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ABSTRACT

An energy reduction program for commercial buildings is implemented for a SW Ohio natural gas utility. The aim of this study is to demonstrate that historical utility data for individual building customers, along with knowledge of pertinent building information (square footage, year built, number of floors, height of floors, wall construction type, and use type) available in county auditor databases, could be used to identify the best candidate buildings for recommissioning in terms of energy savings and simple payback. A study is completed for all natural gas customers of a utility in Montgomery and Clinton Counties in Ohio. A total of 400 candidate buildings for recommissioning are identified. These buildings have (1) seen increases in heating or non-weather-dependent energy over time or (2) have large baseline energy intensities indicative of combined heating/cooling year round. For these buildings, individual energy reports are created and shared with the building owners. For a subset of buildings, on-site recommissioning evaluations were used to confirm estimates derived from utility data alone.

INTRODUCTION

In just the past few years, 37 states have adopted renewable energy portfolio standards. Twenty-three states have energy reduction requirements, and three more states have requirements pending. These states have, in turn, permitted utility customer charges for energy reduction. Thus, utilities are now positioned to incentivize energy reduction. Blanket rebate programs have been most prominently utilized to achieve reduction of energy consumption. While these programs generally have achieved a requisite energy savings/cost benefit, they generally have not benefitted from reliance upon the vast quantities of amassed historical consumption data.

An important criterion for such incentivizing is the total resource cost (TRC) test. This test measures the benefits associated with energy cost reduction against the costs, both utility and participant, to implement measures that seek to realize energy cost reduction over a prescribed time period equal to the life of the improvement (OEB 2006). TRC values of 1 are marginally acceptable. A TRC of 1 simplistically states that energy cost savings are equal to costs incurred to achieve the energy savings. In Ohio, the Public Utilities Commission has set a TRC goal of 2 for energy efficiency improvements (Price and Sedano 2009).

Achieving the most energy reduction with the least incentives has significant economic benefit to utility customers and, arguably, to an entire region. The question is how can higher TRC values be realized?

This paper seeks to show that even monthly utility data can be effectively used to identify priority energy reduction opportunities in both individual commercial buildings and within a utility company's customer base in order to maximize the TRC associated with incentivizing investment in energy reduction.

The first step toward prioritizing buildings for energy reduction investment is to disaggregate energy data for a building into heating and cooling energy dependent upon weather and non-weather-dependent baseline energy. The weather-dependent energy must also be normalized relative to the specific weather conditions at the time energy data were collected. As far back as 1986, methods were developed to weather-normalize monthly energy data, to use this normalization to determine the possibility for energy reduction through different controls, and to measure the impact of

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energy reduction measures on actual energy use. This original system, called the Princeton Scorekeeping Method (Fels 1986), used monthly temperature data in conjunction with monthly energy use to come up with a normalized annual consumption (NAC). The NAC is determined from the combination of three vital parameters: base-level consumption (*Baseline*), a measurement of the raw appliance uses of a residence; heating/cooling slope (*HS/CS*), a temperature-dependent measurement of energy required to heat/cool; and balance-point temperature (T_{bal}), the temperature at the intersection of the heating or cooling slopes and the base-level consumption, which is a reflection of the average outside temperature at which heating or cooling is initiated. What made PRISM's method of normalization unique was the allowance for the balance-point temperature to be unique to a specific building's operation, rather than be a fixed constant. Thus, with the appropriate data input, a least-squares regression for heating energy gives a curve that fits the function according to the model

$$E_h = Baseline_h + (T_{bal,\,h} - T_{ext}) \tag{1}$$

where E_h is the monthly energy consumption, *Baseline* refers to the monthly baseline or weather independent energy, *HS* is the heating slope, $T_{bal,h}$ is the heating balance-point temperature (e.g., the average outdoor temperature above which no heating energy is used), and T_{ext} is the temperature external to the building. A similar relationship exists to describe cooling energy. Below, *CS* is the cooling slope and $T_{bal,c}$ is the cooling balance-point temperature.

$$E_c = Baseline_c + CS(T_{bal,\,c} - T_{ext}) \tag{2}$$

The normal approach in the PRISM system is to combine the above components to achieve a combined NAC using the formula

$$\begin{aligned} NAC = {} & (Baseline_h + Baseline_c) \\ & + HS \cdot HDH + CS \cdot CDH \end{aligned} \tag{3}$$

where *HDH* and *CDH* are the number of annual heating and cooling degree hours in the given month for a typical weather year (Fels et al. 994). Heating degree hours for a given year can be determined as a function of balance-point temperature using

$$HDH = \sum_{i=1}^{8760} T_{bal} - T_{ext,\,i} \tag{4}$$

Here, the temperature $T_{ext,i}$ is the outdoor temperature at any given hour during the period of that year.

While using the PRISM method can give very accurate information about the total amount of energy used in a weather normalized system, without a basis for comparison from building to building or home to home, there is little that can be said about how efficient the system is. Alone, PRISM offers little basis for comparing one building to another.

