Raising the Bar with 8,760 Savings Analyses

Dan Barbieri, KEMA, Middletown, CT
Curt Puckett, KEMA, Clark Lake, MI
Lisa Shea, NSTAR, Westwood, MA

ABSTRACT

Traditionally, the fundamental measure of DSM program performance has been annual kilowatt-hours (kWh) savings. At some utilities, time-sensitive costs and rate structures placed secondary emphasis on coincident reductions such as on-peak energy savings and seasonal peak demand impacts. Now, in some parts of the country, the impact evaluation landscape is changing dramatically and rapidly. With the advent of demand response programs in regions such as New England, efficiency programs have a vested interest in statistically reliable demand impacts in some very specific coincident periods.

To meet this growing challenge, NSTAR instructed its evaluation contractors to pursue program savings for their flagship Business Solutions (BS) and Construction Solutions (CS) programs with improved hourly rigor. This paper explores the background, engineering and statistical challenges, and inherent benefits of reporting on 8,760 hourly impacts associated with measure installations in large C&I retrofit and new construction efficiency programs.

Hourly 8,760 savings analyses represent the future of impact evaluation and are attainable through traditional evaluation techniques without expensive building simulations. Not only are annual hourly 'savings shapes' a key component of attaining reliable peak demand estimates, but also the method intrinsically supports reassessment of coincidence should peak period definitions change. Finally, this hourly detail facilitates in-depth presentations that reveal actual demand fluctuations and inspire thinking about energy consumption in its native dynamic realm.

Background

In June 2006, ISO New England (ISO-NE) received Federal Energy Regulatory Commission (FERC) approval for a new Forward Capacity Market (FCM) to replace the Installed Capacity Market (ICAP). ICAP is a monthly market that compensates generation companies for the net capacity of units sited in New England; an ICAP transition period will persist through May 31, 2010. As its name indicates, a key characteristic of FCM is its forward looking nature, for it is used to procure sufficient capacity to meet forecasted demand and reserve requirements three years into the future. Another key feature is that this new market facilitates participation by both supply *and demand side* resources, with distinct methods for energy efficiency and demand response to serve as qualified capacity in the market.

Transition in New England

ISO New England's <u>Market Rule 1</u> governs the operation of New England's wholesale electric power markets. Market Rule 1 allows "Other Demand Resources" (ODR) to participate in the market in addition to real-time demand response resources. Energy efficiency or "installed measures and/or systems on end-use customer facilities that reduce the total amount of electrical energy and capacity that would otherwise have been needed to deliver an equivalent or improved level of end-use service" now qualifies as a type of ODR (ISO New England 2006).

Throughout the ICAP transition period, qualifying resources will receive monthly ICAP payments based upon kilowatt (kW) capacity according to the following schedule:

December 1, 2006 to May 31, 2008	$3.05/kW-month
June 1, 2008 to May 31, 2009	$3.75/kW-month
June 1, 2009 to May 31, 2010	$4.10/kW-month

These payments are based upon the measured and verified electrical energy reductions achieved during specified performance hours. Summer ODR performance hours are defined as 1 PM-5 PM, non-holiday weekdays during the months of June, July, and August. Winter ODR performance hours are defined as 5 PM-7 PM, non-holiday weekdays during the months of December and January.

For established energy-efficiency programs that achieve megawatts of summer and winter demand reduction each year, this new market for ODR capacity represents a substantial opportunity. Thus, the start of the ICAP Transition Period on December 1, 2006 represented the beginning of a new era in the realm of energy efficiency program design and evaluation. Traditional DSM programs could now participate in this new market and incorporate capacity payments into their efficiency program budgets. But there was a catch. Just as the FCM did not discriminate between supply and demand side resources, nor did its rules. Demand side capacity would be held to comparable qualification, measurement, and verification standards as generation resources. Enter the MVDR.

The New Rulebook

In April 2007, the ISO New England published its first manual for Measurement and Verification of Demand Reduction Value from Demand Resources (M-MVDR). As stated in the manual, "All Demand Resources that participate in the Forward Capacity Market are required to demonstrate performance during specific operating hours in a manner that provides electrical capacity to the New England Control Area" (ISO New England 2007, INT-3). The manual details the measurement and verification (M&V) standards with which qualified Market Participants must comply.

All participants must submit a Measurement and Verification Plan to the ISO-NE that details its compliance with the requirements of the MVDR manual, including M&V methodologies, development of baseline conditions, measurement equipment specifications, and statistical significance. In *Section 7: Statistical Significance*, the MVDR manual specifies statistical accuracy and precision of no less than 80% confidence level and 10% relative precision. In *Section 10: Measurement Equipment Specifications*, the manual asserts that kW measurements be performed with no less than ±2% accuracy.

