Characterization of Energy Conservation Measure End-Use Cross-Effects

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British Columbia (BC) Hydro and their contractor, ERG International Consultants, Inc. (ERG), have developed a method for effectively studying the estimated hourly end-use impacts from implementing various energy conservation measures (ECMs) across various building types, weather regions, and fuel types. Further, we have developed a system for characterizing the cross-effects of these ECMs on end-uses not directly targeted by a DSM measure. This work has resulted in the development of a database and reporting system which provides summaries for 185 implementations of ECMs and 34 commercial building types based on DOE2 simulation results. This method was applied toward existing and future commercial building stock across three weather regions within the BC Hydro service territory. Out of this effort, BC Hydro was able to advance their understanding of the net effect of DSM technologies.

A spreadsheet tool called "End-use Comparison Analysis Program" (ECAP) was developed to summarize the end-use cross-effects. ECAP reports changes in end-use monthly energy and demand coincident with system and building peak, as well as the maximum building demand. This spreadsheet assists BC Hydro in performing sensitivity analysis to see how changes in a primary end-use (e.g., lighting) influence other end-uses (e.g., heating, cooling, fans, etc.). With this capability, BC Hydro will enhance their present engineering calculations, helping them to focus future end-use monitoring and evaluation efforts. Additionally, it will help improve the reliability and accuracy of individual ECM impact estimates.

Introduction

BC Hydro is an electric utility which provides services to its customers located in British Columbia, Canada. As part of their Power Smart Program, BC Hydro wishes to gain an understanding of the estimated end-use impacts from implementing various ECMs on their existing and future commercial building stock. BC Hydro is interested in determining these "cross-effects" between end-uses for advancing their understanding of how DSM opportunities will affect their commercial building requirements.

This cross-effects effort represents a relatively detailed level of modeling analysis. The scope of this effort involved investigating hourly changes in demand for ten end-uses for 185 individual ECMs across three weather regions. At this level of detail, building controls and/or weather driven fluctuations in hourly energy requirements can produce perplexing results which may have escaped previous attention (while reviewing only annual, monthly, or daily average results). This experience has increased the understanding and appreciation for the verification and development of "clean data sets."

Background

This effort originated from past and on-going BC Hydro projects involving dynamic building analysis and the identification of cost-effective DSM strategies for prototype facilities. This includes blending modeled energy use patterns for prototypical electrical and gas heated building types. We performed this process for 34 distinct prototype models (or "cells") across three weather regions. We analyzed an average of approximately five applicable ECMs and a base case per cell for a total of well over 1,000 final DOE2 computer runs.

Work from prior efforts provided a crucial foundation for this study (see references). Previous work helped establish a database of commercial building models which originated from energy audits of existing buildings in British Columbia. Through on-going efforts, these DOE2 energy models were refined and enhanced to better represent BC Hydro's commercial building stock. In fact, the end-use cross-effects study contributed to the refinement of these computer models.

One of the founding building analysis efforts involved the development of the BEEDS (Building Energy End-use Disaggregation Software) tool. This tool is based on an approach to statistically compress extensive DOE2 simulation results into a simple spreadsheet tool. ERG and BC Hydro defined 34 representative commercial buildings cells for the BEEDS project. A second study defined 12 additional building models representative of future buildings (ASH RAE 90.1 compliant). Finally, the most recent efforts employed a subset of 21 buildings from the original BEEDS set and the 12 ASHRAE 90.1 compliant buildings to represent existing and future building stock.

The BEEDS tool indirectly addressed cross-effects issues for some individual (and combined) ECMs. This was useful for double-checking results obtained through the end-use cross-effects study. Using multi-variable linear regression, BEEDS allow the user to modify specific variables which represent specific building characteristics for a particular cell. The user can then instantly see the monthly end-use impact on demand and energy. For example, BC Hydro can instantly visualize the demand and energy impacts on heating, lighting, and HVAC auxiliaries when changing the wall R-value from R-20 to R-30.

Objectives

The main objective for this effort was to examine the magnitude of cross-effects. This helps in fine tuning the existing DSM impact estimates and guiding future DSM programs' design and development. Also, the cross-effects study will help in re-evaluating the effectiveness of current DSM projects.

