Analyzing Energy-Efficiency Opportunities across Building Portfolios

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ABSTRACT

From an energy manager's technical perspective, there are several ways to approach analyzing and retrofitting portfolios of buildings. Relative performance comparisons can be made across the population. Packages of improvements can be applied broadly to groups of similar buildings. Right-timed deep retrofits, which coincide with capital improvement projects, can be planned to increase return on investment. A select few might be considered for innovative pilot projects to provide proof that radical savings reductions are achievable. However, there are challenges associated with evaluating portfolios. For instance, are the needed data available? Can a scaled evaluation be done accurately and cost effectively?

The emergence of new software analysis tools is helping to make portfolio-scale energy assessments easier. Many of these involve a no- or low-touch approach for opportunity assessment. Some helpful tools for making high-level evaluations across the portfolio include: Energy Star Portfolio Manager, FirstView, and LEAN. Examples of workflow tools that reduce costs by streamlining audits and analysis include: simuwatt, Retroficiency, and FirstFuel.

This paper examines the use of these software tools to support the portfolio assessment process. Methods are applied to two portfolio projects, which comprise buildings located across the U.S. The portfolio assessment process is described. The software tools employed are categorized, described, and compared. The challenges encountered and opportunities revealed are discussed.

Introduction

In the 2011 book *Reinventing Fire*, Rocky Mountain Institute (RMI) identified cost-effective paths for transitioning U.S. fossil-fuel use to efficiency and renewables by 2050. For buildings, this represents a 38-percent energy operating cost reduction and a $1.4-trillion net savings opportunity (Lovins, 2011). In 2012, the Rockefeller Foundation published a study that valued the retrofit market for U.S. buildings at $260 billion. If realized, this would result in $1 trillion in energy costs saved over a 10-year period (Rockefeller, 2012). These and other studies indicate that building efficiency not only provides notable investment opportunity, it also has significant societal and environmental benefits, such as job creation and climate-change mitigation. But to realize these compelling opportunities will require a large-scale and systematic approach.

To realize widespread adoption, replicable cost-effective methods are needed for identifying and addressing performance improvements. For commercial buildings, one approach is to work with the key decision makers for a large group of buildings—or portfolios—such as a corporation, franchise, investment fund, university, or government. While non-engineering approaches such as real estate underwriting can be developed in order to encourage better portfolio energy performance (Muldavin, 2010), this paper focuses on the technical approaches for analyzing portfolio energy performance, which provide a powerful lever to get on the path toward a cleaner and brighter energy future.

To foster improved methods in large-scale applications, RMI is working with partners that own and/or manage a portfolio of buildings located across the U.S. As part of our Portfolio Retrofit Program, we are testing a proposed method for evaluating portfolios and developing strategic implementation plans designed to meet long-term efficiency objectives. As part of this work, we are exploring energy analysis methods that support the assessment, identification, and quantification of efficiency opportunities.

Two portfolio assessments in the program are underway. We are refining our engineering method as we go. Our approach utilizes analysis methods that encompass triage and low-cost assessments. We are also conducting a few detailed assessments to provide greater insights into the accuracy and applicability of the lower-cost, more-scalable methods. This paper explains our work to date. It describes the handful of software tools used based on their data requirements, analysis approach, and other features. It concludes with lessons learned and method refinements moving forward.

Approach

The objective for the assessments is to perform streamlined analysis to identify actionable energy-efficiency measures (EEMs) and develop a strategic implementation plan to support long-term energy reduction across the portfolio. Analysis techniques of varying complexity are considered to provide different levels of granularity to support the assessment. Initially, a basic characterization is made for the portfolio of buildings to discern similarities and differences, create groups, and identify each group's energy use contribution. A group is selected for further analysis based on its ability to represent the portfolio and the portion of energy use it comprises. Through high-level analysis of energy performance and property management needs/plans, each building in the group is assigned one or more treatments, that might include: 1) retro-commissioning, 2) a bundle of energy-efficiency measures, or 3) a customized deep retrofit that requires a level-3 investment-grade energy audit. For example, a building that recently had a major renovation and exhibits poor energy performance would be assigned retro-commissioning. A building with average or poor performance with equipment/components at or near the end of useful life would be assigned a deep retrofit. Bundles of efficiency measures would be assigned in buildings where they appear cost effective. Some buildings might also be targeted for pilot studies considered for innovative pilot projects to provide proof that radical savings reductions are achievable.