Analytical Implications

Over the years, program implementation and evaluation staff have grown quite adept at estimating aggregate efficiency impacts with 10% relative precision at the 90% confidence level. While annual kWh savings are rudimentary to quantify with reasonable accuracy, pursuit of coincident peak demand impacts poses some challenges. In a statistical framework, a sample design based upon a modest error ratio usually can yield annual energy impacts with ±10% relative precision. In practice, evaluators have found that upwards of twice this 'normal' sample size often is required to attain comparable precision for coincident peak demand impacts. In a recent evaluation of its 2006 BS/CS programs, NSTAR achieved ±8.2% relative precision at 80% confidence for demand savings during summer ODR performance hours. The corresponding estimate of precision for annual energy savings was ±4.7% at 90% confidence.

For many years, NSTAR's impact evaluations have pursued not only annual kWh savings but also peak demand impacts. This has been the norm at most utilities across New England, particularly in large C&I retrofit and new construction programs. But like most utilities, NSTAR found that their in-house summer and winter peak coincidence periods did not align perfectly with ODR performance hours. In addition to increasing the sample size to achieve new relative precision targets (80/10) for seasonal peak demand, evaluators decided to raise the bar with 8,760 savings analyses for all sampled projects. Thus, when the ICAP Transition Period began on December 1, 2006, increased emphasis was placed on the development of statistically reliable estimates for a widening array of demand savings classifications.

Program Planning and Evaluation

Many utilities use coincidence factors to derive summer and winter coincident peak savings from connected demand impacts, particularly for prescriptive projects. When independent studies revealed incompatibilities between how some coincidence factors are derived and applied, NSTAR incorporated a robust examination of measure coincidence into its 2006 BS/CS program impact evaluation. This decision also addressed concerns that current coincidence factors may be outdated or inconsistent with new ISO-NE definitions. With the assistance of evaluators committed to developing reliable, hourly demand impacts, NSTAR leveraged its ongoing evaluation efforts and spared itself the cost of sponsoring a coincidence study. The 2006 impact evaluation sample of 99 sites served as a valuable resource on measure-level coincidence without additional data collection.

In a sense, this effort represents a departure from the traditional 'top-down' approach to coincident peak impacts. The traditional impact evaluation approach has been to estimate annual kWh impacts first and then derive coincident peak impacts later. In some instances, coincidence factors are applied from separate studies to estimate coincident impacts. With more rigorous verification and reporting requirements looming for coincident peak demand impacts, NSTAR recognized the value of a paradigm shift towards a 'bottom-up' evaluation with full resolution 8,760 impacts.

Impact Evaluation Methods

A critical innovation in this impact evaluation was the development of 8,760-hour load shapes of savings which yielded highly reliable and consistent coincidence estimates by reducing the variability inherent in prescribed or 'off-the-cuff' coincidence factors. Traditionally attainable only through costly DOE2/eQUEST simulations, computation of hour-by-hour savings necessitates examination of both baseline and installed hourly kW by month, day of week, and hour of day with careful consideration given to site-specific holidays, occupancy/production trends, and temperature-dependent and seasonal effects. Evaluators developed 8,760 profiles of savings for each sample project in Excel. SAS® software was employed to compute coincidence of savings according to strict ISO-NE definitions across 99 profiles of 8,760 hours, or 867,240 data points. Copyright, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

Data Analysis

After evaluation engineers developed savings results for each sample project, analysts applied stratified ratio estimation (SRE) techniques to extrapolate the sample results to the program population. Evaluators used the SRE methods built into the RLW Load Research System (LRS) to develop gross and net realization rates or ratios between measured and tracking savings. Typically, analysts perform impact evaluations as 'static' studies within the RLW LRS since primary interest is on total gross and net savings and not on the underlying hourly dynamics. The availability of 8,760 savings for the entire evaluation sample permits 'dynamic' analyses which facilitate examination of load reduction and coincidence within any time period of interest. The analysis phase concludes with an estimation of error ratio associated with the installed measures in order to lay the foundation for planning future work.

Results

EnergyPrints are concise and powerful visualizations of time-series data. The following graphics depict 8,760 hours of net kW impacts in NSTAR's 2006 BS/CS program developed in the RLW LRS. In this orientation, hour-of-day is plotted vertically on the y-axis, and day-of-year is plotted horizontally along the x-axis. Energy impacts are represented by the changes in color intensity indicated on the legend alongside the EnergyPrint. In general, energy increases as the color becomes lighter. EnergyPrints are extremely efficient depictions of hourly interval data with countless applications. Most commonly, one uses EnergyPrints in a diagnostic manner to examine characteristics, trends, and anomalies in the interval energy usage of a particular customer or load research segment.