Methodology

The process of determining cross-effects for related end-uses from the implementation of a specific ECM is a fairly simple task on the surface. It basically requires determining the ratios between respective end-use requirements for an ECM case as compared to a base case. These ratios are referred to as "end-use comparison coefficients." Under the surface, however, this process uncovers anomalies and special situations which require further investigation of the building cell models and their associated data.

The level of detail required by this cross-effects investigation mandates that nearly every data point produced from the DOE2 energy modeling process is as representative as possible. As elementary as this may sound, the "art of energy modeling" yields to situations in which precision must be balanced against valuable modeling time and expense. In other words, diminishing returns must be minimized. Further, since this study did not use any type of pseudo-diversity or "fuzzing" process to average end-use loads, this places further emphasis on developing "clean and consistent" hourly profiles.

Process

The process followed for investigating the end-use cross-effects involved three basic steps:

- the creation of end-use hourly summary data used for determining end-use comparison coefficients,
- the programming and design of spreadsheet processors for accessing and analyzing the hourly data, and
- performance of reality checks.

These three steps depended on each other and did not occur precisely in the above sequence. The performance of reality checks depended on having a spreadsheet processor in place to help with this task. The development of the spreadsheet processors, however, depended on having clean and consistent hourly files for verification purposes. Overall, the process developed toward an iterative approach.

Creation of a Database of Hourly Data. To perform the cross-effects analysis within a relatively short time frame, we used a specially designed processor. This processor manipulates hourly end-use data extracted from the DOE2 energy simulation program and creates data files for simulated "gas heated" and "electric heated" cases. This processor blends the processed DOE2 hourly files based on the saturation of electric end-uses. It then searches for and defines monthly peak and average day profiles and stores these in a "load shape file." This summarized load shape file can be read directly into a spreadsheet for determining key cross-effects.

We created profiles for 185 individual ECMs across three weather regions and distributed among 21 existing and 13 new construction building types. We compressed all 657 load shape files ([34 existing + 185 ECM cases] x 3 weather regions) into 34 "zipped files" which corresponded to the 34 building types. This created a more manageable set of data files.

Spreadsheet Program Design. After creating the database of hourly load shape files, we designed spreadsheet processors, which accessed the appropriate set of base and ECM profile data to:

- perform reality checks,
- analyze the cross-effects between end-uses,
- automatically print comparison coefficient reports, and
- act as the basis for designing the End-use Comparison Analysis Program (ECAP) for BC Hydro's use.

The spreadsheet processors perform the basic function of determining end-use comparison coefficients, which are basically the ratio of end-use ECM data points to the appropriate base data points. The specific end-uses for which cross-effects are analyzed and reported on include:

- space cooling
- refrigeration
- space heating
- exterior lighting
- interior lighting
- transportation
- equipment (plug loads)
- domestic water heating (DHW)
- auxiliaries (fans, pump, etc.)
- cooking.

These end-uses only account for electric contributions. Those end-uses which also utilize other fuel sources (i.e., heating, DHW, and cooking) represent their respective market shares which are electric within the commercial sector. Thus, the commercial electric heating load in hospitals served by BC Hydro, for instance, is averaged over the entire hospital building stock. This allows for a cross-effects analysis which looks at results averaged across a particular building type.

Data sets for performing end-use cross-effects analysis

The spreadsheet processors access profile data for each of the end-uses for analyzing end-use cross-effects. We were particularly interested in viewing and analyzing these cross-effects for four discernible groups of data:

1. System peak demand (SPD)
2. Annual energy (AE)
3. Non-coincident building peak demand (NPD), and
4. Coincident building peak (CPD) demand.

Note that BC Hydro was only interested in analyzing the cross-effects between electric end-uses. Thus, we did not perform the same analysis on the gas-driven end-uses which were modeled.

