NorthWrite

Daily Tracking of Energy Savings: Model and Examples

O&M-based energy savings initiatives are gaining more momentum in the marketplace in large part because of the relative ease in implementing them and the commensurately lower cost. Many authors have extolled the virtues of techniques such as tune-ups, retro-commissioning, etc. These methods can yield extremely attractive paybacks (often a year or less). Unfortunately, they often suffer from a very practical problem—mainly, ensuring that the expected benefits are obtained and just as importantly, ensuring that the benefits persist over time. We describe below a modeling technique that is being successfully deployed by a variety of building owners, operators, and utilities to directly address the issues of measuring the savings of O&M-based efficiency improvements and also making it relatively easy to ensure that these savings persist over time.

Technical Approach

We have found the modeling methodology presented below (and commercialized by NorthWrite in their Energy Expert software application) to be effective in establishing performance baselines from which to measure energy savings associated with operational changes in buildings. This method has the advantage that it can capture both linear and non-linear behavior. The method is based on the concept of data bins borrowed from the field of building energy data analysis. A bin is an interval (bin) of values of an independent variable with which a value of another (dependent) variable is associated. For example, the weather at a location can be characterized by the number of hours per year on average that the outdoor-air temperature falls into 5°F bins between some minimum temperature and some maximum temperature.

When multiple variables are used to explain the variations in energy use, multi-dimensional bins can be used where a multi-dimensional bin is defined as the intersection of one-dimensional bins based on each of the variables. This is shown in Figure for three-dimensional bins that characterize a variable such as energy use in terms of three explanatory variables. A representative value of the dependent variable is assigned to each bin defined by the ranges of values of the independent variables. For an energy use model, the dependent variable is energy consumption.

The model is "trained" by collecting data empirically and assigning it to bins. Given a sample of empirical data with each set of the sample consisting of values for a complete set of N independent explanatory variables (x_1, x_2, x_3, …, x_N) and the corresponding measured value of the dependent variable, an N-dimensional model is created by assigning each set of data in the sample to the bin in which the point defined by the values of its independent variables lies. When a sufficient number of points have been assigned to each bin, the model is considered fully "trained." A representative value of the dependent variable is then assigned to each bin, completing the model. The median of the values of the dependent variable in the bin makes a good representative value for both large and small numbers of points per bin.

The user of this tool defines a "baseline" time period over which they wish to create a model predicting energy use. This baseline can be a period of time prior to retro-commissioning, a preceding year, or other time period of significance for a facility. By using the baseline model with values for the independent variables for times in the post-training period, predictions of what the energy use of the building would have been in the absence of degradation in efficiency or actions taken to improve energy efficiency can be obtained. By comparing the actual energy use to the predictions, energy waste associated with degradation or energy savings from improvements can be determined, while controlling for changes in the independent variables (e.g., outdoor-air temperature).

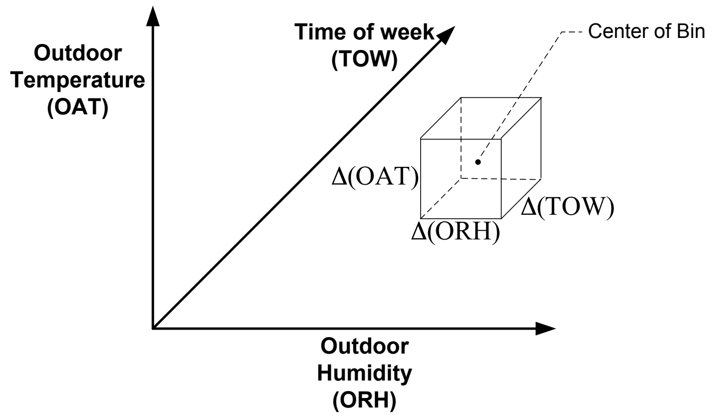

Figure A: An example three-dimensional binning scenario with bins defined by three explanatory variables: outdoor-air temperature, outdoor-air humidity, and time of week.

Examples

Below we provide several examples where facilities have implemented O&M-based energy savings programs and have used the Energy Expert to track their results. One of the analysis features that the Energy Expert provides is called "Cumulative Sum" (CUSUM). CUSUM is simply the integration of the daily differences between the actual and expected energy use for a modeled load. A positive slope on the CUSUM chart indicates that energy is being saved relative to the baseline. A negative slope is an indication of increased consumption relative to the baseline. The days over which the facility experiences the maximum possible positive slope can be considered a "best practice" period and can serve as a model for operating your facility.