Although a focus on data can provide insight into the potential for priority energy reduction, the resulting question is how can savings actually be realized? One of the most effective means in commercial buildings is through recommissioning. The process of recommissioning is defined by the McKinsey Global Energy and Materials paper *Unlocking Energy Efficiency in the U.S. Economy* (Granade et al. 2009) as a "process by which HVAC and other systems are tested and adjusted to ensure proper configuration and operation for optimal efficiency." While testing and adjustments may seem to be of relatively minor importance, of the estimated 1,110 trillion end-use Btus that buildings are expected to consume in 2020, recommissioning of HVAC systems and building shells, along with lighting appliance upgrades, would save 360 trillion Btus of end-use energy—roughly 32.4% of the total building energy expenditure (Granade et al. 2009). Further, recommissioning has a low investment cost. According to a study sponsored by the Department of Energy, the median cost of commissioning existing buildings was only \$0.30/ft^2 (Mills 2009) as compared to typical energy costs of \$2.00/ft^2 nationally.

This paper first shows the value of combining natural gas utility customer energy data, county building databases, and hourly weather data. The resulting combined database is then analyzed with a series of processes, including the PRISM method, in order to benchmark buildings relative to heating energy/ft^2 changes over time, baseline energy changes over time, and baseline energy/ft^2. The analysis then provides an estimate of the energy and energy cost savings potential for recommissioning each of the buildings. With these simple payback estimates, priority buildings for recommissioning are determined. The predictions are then compared to the validated recommissioning savings for buildings, identified as priorities, that were audited. Last, we discuss how this compilation of data can be used to aid policy necessary to most effectively invest in energy reduction.

DATA

The analysis conducted to estimate recommissioning energy savings for each customer within a utility customer base requires (1) utility billing data for each customer over an extended period of time, (2) weather data (hourly) over the same period of time, (3) building data for each building in the customer database, and (4) typical weather data. A detailed description of these follows. In this study, building data and utility energy-consumption databases for Montgomery and Clinton Counties in Ohio were merged, resulting in a data set of over 1200 different commercial buildings with 57 months of natural gas consumption data from 2004–2009.

Natural Gas Data

Natural gas data for each Ohio customer from 2004–2009 was provided confidentially by a regional natural gas utility. These data were made available to the University of Dayton (UD) as part of a building recommissioning contract. Technically, this contract minimally required UD to recommission a

total of 45 buildings over a five-year period. The contract included financial support to UD that would be included in the TRC test evaluation of the program. Our goal, however, was to far exceed the 5–10 buildings required to be directly recommissioned per year. We proposed to evaluate the entire customer base, identifying hundreds or even thousands of buildings from a total of 55,000+ that would most benefit from recommissioning. Our proposal was to estimate energy savings for each customer, were the building to be recommissioned. We would then share this information with customers deemed best able to benefit, thereby promoting much greater collective energy savings than possible from simply selecting 5–10 buildings per year for complete recommissioning.

Weather Data

Actual dry-bulb temperature data for SW Ohio were obtained from the NOAA weather data site.[1] Typical weather year dry-bulb temperature data available through NREL were also required. Only hourly temperature data were needed.

Building Data

Each county in the U.S. maintains property records, many of which are available online in packed formats. If records are not available online, the county auditor's office often provides access to their property databases. For Montgomery and Clinton Counties, we were able to obtain the following relevant building characteristics for each property: address, year built, total square footage, number of floors, height of each floor, use type for each floor, square footage of each floor, and wall construction type. These data generally have to be assembled from multiple databases.

Merged Data

The energy and building data were merged. Energy data associated with each address were linked to building data associated with the same address. A total of 1200 buildings were considered.

DATA ANALYSIS FOR EACH BUILDING

The data analysis for each individual building completed includes the following steps: (1) curve-fits on 12 months of data at a time, (2) establishment of sliding baseline (weather independent) energy and sliding heating energy, (3) estimation of potential energy savings from recommissioning (4) calculation of simple payback, and (5) estimates of uncertainty for these. These steps are described in detail below.

3PH Fits

The first step in the energy data analysis is to normalize monthly energy data for each building relative to its square footage and hours in a billing period. Thus, the energy data for each billing period are expressed as the average power per square foot (Btu/h/ft^2) and are thus truly comparable from month to month and building to building. For the same billing period, the average monthly temperature is computed from the known hourly temperature data.

With the goal of determining how energy use or power changes over time, irrespective of weather, a 3-parameter heating (3PH) regression of the form given in Equation 5 is employed.

$$E_{h,i}\left(\frac{\text{Btu}}{\text{h}\cdot\text{ft}^2}\right) = Baseline_{h,i}\left(\frac{\text{Btu}}{\text{h}\cdot\text{ft}^2}\right) + HS_i\left(\frac{\text{Btu}}{\text{h}\cdot\text{ft}^2\cdot{}^\circ\text{F}}\right)(T_{balh,i} - T_{ext,i}) \quad (5)$$

Figure 1 shows the nature of this regression. For each 12 months of data, a 3PH fit is made to determine HS, $T_{balh,i}$, and $Baseline_i$. These respectively characterize the heating characteristics of the building ($UA_{overall}$/efficiency), the user characteristics (e.g., how the building is controlled from a temperature setpoint perspective), and non-weather- dependent usage. Note that these are independent of the specific weather for the year.