Portfolio Assessment

The general approach being applied in the portfolio assessments involves seven steps that fall into three assessment phases: 1) a high-level portfolio assessment to benchmark, compare, allocate potential treatment type and roughly size efficiency opportunity; 2) a more detailed investigation that includes additional data collection, select investigations, and identification of specific energy conservation measures; and 3) the extrapolation and scaling of findings across the portfolio. These project phases and steps are summarized in Table 1.

Table 1. Portfolio assessment methodology

Phase	Procedure	Description
High-Level Assessment	Group	Divide into groups by type, size, and other distinguishing features that can influence the relevancy of efficiency measures. Select most influential group for further analysis.
	Benchmark	Perform high-level assessment to identify the general condition of the buildings in the group and the magnitude of savings opportunities.
	Triage	Sort and allocate group buildings into subsets according to their probable treatment.
Detailed Assessment	Inform	Collect additional data, confirm general conditions, perform select detailed investigations on a few sites, and establish savings potential of treatments.
Scaled Assessment	Scale	Utilize workflow analysis tools and/or streamlined, affordable methods to develop a suite of implementation options.
	Plan	Apply the suite of implementation options according to treatment category across the subgroup and portfolio. Develop a strategic implementation plan to meet economic and efficiency targets.

Corporate Real Estate Portfolio Analysis

The corporate real estate portfolio project is comprised of 146 office buildings totaling 20.2 million square feet (1.9 million square meters) located across the U.S. The assessment steps completed for the project are reported below.

Group

Several sorting factors were initially explored for grouping the office buildings. The factors included: floor area, number of floors, ASHRAE climate zone, and window-to-wall ratio (WWR). Floor area and number of stories were known. ASHRAE climate zone was determined from the building zip code. The WWR was estimated from Google maps. Factors were eliminated (WWR) and bins were combined to reduce granularity. The sorting that led to the selection of the archetype group categorized the 146 buildings based on 2 size bins (< 100,000 sq. ft. , >= 100,000 sq. ft), 3 climate bins (heating dominant, mixed heating and cooling, cooling dominant), and 2 floor number bins (1–2 floors, >= 3 floors). The group of buildings selected for analysis consists of 51 buildings that are at least three stories tall and 100,000 square feet [9,300 square meters]. The group was selected since it represents a large portion of the portfolio, equaling 53% of the floor area and 49% of the energy use. Also, its mixed climate can provide insights for both heating- and cooling-related measures that are relevant across the portfolio.

Benchmark

Utility billing energy use and costs were collected for the group of 51 buildings, including electricity and natural gas data. The energy use intensity (EUI) for each building was determined and compared to the portfolio average and the national average of 93 (based on the 2003 Commercial Building Energy Consumption Survey - CBECS). Of the 51 buildings, 15 were identified as having data of questionable quality due to missing months, potentially incorrect building size information, or buildings identified as extreme outliers. Those with low-end energy use intensity values might indicate lightly occupied or extremely efficient buildings. Those on the high end might indicate buildings with large data centers. Both types might not represent the group. For the 36 buildings deemed reliable for analysis, the minimum, maximum, and average EUI were determined to be 40.5, 174.1, and 71.5 kBtu/ft^2/year (462, 1180, and 815 kJ/m^2), respectively.

The EPA ENERGY STAR Portfolio Manager (EPA, 2013) was used to calculate an adjusted benchmark that accounts for occupant density, number of personal computers, building size, and location. The additional data needed for the ENERGY STAR calculation were available for 25 of the buildings. The corporate buildings had an average rating of 61 (standard deviation of 22) and a median rating of 65, which is 15 points better than the national average of 50 (compared to CBECS 2003). There were 7 buildings (28%) with a score of 75 or higher, which qualifies them for ENERGY STAR certification. Many of the buildings (10) had a score of 50 or less indicating ample opportunity for improvement.