In this case, EnergyPrints are used to reveal the patterns evident in interval energy savings achieved in a large C&I efficiency program. This is a very important distinction, especially for readers already familiar with EnergyPrints of metered data. Profiles of energy *savings* do not necessarily follow patterns of energy *usage*. Consider how control measures such as occupancy sensors, energy management systems, and variable speed drives reduce energy usage when creating more savings.

Net Non-Lighting Impacts

NSTAR's 2006 BS/CS impact evaluation focused upon the following non-lighting end use categories: Compressed Air, Cool Choice, HVAC, Industrial Process, Motors, and Refrigeration. Lighting measures were included in the 2005 program evaluation and are the current 2007 program evaluation focus. Accordingly, 8,760 hourly savings were unavailable for lighting measures in the 2006 evaluation of the BS/CS program.

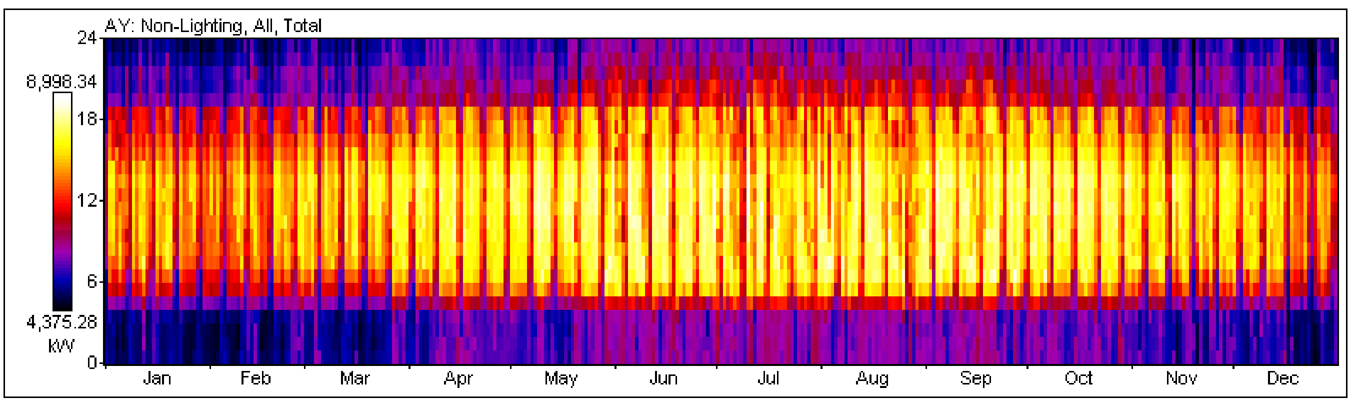

Figure 1. 2006 BS/CS Impact Evaluation Results, Net Savings, Non-Lighting

Figure 1 depicts total savings across all non-lighting end use categories for the 2006 BS/CS program. At a glance, this aggregate EnergyPrint displays elements of both schedule-dependent and temperature-dependent impacts. In this EnergyPrint, schedule-dependence is evidenced by sharp demarcation or 'banding'. Horizontal bands indicate that savings rise sharply around 5 AM and drop off around 7 PM. Vertical stripes indicate reduced weekend impacts. Temperature-dependence is evidenced by seasonal 'swells' in brightness; in New England this tends to occur in the middle months of May through August. In this EnergyPrint, temperature impacts are more subtle; winter impacts average perhaps 1,000 kW below summer impacts.

Note the bottom end of the legend scale: these 2006 non-lighting measure installations yield no less than 4,375 kW of demand reduction across every hour of the year. The average reduction across peak periods of interest is considerably higher. Consider the following more traditional net impact profiles:

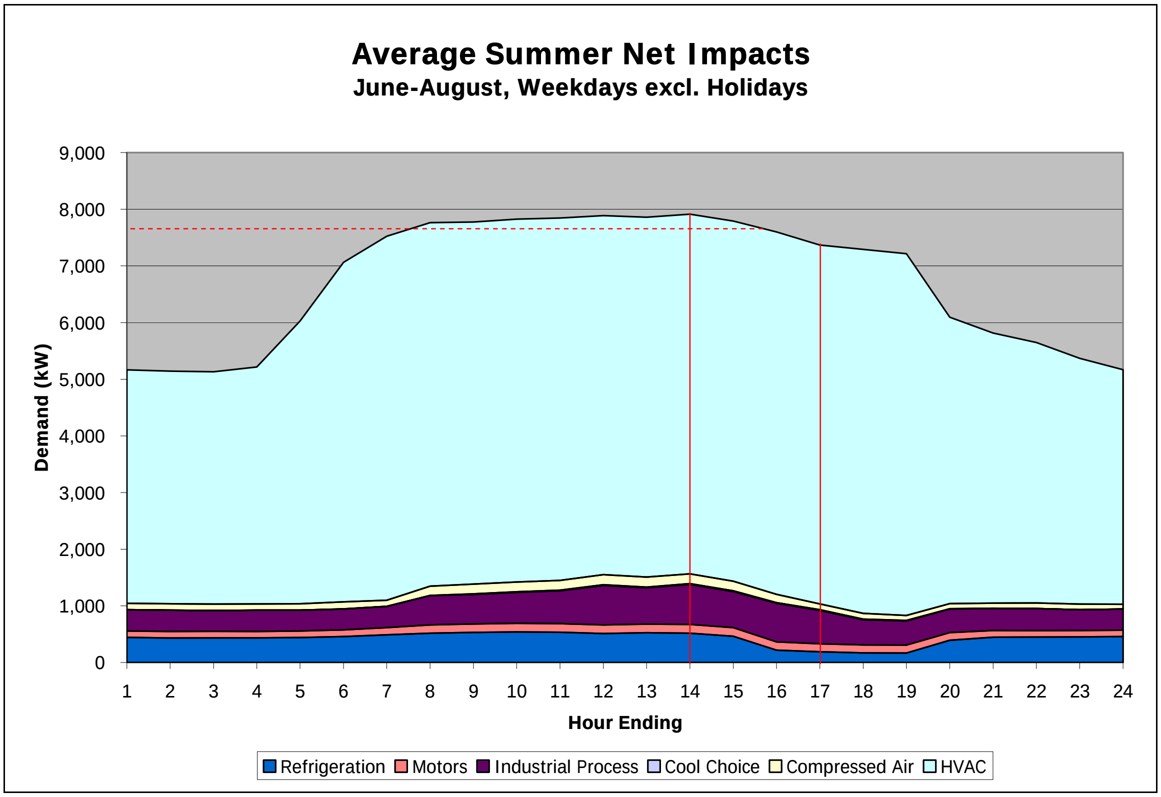

Figure 2. Average Summer Impacts, Net Savings, Non-Lighting

Figure 2 is an hourly savings profile which represents the average net impacts achieved across the summer ODR performance hours. In this figure, the contributions of each non-lighting end use are stacked to depict the total summer impact profile which ranges from 5,206 kW in hour ending 3 to 7,979 in hour ending 14. For summer, specific performance hours lay between the two red lines (1-5 PM) and average 7,670 kW of net impacts for non-lighting measure installations.

Prior to incorporating 8,760 analyses into its 2006 BS/CS impact evaluation, NSTAR could not develop this profile of net coincident summer impacts with sufficient statistical confidence and precision to support FCM reporting requirements. Now armed with this profile, NSTAR can express coincident demand impacts *even if ODR performance hours change downstream*. The expected lifetime for most of these measure installations is 15 years. In order to submit these impacts as ODR throughout their measure life, one must be able to translate the impacts should the definition of summer/winter ODR performance hours change.