In order to compare heating energy from month to month or year to year, these characteristics are applied to a typical weather year for the city or region. NREL tmy3 typical dry-bulb temperature data are employed. Thus, the weather normalized annual heating energy is determined for each twelve-month period to be equal to

$$Annual\ Heating\ Energy(\text{Btu})_i = HS_i \times \text{ft}^2 \times HDH_i \quad (6)$$

where the heating degree hours for any twelve-month period can be well represented for Montgomery and Clinton Counties in Ohio, and the estimated balance-point temperature $T_{balh,i}$ for each twelve-month period can be represented by

$$HDH_i = 54963 - 3464.7 \cdot T_{balh,i} + 74.973 \cdot T_{balh,i}^2 \quad (7)$$

The annual baseline energy or non-weather-dependent energy is roughly constant all year, so the total annual baseline energy is equal to the hourly baseline energy times the number of hours per year.

$$Annual\ Baseline\ Energy(\text{Btu})_i = Baseline_i \times \text{ft}^2 \times 8760\ \text{h/year} \quad (8)$$

Disaggregation of the total weather normalized energy into heating and baseline energy components is necessary since increases in either of these are symptomatic of different problems that might exist in the building. Increases in the annual weather normalized heating energy over time reflect potential problems with building heating controls, changes in occupant behavior (temperature set-points), reductions in furnace or boiler efficiency, problems with the air handling

1. NOAA National Climate Data Center (http://lwf.ncdc.noaa.gov/oa/climate/climatedata.html)

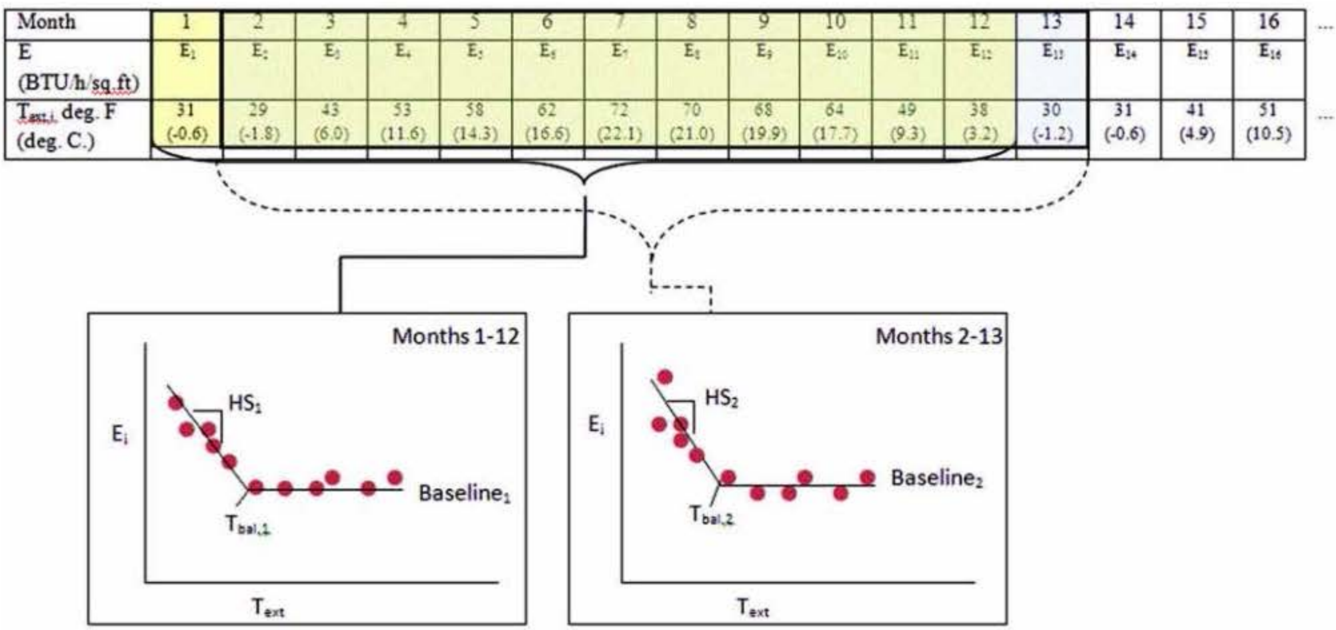

Figure 1 *Sliding 3PH fit progression.*

units (e.g., too much air), or increases in building infiltration rates. If annual weather normalized heating energy increases over time, then all of these possibilities must be considered when doing an on-site building recommissioning investigation. Increases with time in annual baseline energy provide more targeted issues to examine. Significant annual baseline energy increases are a result of either controls issues, which result in combined heating/cooling year round, or in changes in building use.

There is one other benefit of this analysis in helping to inform the recommissioning investigations. If there have been annual weather normalized heating energy increases over time and if the balance-point temperature has not increased, then the on-site investigation focuses on the heating system, the air handling units, and infiltration changes. As well, this analysis helps to target recommissioning investigations, reducing time and thus cost needed to conduct the analysis.

Our strategy for estimating potential savings is as follows. Figure 2 details our reasoning for changes that have occurred over time. The potential energy savings are estimated to equal the final annual energy use (either heating or baseline) minus the minimum energy use observed over the observation period. More exactly, a filtering approach is employed to minimize the effect of variation in the data. A four month averaging window for the sliding annual energy is used to determine both the minimum and the final annual energy use.

$$\textit{Moving Average Annual Energy Use}_i = \bar{E}_i = \sum_{i}^{i+3} E_i/4 \qquad i = 1 \ldots 6 \text{ \# months - 3} \tag{9}$$

$$\textit{Annual Energy Savings} = \bar{E}_{i,final} - \bar{E}_{i,min} \tag{10}$$

Finally, the simple payback is estimated from knowledge of the building square footage and using the low end of the spectrum for recommissioning costs. Lower recommissioning costs are feasible, given that the utility analysis employed helps to narrow the focus of recommissioning efforts. The simple payback is equal to

$$\textit{Simple Payback (years)} = \frac{\Sigma\left(\begin{array}{l}\textit{Annual Baseline Cost Savings}\\ + \textit{Annual Heating Cost Savings}\end{array}\right)}{(\$0.30/\text{ft}^2) \times \text{ft}^2} \tag{11}$$

Note that a net present value economic analysis could have been employed; however, this approach would have identified the same priority buildings as a simple payback method.

