MEMORANDUM

To: Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants

From: The Residential Evaluation Team

Subject: Lighting Interactive Effects Study Preliminary Results - Draft

Date: April 6, 2015

Summary

This memo details the preliminary findings of the Lighting Interactive Effects study evaluated for the Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) consultants to better understand and report the true impact of energy efficient lighting retrofits.

The goal of this study is to determine a statewide average for the heating, ventilation, and air conditioning (HVAC) impacts, quantified using interactive effects (IE) factors, to account for energy efficient lighting retrofits. To accomplish this, the Residential Evaluation Team ("the team") developed simulation models based on a combination of Home Energy Services (HES) and High-Efficiency Heating Equipment (HEHE) program data. The models were calibrated to actual customer billing data from the HES Realization Rate analysis in 2013[1] for an electric and non-electrically heated home. Table 1 details the preliminary findings from our analysis.

Table 1: Average IE Factor in Massachusetts

Factor	Average IE Factor
Electric Energy IE Factor	1.02
Electric Demand IE Factor - Winter	0.93
Electric Demand IE Factor - Summer	1.28
Heating Fuel IE Factor (Btu/kWh)	2,237

The following sections provide additional details on the IE factors developed in Massachusetts, methodology, and additional tables showing a breakdown of results.

[1] Billing data included customer bills from 2010-2013. The team analyzed more recent customer billing information but due to issues found in the data, decided to use existing consumption data utilized in the HES Realization Rate analysis completed in 2013.

Introduction

Energy-efficient lighting fixtures emit less heat than higher wattage fixtures, which impacts the heating load in the winter and the cooling load in the summer in conditioned spaces. This study attempts to determine the heating, ventilation, and air conditioning impacts, quantified using interactive effects factors, from energy efficient lighting retrofits. Each of these factors defines secondary impacts of HVAC energy caused by the primary electricity savings from reduced-wattage lighting efficiency installations:

- Electric Energy IE Factor –the ratio between the total annual energy savings (primary lighting and secondary HVAC impacts) and the primary, lighting-only savings.
- Electric Demand IE Factor –the ratio using the total kW savings for lighting and HVAC end uses and the primary lighting kW savings during the winter and summer peak periods.
- Heating Fuel IE Factor – the ratio of the whole-building heating fuel increase to the electric energy savings resulting from the lighting retrofit.

In addition to the IE Factors listed above, the evaluation team plans to develop multiple interactive effects load shapes to show the distribution of savings for each hour of the year for use in the Demand Impact Model. These load shapes will be developed and provided after results have been finalized.

Methodology and Results

This section provides more details on the specific activities and preliminary results from the Lighting Interactive Effects study.

Simulation Models

In order to best estimate the HVAC interactive effects attributable to lighting retrofits, the team developed simulation models based on building characteristics compiled from three sources:

1. HES dataset containing audit data from 2010-2014
2. Existing HEHE models used in a recent program study
3. The HES Realization Rate analysis completed in 2013

The team built and calibrated four models based on heating type and number of stories using billing data which included statewide HES participants from 2010-2013. Models were calibrated using Navigant's end-use disaggregation tool with customized inputs reflecting the HES participants. In order to calculate a single statewide average, the team choose Worcester as the centralized location to reflect both the coastal weather patterns and those found inland. Models were calibrated to within 2% of the calibration targets helping to ensure an accurate reflection of an average home in Massachusetts.

The team also utilized efficient lighting load shapes developed for the Market Adoption model. The baseline was modeled as a simple 20% increase in lighting consumption. Load shapes were extracted and analyzed to determine the specific IE Factors.

Electric Energy IE Factor

As we mentioned previously, each of the factors analyzed explains secondary impacts of HVAC energy caused by the primary electricity savings from reduced-wattage lighting efficiency installations. The team began its review by analyzing the Electric IE Factor. The Electric IE Factor can be defined as:

- The ratio between the total annual energy savings (primary lighting and secondary HVAC impacts) and the primary, lighting-only savings or simply stated,

$$Electric\ IE\ Factor = \frac{Total\ Building\ Annual\ Electric\ Energy\ Savings}{Lighting\ Annual\ Electric\ Energy\ Savings}$$

Table 2 details the preliminary results for the average Electric IE Factor.

