Enabling Smart Cities By Leveraging IoT Sensors, Multi-Building Modeling And Analysis, And Smart Energy Business Case Analytics

Digital Transformation For Energy Savings Programs

A Technical Paper prepared for SCTE•ISBE by

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Introduction

Modern IoT smart energy platforms have the potential both to power smart city intelligence via sensors, analytics and services, and to drive cities to become smarter. Platform providers and ultimately cable operators themselves can do this by leveraging their knowledge and experience in traditional large-scale smart building practices that have been undertaken in recent years in both telecom and non-telecom infrastructure. They can also leverage their experience in selecting the right energy efficiency improvements for small- and medium-sized cable edge facilities that can be applied to small and medium businesses with similar size and payback constraints. The platforms and tools already used for large scale analysis of cable facility portfolios can now be applied to any building type at the portfolio, campus, city and national scales. Recent use of these tools has resulted in business cases being made for early retirement of aging HVAC equipment, deployment of cost-effective energy conservation measures that payback on the order of 3 years (even for edge facilities in states with low utility rates), and analysis and prioritization of LED lighting improvements. And these are just some of the potential energy conservation measures that can be analyzed, prioritized, and planned with a comprehensive platform for helping buildings, portfolios and cities get smart about energy use. In this paper, the experience and lessons learned in cost-effectively selecting and deploying energy conservation measures in cable infrastructure and facilities will be shown to be directly applicable to new services and revenue streams that platform providers and cable operators can develop or partner on for smart city initiatives using IoT technologies and smart energy tools. Coupling these tools with diverse funding models will further enable companies and entire cities to deploy smart energy management and energy conservation measures cost-effectively and even as a service.

Content

1. Portfolio Energy Savings

The facility portfolio of a cable provider often has a wide breadth of building types, a split on leased and owned buildings and typically covers a diverse geography and can scale from as small as a few hundred facilities to as large as tens of thousand facilities when including retail. Characteristics of the portfolio include a wide distribution in facility age, equipment age, mixed use facilities and various facility types like headend, hubs, service centers and administrative office space. Not to mention what also gets included from mergers and acquisitions. More than ever before there is pressure to reduce and control energy spend as a function of these facilities, with energy and maintenance typically being two of the larger expenses to the P&L from a building lifecycle perspective. Two important business directives from the top down are cost savings (aka energy savings) coupled with sustainability reporting or what is sometimes called carbon dashboards. Relevant energy savings achieved can be leveraged in quarterly and annual company financial reporting to help demonstrate the cable operator cares about the environment and to keep sustainability goals in front of their subscribers and key financial stakeholders.

When portfolios are large like this cable operators seek to identify and run energy savings programs against the portfolio that are designed to produce a relatively fast return on investment. Technologies in the form of energy conservation measures, e.g. lighting upgrade, often produce a simple payback in 2-3 years. The sought out win here is to apply company investment in a way that delivers a quick near-term result generated from the savings the program can achieve. This approach often works well for a handful of large facilities or select targeting of facilities that have a proportionately larger than average energy bill. After capitalizing on what’s often referred to as the low hanging fruit, the problem gets harder when trying to make the determination of which facilities to treat next and how far to go into the long tail of the building portfolio. This is where finding the energy opportunity for savings can become a more difficult challenge. Two examples for cable operators are cable hubs, which is often one of the highest count in the total number of building in a portfolio and headend and retail locations. The table below provides a representative example facility distribution of a typical cable operator portfolio in the USA.