Example Buildings

The following provides energy data and analysis for two example buildings, one in prime need of recommissioning and another for which recommissioning is not needed. Figure 3 presents results for a 1516 ft^2 building built prior to 1930 for which recommissioning is absolutely needed. Figures 3a, 3b, and 3c show actual historical monthly natural gas use, disaggregated normalized annual heating energy cost, and disaggregated normalized annual baseline or weather dependent energy cost, respectively. It can be seen from this data that total energy use, heating energy, and baseline energy use have increased substantially during the past six years. Increased annual heating and baseline energy costs are estimated to be

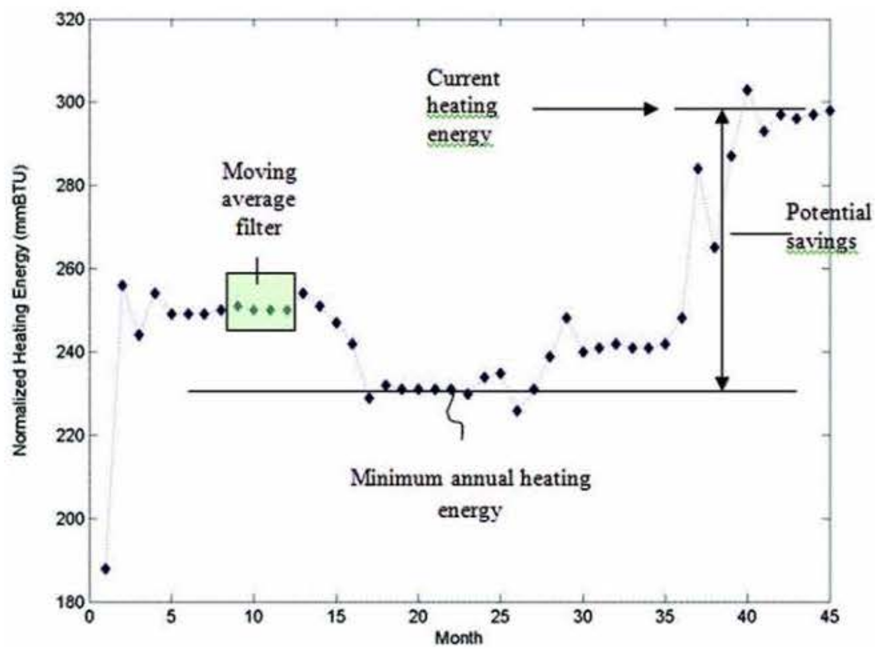

Figure 2 *Methodology used to estimate potential annual energy savings from recommissioning.*