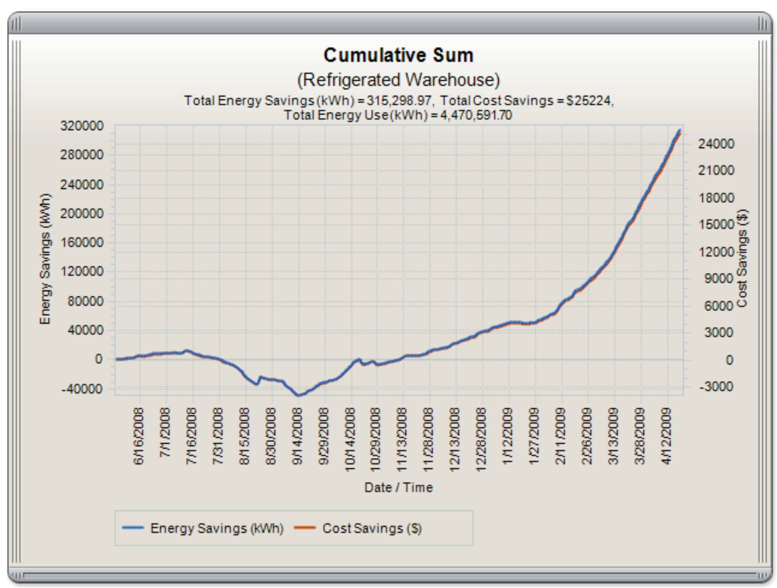

Figure B: CUSUM Graph for Refrigerated Distribution Center

The first example is of a large refrigerated distribution center. This building underwent a facility tune-up in which approximately 30 energy savings measures were identified as appropriate for the systems and operational needs of the facility. The site visit occurred in mid-October 2008 and approximately half of the measures were implemented while the technical team was onsite. Figure indicates that the Energy Expert immediately starts indicating positive savings following the facility tune-up. These savings are relatively consistent for a period of several months. During this time, no additional changes were made to the facility. However, early in 2009 the remaining measures were implemented by the operations staff and the slope of the CUSUM line steepened (indicating a positive step-change in savings).Another way to see the implementation progress of an energy savings program is by viewing the daily results of the Energy Expert using the Calendar view. This feature enables you to view the days during the month where your facility uses more (red), less (blue), or about the same (green) amount of energy as the baseline.

Figure shows a chronological progression for this distribution center from before the tune-up on the left, to after the tune-up on the right. The month in the middle shows the period of time in which the first phase of the tune-up occurred.

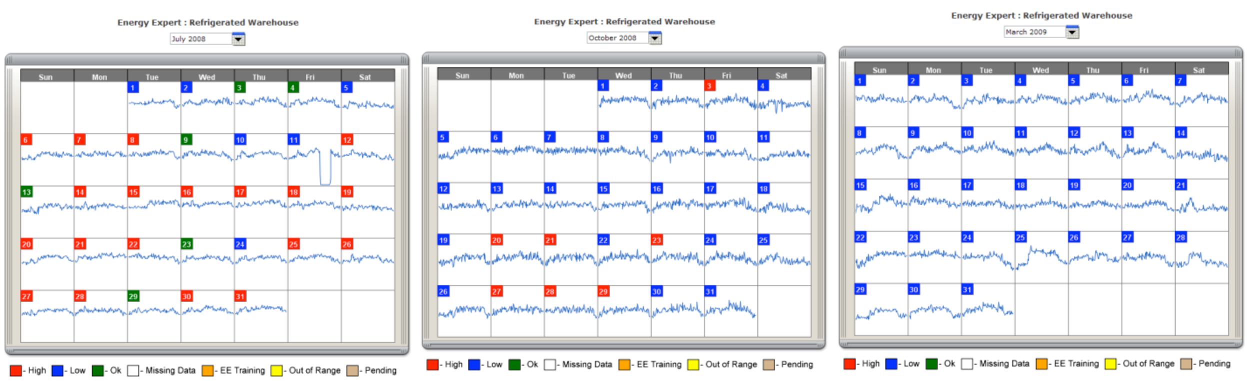

Figure C: Monthly Calendar View of Energy Expert Results

The next example (Figure D) is of a retail store that has been receiving significant energy savings as a result of implementing a number of changes to their building control system. However, in early April 2009, the controls vendor upgraded the software and overrode the tuning by resetting the set points and control strategies to an earlier version that had been archived. As a result, the store savings went from approximately $1,000 per month to $0 per month relative to the baseline (notice the decrease and overall flattening of the lines in Figure D after about April 5).

