to Determine Accuracy of eIQ Reported Savings

This section is a placeholder detailing the preliminary measurement and verification results. It will be updated with findings made by LaBella Associates once they complete their M&V report.

The measurement and verification activities were aimed to determine the relative accuracy of the eIQ predicted savings and the savings calculated through mode switching. As discussed previously, savings calculated through mode switching are reported to a higher degree of accuracy because they are a direct comparison instead of a calculation based on expected unit operation.

The calculations below use data reported by the CATALYST, which was assumed to be accurate. LaBella Associates previously determined the data to be accurate to within 5% and they are completing the same check on the CATALYST data for this deployment.

Table 6. Comparison of eIQ predicted electrical savings (kWh) to savings calculated through mode switching (kWh). The eIQ predicted savings include the 12.5% savings lost due to mode switching during this period.

	Site #1		Site #2	
Data Source	**M&V**	**eIQ**	**M&V**	**eIQ**
Standard Usage (SOM)	49,868	52,461	26,677	18,007
Post-Retrofit Usage (ESM)	22,166	21,289	9,663	7,806
Difference	27,702	31,171	17,014	10,201
Percent Reduction	**56%**	**59%**	**64%**	**57%**

Table 7. Comparison eIQ predicted gas savings (Therms) to savings calculated through mode switching (Therms). The eIQ predicted savings include the 12.5% savings lost due to mode switching during this period

	Site #1		Site #2	
Data Source	**M&V**	**eIQ**	**M&V**	**eIQ**
Standard Usage (SOM)	885	672	2,045	2,117
Post-Retrofit Usage (ESM)	530	542	1,611	1,699
Difference	**355**	**130**	**434**	**418**
Percent Reduction	**40%**	**19%**	**21%**	**20%**

The percent over or under estimation of the eIQ reported savings vs the savings calculated through mode switching was determined using the following formula:

$$\frac{eIQ\ value - M\&V\ value}{M\&V\ value}\ x\ 100 = \%\ Over\ or\ Under\ estimated$$

The percent over or underestimated was calculated for each site then averaged together to produce an average for the two sites analyzed.

The average accuracy for the two sites are shown in the table below. Note, the eIQ values with the 12.5% savings added back were used in the comparison. A value of 0% means the eIQ predicted savings match perfectly with the savings calculated through mode switching, while a positive percentage means eIQ over represented savings on average and a negative percentage means eIQ under represented savings on average.

The results in Table 8 are based on analysis from 2 sites. However, the final report will have 16 sites and therefore will be able to draw stronger conclusions about the relative accuracy of eIQ predicted savings.

Table 8. Accuracy of eIQ Reported Savings. Negative values mean that eIQ is under representing savings on average while a positive value means eIQ is over representing savings on average

Measurement	**Percent Over/Under Estimated**
kWh Savings	−14%
kWh Percent Savings	-3%
Therms Savings	-88%
Therms Percent Savings	-30%

The kWh savings reported by eIQ, as displayed in Table 6, were overestimated for Site #1 by about 12% and underestimated for Site #2 by about 40%, meaning on average eIQ underestimated the kWh savings by about 14%. The kWh percent savings reported by eIQ were overestimated for Site #1 by about 5% and underestimated for Site #2 by about 11%, meaning eIQ underestimated percent kWh savings on average by about 3%. Both the therm savings and therm percent savings were underrepresented in eIQ for Site #1 and Site #2. Overall, eIQ appears to underrepresent savings values on average.

The over and underrepresentation by eIQ is driven primarily by the inaccuracy of SOM usage reported by eIQ and calculated through mode switching. On average, ESM usage calculated by eIQ and mode switching agreed by about 92% on average. In comparison, SOM usage agreed to only about 82%. In the cases where the savings differences were most pronounced (Site #1 Therms savings and Site #2 kWh savings), the SOM usage agreed by only about 71% while the ESM usage agreed closer to 96%.

Transformative Wave expects the savings calculated by eIQ to be about 80%-85% accurate. The eIQ values lack accuracy because the savings are calculated based on assumptions about how the unit would have been operating in pre-retrofit conditions instead of based on actual usage data. The pre-site conditions are combined with actual operating conditions in equations, which can be found in Appendix C: Savings Calculation Details, to calculate the avoided energy use. However, these equations do not capture in all cases how the unit would be functioning but is rather an equation to capture the overage unit operation. Therefore, small changes in actual unit operation would lead to data inaccuracy. Overall, the inaccuracies would only affect reported SOM usage and not ESM usage, since ESM usage is measured by the CATALYST. This overall explains the finding above that the over and under kWh and therm estimates are driven by differences in SOM usage between the two calculation methods.

Further findings will be discussed in the Final draft of the report.

Comparison to Previous Studies

The savings reported by the sites in this deployment were compared to the savings reported in the Pacific Northwest National Labs study. Overall, the savings in this deployment are about 15% lower than the savings reported in the PNNL study. This difference could be explained in part due to the location of the sites along with general deployment assumptions. A portion of the sites in the PNNL study were in Washington State, near Seattle. The cooler climate in that region would likely increase the savings provided by the CATALYST because of the CATALYST's use of outside air to provide cooling whenever possible. New York State, with its hotter summer climate, has fewer opportunities for the CATALYST to leverage outside air and a greater need for compressor energy, reducing the available savings in the NYSERDA deployment.

The PNNL study concluded that run-hours was a strong driver for percent energy savings. The finding in that study agrees with the findings from this deployment.

FINANCIAL METRICS

The CATALYST reports cost savings as one of the savings metrics. To calculate cost savings, eIQ assumes a flat kWh and therm rate, which are both blended rates based on the customer's actual rate schedule. Sites with at least 1 full year of data reported about a 33% reduction in energy costs. All project data will be updated These financial return values will be updated once all projects have reported data for at least 1 full year.