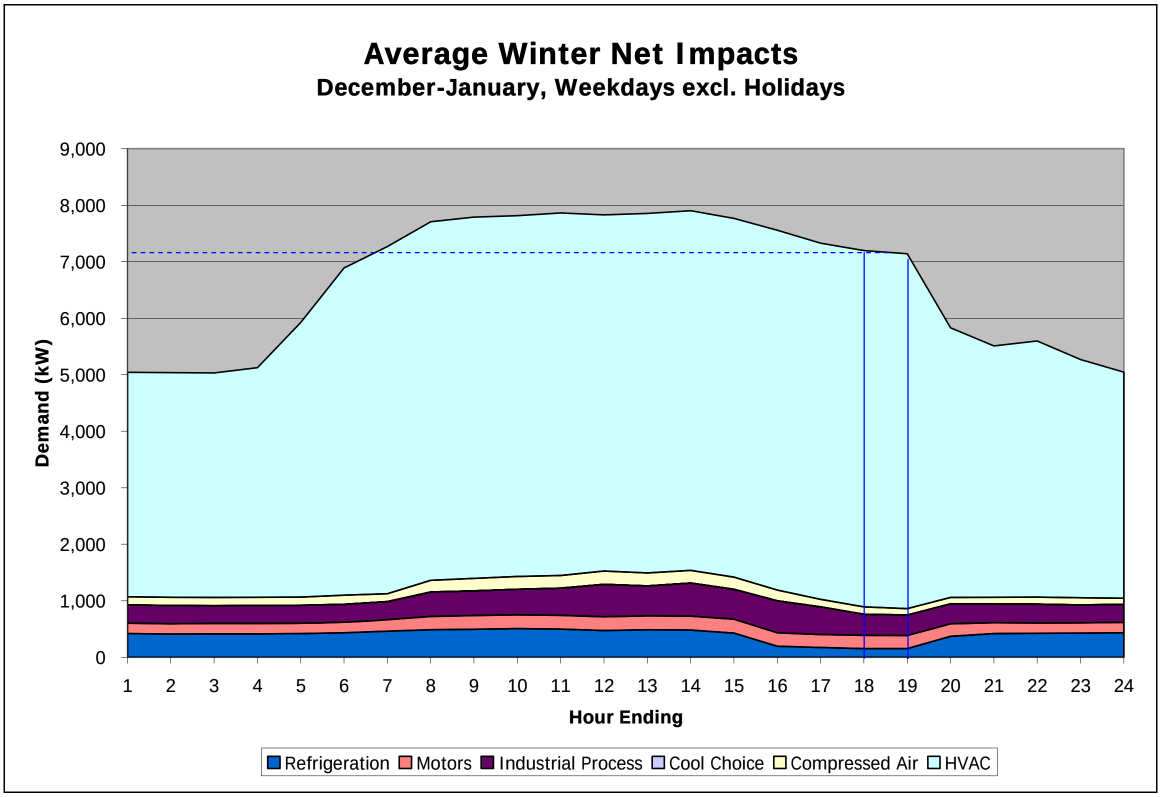

Figure 3. Average Winter Impacts, Net Savings, Non-Lighting

Figure 3 is a distinct, yet remarkably similar, hourly savings profile which represents the average net impacts achieved across the winter ODR performance hours. In this figure, the total winter impact profile ranges from 5,030 kW in hour ending 3 to 7,902 in hour ending 14. For winter, specific performance hours lay between the two blue lines (5-7 PM) and average 7,169 kW of net impacts for non-lighting measure installations.

Net Impacts by End Use

For NSTAR's BS/CS program, the distribution of savings by end use varies each year. Lighting and HVAC dominate, yet other measure types can be significant. It is important to realize that the EnergyPrints presented herein are weighted profiles across the impact evaluation sample of 99 non-lighting projects. Depending upon the coverage and representativeness of the sample, EnergyPrints at the end use level may, or may not, be indicative of typical or expected savings into the future.

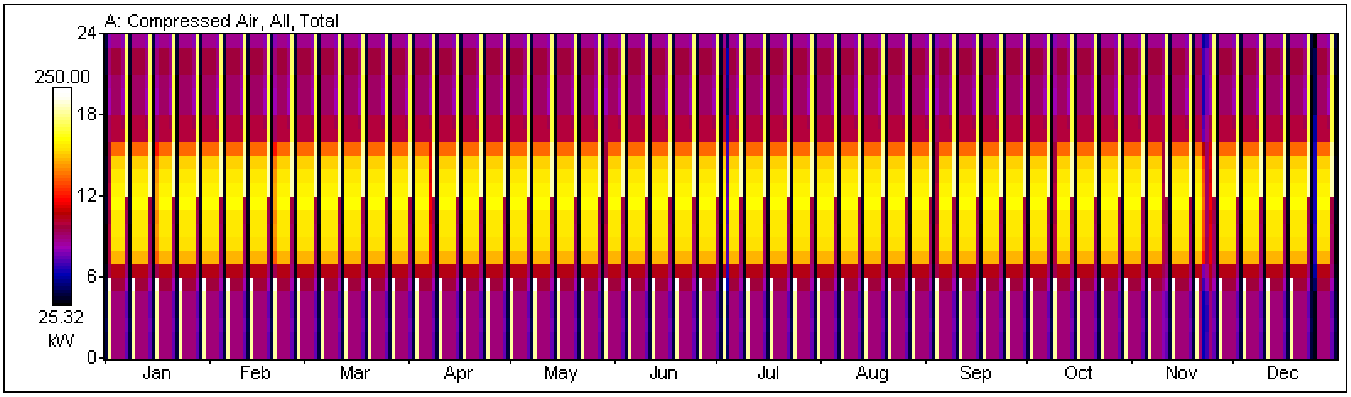

Figure 4. 2006 BS/CS Impact Evaluation Results, Net Savings, Compressed Air

Figure 4 depicts net savings for compressed air measures installed in the 2006 BS/CS program. The evaluation sample was comprised of 9 compressed air projects which represented about 2% of the overall non-lighting savings. This EnergyPrint is completely schedule driven, i.e. there is no perceivable seasonal or temperature influence in the savings profile. The savings weighted impacts in this evaluation sample are dominated by first shift operations, six days per week. Savings impacts drop to about 25 kW each Sunday, but hold steady at approximately 100 kW throughout second and third shifts.