Triage

The FirstView diagnostic benchmarking tool,[1] developed by the New Buildings Institute (NBI), was applied to the 36 buildings. The tool uses an inverse-model analysis to regress utility billing data energy use against average billing period temperature to develop energy signatures across the group. The regression coefficients determined from the inverse-model indicate physical conditions (Kissock, 2007). The physical interpretation helps illuminate potential causes for differences in EUI. FirstView compares the building utility-billing regressions to a “design model” case to interpret the physical significance, problem characteristics, and general areas for improvement.

The aggregate plot shows energy signatures for all of the buildings. It indicates the spectrum of performance, relative trends of each building, and diversity across the group. The regression results are extrapolated into energy use intensities in four categories. The end-use breakdown indicates the significance and range of end-uses by building across the group, as indicated in Figure 1.

[1] FirstView software and services (see http://newbuildings.org/firstview).

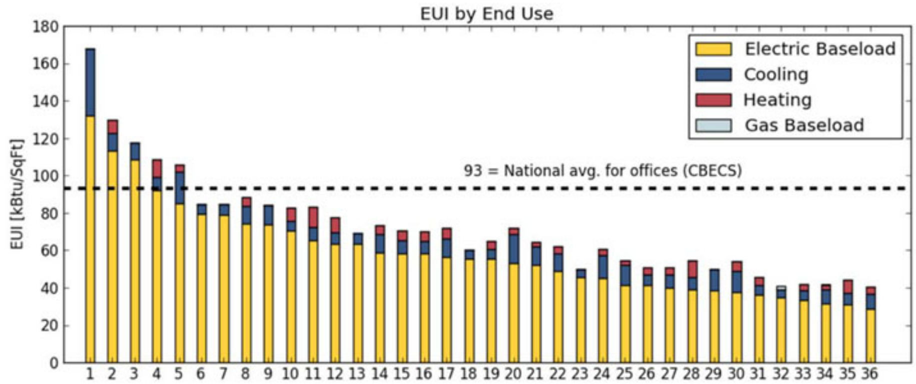

Figure 1. First view benchmarking and end-use breakout.

The wide range of EUI values attributed to electric base load performance in the FirstView analysis indicated that many of the buildings had data server rooms. On follow up, RMI learned server rooms are present but information regarding their size by location was not available. RMI also learned that the corporation supports a progressive telecommuting policy and is in the early stages of consolidating space. As a result, some buildings can have low occupancies—as low as 20%.

Inform

To gain further insights, an on-site visit and energy assessment was completed for one of the corporate building sites, consisting of two office buildings and a data center. The purpose of the assessment was to develop an extensive EEM list that could be considered in part or whole across the group. To support the EEM evaluation, we used two different tools for comparative purposes: the Retroficiency Automated Energy Audit tool (AEA)[2] and the FirstFuel Remote Building Analytics (RBA) platform.

The AEA can be used with limited or more detailed building data. For sites with limited information, it makes inferences using data from tens of thousands of real-world energy audits. It streamlines data input, makes EEM calculations, evaluates thousands of retrofit and operational opportunities, and allows for custom measure development. It includes a calibration feature that gives the user access to a handful of input parameters that can be manually adjusted to improve the visual match between the actual and modeled monthly performance. In performing the EEM evaluation, AEA combines measures into three packages that represent a short-term, mid-term, and long-term return on investment (ROI). To complete the analysis, measure costs integrated within the software are used.

We used the AEA with detailed building information and monthly utility billing data for the corporate site surveyed. The analysis resulted in the identification of over 50 EEMs, including several added to the analysis through a customization feature. Typical of many corporate building clusters, these buildings shared an electric meter, and the data center was not

[2] The full Retroficiency software platform was not utilized but includes: Virtual Energy Assessment, Automated Energy Audit, and Efficiency Track (see http://www.retroficiency.com/).

sub-metered, creating an assessment challenge. Through analysis of the equipment and operation, we determined a load per square foot per hour for these spaces and incorporated these estimates into the model.