Project Financial Metrics and Impact of Incentives

Project costs were compared to annual estimated cost savings to determine overall financial impacts. Table 9 shows both the simple payback and savings to investment ratio (SIR) for each building type. The chart shows what the simple payback and SIR would be as well without the addition of the incentive. The deployment's incentive of $2,400/unit was used in a majority of the projects to buy down the cost of installation. The use of the incentives was either noted on the invoice by the inclusion a line item, or it was noted by contractors during interviews after the conclusion of the deployment.

Table 9. Simple payback and SIR by dollars. The SIR calculations assume a 6% discount rate and that the CATALYST will be in operation for 7 years[21]

	With Incentives		Without Incentives	
Building Type	**Simple Payback (Years)**	**SIR ($/$)**	**Simple Payback (Years)**	**SIR ($/$)**
Assembly	6.8	0.7	9.9	0.5
Education	5.1	1.0	7.1	0.7
Office[22]	4.3	2.8	6.2	1.5
Restaurant	2.2	2.1	3.1	1.5
Retail	3.1	1.6	4.3	1.2
Average[23]	**4.0**	**1.9**	**5.8**	**1.2**

According to the data collected at this point in the deployment, the office represents the best financial return with $2.80 for each $1 invested. Restaurants had the shortest payback period, which is consistent with the shorter investment timelines typically required in that industry.

Overall, the NYSERDA incentive decreased the average payback by about 1.8 years and increased the SIR by about 0.7. The incentive had the highest impact for office building types, which typically had many smaller units, meaning there was a higher overall incentive paid out to those customers. The high participation rate of office building suggests that the flat incentive structure successfully supported the deployment of the CATALYST on smaller projects with longer simple paybacks.

Project Cost and Energy Saving Drivers

The primary CATALYST cost driver is the size of the unit being controlled because the VFD size and cost (including installation cost) will increase with unit capacity. Data generated through Transformative Wave's pricing tool shows the relationship between installation cost and unit capacity. The installation cost provided included both the material and estimated labor cost. The cost data showed while both the material and labor costs increase with unit capacity, the project cost per ton and per fan horsepower both decrease with unit size.

[21] As discussed in the Market Characterization section, the CATALYST is most financially viable on RTUs with at least 7 years of life remaining.
[22] One office site was excluded from the financial analysis because the project costs were reported for only the 2 units that qualified for incentives while the site cost savings was aggregated together for all 37 units at the site.
[23] Average is weighted based on number of sites.

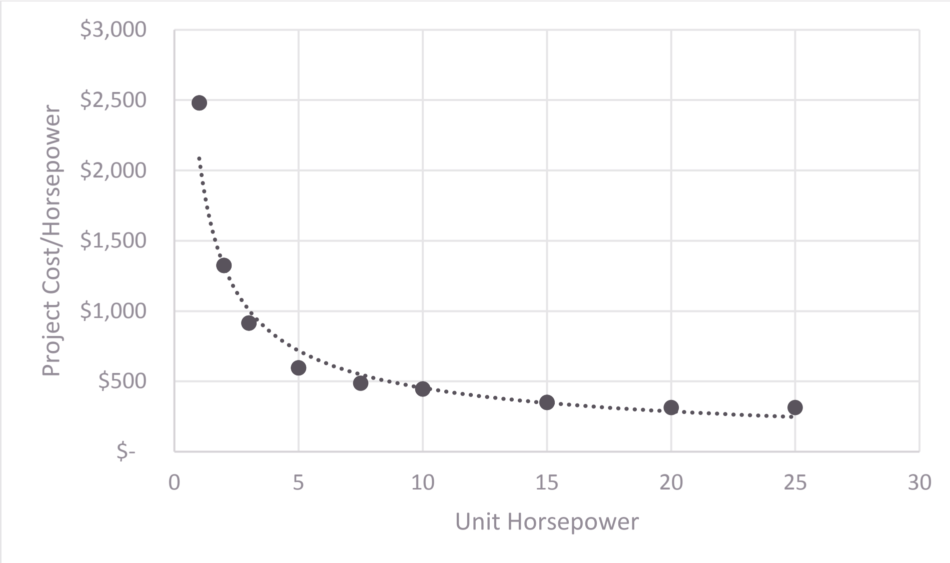

Figure 10. Project Cost/Horse Power vs Unit Horsepower. The Project cost includes the material and labor costs

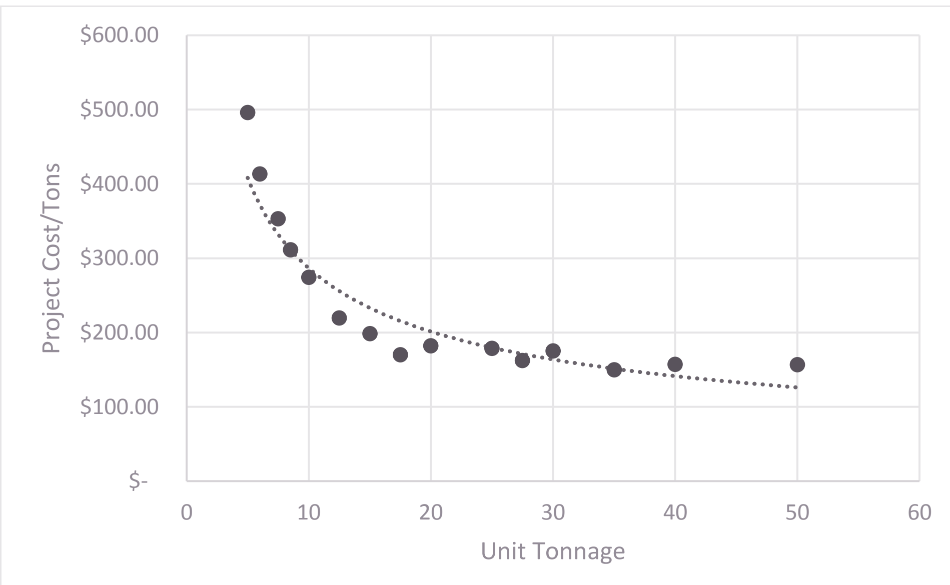

Figure 11. Project Cost/ton vs Unit Tons. The project cost includes the material and labor costs

The VFD cost increases with motor horsepower, while the labor hours remain consistent up until the unit increases size increases past about 50 tons with a 25-horsepower fan. This consistency in labor cost is what drives the overall cost per ton to decrease with unit size.