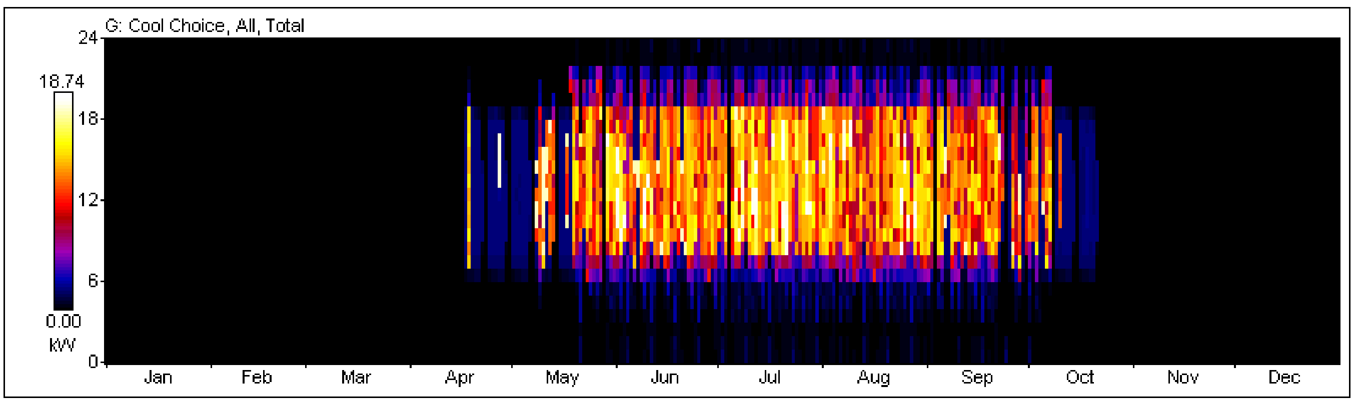

Figure 5. 2006 BS/CS Impact Evaluation Results, Net Savings, Cool Choice

Figure 5 depicts net savings for Cool Choice measures installed in the 2006 BS/CS program. Cool Choice is a marketing-based program for unitary air conditioners (AC) and heat pumps that meet Consortium for Energy Efficiency (CEE) efficiency specifications. With only 6 Cool Choice projects in the 2006 BS/CS population, the evaluation sample was limited to just two sample points. This EnergyPrint has a time-dependent component between roughly 8 AM and 8 PM, but the dominant factor is clearly temperature. These two Cool Choice projects were unitary AC, not heat pumps, and hence delivered no winter peak impacts.