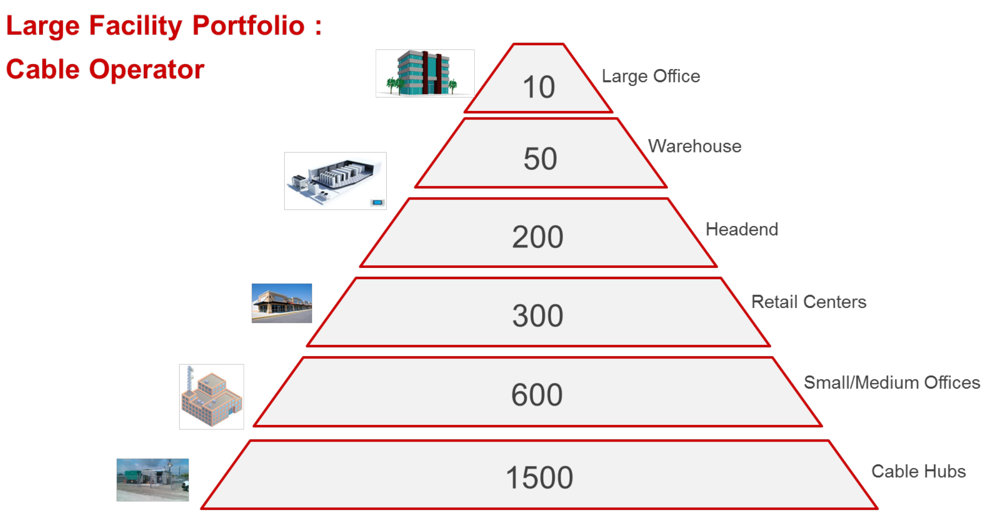


Figure 1 - Example: Large Cable Operator Portfolio

A large building portfolio like this has vast differences between mission critical facilities and general office buildings. The need remains to find energy savings potential deeper within the facility portfolio at scale for a larger number of typically smaller, medium size and specialized facilities like outside plant or other edge facilities. The next section demonstrates a new approach to solve this problem by leveraging building energy modeling and simulation designed to help yield the best potential energy savings for cable operators with large building portfolios.

2. Building Energy Modeling at the Portfolio Level

Building energy modeling is not new, however, the application of it at the portfolio level and focused on the energy savings economics and efficiency programs is new. The age-old mindset in the industry is that every building is a snowflake, for which there is some valid truth, but we have found through specialized building modeling approaches that information can be analyzed to help make better investment decisions when looking at this problem from the perspective of the entire building portfolio. Utilizing a basis of Energy Plus modeling from the Department of Energy, and leveraging data science and cloud based computational scale, as a team we modified the models and embodied them in a software application that allows building energy engineers to load data representing the building portfolio and run various scenarios to determine what are the lowest risk, highest paying investment options that yield the highest potential for energy savings within the portfolio. Going well beyond the Energy Plus models, new modeling of multiple energy conservations measures and modeling implementation cost based on materials and labor is included to help drive data centric business decisions. In the industry we call this investment grade decision making. The more information we have the better the decision we can make.

Examples of inputs at this level, but insufficient to give away our proprietary approach, are number of buildings, building addresses, building size and actual energy history. Once we have the client data on the building portfolio, we initiated a mapping exercise. If you are familiar with building energy models, rather than develop a unique model for each building, we group the facility portfolio into facility types and then customize a building energy model (BEM) per building type. This proto-typical model becomes the base model that is utilized to inherit the individual information of all facilities of that type, for example cable hubs or medium size office buildings. The below figure is an example of just such a mapping of the facilities within the portfolio grouped together by type and energy spend.