Savings are predominantly driven by unit size and occupancy. Occupancy appears to be a primary driver (as shown in Figure 9) and unit size to a lesser degree. An in-depth analysis of the energy savings drivers will be included in the final version of the report.

NON-ENERGY VALUE

CATALYST NON-ENERGY BENEFITS

Based on discussions with building owners and affiliate contracts, one of the major benefits is increased comfort within a conditioned space. The CATALYST's ability to provide the appropriate amount of cooling or heating needed at a given moment ensures that the space will hover around the defined temperature setpoint instead of experiencing large swings in temperatures that could occur when a unit provides cooling or heating at full unit capacity. The CATALYST's carbon dioxide sensors also ensure that the air quality is at a comfortable level at all times, and the use of outside air ensures that the internal space temperature will match that of the outdoor ambient air. Internal space comfort is a key benefit across all building types.

In an interview to learn about the benefits experienced from the CATALYST installation, a franchisee owner of a major fast-food chain noted that customer comfort is "probably one of the most critical drivers in terms of someone being in a restaurant. They are coming in from the hot or cold and want a comfortable place to enjoy a meal while warming up or cooling down or whatever it may be". A children's day care center also highlighted that a major benefit from the CATALYST installation was the improvement of air quality as their main building occupants particularly sensitive to the indoor air quality.

eIQ PLATFORM NON-ENERGY BENEFITS

eIQ's portfolio view, fault detection and diagnostics, and energy monitoring and graphing features all provide benefits beyond energy savings.

FAULT-DETECTION AND DIAGNOSTICS

The fault detection feature allows building operators to identify and fix problems with the RTUs shortly after they develop. The fault detection and diagnostics system works first by monitoring the operation and energy draw of many of the RTU components for regular usage. The system then alerts the user to any abnormalities that are potentially the result of a unit malfunction. The eIQ dashboard interface provides building operators alerts and transparency into real-time RTU performance, allowing for quicker detection of underperforming RTUs. In many cases building operators can use the information from eIQ to diagnose the problem with an RTU so they set foot on the roof with the necessary knowledge and equipment to resolve the issue. Overall the fault detection, diagnostics and alert system benefits everyone involved with the management of the building for various reasons:

Building Owners and Operators
Early fault detection and diagnostics lead to cost savings for the building owner because they can repair malfunctions before they lead to larger catastrophic issues which mean major repairs or unit replacement. The automatic alert system and unit visualization system also allows for building operators to focus on tasks other than regular manual unit checks because they can be assured that they will be notified of any potential issues as they occur.

A building owner from a participating site noted the benefits of the site monitoring by saying that CATALYST's ability to constantly monitor the units ensures that all systems are working 100% well, which is not something he would have been manually monitoring previously.

Space Occupants and Business Owners

Occupants are less likely Units that are repaired quicker are going to experience less downtime. This means that occupants are less likely to experience space comfort issues. Increased occupant comfort benefits the building owners' bottom line because when workers are more comfortable they are more productive and customers will likely spend longer amounts of time in the space.

One business owner from a participating site noted that the built-in fault detection and diagnostics system was saving upwards of five hours between the time an issue occurs and when it is detected.

Contractors

Fault detection and diagnostics could lead to increased revenue for the contractor because they can spend less time diagnosing the issue and more time resolving it. A contractor realizes increased revenue when they can complete more jobs, and spending less time diagnosing the issue will allow for them to do just this. It will also allow the contractor to spend less time completing repairs for a client and more time completing higher value add tasks such as identifying areas the building could run even more efficiently. Identifying this additional business value will likely strengthen the relationship between the building owner and the contractor.

EIQ INTERNAL GRAPHING FEATURE

eIQ also has a graphing function that allows the user to view energy and cost savings on a specified time scale. These graphs can be viewed in the eIQ dashboard itself (shown below) or exported to an excel file. The user can also make fully customized graphs with any of the about 40 data points captured by the CATALYST. Typically, creating these graphs requires a large data set that could be exported from a sophisticated BES, which can then be further analyzed for trends on a large complex spreadsheet. In addition, these spreadsheets a lot of the time need to be updated manually, or programmed to be run automatically, which can be extremely complex to initially program. The graphing feature of eIQ decreases the amount of time needed to create the graphs and increases the likelihood that the information on it is correct because the data processing takes place by the eIQ system itself. This means the building operators can spend more time analyzing and acting upon trends, instead of setting up systems to determine them.

5. FINDINGS AND RECOMMENDATIONS

Finding #1- Sites participating in the deployment achieved an average of 42% electricity savings and 7% therms savings

Across the 130 units from 13 project sites with monitoring data of twelve months or more, electricity savings ranged from 24% to 57% with an average of 42% electricity savings, and 75% of projects achieved at least 32% electricity savings. These interim results support Transformative Wave's claim that the CATALYST saves between 25%-50% RTU energy consumption. Complete results from the full 24-site, 191-unit deployment will be provided in an updated report in June 2019.