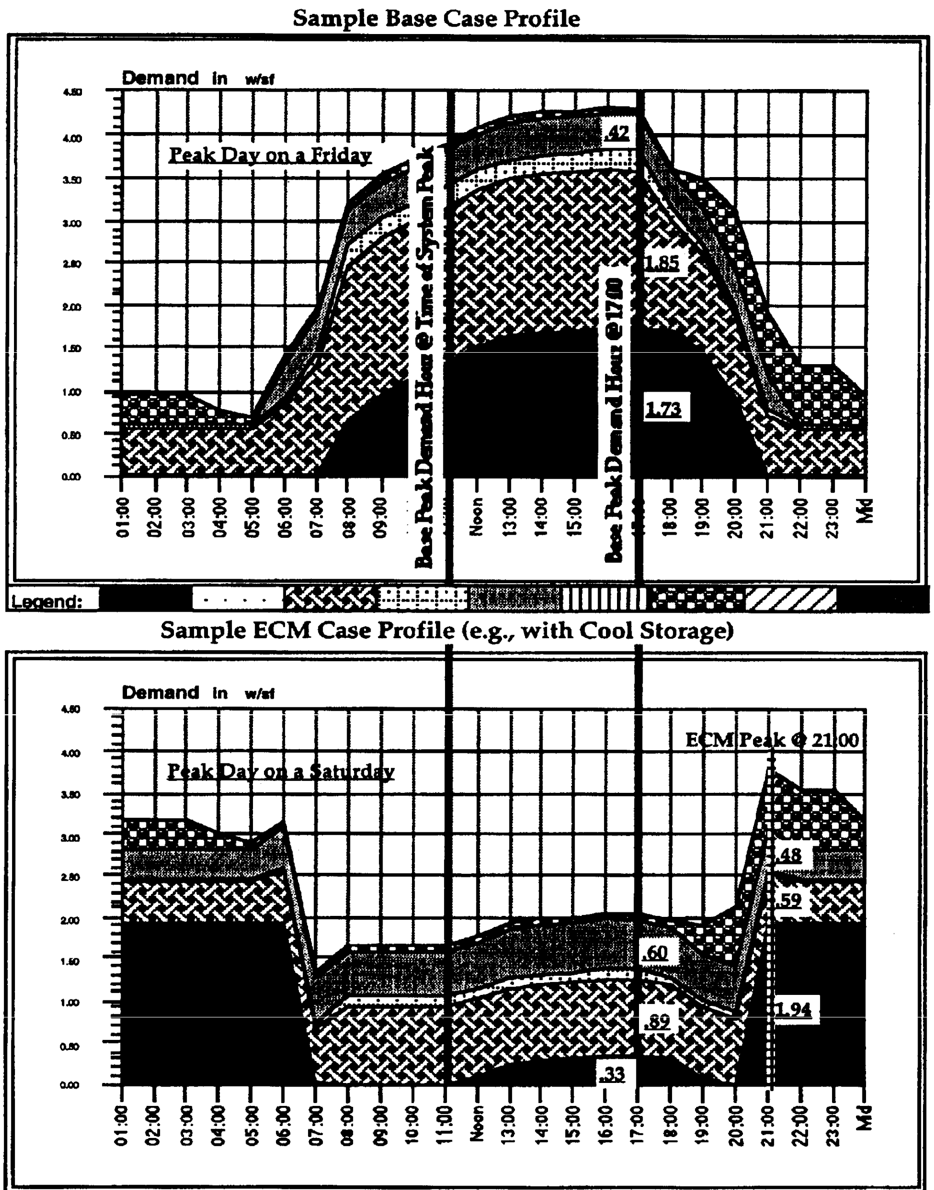
System peak demand refers to the comparison between a base case and its corresponding ECM case at the time of BC Hydro's monthly system peak. *Annual energy* refers to the comparison of electric energy between a base case and its corresponding ECM case. The spreadsheet processors report on end-use comparison coefficients for energy on both a monthly and an annual basis. *Non-coincident building peak demand* is the comparison between the maximum building peak demands for a base and corresponding ECM case. The *coincident building peak demand* compares the ECM case to the base case at the hour when the base case experienced its peak demand.