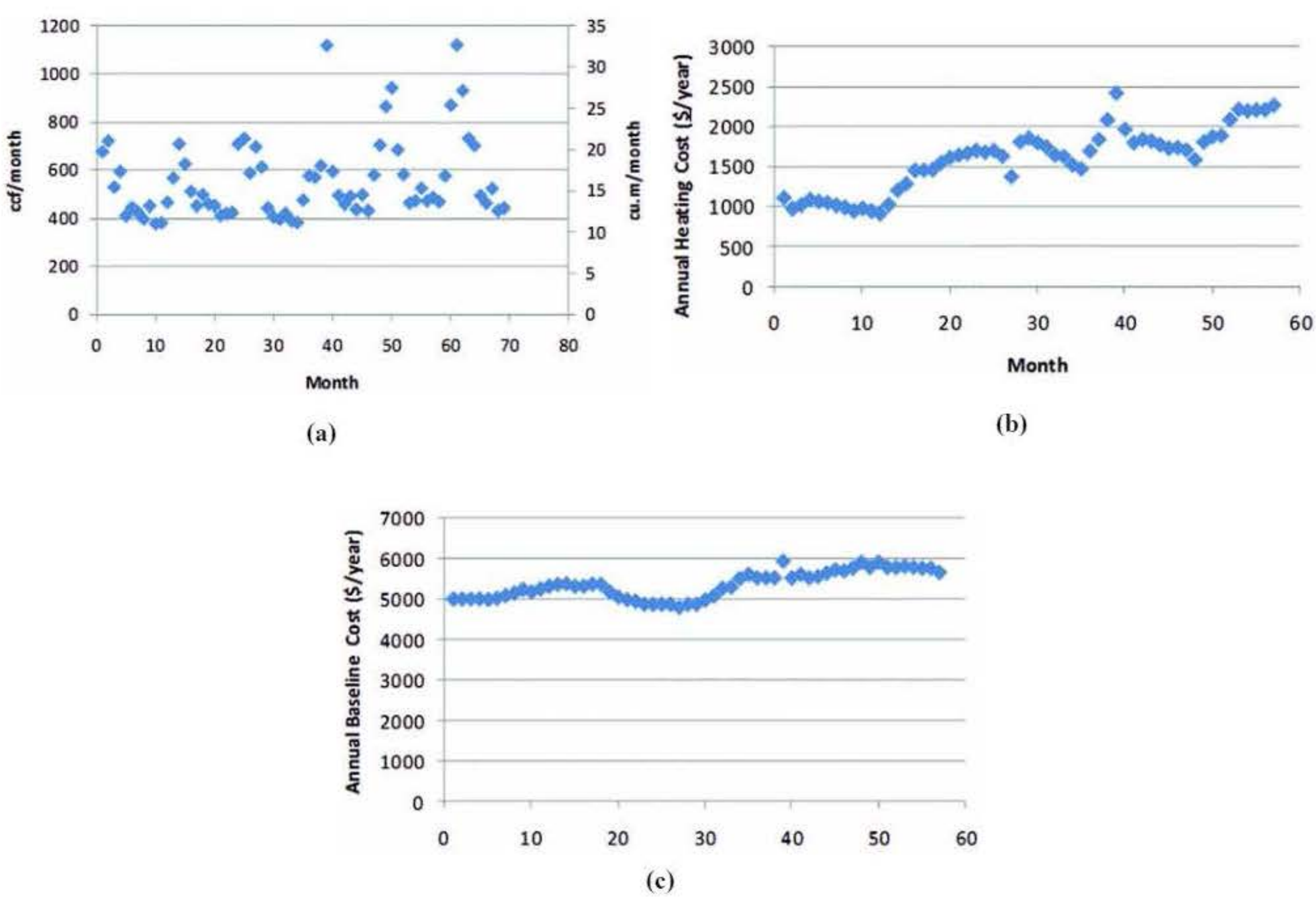

Figure 3 *(a) Monthly natural gas consumption (ccf/month), (b) normalized annual heating cost ($), and (c) normalized annual baseline cost ($) for 1930 era, 1516 ft^2 (140.8 m^2) building. Month 0 = January 2004.*

$1669 and $1154, respectively, assuming a natural gas price of $1.30/ccf. We estimate that these increases can at least be reduced from recommissioning.

Figure 4, which presents the estimated heating balance-point temperature T_{balh} versus month, provides insight into the nature of the heating energy increases. As seen, the balance-point temperature increases over time. An on-site inspection of this building revealed year-round boiler operation and controls problems, such that combined heating and cooling was observable in the summer. Also, the building owner had eliminated night setback temperatures. The payback estimate was deemed to be reasonable.

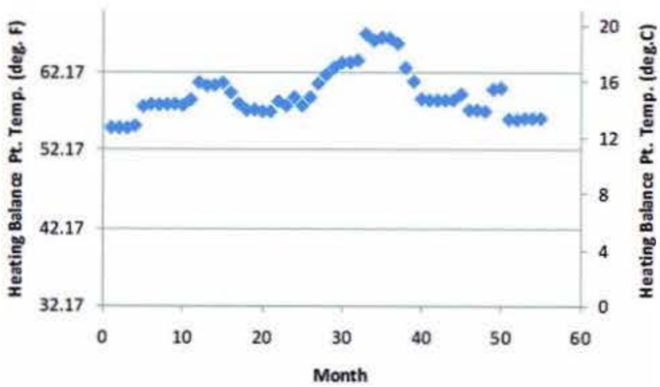

Figure 4 *Estimated heating balance-point temperature changes over time for building illustrated in Figure 3.*

Figure 5 shows a sample building for which recommissioning isn't called for. Figures 4a, 4b, and 4c show similar data for the monthly natural gas consumption, normalized annual heating cost, and normalized annual baseline cost. Clear from these figures is that the normalized annual heating and baseline energy have declined with time. Comparing the energy intensity of this building to that illustrated in Figure 2, one sees that the annual heating energy intensity is roughly one-half that of the building where substantial savings can be realized from recommissioning. Close examination of this building revealed dramatic building owner changes to include use of night setback temperatures, reduction of water heater temperature, and improvement in the building envelope.

Figure 6 presents the estimated heating balance-point temperature for this building as a function of time. In contrast to the former building, the balance-point temperature for this building has been observed to decrease. On-site examination revealed dramatic building owner changes to include use of night setback temperatures, reduction of water heater temperature, and improvement in the building envelope.

Additionally, cost savings from reduced annual baseline energy intensity can be estimated regardless of whether increases in baseline energy were observed over time. For typical buildings, the baseline energy use for natural gas is that