Finding #2 The CATALYST is particularly well-suited to buildings with long operating hours, large capacity units, and/or proportionally large HVAC loads, such as restaurants and retail.

Energy savings are affected by two primary drivers: total occupancy hours and fan size. Based on these drivers, the CATALYST is particularly well suited for restaurants, retail and other building types with increased annual occupancy hours. Restaurants also have proportionately high HVAC loads and therefore achieve strong total savings.

Finding #3 – Successful deployment of CATALYST and other ARC technologies at scale requires a dedicated focus on workforce education and training.

Selling and installing ARC solutions (and intelligent controls more broadly) has an initial learning curve and requires dedicated training and experience to successfully integrate this into contractor core competencies. Of the four affiliates who participated in the deployment, 80% of affiliate sales came from the two affiliates who participated in sales training and had previous experience selling intelligent controls. Affiliates that attended sales strategy training in addition to the required installation training, were more equipped to identify new customer opportunities. 88% of total sales were either from experienced affiliates or national chain accounts. These affiliates were able to communicate the business value of ARC technologies to new customers and can use this new area of expertise to seek opportunities for business growth.

Recommendation #1 – Utility program measures should integrate the CATALYST into their program portfolios as standalone measures or large-scale pilots.

Savings results from this deployment and previous CATALYST studies, provide utility program managers with sufficient data to support the development of a measure for the CATALYST in their energy efficiency programs.

We recommend that programs use the CATALYST energy monitoring capabilities to collect data on an ongoing basis to refine program assumptions over time. However, the technology is sufficiently well demonstrated that in most cases should not require further "field demonstrations" prior to integrating into a program. If a pilot is necessary, we recommend that it include be at sufficient scale (at least 150 units) to ensure that all relevant information is collected and that the pilot activities warrant the time and investment required by the manufacturer.

Recommendation #2 – Utility ARC programs should develop deemed estimates by leveraging real-time reporting capabilities of ARC technologies and consider adopting a standardized reporting format to facilitate program participation and streamline the process

Deemed savings programs play a critical role in scaling new technologies since they simplify participation in utility incentive programs. A major barrier to deemed energy efficiency programs is a lack of a streamlined data collection method to develop and update deemed savings over time. While the CATALYST has over 12,000 units in the field with real-time reporting capabilities, the largest published monitoring study is 130 units. Rather than complete additional small-scale demonstrations that are unlikely to substantially improve industry knowledge of ARC performance and improve deemed savings estimates, we recommend future demonstration efforts focus on standardizing energy monitoring data specifications so that deemed savings estimates can be based on a much larger scale and on an ongoing basis. In additional to ongoing performance validation, future pilot program should focus on scaling market adoption through new delivery mechanisms.

Recommendation #3 – Utility programs and other national entities should incorporate significant workforce education and training components into programs to ensure increased awareness and training for ARCs (and intelligent controls more broadly).

While controls can provide significant new business value to customers by reducing energy costs, improving insight into facility operations and ensuring occupant comfort, there is an important learning curve for both customers and contractors. In addition to providing financial incentives to reduce first cost, utility programs which target ARCs and other intelligent controls should provide a series of education and training programs that include introductions to the technologies, as well as more in-depth trainings to help contractors understand how to sell and install the technology and highlight the business value intelligent controls to customers.

Recommendation #4 - As the number of trained affiliate contractors familiar with the CATALYST and other ARC solutions grows, utilities should consider additional program mechanisms to focus on achieving scale.

As familiarity with ARC technologies and the number of trained contractors grows over time, utility programs should pilot new deployment mechanisms for the CATALYST and other ARC technologies such as midstream promotion through distributors to scale its adoption. Midstream approaches typically achieve far higher uptake than downstream programs, but do require resolving important issues such as ensuring successful installation and operation.

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7. APPENDIX A: PROJECT PROCESS