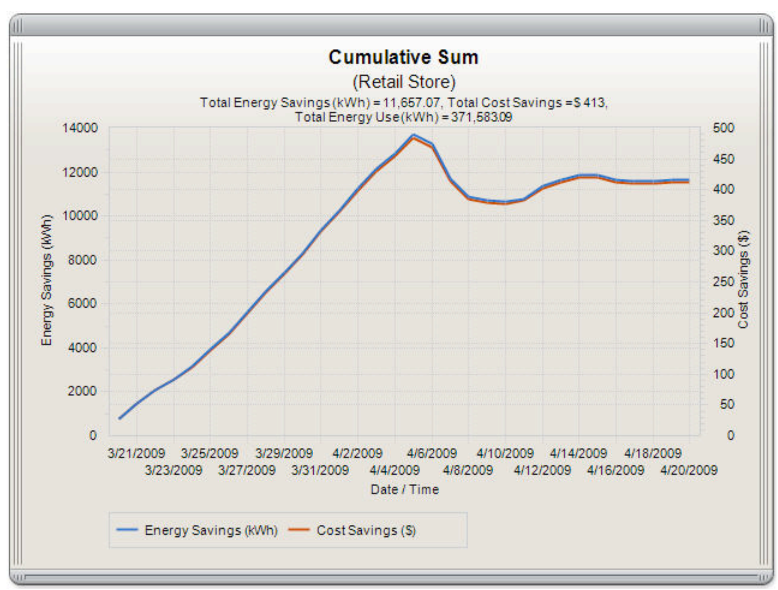

Figure D: CUSUM Graph for Retail Store

The Energy Expert provides 2 valuable services in this case. First, it notifies the operator that that savings the building had been enjoying are no longer accruing. Second, it provides a clear and unambiguous benchmark for returning the facility to its energy saving state.

The final example is for a portfolio of 9 office buildings (Figure E). Each building has an Energy Expert with a baseline set to the prior year (2008). The owners of the portfolio tasked the facility manager responsible for each building with "beating" their prior year energy use by as much as possible. The office buildings are 75,000 – 150,000 ft^2. As you can see from the Enterprise Roll-Up Report below, all the buildings but one are making significant progress towards their year-over-year energy savings goals. The owners know exactly which site(s) need more attention by simply scanning down the savings column.

Energy Expert Results for: Jan 1, 2009 - Apr 20, 2009

	High Demand	Actual Consumption	Expected Consumption	Consumption Δ	Savings ($)	Low	OK	High
Office Bldg. 1	120	178,573	287,911	109,338	8,747	110	0	0
Office Bldg. 2	206	265,015	321,088	56,073	4,486	100	6	4
Office Bldg. 3	770	777,083	860,868	83,785	6,703	73	12	24
Office Bldg. 4	331	376,728	419,051	42,324	3,386	89	13	8
Office Bldg. 5	323	251,769	303,499	51,730	4,138	105	5	0
Office Bldg. 6	294	418,752	454,795	36,043	2,883	86	15	9
Office Bldg. 7	169	280,683	317,090	36,407	2,913	109	1	0
Office Bldg. 8	801	1,083,433	1,023,492	-59,941	-4,795	34	13	63
Office Bldg. 9	303	434,943	477,023	42,081	3,366	79	22	9
Total		4,066,979	4,464,817	397,838	31,827	785	87	117

Figure E: Enterprise Roll-Up Report

These examples demonstrate how use of the models like the one in Energy Expert for monitoring can be used to quantify savings from re- and retro-commissioning and to detect when operation practices are implemented or faults occur that reduce or eliminate savings. When used on a continuous basis, such monitoring and diagnostic tools inform building management and operations staff, enabling them to maintain the persistence of savings over time.