We utilized the automated, remote FirstAudit tool, within the FirstFuel RBA platform,[3] on the same corporate building. For this analysis, detailed building data was not needed. The FirstFuel automated audit relies on electric interval data and natural gas data, which was obtained from the utility. Using advanced inverse modeling (coupled, multi-parameter regression analysis with optimization routine), FirstFuel disaggregates energy use and peak demand by major end uses. As shown in Figure 2, the remote audit's disaggregation is benchmarked on an annual electric consumption per square foot basis for seven major end uses. The rating is made against expected ranges of performance based on FirstFuel's proprietary audit database. FirstAudit adeptly interpreted the end-use breakdown to reveal several insights, including that the occupancy-related end uses are lower than expected. This was attributed to the building being under-utilized or having several vacant floors. The analysis correctly surmised that the lighting consumption was lower than expected, given the extended hours of operation and less efficient lighting fixtures. The miscellaneous-electric category represented the largest end-use category, which was driven by the tool's ability to accurately identify the power required by the data center/switchgear (power for servers, air conditioning, power backup, and conditioning equipment), as well as other IT-related electrical consumers. The report included a detailed description of low/no-cost operational savings measures, retrofit measures, and savings potential.

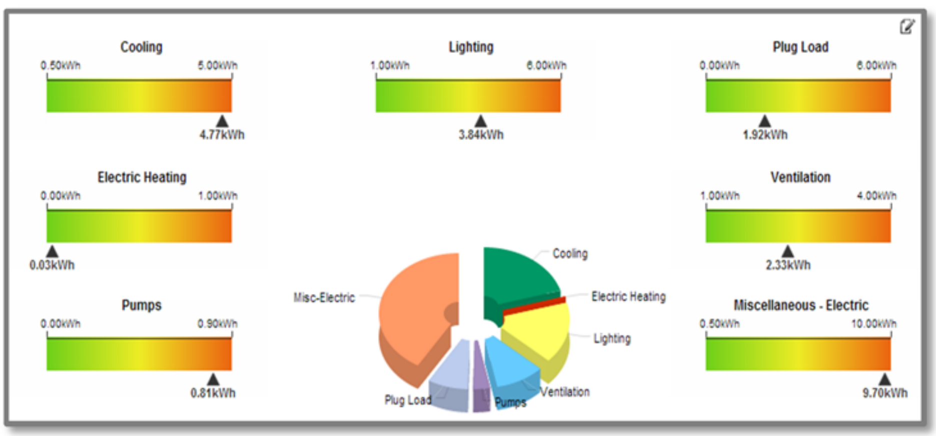

Figure 2. Building energy use dissaggregation determined by FirstFuel.

We crosschecked the FirstFuel analysis findings against the AEA analysis results, which were based on detailed building data. The two tools produced similar results: the mid-term return on investment AEA package estimated 18 percent energy cost savings, while the First Fuel analysis estimated a 15 percent savings potential, which was purely inclusive of cost-effective savings.

[3] The full FirstFuel software platform was not utilized but includes: FirstScreen, FirstBenchmark, FirstAudit, FirstPortfolio, and FirstMonitor (see http://www.firstfuel.com/)

Scale

We conducted an expanded Retroficiency AEA analysis for 25 of the corporate office buildings in the group using basic building information (location, floor area, building age, monthly utility billing data). For each building, bundles of measures that met specified ROI criteria (5-year, 10-year, and 50-year) were determined automatically. The aggregate results for the group analysis are presented in Figure 3. The EEM bundle with the very high ROI represents the "technical potential" or the maximum achievable savings without consideration for cost or constructability of the EEMs. Determining the technical potential is helpful for bounding the savings potential, setting long-term energy targets, and compels building owners to justify energy consumption.

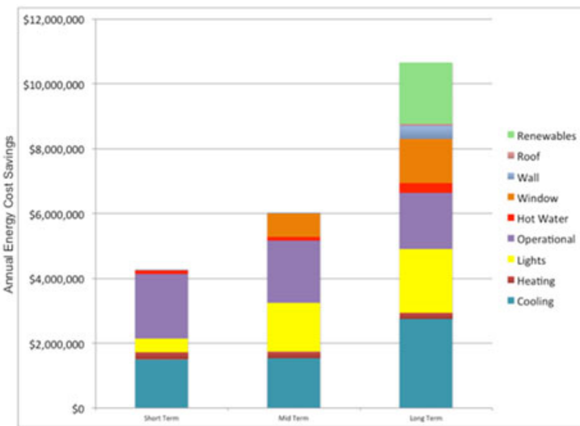

Figure 3. Aggregate savings identified with retroficiency for EEM bundles.