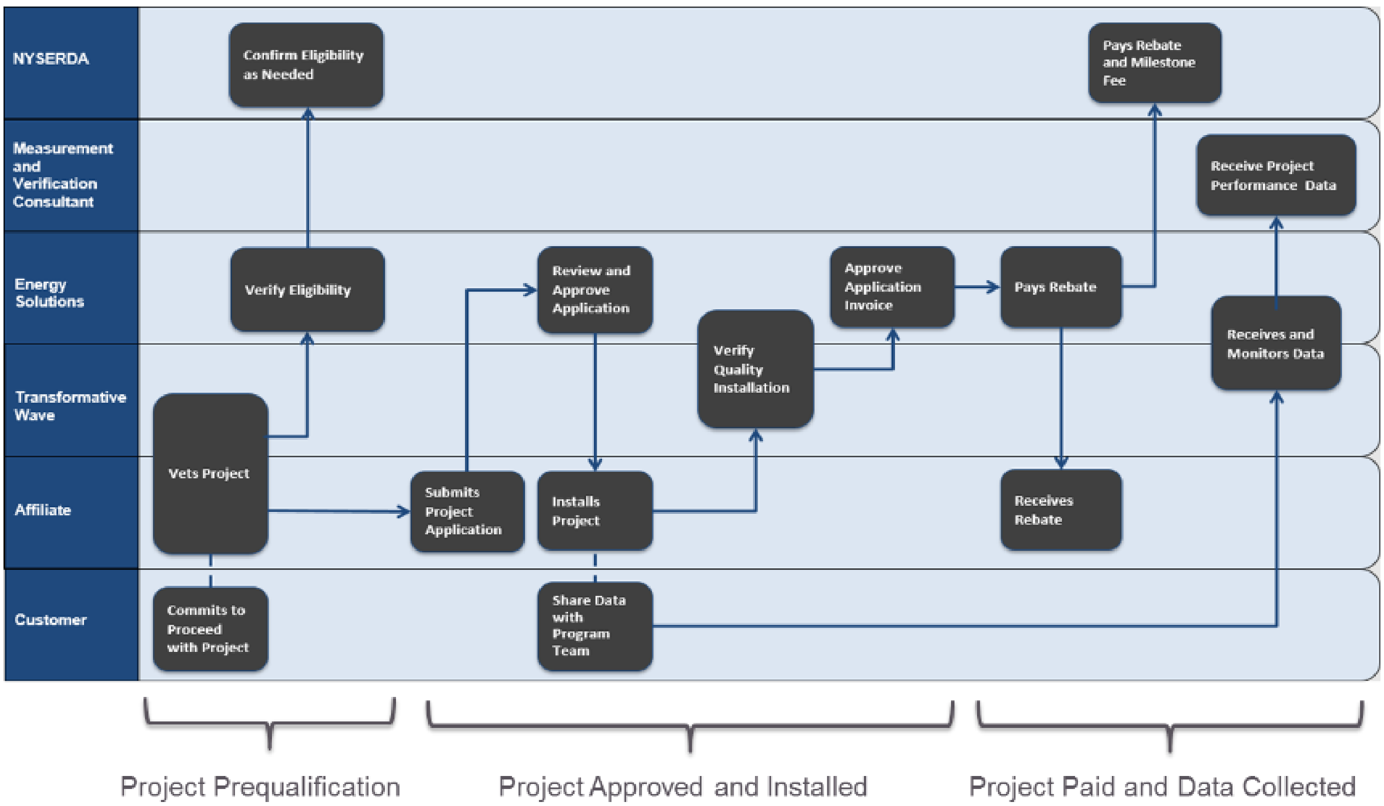

Figure 12. Project process flow and deployment stages

Once an affiliate is certified by Transformative Wave and enrolled in the incentive deployment they can now submit a project. The project process is outlined in Figure 12 starting from project submission to incentive distribution and data collection.