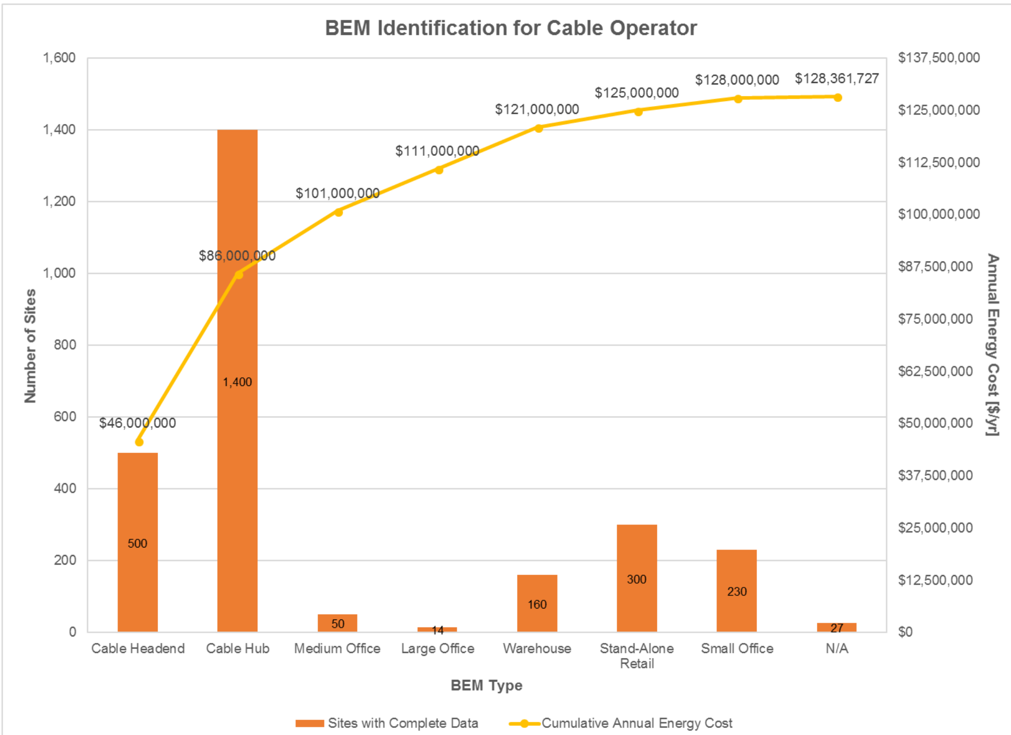


Figure 2 - Building Energy Modeling Mapping To Portfolio

To ensure our modeling was correct an engineer performed a review on the buildings to determine typical approaches to cooling, heating, weather-based location and many other factors to ensure the attributes of each building in the portfolio are accurately represented at this level. It is important to note at this level a deep audit or assessment at the facility is not required, as the purpose here is to model at the portfolio level to achieve a business outcome.

2.1. Energy Conservation Measures and Cost Simulation

Energy conservation measures are improvements that can be made to existing facilities to improve their overall energy performance and optimization. Often technical in nature, examples are HVAC controls, new refrigerant technologies, air flow optimization, efficient lighting and many others. Building energy models do a great job at modeling the existing building and its core infrastructure. However, the Energy Plus software provides limited ECM modeling capabilities today. We enhanced the building energy models to include select ECM technologies and more importantly modeled their cost characteristics.

While building modeling leverages statistical techniques to converge on both overall building calibration and sensitivity analysis. The modeling of the ECM and cost allows us to go further and simulate the impact of potential energy improvements to the building. Cost modeling and simulation like this is new and has the extremely valuable result of gauging which ECM or combination of ECM enhancements make the most sense across a diverse and large building portfolio. We call this the optimal yield, that is a data driven approach to making better informed decisions about where to make portfolio improvements versus the more standard industry approach of vendor quoted savings and payback terms based on a flat savings rate.

2.2. Data Science and Cloud Computing

Data scientist were leveraged to develop software algorithms to create a statistical approach to the building energy modeling and the associated convergence process. Historically, buildings are modeled one by one on what is often called a desktop analysis by individual engineers to help determine where in the facility to save energy. In our approach cloud computing was leveraged to run 1000s of iterations enabling statistical convergence of the solution at scale for a large number of facilities in a reasonable time and within very specific confidence levels to ensure results are accurate at this level. We leverage AWS as the platform and elastically we run as many EC2 instances as required to generate results quickly, often within days for a large portfolio.

The data science becomes extremely interesting at this level. For those familiar with this subject, there are guidelines in the industry around approaches and methodology for ASHRAE guidelines, regional building codes and many other factors. The data science gets applied in the statistical approach, for those fascinated by these things, like non-sorting genetic algorithms (NSGA2), Strength Pareto Evolutionary algorithm (SPEA), Linear Discriminant Analysis algorithm, hierarchical clustering algorithm. It's amazing to think that genetic algorithms are being utilized to improve building efficiency and embarking us on the path to introduce more machine learning and artificial intelligence.

As part of this work, we also had to develop specialized tools for automation, enabling the launch of multiple parallel jobs, multiple docker containers, a common data repository and we are still working on things like automating geometry generation.