The end-use comparison coefficients for demand can vary significantly for all ten end-uses because of a possible shift in the peak day and time. For example, a high-rise office building may experience its peak demand for June on a warm Monday afternoon. After the installation of a cool storage system, however, the May peak could shift to the morning of the following day. In this situation, comparison of the end-uses for the non-coincident building peaks would vary dramatically. Figure 1 demonstrates this concept. Figure 1 also illustrates how the coincident building peak demand is determined. Notice how the cross-effects in end-use demand are demonstrated independent of the ECM's peak hour.

ECM end-use cross-effects equations

Table 1 supplements Figure 1 by illustrating the method followed for calculating end-use comparison coefficients for non-coincident and coincident building peak demand. We show only sample coefficients for cooling, lighting, and auxiliaries, but the method applies to all ten end-uses. In addition, the same method used for determining the building peak demand applies directly for the system peak demand, except we use the data set of end-uses coincident with the system peak hour.

Note that it is possible for an end-use to have no load for the base case at a specific time and have at least a minimal load for the ECM case at the same time. Conversely, the ECM base case shows no load during a specific time while the base case exhibits a load at this same corresponding time. For example, in Figure 1, notice that the cooling demand during the system peak changes from about 1.3 W/sf to zero. This yields a cooling comparison coefficient of zero. When the opposite occurs with the ECM case showing an increase demand (or energy) from



*Labeled numbers refer to cooling, lighting, and auxiliary end-use's W/sf

Figure 1. Example of Building Peak Demand Comparisons

Table 1. Sample End-Use Comparison Coefficient Calculations

	Non-Coincident Bldg Peak			Coincident Bldg Peak		
End-Use	ECM W/sf	Base W/sf	Coefficient	ECM W/sf	Base W/sf	Coefficient
Cooling	1.94	÷ 1.73	= 1.12	0.33	÷ 1.73	= 0.19
Lighting	0.59	÷ 1.85	= 0.32	0.89	÷ 1.85	= 0.48
Auxiliaries	0.48	÷ 0.42	= 1.14	0.60	÷ 0.42	= 1.43

a base starting point with no requirements, the infinite sign (∞) is shown, indicating that the comparison coefficient is undefined.

When all of the end-use comparison coefficients are determined for a particular data set, they can be used directly in a formula to describe how the base case electricity requirement changes after implementing an ECM. Thus, the formula describing the ECM requirements by end-use follows the form shown in Figure 2.

The final E factor seldom is needed. This is because situations rarely occur when the base case's demand or energy increase from zero. One of the most common occurrences of this situation is during shoulder months when heating was not necessary in the base case, but a relatively small amount was needed when internal gains were removed, as with lighting ECMs. Another example of how this situation might occur also is demonstrated in Figure 1 with the cooling end-use. From 21:00 to 7:00 the base cooling demand is zero and increases to 1.94 W/sf for the ECM. Thus, the ECM cooling requirement (C_{Clg}*CLG_{base}) equals zero since CLG_{base} is zero. However, the 1.9 W/sf would have to be accounted for to properly represent the total ECM requirements. This would be accounted for by assigning E_{∞} equal to 1.9 W/sf and adding this to the rest of the end-use requirements. Other end-uses experiencing this same affect would be included in the E_{∞} factor as well.

End-use cross-effects and ECAP sensitivity analysis

Once the end-use cross-effects equation for an ECM is determined, it is possible to define a process which alters this equation based on how a particular end-use changes. In other words, we can determine a linear equation which describes how secondary end-use energy and demand requirements vary with the end-use directly impacted by the ECM. This is done by making all of the secondary end-uses a function of the independent end-use directly affected by the ECM. This independent end-use is referred to as the "primary end-use. " We define the primary end-use as a function of the remaining end-use cross-effects.

Primary end-uses are those end-uses which are directly affected by the implementation of a specific ECM. For instance, energy efficient lighting directly impacts the lighting end-use, and therefore, lighting would be considered the primary end-use in this case. *End-use cross-effects* involve end-uses which indirectly change in response to the building dynamics involved when an ECM is introduced into the base building. The end-use cross-effects can be caused by any of the following.