8. APPENDIX B - EIQ SCREENSHOTS

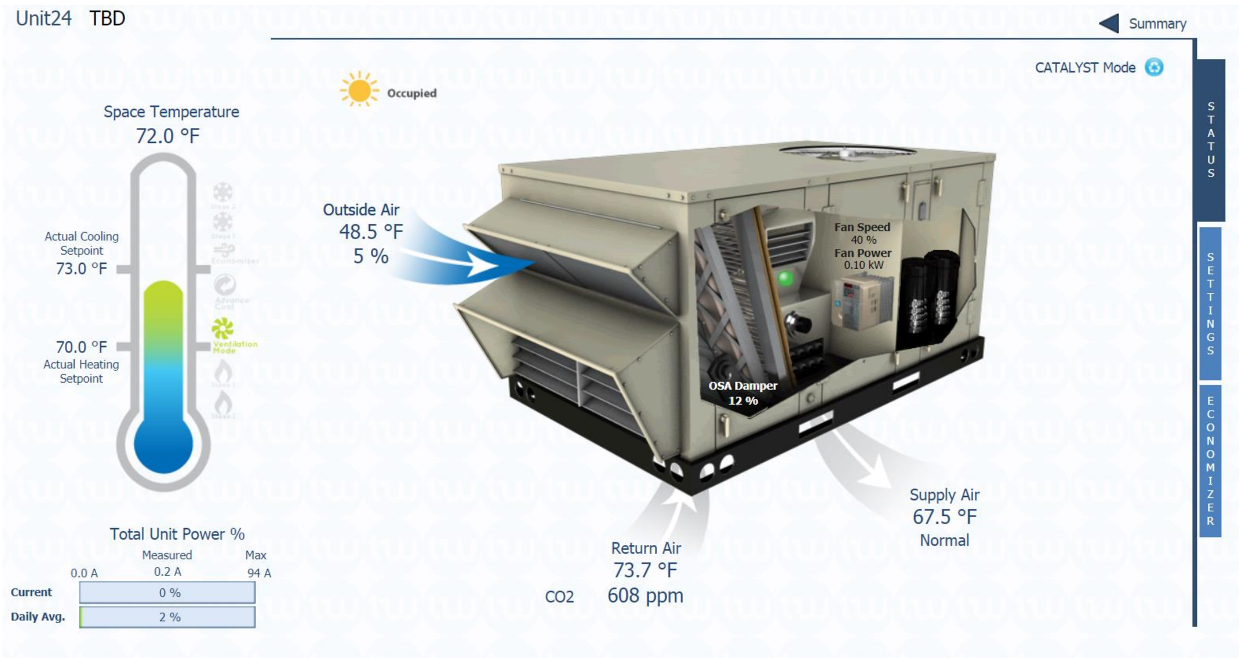

Figure 13. View of a Single RTU without any faults identified

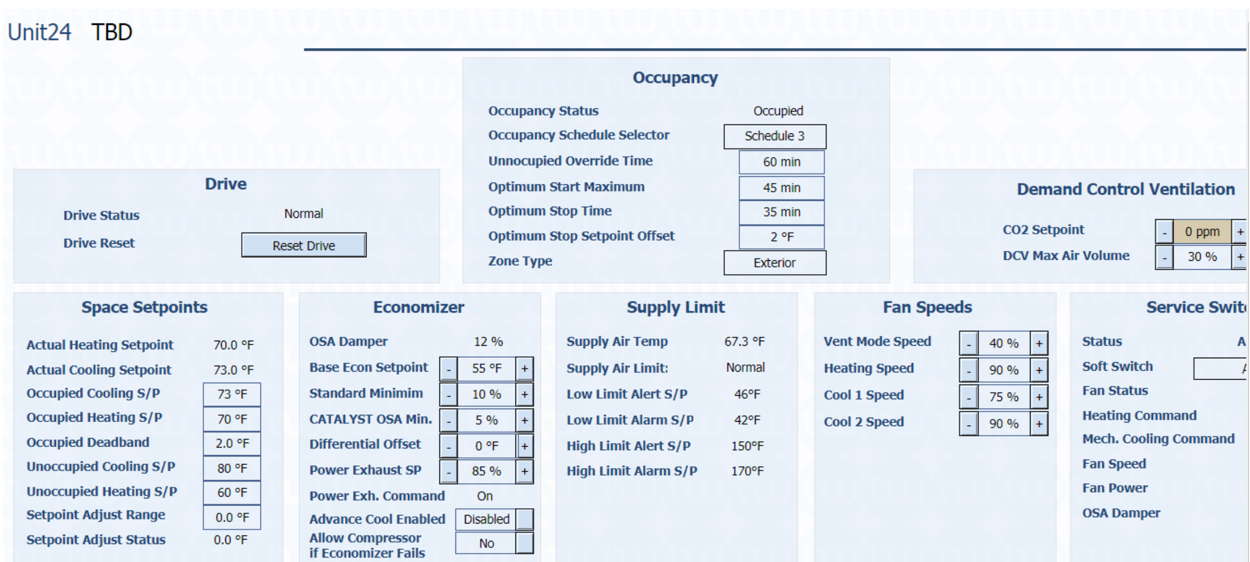

Figure 14. Setpoint Adjustment User Interface

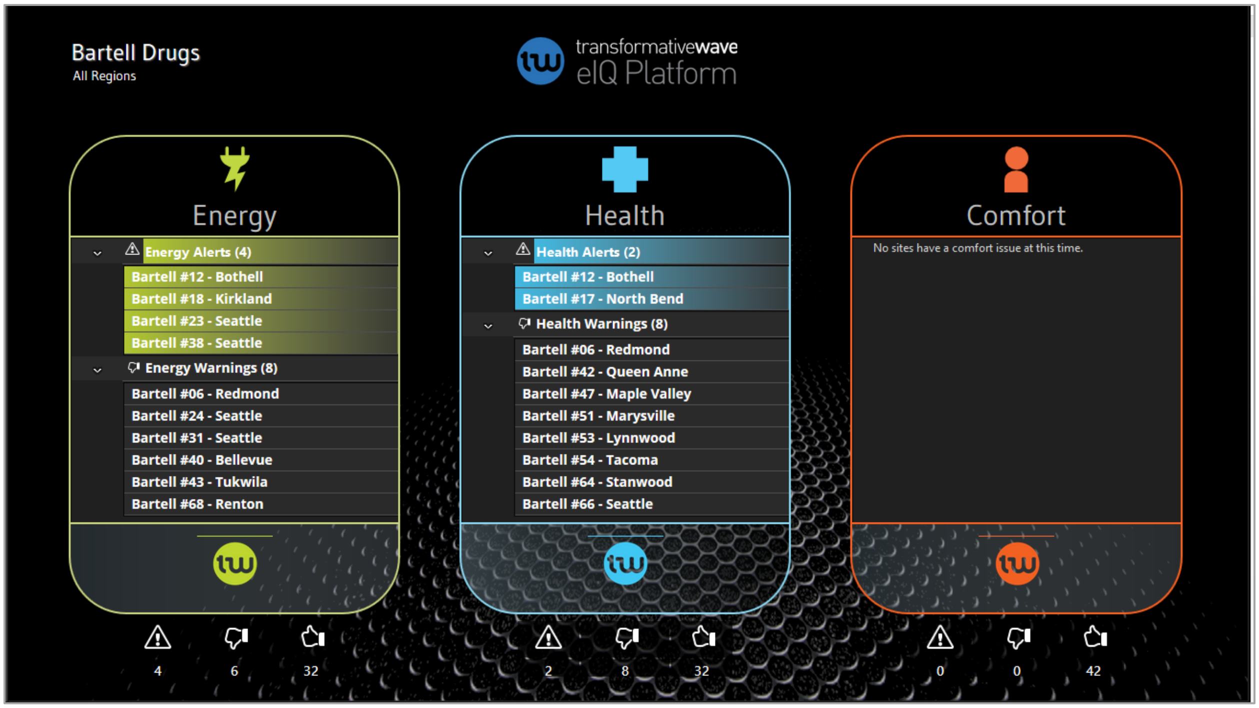

Figure 15. Portfolio View showing faults identified at multiple locations

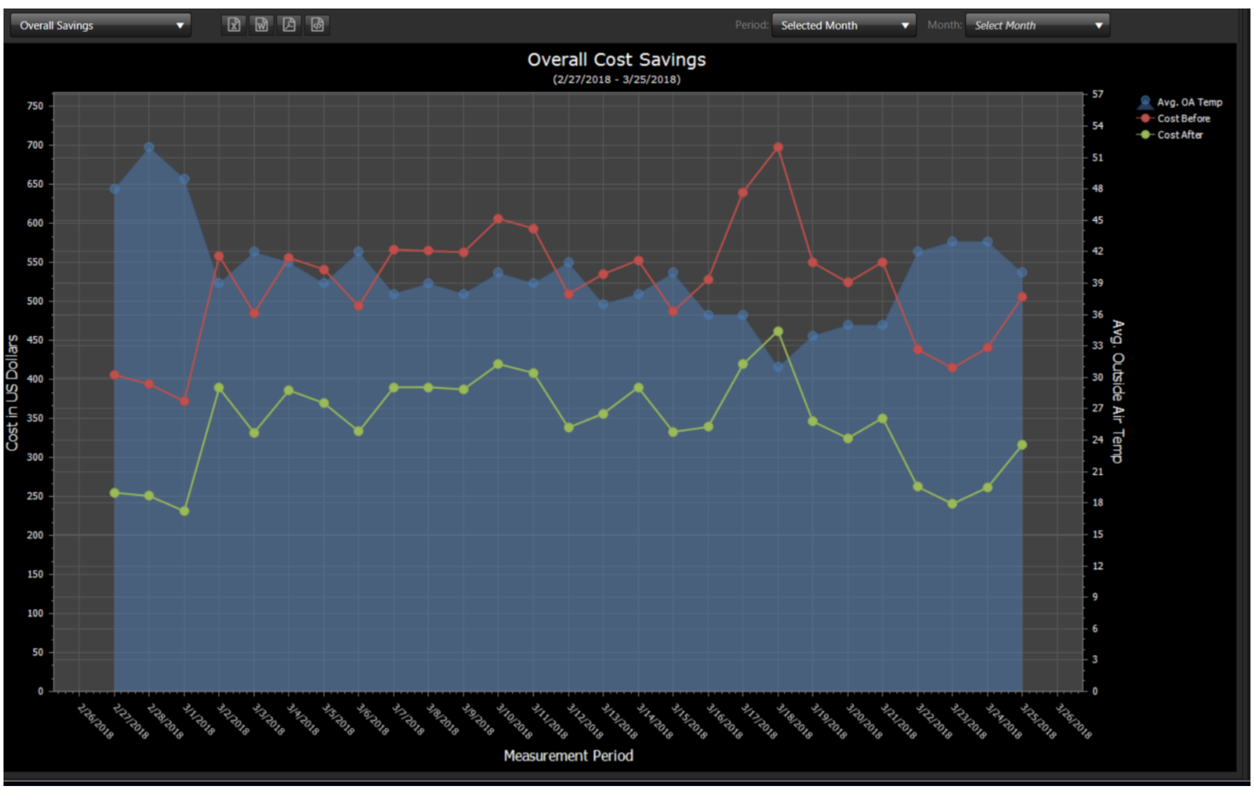

Figure 16 eIQ Graphing User Interface. This current view shows the actual estimated daily cost vs the estimated baseline cost. The outdoor air temperature is also plotted

9. APPENDIX C: SAVINGS CALCULATION DETAILS

The report used two separate savings calculation methods: eIQ calculated savings and Retrofit Isolation / Calibrated Simulation Approach. This appendix details how the savings are calculated for each method.

eIQ Calculated Savings

This section details how eIQ reported savings values are reported. The inputs to the savings equations are either quantities measured by the CATALYST sensors, inputs from the building's EMS, quantities measured prior to CATALYST installation, or estimated/assumed quantities.

Savings for each conservation measure are calculated based on the following operational parameters at one-minute intervals:

- maxcfm = total unit airflow estimated at 400 CFM/Ton (CFM)
- stdfankw = static baseline fan power (100% Fan Speed) measured at drive during startup (kW)
- fanpower = real time fan power measured at drive (kW)
- esmmode = command to run in energy saving mode (CATALYST Mode)
- stdeconmin = As found (Standard Mode) minimum damper position recorded during DSI (%)
- stdeconstpt = As found (Standard Mode) single point economizer changeover setting recorded during DSI (F)
- fanspeed = commanded fan speed (%)
- damper = commanded damper position (%)
- oatemp = measured dry bulb outside air temp (F)
- ratemp = measured dry bulb return temp (F)
- coolcall = cooling request from stat or BMS
- heatcall = heat request from stat or BMS