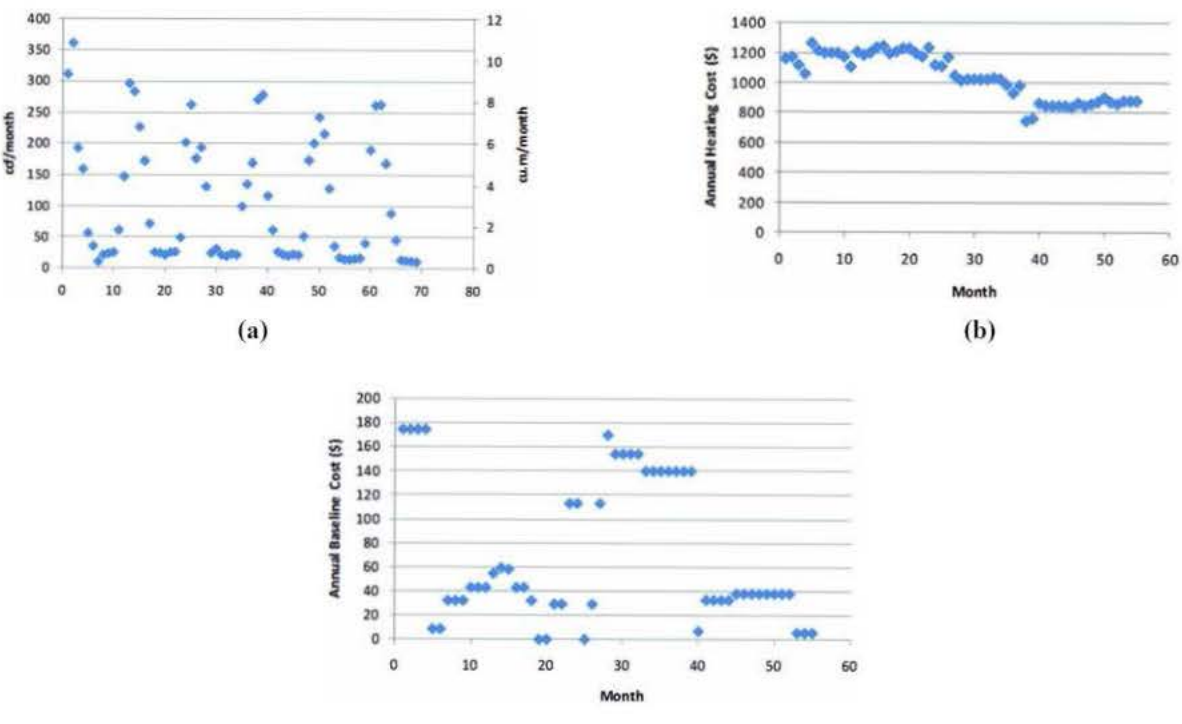

Figure 5 *(a) Monthly natural gas consumption (ccf), (b) normalized annual heating cost ($), and (c) normalized annual baseline energy ($) for 1930 era, 1569 ft² (140.8 m²) building (Month 0 = January 2004).*

used for water heating and cooking, unless the building use is manufacturing. The Energy Information Agency Commercial Building Energy database (CBECs 2003) provides typical water heating and cooking natural gas energy intensity for various building types. Thus, the typical baseline energy intensity for building type is known. These data are summarized in Table 1.

The energy savings realizable from baseline energy reduction can then be estimated according to the following equation:

$$\textit{Baseline Energy Intensity Savings}_i = \max\left(\begin{matrix}\textit{Baseline}_i \\ -\textit{Typical Baseline Energy Intensity}, 0\end{matrix}\right) \times \text{ft}^2 \quad (12)$$

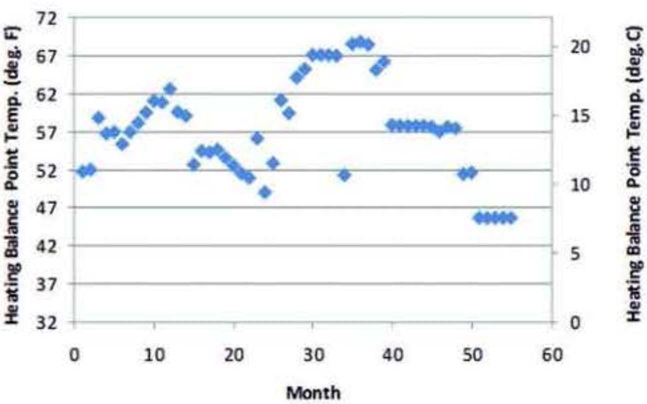

Figure 6 *Estimated heating balance-point temperature as a function of time for the building shown in Figure 5.*

For the two buildings of equivalent type (food service) illustrated in Figures 3 and 5, the respective baseline energy intensities are 382 kBtu/ft^2 (4338 MJ/m^2) and 52.2 kBtu/ft^2 (592.8 MJ/m^2). The first building had a baseline energy use well above a typical building of the same type, while the second building had about one-half the typical energy use. As noted, the high baseline energy use in the first building is due to the fact that there was year round combined heating and cooling. If the baseline energy intensity of the higher energy use building could be reduced to typical values, total annual cost savings of $4202 would be realized from both baseline energy and heating energy reduction.

CUSTOMIZED ENERGY REPORTS

Automated energy reports for each building were completed using Microsoft Access. A sample report for the first building considered in the previous section is shown in Figure 7. The intent of the reports is to provide simple feedback to building owners, relative to their annual heating and baseline costs and the associated energy savings estimated. Additionally, the customized report summarizes issues to evaluate during a recommissioning study.

COLLECTIVE RESULTS

In this section, we present collective energy savings for the commercial customers reviewed specifically in Clinton County. A total of 109 buildings were deemed to have potential for energy savings from recommissioning. These were ranked according to simple payback in years (recommissioning costs/annual energy savings).

Figure 8 shows the estimated simple payback versus energy cost savings for each of these 109 buildings in rank order according to simple payback. In general, the total energy savings become progressively larger. So too does the simple payback for recommissioning of these buildings. Notice also that the maximum simple payback permitted is ten years.