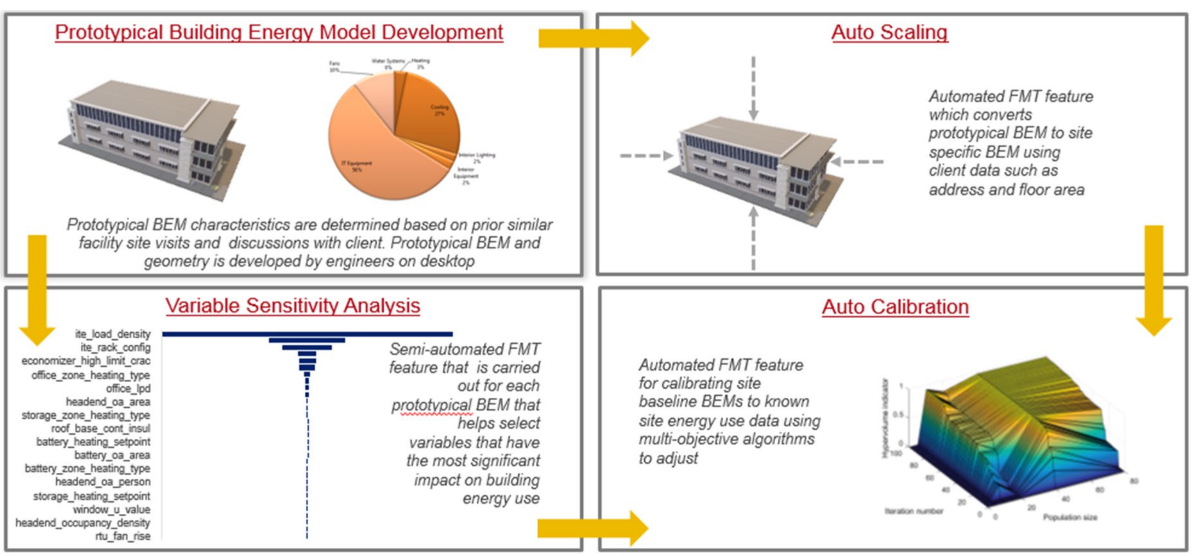
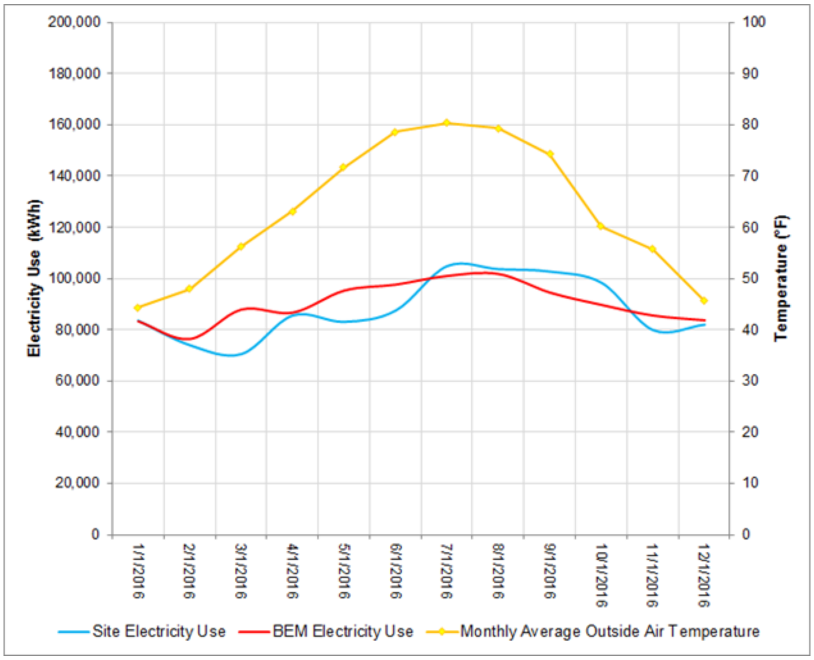


Figure 3 - Building Energy Model Process



Calibration Statistics

CV(RMSE) = 9.4%, NMBE = 2.7%

Figure 4 - Example Calibrated Modelings

Energy engineers guide the entire process to check and confirm results make sense. The immense value of this approach is again the ability to approach an entire building portfolio independent of size and drive meaningful investment grade savings decisions.