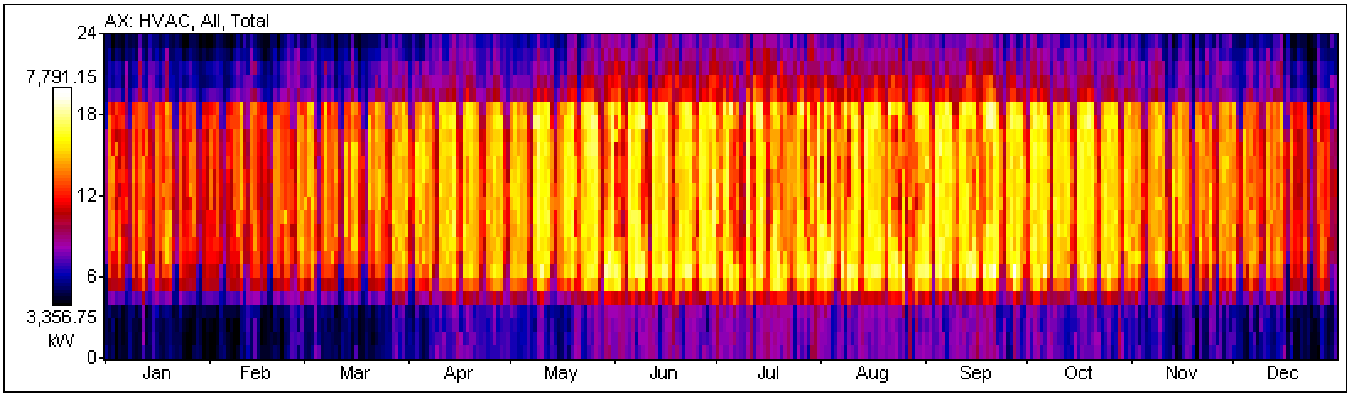

Figure 6. 2006 BS/CS Impact Evaluation Results, Net Savings, HVAC

Figure 6 depicts net savings for heating, ventilation and air conditioning (HVAC) measures installed in the 2006 BS/CS program. HVAC measures dominated this impact evaluation, representing 69 of the 99 sample points and nearly 80% of non-lighting savings. Obviously, HVAC dominates the aggregate non-lighting savings profile. All the features of Figure 1 are evident in this profile: schedule-dependence on weekdays between 5 AM and 7 PM and increased heat-influenced savings in May through August. If the minor distinction between summer and winter seems counterintuitive, remembers that this is an EnergyPrint of *savings* across a broad array of HVAC measures such as chillers, unitary AC, EMS, and variable speed fans and pumps. Much large C&I fan and pump activity persists year round. Many EMS measures focus upon reducing unoccupied energy usage. High efficiency or variable speed cooling equipment tends to deliver the most savings at part load, not peak load. This 8,760 insight afforded by this evaluation has revealed an HVAC savings profile that is surprisingly consistent between the summer and winter seasons. Since winter savings extends to about 7 PM, HVAC is a good candidate for both summer and winter ODR impacts.

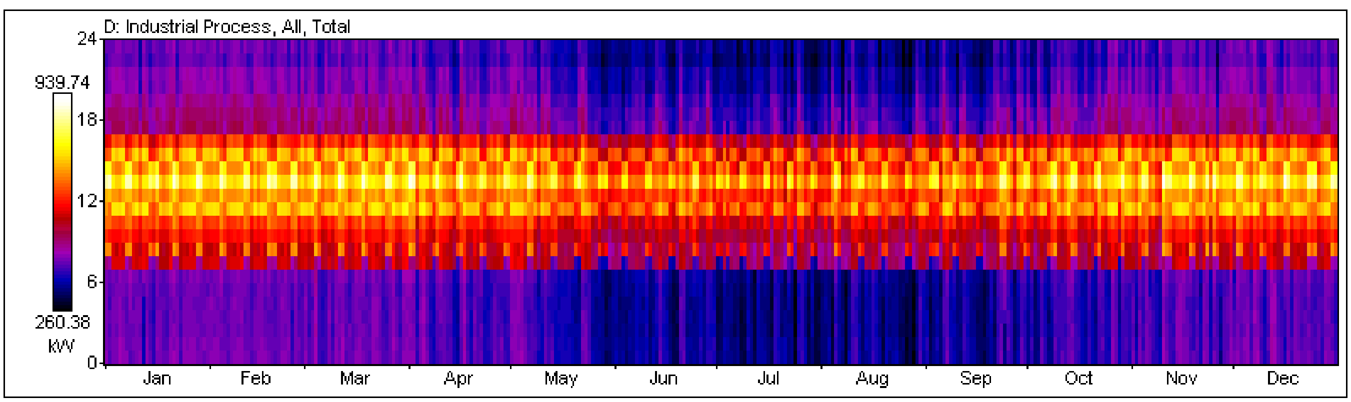

Figure 7. 2006 BS/CS Impact Evaluation Results, Net Savings, Industrial Process

Figure 7 depicts net savings for industrial process measures installed in the 2006 BS/CS program. The evaluation sample was comprised of just 6 industrial process projects representing nearly 8% of the overall non-lighting savings. In many ways, this EnergyPrint is not unlike compressed air: largely schedule driven with little seasonal influence. Interestingly, this industrial process EnergyPrint dips somewhat in the summer. Given the small sample size, one should take care drawing any broad conclusions about the industrial process end use category.