Plan

The scaled AEA analysis provides an indication of the level of savings available and the potential treatments applicable across the subgroup. Within the portfolio subset, the analysis revealed that an $18 million retrofit investment could produce $6.2 million in annual savings for a 16% five-year internal rate of return. If applied to the portfolio, 2008 base year energy use could be reduced by over 30%. While the opportunity was attractive, two major barriers challenged implementation: the corporation's limited investment in improvements not linked to business volume growth and lack of motivation for building managers and occupants to save energy.

Retailer Portfolio Analysis

The retailer portfolio project includes 124 retail shopping malls located across the country. Typically, each mall consists of retail space (~65%), food court with dining area (~7%), stock floor, and back-of-house (~20%), with the remaining space being corridors. The analysis plan for the portfolio has been developed and initial assessment is underway. The work completed to date and planned evaluations are described below. Per the client's request, the case study graphics show relative and not absolute performance.

Group

The sorting factors used for grouping the retail malls included floor area and climate zone. The other two factors considered for the office portfolio were not relevant for the malls since they were all single story with limited window area. For this portfolio to select a archetypal group, the buildings were sorted into six categories including two floor area bins (< 100,000 ft^2, >= 100,000 ft^2) and 3 climate bins (heating dominant, mixed heating and cooling, cooling dominant). Floor area and number of stories were known. ASHRAE climate zone was determined from the building zip code. The group selected for further assessment consists of 24 buildings greater than 100,000 ft^2 [9,300 m^2] located in a mixed climate. The group represents 34% of the portfolio floor area and 38% of its energy use.

Benchmark

The EUI was provided by the client for 83 of the retail centers with utility billing data. They are shown as single data points in Figure 4. Floor area is indicated by space type in the stacked bars. The median building size for the data set is about 100,000 ft^2. The figure indicates a large variation in total building size and composition. The average EUI is 105 kBtu/ft^2 year. Its range varies from +200% to -50%. As one would anticipate, sites with large food court areas have high EUIs and vice versa. The national average site energy use for retail malls built between 1990 and 2003 is 99.5 kBtu/ft^2/year (EIA/CBECS, 2003)

Triage

A Lean Energy Analysis (LEAN) was conducted using Energy Explorer software for all 83 sites in the group. The analysis is based on a temperature change-point regression model in which indications of the building physical condition are garnered from regression coefficients (Kissock 2007).

RMI examined the regression expressions and their variance for several sites over 3 years of utility billing data. This activity provided us with an appreciation for the swing in regression base loads, slopes, and change points that results from scrolling through different sets of 12 consecutive months of data. For some sites, irregularities in billing data became apparent. For others, improvements in performance occurring over several years were revealed. The detailed review exposed richness to the data set that would have gone unnoticed through an automated, generalized assessment.

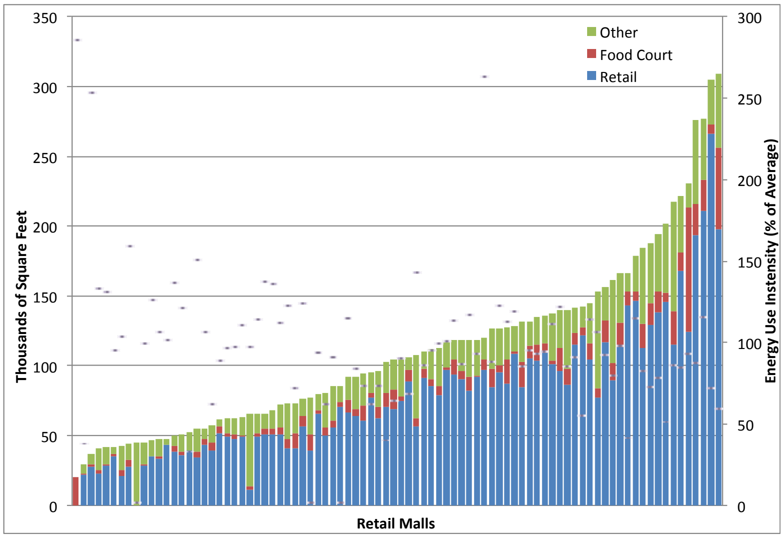

Figure 4. EUI and floor area data for the retail portfolio group.