- Altered cross-effect end-use requirements. This stems from a direct change in the primary end use. For example, reducing lighting decreases cooling requirements but increases heating requirements.

- Secondary and tertiary cross-effects. For example, the altered secondary cooling and heating requirements caused from reducing lighting changes the usage

$$\begin{aligned}\text{ECM Req'ts} = {} & (C_{clg}*CLG_{base}) + (C_{htg}*HTG_{base}) + (C_{ltg}*LTG_{base}) + \\ & (C_{equip}*EQUIP_{base}) + (C_{aux}*AUX_{base}) + (C_{refrig}*REFRIG_{base}) + \\ & (C_{trans}*TRANS_{base}) + (C_{dhw}*DHW_{base}) + (C_{ckg}*CKG_{base}) + (E_{\infty})\end{aligned}$$

there,

$(C_{clg}*CLG_{base})$ = ECM Cooling Requirement (i.e., demand or energy)
C_{clg} = Appropriate cooling end-use comparison coefficient
CLG_{base} = Base cooling requirement
$(C_{htg}*HTG_{base})$ = ECM Heating Requirement
C_{htg} = Appropriate heating end-use comparison coefficient
HTG_{base} = Base heating requirement

- *remaining end-use calculations*

$(C_{ckg}*CKG_{base})$ = ECM Cooking Requirement
C_{ckg} = Appropriate cooking end-use comparison coefficient
CKG_{base} = Base cooking requirement
E_{∞} = Additional requirements in cases when a base's end-use requirement has increase from z

Figure 2. Basic ECM Cross-Effects Formula

patterns of the auxiliary pump and fan motors. This, in turn, can affect heating and cooling because the respective heating and cooling loads are altered by the heat contribution from these motors.

- Peak time shifts. Building dynamics and HVAC controls can cause end-use cross-effects in demand by shifting the peak hour and/or day. For instance, implementing a high efficiency lighting ECM may cause the building to peak on February 10th at 8:00 am instead of February 1st at 10:00 am.

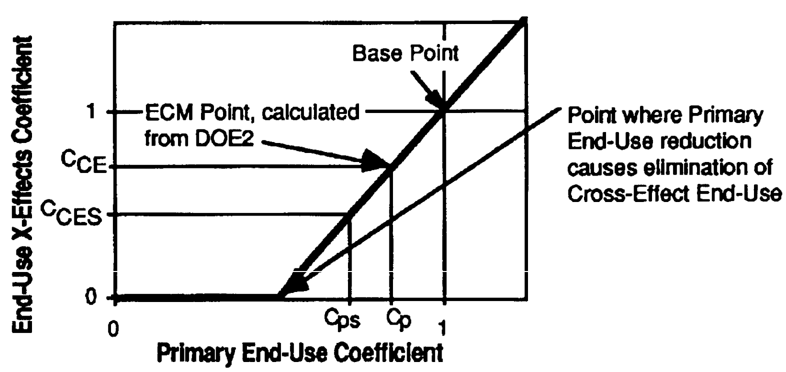
The formula for determining end-use cross-effects as a function of a primary end-use is illustrated in Figure 3. This formula linearly interprets an end-use cross-effect as a function of the primary end-use's change in annual energy. For instance, the end-use cross-effects formula describes how cooling will change if lighting is reduced another 20%, assuming that lighting is the primary end-use.

Reality Checking. A final key step in the process to determine end-use cross-effects was the performance of reality checks to insure representative data sets. This study required a detailed look at the hourly end-use data individually for all weather regions. Not surprisingly, anomalies in the DOE2 processed data surfaced. We investigated such anomalies and corrected or interpreted them accordingly to make sure the end-use data was as realistic as possible.

Many anomalies stemmed from simply confirming how the DOE2 energy modeling program 's algorithms calculated certain energy use requirements. For example, the variable air volume (VAV) and packaged single zone (PSZ) systems do not give the same results even if everything is set the same (e.g., both at same fan type, fan power per CFM, outside air ratio, etc.). The VAV system has the desirable feature of being able to model variable fan speed while the PSZ system does not. Thus, the cross-effects comparison for variable speed drives would not be representative without changing the base case. The remaining peculiar end-use hourly results originated from erroneous computer processing and/or human error.