- EERadj = recorded unit energy efficiency ratio adjusted to remove fan power (Btu/Wh)
- COP = recorded coefficient of performance for heat pumps (Btu/Btu)

The energy reduction associated with each conservation measured is calculated at the one-minute interval level as follows:

Fan Speed Control
fankwsavings = (stdfankw –fanpower)/60
WHEN: fancall = 1 AND esmmode = 1

Advanced Economizer
diffeconkwh = (1.08 * (ratemp - oatemp) * ((fanspeed * .01 * damper * .01 - stdeconmin * .01) * maxcfm))/
(EERadj * 1000) / 60
WHEN: coolcall = 1 AND oatemp < ratemp AND esmmode = 1 AND oatemp > stdeconstpt

Demand Control Ventilation (DCV)
Cooling
Cooldcvkwh = 1.08 * (maxcfm * stdeconmin * .01 - maxcfm * fanspeed * .01 * damper * .01) * (oatemp - ratemp) / (EERadj * 1000) / 60
WHEN: coolcall = 1 AND oatemp > ratemp AND esmmode = 1

Heating-Electric (Electric Resistance or Heat Pump)
heatdcvkwh = 1.08 * (maxcfm * stdeconmin * .01 - fanspeed * .01 * damper * .01 * maxcfm) * (ratemp - oatemp) / 3412 / 60
WHEN: heattype = (Electric OR (heattype = HeatPump AND oatemp < 35)) AND heatcall = 1 AND esmmode = 1

OR
heatdcvkwh = 1.08 * (maxcfm* stdeconmin * .01 - fanspeed * .01 * damper * .01 * maxcfm) * (ratemp - oatemp) / 3412 / 60 / COP
WHEN: heattype = HeatPump AND oatemp >= 35 AND heatcall = 1 AND esmmode = 1

The savings from each individual energy asvings measured are summed together to calculate the full system savings.

<u>Retrofit Isolation / Calibrated Simulation Approach</u>

The annual savings is calculated using the following equation:

$$Savings = (Annualized\ SOM\ Energy\ Use - Annualized\ ESM\ Energy\ Use) \frac{+}{-} Adjustments$$

There are 3 components that need to be calculated separately:
1. Fan kWh (not weather dependent)
2. Cooling kWh (weather dependent)
3. Heating Therms (weather dependent)

The cooling kWh and heating therms are both weather dependent meaning they must be weather normalized to allow for true comparisons between ESM and SOM energy usages.