The report summarizing all the analysis results is currently being prepared. The deliverable will include identification of sites with data irregularities and an interpretation of the regression parameters. LEAN uses regression results to indicate the relative condition of the base load, cooling sensitivity, cooling breakeven temperature, heating sensitivity, and heating breakeven temperature. RMI plans to use the results to allocate sites into general treatment categories, each with an associated energy savings potential.

Inform

Detailed energy audits were performed for two of the retailer buildings to better understand the installed systems, facility operation, and maintenance issues, and identify potential energy-saving opportunities, including integrated design solutions supporting deep retrofits. Based on the site observations, a detailed measure list of over 50 improvements were compiled and their installation costs estimated. The measures list includes 18 HVAC, 3 envelope, 14 lighting, 4 domestic hot water, 4 operational, and 13 food court equipment improvements.

For the two sites, a detailed, calibrated simulation model was prepared using the eQUEST building simulation program. For the calibration, a weather file was developed based on the actual weather that coincided with the utility billing data period. On-site observations, manufacturers' data, and short-term metering informed the model inputs. The LEAN analysis, which was completed for the two sites, helped establish the values for model inputs that impacted electric and gas base loads. Reconciling modeled performance to measured performance through the calibration process revealed existing operational issues. Quantifying the impacts of these issues using the model provided an estimate of the anticipated savings from retro-commissioning. For one of the sites, the retro-commissioning savings were significant, totaling 15% of current energy costs. Retrofit savings were evaluated for bundles of measures for the sites using the simulation program. Including retro-commissioning, the improvements had the potential to reduce energy costs by 50% or more. Figure 5 provides the modeling results for the existing building and bundle options for one of the sites.[4] The life-cycle cost analysis showed all the bundles, except the high-efficiency case, with net present value costs lower than the business as usual. This site has good potential for a deep retrofit since many of the existing systems are at the end of life and ready for replacement.

Scale

The findings from the simulation analysis will be used in conjunction with the LEAN results to extrapolate the savings potential for other sites in the group. The simulation models will be used to estimate savings associated with different treatments in several representative climate zones. The treatment options will include: 1) no-cost/low-cost operational improvements, 2) a cross-cutting set of EEMs, and 3) a deep retrofit bundle. For example, cross-cutting EEMs will be sorted into several groups identified as being beneficial to subsets with high electric base load, high gas base load, cooling sensitivity, or heating sensitivity. Sites identified through LEAN as needing these improvements will be assigned the corresponding group of EEMs with their associated savings.

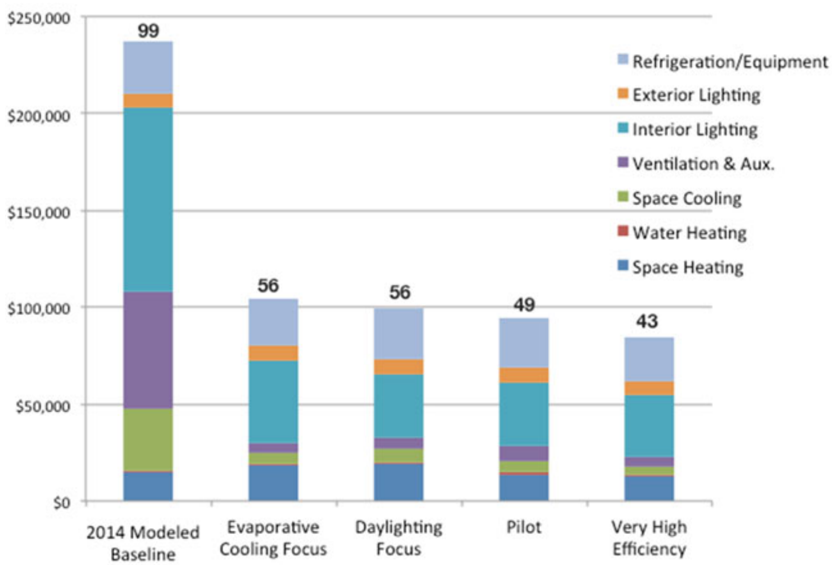

Figure 5. Building simulation results for baseline and bundles – costs and EUI (kBtu/ft^2 yr).