Limitations and Conditions on Data Significance

Several key limitations existed in the analysis of the end-use cross-effects results.. These results provide a great deal of significant insight into the cross-effects of performing various ECMs on different building types in



Assuming the equation of the line is linear and takes the form of:
Y = MX + B, where:

$Y = C_{CES}$ = cross-effect end-use coefficient estimated from sensitivity analysis
$X = C_p$ = primary end-use coefficient used in sensitivity analysis
$M = (1-C_{CE})/(1-C_p)$
where:
C_{CE} = cross-effect end-use coefficient determined from DOE2 analysis
C_P = primary end-use coefficient determined from DOE2 analysis

From the following initial condition, B can be calculated:
$C_{CE} = C_{CES}$ when $C_P = C_{ps}$
$B = C_{CE} - C_p((C_{CE}-1)/(C_p-1))$

The final form of the equation can be written as:
$C_{CES} = (C_p - C_{ps}) * ((1-C_{CE})/(1-C_p)) + C_{CE}$

Figure 3. End-Use Cross-Effects Formula for Performing Sensitivity Analysis

various regions. However, the following key limitations and conditions must be kept in mind when reviewing and analyzing the cross-effects from various ECMs.

- Cross-effects are analyzed for a *single* building cell and ECM by weather region, instead of in aggregation with a significant set of ECMs and cells. The climatological and building-to-building impacts are not smoothed as would be representative of an average effect.

- The appropriate comparison between corresponding base and ECM cases for system peak, non-coincident building peak, and coincident building peak demand analysis depends on DOE2 modeling dynamics. In these cases, the introduction of an ECM may cause the monthly peak hour and/or day to change.

- DOE2's (version D) limitations yields results which may not fully represent all cross-effects. Examples of such limitations include the program's ability to model thermal heat storage and adjustable speed drives.

- End-use comparisons between very low base situations with ECM cases where the same requirements increase even a small amount can produce relatively large end-use comparison coefficients. Conversely, base end-use requirements which decrease slightly to nearly zero can produce relatively small end-use comparison coefficients. Checking the absolute end-use requirements help in identifying and understanding these situations.

Summary Results

The implementation of various ECMs can have significant impacts on various end-uses which vary from building to building. This is especially true for peak demand since it is a snapshot of how a building is using energy at a specific moment in time. The results uncovered through this study demonstrate how the individual building models respond to various ECMs at a specific moment in time (i.e., peak demand) and over a period of time (i.e., energy).

Cross-Effects of ECMs

This section describes which end-use is primarily affected by a particular ECM. It also discusses the key end-use cross-effects for each ECM. Finally, we briefly discuss the following categories of ECMs:

- Economizer Cycle
- Cool Storage
- High Efficiency Air Conditioners
- Daylighting Controls
- EMS Lighting Controls
- Occupancy Sensors
- High Efficiency Motors
- High Efficiency Cooking Equipment
- Window Treatments
- High Efficiency Lighting
- Refrigeration Efficiency Improvements

Table 2 presents a statistical summary of the cross-effects of these ECMs[1]. The first end-use italicized under the ECM is the primary end-use. The other ECMs listed are those that experienced significant cross-effects. Several of the cross-effects demonstrate relatively large ranges (as indicated by the "±"). This indicates that the end-use reactions ranged widely between ECM applications from building to building. In most cases, the ECM affected more than just the end-uses listed in this table. These were not included because the cross-effects were negligible. The system peak demand value reported in this table is coincident with BC Hydro's system peak which occurred on a weekday in February at 6:00 pm for the baseline year analyzed.

The primary end-use for the *economizer cycle* ECM is cooling. Auxiliaries in the form of mainly fan energy experience cross-effects from this ECM. Consequently, heating energy had slight cross-effects from the contribution of motor heat from auxiliary fans. In a few cases, heating changed more significantly in zones which do not have independent controls from main zones which simultaneously require cooling. In these relatively rare cases, the introduction of increased levels of outside air cap increase the heating load.