Table 1. CBECs Data (2003) for Water Heating Energy Intensity for Various Building Types

Building Type	Typical Baseline Energy Intensity, kBtu/ft^2 (MJ/m^2)	Building Type	Energy Intensity, kBtu/ft^2 (MJ/m^2)
Education	5.9 (67.0)	Public assembly	1.9 (21.5)
Food Sales	14.4 (163.5)	Public order and safety	15.1 (171.5)
Food Service	105.4 (1195.9)	Religious worship	1.9 (21.5)
Health care (inpatient)	44.6 (506.5)	Service	0.9 (10.2)
Health care (outpatient)	39.4 (447.4)	Retail	1.9 (21.5)
Lodging	32.5 (369.1)	Warehouse and storage	0.7 (7.95)
Office	1.9 (21.5)		

Customized Energy Report for: ______________________

Customer ID: ____________ Baseline Cost Intensity, $/sq.ft. ($/sq.m.): $3.24 ($34.87)

Year Built: 1928 Heating Savings: $1,669

Square Footage: 2,898 Baseline Savings: $4,902

Current Heating Cost: $2,869 Total Savings: $6,571

Current Baseline Cost: $9,402 Recommissioning Cost: $869 Simple Payback (Years): 0.13

Recommissioning Emphasis:

The baseline energy intensity is greater than $0.50/sq.ft. ($5.38/sq.m.). The assessment should focus on understanding why the baseline energy is so high. Your annual heating current heating energy cost is at least $1,669 greater annually than it has been in the past. Your heating system controls should be evaluated. Finally, your potential baseline energy savings is substantially greater today than it has been in the past, $6,571. Your on-site assessment should seek to understand why this increase has occurred.

Figure 7 *Customized energy report for first example building benefitting from recommissioning.*

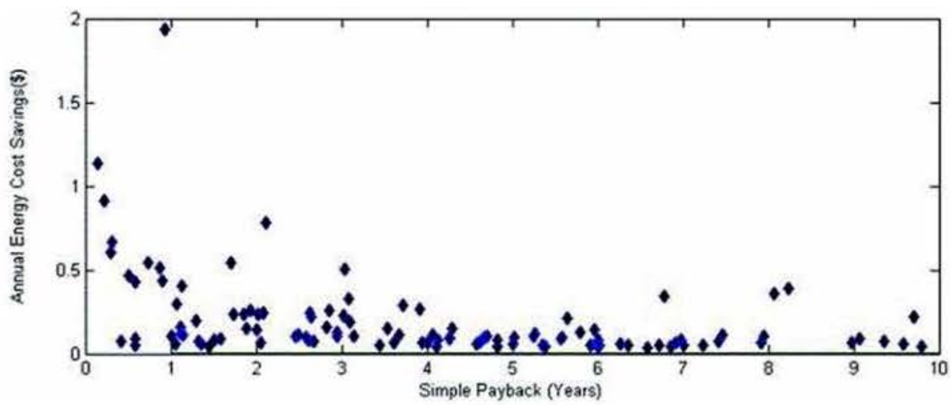

Figure 8 *Annual energy cost savings ($) vs. simple payback years for each candidate recommissioning building.*

An important feature of this collective energy reduction approach is that if deep energy reductions are desired from the collective grouping of buildings, then the high energy reduction/low simple payback buildings can be used to help pay more costly energy reduction for other buildings. Thus low cost savings can be used to expand the total energy savings and energy cost savings from among an entire utility customer base. As well, investment of energy reduction dollars can be made much more strategically than through simple rebate programs that may or may not attract customers deriving the greatest energy reductions from the rebates.

The collective simple payback for buildings, $1 \rightarrow i$, is determined from the sum of the ratio of expected energy savings to recommissioning costs for the collective buildings from $1 \rightarrow i$, as shown below.

$$Collective\ Simple\ Payback_i = \sum_{n=1}^{i} \frac{Individual\ Building\ Energy\ Savings_n}{Individual\ Building\ Recommissioning\ Cost_n}$$

Figure 9 shows the collective simple payback versus collective cost savings when adding each successive building. It is apparent that the low cost energy savings associated with the worst buildings (e.g., buildings with the smallest simple payback) can be used to help support the recommissioning efforts for buildings with much higher simple paybacks. As shown, the collective simple payback is roughly 1.7 years, were recommissioning efforts to be focused on all 109 of the candidate buildings, much less than the maximum simple payback of nearly ten years for the least attractive buildings for recommissioning observed in Figure 9.

A final plot (Figure 10) shows the relative importance of savings from heating energy reduction to savings from baseline energy reduction. Building 1 in this figure is associated with the lowest simple payback from recommissioning. Not surprisingly, this approach captures first buildings that have experienced large increases in heating energy over time. Thus, the lowest hanging fruit is heating energy reduction. As a much larger population of buildings is considered, the ratio of