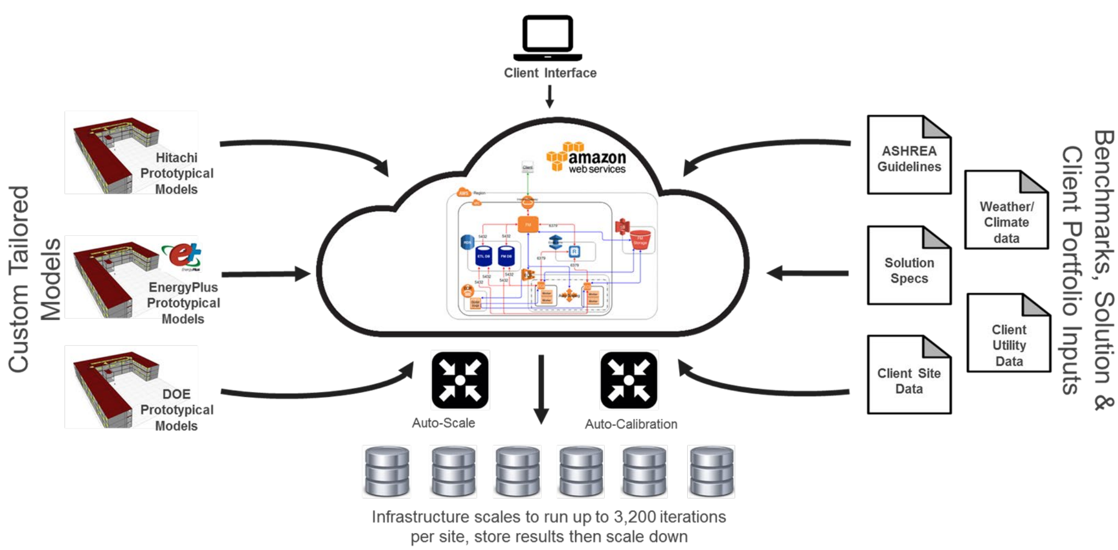
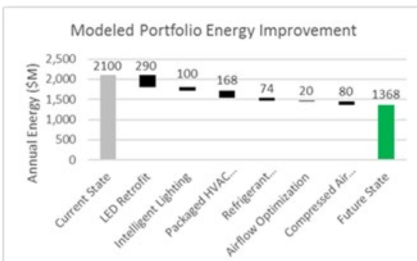


Figure 5 - Cloud Computing Environment

3. Enabling Investment Grade Savings

Those investing in energy efficiency and savings programs are business owners. They are making business decisions and want the information and data that helps them become more informed in the way they make decisions. The information below is an example of some output and recommendations that comes from a portfolio analysis at a very high level when using building energy modeling at the portfolio level. The essential take away is how to determine where in the portfolio you can yield the most savings and what it will cost to run a program, understanding the simple payback and return on investment.

What is net Energy Efficiency Impact of Recommended ECMs?



What is the estimated program cost and payback by ECM?

($ in millions)	Cost Estimate Low	Cost Estimate High	Savings Estimate Low	Savings Estimate High	Payback (Year) Low	Payback (Year) High
LED Retrofit	2.30	2.80	0.75	1.25	1.84	3.73
Intelligent Lighting	1.20	1.50	0.60	0.70	1.71	2.50
Packaged HVAC Compressor Control	0.75	1.20	0.60	0.80	0.94	2.00
Variable Frequency Drives	1.10	1.30	0.40	0.50	2.20	3.25
HVAC Replacement	3.30	4.00	0.35	0.55	6.00	11.43
Refrigerant Replacement	1.40	1.60	0.40	0.50	2.80	4.00

What is the program benefit, cost and simple payback by geography, division or facility type?

	Total Cost			Total Savings			Simple Paybacks		
Division	Est. Total Cost (Low)	Est. Total Cost (Medium)	Est. Total Cost (High)	Est. Total Savings (Low)	Est. Total Savings (Medium)	Est. Total Savings (High)	SPB (Low)	SPB (Medium)	SPB (High)
Central	$3,235,339	$5,392,232	$8,627,571	$999,214	$1,665,357	$2,664,571	1.2	3.2	8.6
HQ	$216,266	$360,443	$576,709	$69,431	$115,718	$185,149	1.2	3.1	8.3
Northeast	$2,236,480	$3,727,466	$5,963,946	$695,205	$1,158,675	$1,853,880	1.2	3.2	8.6
Other HQ Ops	$1,795,968	$2,993,280	$4,789,248	$604,830	$1,008,050	$1,612,880	1.1	3.0	7.9
West	$2,152,211	$3,587,019	$5,739,230	$683,620	$1,139,367	$1,822,987	1.2	3.1	8.4
Grand Total	$9,636,264	$16,060,440	$25,696,704	$3,052,300	$5,087,167	$8,139,467	1.2	3.1	8.4

Figure 6 - Building Case Output & Recommendations

The results are designed to help guide facilities management and corporate energy and sustainability teams to select which approach makes the most sense based on priorities, funding and business climate. However, in all cases a next step in our scenarios is to recommend a pilot, proof of value or proof of concept.