Table 2: Average Electric Energy IE Factors by Cooling Configuration and Heating Fuel

Factor	Primary Heating Type		Overall
	Electric	Non-Electric	
Central Air Conditioner	0.58	1.05	**1.03**
Room Air Conditioner	0.59	1.06	**1.03**
No Cooling	0.50	0.98	**0.95**
Overall	0.57	1.05	**1.02**

[a] Weightings reflect single family and multi-family from the MA RASS study[2].

The overall average Electric IE Factor found by weighting the cooling and heating fuel types is 1.02 showing that an average lighting retrofit will result in an additional 2% savings attributable to the secondary HVAC impacts from the efficient bulbs.

Electric Demand IE Factor

The team then analyzed the 8760 load shapes developed from simulation models to calculate the Electric Demand IE Factor. The Electric Demand IE Factor[3] can be defined as:

- The ratio using the total kW savings for lighting and HVAC end uses and the primary lighting kW savings during the winter and summer peak periods or simply stated,

$$Electric\ Demand\ IE\ Factor = \frac{Total\ Building\ Peak\ Electric\ Demand\ Savings}{Lighting\ Peak\ Electric\ Demand\ Savings}$$

Table 3 details the preliminary results for the average Electric Winter IE Factor.

[2] Equipment saturations from the Massachusetts Residential Appliance Saturation Survey (RASS) which can be found at http://ma-eeac.org/wordpress/wp-content/uploads/11_MA-Residential-Appliance-Saturation-Survey_Vol_1.pdf

[3] Peak periods align with the ISO NE as winter peak in December-February, hours 6-7pm and summer peak in June-August, hours 2-5pm.

Table 3: Average Electric Winter Demand IE Factors by Cooling Configuration and Heating Fuel

Factor	Primary Heating Type		Overall
	Electric	Non-Electric	
Central Air Conditioner	0.30	0.97	**0.93**
Room Air Conditioner	0.30	0.97	**0.93**
No Cooling	0.30	0.97	**0.93**
Overall	0.30	0.97	**0.93**

[a] Weightings reflect single family and multi-family from the MA RASS study.

Table 4 details the preliminary results for the average Electric Summer IE Factor.

Table 4: Average Electric Summer Demand IE Factors by Cooling Configuration and Heating Fuel

Factor	Primary Heating Type		Overall
	Electric	Non-Electric	
Central Air Conditioner	1.31	1.35	**1.34**
Room Air Conditioner	1.31	1.35	**1.35**
No Cooling	1.00	1.00	**1.00**
Overall	1.25	1.28	**1.28**

[a] Weightings reflect single family and multi-family from the MA RASS study.

The overall average Electric Winter and Summer Demand IE Factor are found to be 0.93 and 1.28 for an average home in Massachusetts.

Heating Fuel IE Factor

The team then analyzed the gas consumption developed from simulation models to calculate the Heating Fuel IE Factor. The Heating Fuel IE Factor can be defined as:

- The ratio of the whole-building heating fuel increase (Btu) to the electric energy savings (kWh) resulting from the lighting retrofit or simply stated,

$$Heating\ Fuel\ IE\ Factor = \frac{Total\ Building\ Annual\ Heating\ Fuel\ Increase}{Lighting\ Annual\ Electric\ Savings}$$

Table 5 details the preliminary results for the average Heating Fuel IE Factor, with a focus on Gas homes.

Table 5: Heating Fuel IE Factor for Non-Electric Heating Homes (Btu/kWh)

Model	Heating Fuel IE
Natural Gas - 1 Story	2,243
Natural Gas - 2 Story	2,233

Overall	2,237

[a] Weightings reflect HES saturations

The overall average Heating Fuel IE Factor is found to be 2,237 which indicates that a lighting retrofit will have an average of 2,237 Btu increase in consumption per kWh reduced in lighting.