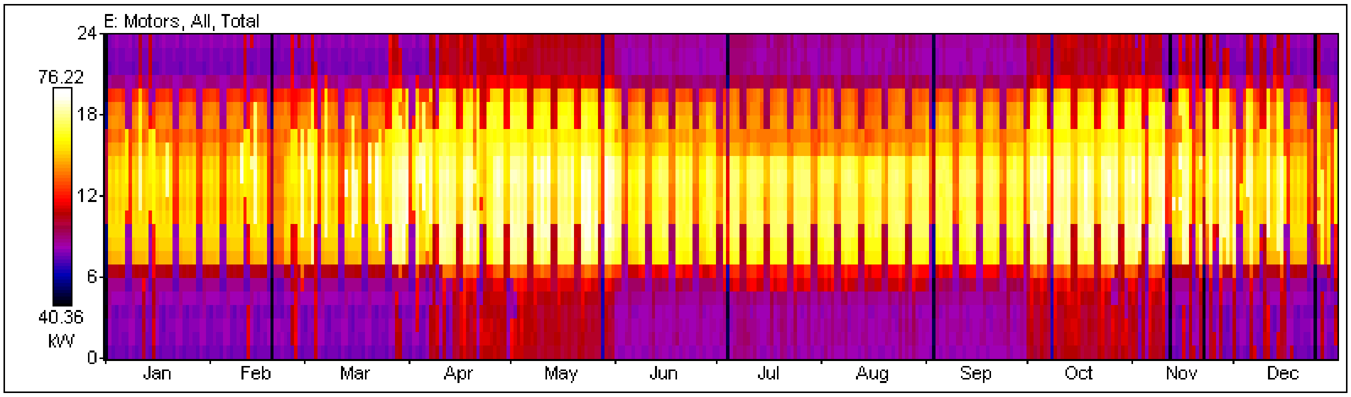

Figure 8. 2006 BS/CS Impact Evaluation Results, Net Savings, Motors

Figure 8 depicts net savings for motor measures installed in the 2006 BS/CS program. Another end use with low representation, the evaluation sample was comprised of 10 motor projects representing less than 1% of non-lighting savings. These projects appear to be mostly schedule dependent with some round-the-clock savings. An interesting feature of this EnergyPrint is the increase in savings impacts in the shoulder months of April-May and October-November. With seasonal consistency and winter savings extending to about 7 PM, the motor end use appears to be a good candidate for both summer and winter ODR impacts.

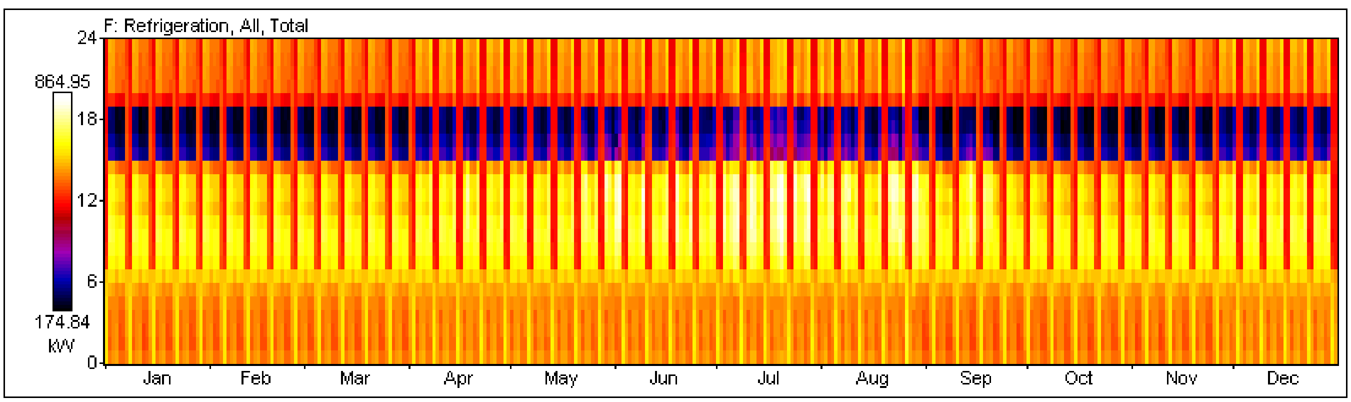

Figure 9. 2006 BS/CS Impact Evaluation Results, Net Savings, Refrigeration

Finally, Figure 9 depicts net savings for refrigeration measures installed in the 2006 BS/CS program. The evaluation sample consisted of only 3 refrigeration projects, yet they represented almost 11% of non-lighting savings. These refrigeration projects were savings intensive, and refrigeration applications tend to offer fairly consistent savings year-round. One of the three projects was the largest in the entire evaluation sample, and its profile dominated the end use and is even slightly apparent in the non-lighting totals. But this particular facility had a unique profile which reflected corporate policy to make ice during off-peak hours. The blue banding in the savings profile from 4 PM to 9 PM is a consequence of this scheduling anomaly.

Conclusions

Hourly 8,760 savings analyses represent the future of impact evaluation and are attainable through traditional evaluation techniques without expensive building simulations. Not only are annual hourly 'savings shapes' a key component of attaining reliable peak demand estimates, but the method intrinsically supports reassessment of coincidence should peak period definitions change. Finally, this hourly detail facilitates insightful presentations that reveal actual demand fluctuations and inspire thinking about energy consumption in its native dynamic realm.

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