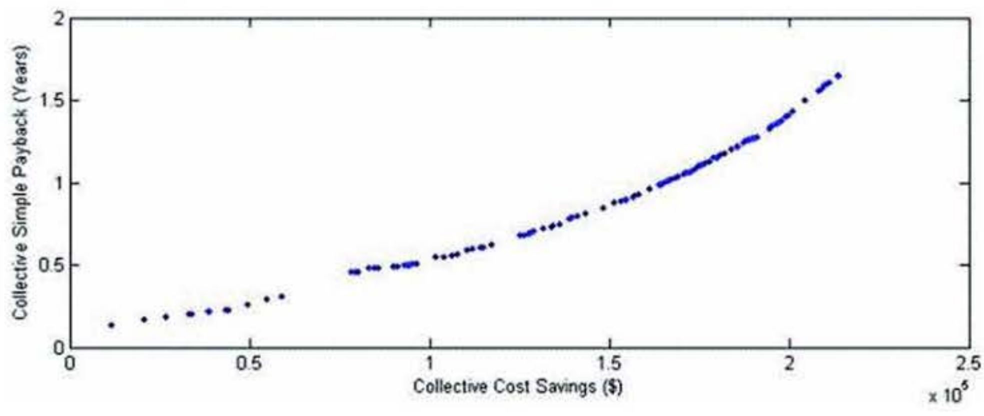

Figure 9 Collective simple payback (years) vs. collective cost savings from recommissioning among candidate buildings.

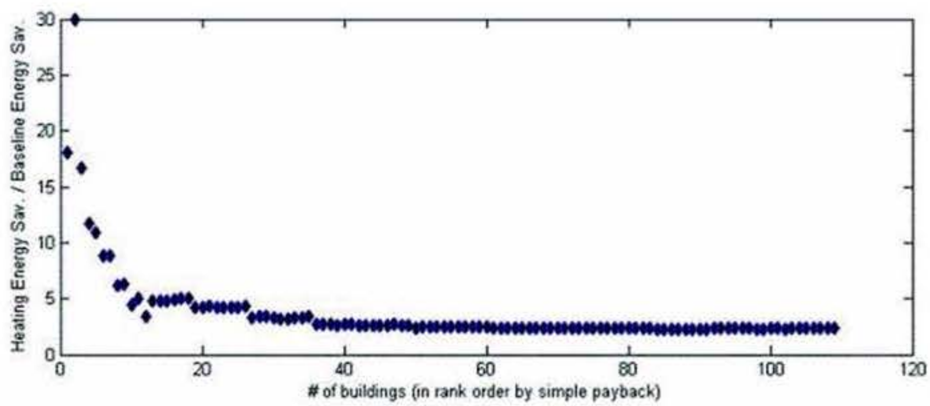

Figure 10 Ratio of heating energy cost savings to baseline energy cost savings for individual buildings.

heating to baseline energy savings appears to asymptotically approach a constant value of around 2.6. Of course, if this ratio has relevance, it certainly depends upon the region of the country considered.

MEASUREMENT AND VERIFICATION

In year 1 of the program, we were simply asked to recommission five buildings. Five buildings were evaluated: two office buildings owned by nonprofit organizations, two restaurants, and a private school. Table 2 describes the predicted energy savings for each of these buildings using the methodology described earlier. Buildings with recommissioning projects already implemented are noted. Estimated and actual recommissioning costs are noted. Predicted recommissioning energy savings from on-site audits are also noted. Only one of the buildings has had enough time after recommissioning to measure savings. These savings are also noted.

Generally, the estimates based simply upon analysis of combined utility, building, and weather data matched well those obtained from on-site energy audits. Also, except for the second building shown in Table 2, the costs for recommissioning were at least on the same order of magnitude as the actual costs for a local contractor. The substantially larger-than-estimated cost for building 2 (Nonprofit 2: Religious Service Outreach), as it turns out, is due to the fact that the building energy control system included in the design of the building was never installed. Thus, the building was never truly commissioned relative to its design.

As a final point, the energy savings shown are only associated with natural gas energy reduction. Electrical energy reduction on the same order or more as that for natural gas was predicted for each building from the on-site evaluations. In fact, for building 1, the on-site evaluation revealed that the chiller was running continuously. Thus, the heating energy reduction predicted from the natural gas utility analysis alone underestimated what was actually realized. The building was being cooled in the winter, which in turn required additional heating energy.

CONCLUSION

We have shown that analysis of historical energy data for a utility's customers can be used to identify priority buildings for recommissioning based upon potential energy savings. A weather normalized calculation of baseline and heating energy

Table 2. Predicted Energy Savings in Buildings Recommissioned

Building	ft^2	Year Built	Recommissioning Cost (Estimate), $	Recommissioning Cost (Actual), $	Heating Cost Savings, $	Baseline Cost Savings, $	Baseline Energy Inten. Cost Savings, $	Total Cost Savings (Estimate), $	Total Cost Savings (from Audit), $	Total Cost Savings (Realized), $
Nonprofit 1 (Psychological Services)	55,000	1960	16,500	22,000	0	0	8780	8780	9854	17,160
Nonprofit 2 (Religious Service Outreach)	13,890	2001	4167	22,000			10,800	10,800	10,800	Project not done yet
Restaurant 1	3725	1970	1117	500	5960	4470	4971	10,391	7042	Project done—savings not measured
Restaurant 2	1522	1980	456				1065	1065	600	Project not done
Private School*	32,600	1950	9750	15,000			N/A	N/A	2350	Project done—savings not measured

* This building was selected because of high energy use per square foot rather than energy changes over time. Baseline energy intensity was small and there had actually been both heating and baseline energy reduction over time.

over time reveal the customers that have seen the greatest degradation of one or both of these.

This research holds significant implications relative to state and national policy with regard to energy reduction. With more than one-half of U.S. states adopting energy reduction requirements, we believe we have established a process for saving the most money with the least investment for existing building stock. This success hopefully can guide state utility commissions in processes for establishing energy reduction programs.

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