4. Hardening the Business Case with Pilots/POC

Before moving to a larger scale investment across a sub-section of the portfolio, it is highly recommended that a limited pilot of a specific building type associated with a prototypical be run as the next step in this journey. The reason for this is that the recommendation can be implemented on a limited scale and tested to ensure that in the real-world the program at scale will produce empirical results that validate the savings potential. This is used as a methodology to harden the business case with more specific site values and conditions, which as a second phase helps to further verify and provide information that further reduce risk and ensures savings are still aligned with the investment strategy.

4.1. Leveraging IoT for M&V

At the pilot level limited deployment of the proposed energy conservation measures is typically insufficient. Often a M&V process is utilized to measure before and after results of the technology improvements. Doing this on a limited scale helps prove the savings really exist. More importantly, doing this on a limited scale help prevent the issue of pre-maturely investing and scaling without knowing the return will manifest itself over time. Reducing investment risk is the key concept we are pursuing here.

This is where IoT comes into play and helps with the digital transformation of the M&V process but also sets the stage for measuring and monitoring energy for the long term to ensure continuously programs are generating the savings they set out to accomplish.

This is where our approach and methodology becomes more interesting. Leveraging the building model as a digital twin and through the pilot process, a deeper audit and assessment of the facility is performed. This improves and deepens the data that goes into the building energy model. This is important because it lays the groundwork for what's call IPMVP Option D or calibrated simulation, which leverages the ASHRAE guideline 14 for M&V procedures. Only for our purpose, we were pursuing this for real-time calibrated simulation using real-time telemetry by using IoT submetering of the facility and ECM technology.

By introducing real-time submetering associated with the assets which had ECM improvements we could measure a more accurate before and after. Why this is important is due to the dynamic load changes, workload changes, upgrades, and equipment changes typical of what cable facilities go through over time. Straight line regression is no way to pursue an investment for 3 or more years. It's become downright impractical. We wanted to truly measure the before and after and apply IPMVP methodologies to make it more standardized.

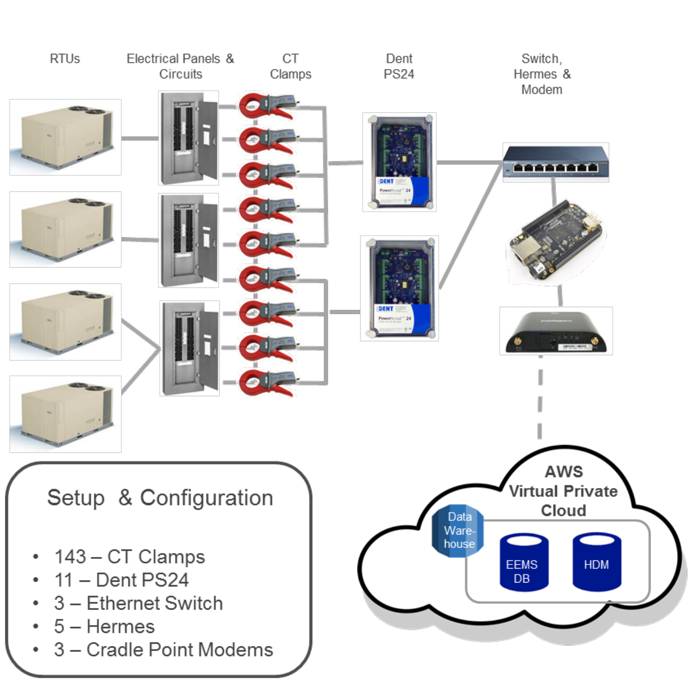


Figure 7 - IoT System Deployment Onsite

The data captured onsite is transported via a raspberry PI device to the Amazon cloud where specialized dashboards were created to track the energy use trend from the facility and sub-metered at several points within the facility. The facility building energy model in this circumstance is utilized to forward model the previous state of the building creating a relative baseline that changes with the building, to model the facility in a predictive way to model the behavior in the future. We call this a relative baseline. Why this is so important is simple, far too often we have seen improvement made to a building and the savings get washed out because of other changes and modifications to the facility over time. This makes it impossible for the energy or facility manager to prove the investment was worthwhile when their boss asks the question as to why the energy bills are now higher a year into the program.