The following procedure was followed to calculate the annualized energy use for each component above:

kWh (Fan Demand Only):
1. Fan demand at 100% speed was determined by isolating periods where the RTU was in vent mode only for the full hour, meaning there was no compressor use
2. Fan demand at 40%, 75% and 90% speeds was calculated using the following fan speed and power relationship:

$$Fan\ Demand\ for\ Y\%\ Speed = (Fan\ Demand)_{100\%}\ x\ Y^{2.5}$$

3. Fan total energy use during each hour was calculated by adding up the fan usage in each run mode

4. The fan total kWh for ESM and SOMs were divided by the number of fan run time hours in each mode during to calculate an average fan kWh per hour of fan runtime in both SOM and ESM
5. The average fan kWh for ESM and SOM were multiplied separately by the total fan call hours during the period of data recording. The results are the estimated total fan usage during each mode over the course of the reporting period.

kWh (Cooling Demand Only):

1. The cooling demand needs to be separated from the fan usage because it is weather dependent so it needs to be normalized by historical weather values. The fan usage is not weather dependent which is why the same normalization is not needed
2. The cooling load is calculated during each hour by subtracting the fan energy calculated above from the total unit energy usage
3. The total cooling load for each mode is normalized by the cooling degree days (CDD) that occurred while the unit was in each mode to calculate a normalized kWhcooling / CDD.
4. The kWhcooling / CDD for each mode are multiplied by the total CDD during the period of data collection to calculate the estimated total kWh cooling for each mode

The total kWh usage was then calculated by adding together the fan kWh and then cooling kWh. Estimated kWh savings were then calculated using the equation above.

Therms Savings

1. Therm usage was calculated at each during ESM and SOM runtimes by multiplying the number of hours the CATALYST called for stage 1 and stage 2 heating by the RTU's stage 1 and stage 2 therm inputs, which were collected during unit installation.
2. Total therm usage was added together for each mode and divided by the total number of heating degree days (HDD) during each time period to calculate a weather normalized therm/HDD
3. The therm/HDD for ESM and SOM were multiplied by the total number of HDD during the data collection period to calculate the baseline and energy savings mode estimated annual therm usage
4. The energy savings mode therm usage is subtracted from the baseline therm usage to calculate the estimated savings

10. APPENIDIX D: ADDITIONAL DASHBOARD SCREENSHOTS

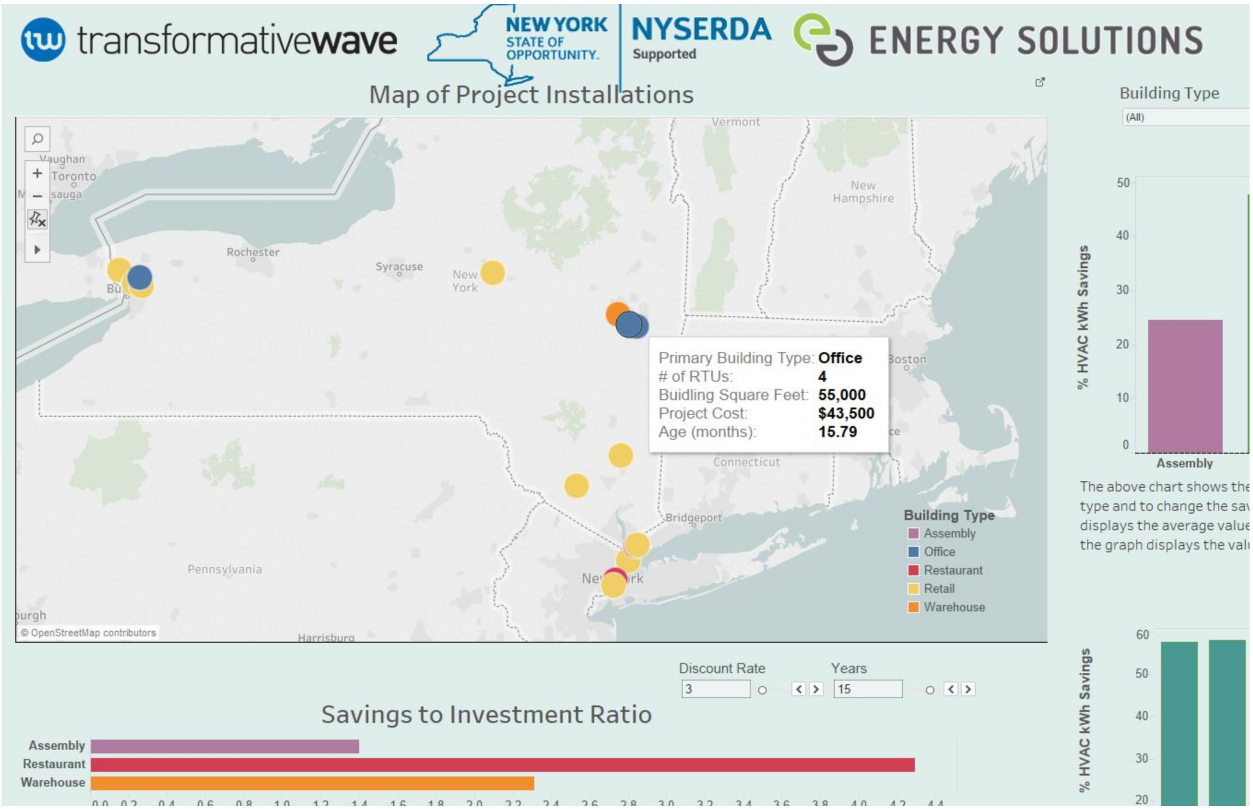

Figure 17. Dashboard Map View Showing "Hovering" Capability