The primary end-use for the cool *storage* ECM is cooling. Auxiliaries represent a significant cross-effect from the altered use and introduction of pump motors, fans, and controls. The increased use of auxiliaries often caused heating to decrease as well. This cross-effect on heating, however, is very slight and often negligible since much of the added auxiliary heat gain is contributed to unconditioned equipment room spaces.

The primary end-use for the *high efficiency unit air conditioners* ECM is cooling. Auxiliaries can be a relatively small cross-effect if the cooling effect delivered by the cooling plant changes. This effect is negligible in most cases and only may apply to relatively rare cases where simultaneous heating and cooling may occur within the same system. In these cases, the cooling plant may make use of increased amounts of outside air to help with cooling. This has the effect of increasing auxiliaries and heating energy as well.

Lighting obviously is the primary end-use affected by the *daylighting controls.* Significant end-use cross-effects

Table 2. Statistical Summary Results

	System Peak Demand		Annual Energy		Building Peak Demand Non-Coincident		Building Peak Demand Coincident	
Cool Storage								
Cooling	-80%	±12	-30%	±4	20%	±10	-58%	±7
Auxiliaries	27%	±5	39%	±6	30%	±10	30%	±10
High Efficiency Air Conditioners								
Cooling	-6%	±2	-19%	±1	-23%	±4	18%	±3
Auxiliaries	-		+		+		+	
Daylighting Controls								
Lighting	+		-		-8%	±2	-16%	±2
Cooling	-1.1%	±0.3	-7%	±1	-23%	±4	-10%	±2
Heating	9%	±7	4.2%	±0.8	+		7%	±11
Auxiliaries	2%	±4	-5%	±1	-6%	±2	-9%	±1
EMS Lighting Controls								
Lighting	-10%	±4	-8%	±1	no change		no change	
Cooling	-		-		+		-	
Heating	9%	±7	4%	±1	+		+	
Auxiliaries	5%	±4	+		-		-	
Occupancy Sensors								
Lighting	-28%	±2	-26%	±2	-26%	±2	-26%	±2
Cooling	-8%	±3	-9%	±1	-9%	±2	-8%	±2
Heating	50%	±20	13%	±2	+		-	
Auxiliaries	5%	±5	-3%	±1	-6%	±1	-8%	±1
High Efficiency Motors								
Auxiliaries	-4.3%	±0.4	-4.5%	±0.3	-4.3%	±0.3	-4.4%	±0.3
Transport.	-		-		3%	±3	3%	±3
Cooling	-		-1.0%	±0.1	+		-	
Heating	+		+		+		+	
High Efficiency Cooking Equipment								
Cooking	-		-27%	±2	-		no change	
Cooling	-3%	±3	-2%	±0	-		-	
Heating	3%	±3	1.7%	±0.3	+		+	
Auxiliaries	+		-		+		-	
Refrigeration Efficiency Improvements								
Refrigeration	-10%	±2	-10%	±2	-10%	±3	-11%	±2
Cooling	no change		70%	±30	+		60%	±60
Heating	-7%	±3	-14%	±4	-6%	±12	-5%	±3
Auxiliaries	10%	±5	10%	±5	10%	±5	10%	±5
Window Treatments								
Cooling	-11%	±4	-8%	±2	-11%	±3	-12%	±3
Heating	10%	±10	-5%	±4	60%	±110	10%	±20
Auxiliaries	no change		-9%	±1	-11%	±2	-12%	±2
High Efficiency Lighting								
Lighting	-29.7%	±0.2	-29.7%	±0.2	-32%	±1	-29.7%	±0.2
Cooling	-6%	±2	-15%	±1	-7%	±8	-9%	±1
Heating	25%	±9	31%	±7	no change		+	
Auxiliaries	-5%	±1	-7%	±1	-7%	±1	-9%	±1

include changes in cooling and heating. This, in turn, causes auxiliary energy and demand to change as well. The non-coincident building peak demand demonstrates a good example of how results can initially be misleading if not fully understood. The doubling of heating demand stems from the increase in a relatively small heating requirement to something twice as large, but still relatively small.