Data through IoT can solve this problem. It demonstrates where all the changes are coming from and helps to differentiate between weather normalization, new IT load, facility improvements/changes and many other factors that could impact energy consumption over time.

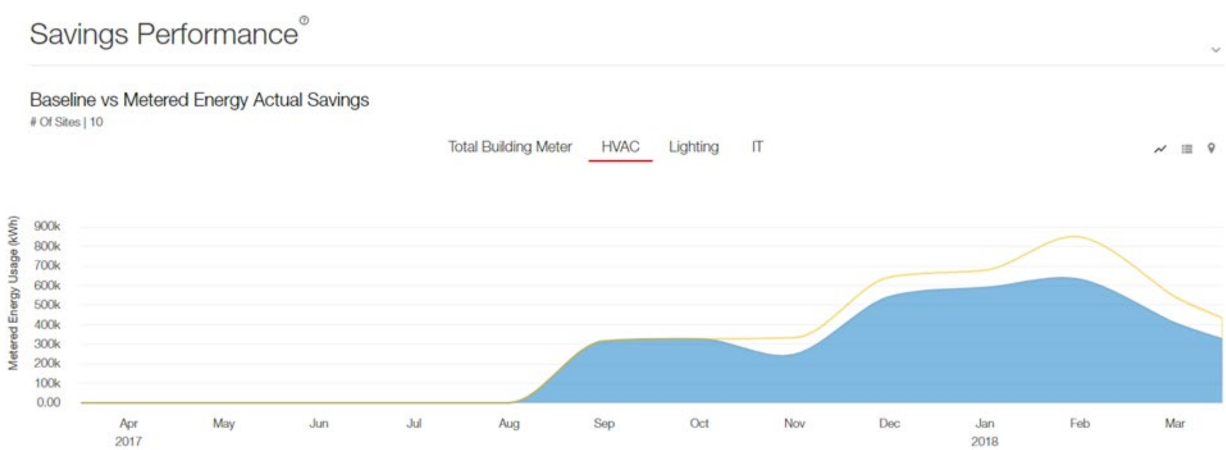


Figure 8 - Actual and Relative Baseline For Savings Performance

IoT is wonderful in this way, as the system telemetry tells the truth about what happening and provides a fresh perspective on how operations are performing over time. This has the added benefit of enabling better insight into long term optimization. For example, things like performance drift can be spotted related to maintenance conditions allowing for appropriate corrective actions.

Ultimately, if the pilots go well and prove successful, then this can lead into a scale-out program to introduce changes across the majority of the buildings under consideration. The IoT and telemetry are optional at scale, however, it clearly can provide significantly more insight than previously.

Conclusion

In conclusion the use of building energy modeling with enhancements and paired with IoT becomes a very powerful approach to understanding and allowing facility and energy managers to better understand and have firsthand data and information for making energy related decisions. The portfolio approach helps in selecting programs with the best potential savings yield for the business. The building digital twin combined with IoT through pilot ECM deployment helps further reduce the risk and greatly improves the understanding of potential deployments. Then keeping the IoT in place helps with the process of continuously optimizing and understanding relative changes over time. It doesn't make the building any smarter, but it certainly makes those responsible for energy and facility management a lot smarter and much more insightful regarding that status of building operations over time.

It is our goal to help introduce this energy insights capability as a more productized offering. If we can scale this solution across the entire building portfolio to measure and monitor energy consumption and savings in real-time, the same holds true for the cable operators to potentially offer the same services to their business clients. The commercial potential is virtually limitless when considering leveraging the cable operator network to enable new services like this in their own solutions portfolio.

Abbreviations

ECM	Energy conservation measure
IPMVP	International Performance Measurements & Verification Protocol
ASHRAE	American Society Heating, Refrigeration and Air-Conditioning Engineers, Inc.
BEM	Building Energy Model
SCTE	Society of Cable Telecommunications Engineers

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