The scaling approach planned for the retailer buildings also includes a parallel effort involving the use of a soon-to-be-released workflow tool, simuwatt,[5] developed by Concept3D. Simuwatt aims to be an efficient, streamlined approach for delivering investment-grade audits. The tool is tablet based and incorporates standardized auditing processes, data management, and simulation analysis. The tool taps into several software applications developed by the Department of Energy, including; the Building Component Library[6] and the OpenStudio[7]

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[4] The "daylight" and "evaporative cooling" bundles include all the same measures except for daylighting or evaporative cooling. The "pilot" bundle includes all the same measures plus daylighting and evaporative cooling.
[5] simuwatt by Concept 3D (see http://www.simuwatt.com/)
[6] DOE/NREL Building Component Library (see https://bcl.nrel.gov/)
[7] DOE/NREL OpenStudio (see https://openstudio.nrel.gov/)

interface to the EnergyPlus computer simulation program. Simuwatt will be used to evaluate one of the retailer sites that has already been audited and modeled. The two auditing-modeling approaches (traditional versus tablet based) will be compared, as well as the findings produced by each.

Plan

Several variations of implementation options will be evaluated to determine their ability to meet overall project goals for economics and energy savings over time. Cost offsets from incentives provided through utility efficiency programs are being taken into account.
A key factor in the implementation roll out is integrating the proposed efficiency improvements into equipment replacements and interior upgrades currently planned for the retail centers. Two pilot projects will be conducted to verify the effectiveness of a bundle of EEMs and a deep retrofit. Methods for applying lessons learned from the pilots are being developed to inform project scope, streamline contracting, and train building operators.

Discussion

An overview of the analysis techniques applied in the two portfolio case studies are outlined in Table 2. The tools and associated analysis methods represent a partial list of currently available software. Inclusion in the list does not imply endorsement. The tools used in the Corporate Real Estate Portfolio assessment (EnergyStar Portfolio Manager, First View, Retroficiency, and FirstFuel) have overlapping capabilities and some analyses were redundant. Using a mixed selection of tools allowed us to compare their capabilities and application benefits but this approach is generally impractical for most evaluations.

The high-level assessment provided by metrics (EnergyStar) and inverse modeling (First View and LEAN) was helpful for making gross comparisons across the portfolio group. The inverse model provided additional insight. For the corporate real estate portfolio, the inverse modeling indicating the presence of a large and variable base electric load across the group. The ability to account for such loads proved challenging for some tools. The advanced inverse model analysis tool (FirstFuel) proved capable of providing detailed end-use disaggregation and performance insights without requiring any on-site data. This allows portfolios with little available data to be evaluated with reasonable accuracy.
The calibrated simulation analysis with inferred inputs (Retroficiency) was not as strong at discerning data center loads and low occupancies in its end-use disaggregation with only basic building information specified. Retroficiency worked well to evaluate many specific measures performance impacts. It also permitted the investigation of integrated solutions resulting in significant savings. However, it is time consuming, costly, and requires specialized expertise.

Conclusion

We pursued portfolio projects to explore effective methods and analysis techniques for scaling efficiency. Our general method includes: assessing savings potential across the portfolio, identifying types of treatments, and developing a strategic implementation plan. Our investigation into portfolio assessment methods using a variety of analysis tools has informed our approach for future portfolio work in several ways. Our process refinements are summarized below.