It also is interesting to note that daylighting can either increase or decrease cooling and heating depending on the balance between solar gains and internal heat gains from electric lighting. New construction prototypes fluctuate the most in this regard since glazing is being reconfigured in many cases.

The primary end-use affected by *lighting controlled by an energy management system (EMS) is* also lighting. Significant end-use cross-effects include changes in cooling and heating. This, in turn, causes auxiliary energy and demand to change as well.

The primary end-use affected by the implementation of *occupancy sensors* is lighting. Significant end-use cross-effects include changes in cooling and heating. This, in turn, causes auxiliary energy and demand to change as well. In a few rare cases, refrigeration decreases slightly due to decreased heat gains. Finally, note that non-coincident building peak heating demand varies dramatically because of a relatively small increase over an even smaller base heating requirement (like with daylighting).

The primary end-use affected by the introduction of *high efficiency motors* is auxiliaries. In a few cases, the primary end-use is either auxiliaries or transportation. The decrease in auxiliary motor heat has a cross-effect on cooling and heating to a lesser extent.

The primary end-use affected by the use of *high efficiency cooking equipment* is cooking. In some cases, the equipment end-use may be considered a "lesser primary end-use" since it can include equipment closely tied to cooking. Significant end-use cross-effects include changes in cooling and heating. This, in turn, causes auxiliary energy and demand to change as well. Refrigeration also can decrease slightly due to decreased heat gains in kitchen zones.

In nearly all cases, the primary end-use of *refrigeration efficiency improvements is* refrigeration. In the refrigerated warehouse, however, the primary end-use is cooling since the refrigerated zone of the warehouse is modeled with an HVAC system model. Significant end-use cross-effects include cooling and heating since the reduction of refrigeration reduces the equipment heat dissipated to the conditioned space. The altered characteristics between cooling and heating then causes a cross-effect on auxiliaries.

In most situations, cooling may be considered the primary end-use of *window treatments.* In some new construction, however, the primary end-use also may include heating. Heating and cooling also represent the most significant cross-effects, depending on the situation. This, in turn, causes auxiliary energy and demand to change as well.

The primary end-use for *high-efficiency lighting* in this study was interior lighting. Significant end-use cross-effects included changes in cooling and heating. This, in turn, caused auxiliary energy and demand to change as well. This ECM also caused slight cross-effects in refrigeration in some applicable cases.

Conclusion

The results and ECAP spreadsheet tool produced through this study represent a significant resource for estimating the commercial end-use cross-effects from implementing certain individual ECMs. Without performing extensive end-use monitoring, BC Hydro can quickly analyze how various ECMs impact the electric demand and energy requirements across ten distinct end-uses. This analysis may be performed on 185 variations of 13 general ECMs across 34 different building types in three different weather regions. Moreover, BC Hydro may perform sensitivity analysis on how changes in a primary end-use influence other end-uses.

Information from this study is proving very valuable in guiding BC Hydro's DSM program development and design work. It is helping refine present monitoring efforts for examining and validating the cross-effects addressed by this study. The monitoring results will, in turn, be used to fine tune the estimates from the detailed energy modeling. In calibrating the prototype models, however, data sets of monitored 15-minute data (or of less duration) would need to be statistically processed to acquire comparable load shape information to hourly DOE2 results.

The information from ECAP also is being applied toward the aggregation of different building cells together to create weight averaged profiles. These profiles are representative of a commercial building segment or the entire commercial sector. Aggregating building cells and their associated ECMs provides a more representative, "smoothed average" of cross-effects for building classes as compared to providing the same information for individual cells in specific climates.

ECAP and other related tools will be used to integrate with BC Hydro's other load forecasting and strategic planning models. Integration with an integrated resource planning (IRP) model also is being contemplated. The overall goal is to create one all encompassing networked model which allows DSM and system planners to choose and plan DSM strategies effectively. The information produced from the end-use cross-effects study would play a key role in developing such a model—possibly in the near future.

Acknowledgments

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Endnote

1. At the time of this writing, this study is being finalized. Thus, results presented in this paper are preliminary.

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