Table 2. Insights gained from analysis of portfolio case studies

Analysis Approach	Data Requirements	Analysis Output	Tool Example from RMI Portfolio Case Studies	Potential Use in Assessment Methodology	Insights Gained
Metric	Monthly utility billing data, basic building information	Building level performance indicator	Energy Star Benchmark	Benchmark	Using benchmarking to compare the sites in the group to each other and a reference condition is low effort. It provides a good overview and rough indication of saving potential.
Inverse Model	Monthly utility billing data, basic building information	Five indicators of overall building operation and physcial condition inferred from regresion parameters; estimate of savings potential in five areas	FirstView, LEAN	Benchmark, Triage, Scale	Using the same data needed for benchmarking, inverse models provide greater insights into the cause of variations across the group. This helps identify sites ripe for energy improvements and their general form of treatment (recommissioning, general upgrade, deep retrofit).
Advanced Inverse Model	Utility billing data (interval data for electricity), building address	Seven indicators of energy end-uses and their savings potential; recommendations for specific cost-effective EEMs for operation and capital improvements	FirstFuel	Benchmark, Triage, Scale; also Inform if used with detailed building data	Using interval data and a more sophisticated regression analysis provides increased accuracy and greater insights compared to inverse models. The analysis capably differentiated end-use conditions and operational characteristics, which improves credibility of assessed savings. Tool should work well when applied across a portfolio for low-touch, scaled assessments.
Calibrated whole-building simulation model with inputs inferred from audit database of similar buildings	Monthly utility billing data, basic or detailed building information	Energy end-use estimates, extensive EEM evaluation for operation and capital improvements, EEM bundles evaluated for several ROI levels	Retroficiency	Benchmark, Triage, Scale; also Inform if used with detailed building data	Inconsistencies in occupancies and data center loads across the group made applying a low-touch scaling approach challenging for the corporate building portfolio. More detailed input improves accuracy of findings. User must negotiate the balance between results accuracy and input data requirements.
Streamlined on-site data collection coupled with calibrated whole-building simulation analysis	Building address, floor plans, utility billing data and site data collected through tablet-based audit software	Extensive EEM savings evaluation based on whole building simulation model informed by audit data and utility bills;	simuwatt	Inform, Scale	Approach offers potential for affordable analysis that provides detailed EEM evaluation with reasonable accuracy. Side benefit includes development of equipment inventories across the portfolio.
Calibrated whole-building simulation analysis	Utility billing data, building construction documents, audit data, spot/short-term measurements	Extensive EEM savings evaluation based on whole building simulation model informed by audit data and utility bills; retrocommissioning savings potential	eQUEST	Inform	Development of calibrated modeled by experienced practitioner based on detailed site data provides extensive insight into a range of treatments but effort is time-consuming and costly. Helps differentiate between recommissioning, operational, and capital improvement impacts. Supports development of integrated design solutions for deep retrofits.

- Whenever possible, we will extend our benchmarking analysis to include an inverse model analysis due to the ease in which additional information can be gained from the same set of data.
- Our choice of analysis approach for doing a scaled assessment across the portfolio using low-touch methods will depend on several considerations, including: 1) the uniformity of the characteristics of the buildings within the analysis group, 2) the similarity of the buildings in the analysis group to a standard building, and 3) the building information available for each site in the group.
- Performing a customized whole-building simulation provided us with invaluable insights into retro-commissioning issues and integrated design solutions for deep retrofits. However, we will limit our level of effort since the inaccuracy of other information (e.g., implementation cost estimates) limits the value of producing accurate savings estimates.
- Aligning efficiency projects with planned capital improvement projects was key to meeting our clients' investment criteria.
- Developing a successful portfolio strategic plan must account for internal corporate processes that, if not addressed, could hinder implementation. This may include financing criteria, knowledge transfer from pilot projects, capital improvement plans (or lack there of), and incorporating efficiency considerations into job tasks and contractor scope.

References

Energy Information Agency, 2013. Commercial Building Energy Consumption Survey 2003. Retrieved from: http://www.eia.gov/consumption/commercial/

Environmental Protection Agency, 2013. ENERGY STAR Portfolio Portfolio Manager. Retrieved from http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

Kissock, J.K. and C.W. Eger, 2007. "Understanding Industrial Energy Use through Sliding Regression Analysis."ACEEE Summer Study on Energy Efficiency in Industry

Lovins, A. & Rocky Mountain Institute, 2011. Reinventing Fire: Bold Business Solutions for the New Energy Era, Chelsea Green Publishing.

Muldavin, Scott, 2010. Value Beyond Cost Savings: How to Underwrite Sustainable Properties. http://www.greenbuildingfc.com/

Rockefeller Foundation & Deutsche Bank Climate Change Advisors, 2012. United States Building Energy Efficiency Retrofits: Market Sizing and Financial Models. Retrieved from http://www.rockefellerfoundation.org/news/publications/united-states-building-energy-efficiency