CONNECTICUT ENERGY EFFICIENCY BOARD

Evaluation Studies and Results, 2014

A REPORT TO THE ENERGY AND TECHNOLOGY COMMITTEE OF THE CONNECTICUT GENERAL ASSEMBLY

Connecticut Energy Efficiency Board Evaluation Committee

May, 2015

REVISED Report

PREFACE FROM THE EEB EVALUATION COMMITTEE

The Energy Efficiency Board (EEB) Evaluation Committee is proud to present the Annual Report of the studies, results and recommendations via the EEB program evaluation, measurement, and verification (EM&V) process. Connecticut has one of the longest EM&V histories, contributing to some of the nation's strongest efficiency programs.

EM&V is very important to the efficiency programs' successes. Evaluations are designed to be comprehensive, independent, actionable and cost-effective. Impact results provide verification that the Fund is being used appropriately and provide beneficial programs and savings. Recommendations also provide essential information on how programs can be improved, additional measures developed and customer needs met. The use of outside evaluators provides for independence and also allows Connecticut to take advantage of the successes and failures of other programs and jurisdictions. The EEB EM&V evaluation process provides funding, leadership, and data, and also reviews studies managed by Northeast Energy Efficiency Partnerships (NEEP).

What follows is a compilation of results and recommendations from studies completed in the last year. Links to the appropriate sections of the Board website will lead you to the full reports, should you want more detail.

Additionally, this report is intended to provide an introduction to the wide range of studies typically completed by the EEB. These current and new studies cover evaluations of program savings, customer and vendor reception to program offerings, assessment of new opportunities and examinations of what pockets of savings remain available in areas already covered.

We believe that you will find the report informative. Please contact us with any questions you may have.

Offered by the EEB Evaluation Committee
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PREFACE FROM THE EVALUATION OVERSEERS --- OVERVIEW AND VERIFICATION OF THE 2014 EVALUATION OF CONNECTICUT'S ENERGY EFFICIENCY FUND ACTIVITIES

The evaluation efforts conducted in 2014 were designed and managed by third-party independent experienced evaluators.[1] The evaluations themselves were also conducted by independent evaluation teams, operating under the guidelines of Connecticut's Evaluation Roadmap, which instituted policies to assure independence.

The evaluations completed in 2014 add to the evaluation evidence of accomplishments from the use of Connecticut's Energy Efficiency Fund (EEF).

The Evaluation Consultant Team[2] verified that the 2014 completed evaluations and on-going evaluations meet or exceed the rigor and energy efficiency evaluation practices conducted across the United States. The evaluation results and recommendations are similar to energy efficiency evaluation results elsewhere. The accumulation of the evaluations continues to demonstrate that activities supported by Connecticut's EEF are making reasonable energy efficiency achievements.

Evaluation Consultant Team
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[1] The Evaluation Consultant and the evaluation contractors conduct energy efficiency program evaluations across the nation and beyond. They are independent from Connecticut utilities and Connecticut boards, state regulatory staff and state agencies. All of the evaluators conducting Connecticut evaluation activities provide objective evaluation and verification, following evaluation ethics and "Guiding Principles for Evaluation" from the American Evaluation Association.

[2] The current Evaluation Consultant, contracted in February 2013, is a team of experienced independent evaluators led by Skumatz Economic Research Associates (SERA) and includes Apex Analytics, LLC. and Analytical Evaluation Consultants, LLC. Each consultant on the team has between 20 and 35 years of experience in the field, and has conducted work nationwide. The offices of these firms are located in Colorado, Washington and Massachusetts.

Contents

1. INTRODUCTION

The Energy Efficiency Fund (EEF) and Utility Companies have a long history of providing efficiency programs to Connecticut energy consumers. An integral part of creating, delivering and maintaining quality programs is performing independent evaluations of programs and the markets they serve. The evaluators make recommendations for program modifications that are considered in prospective program development and implementation.

In 1998 the Energy Efficiency Board or EEB (previously the Energy Conservation Management Board) was formed and charged with responsibility to advise and assist the utility distribution companies in the development and implementation of comprehensive and cost-effective energy conservation and market transformation plans. The EEB has worked closely with the Companies to ensure all evaluations are relevant, independent, cost-effective and meet the needs of program administrators and planners who are charged with achieving substantial public benefits. In 2005, the EEB formed an Evaluation Committee that works with an EEB Evaluation Consultant to oversee evaluation planning and completion. In 2009, the Department of Public Utility Control (DPUC) decided that the EEB's Evaluation Committee and their consultant would be independent from and totally responsible for all aspects of the evaluation process.

Since that time, the evaluation process and oversight have changed through additional DPUC (now Public Utility Regulatory Authority (PURA)) decisions which were adopted and extended by PA 11-80, sec. 33, amending Conn. Gen. Stat. sec. 16-245m, in 2011. PA 11-80 required an independent, comprehensive program evaluation, measurement and verification process to ensure the Connecticut Energy Efficiency Fund's (CEEF) programs are administered appropriately and efficiently, comply with statutory requirements, and programs and measures are cost effective; evaluation reports are accurate and issued in a timely manner; evaluation results are appropriately and accurately taken into account in program development and implementation; and information necessary to meet any third-party evaluation requirements is provided.

The essential information gained through studies such as those discussed in this report is provided very cost-efficiently.

Research completed within the evaluation group provides many types of information. Impact and process evaluations form the bulk of budget for studies completed. Additional studies support how the current and future efficiency programs are developed, supported and improved through careful research into:

- Current market opportunities for program expansion
- New end uses and equipment that may be included cost-effectively, including assessment of the associated barriers for inclusion of each
- Customer segmentation, market assessment, market progress, and market research,
- Examination of best practices in other jurisdictions

The EEB Evaluation Committee ensures the independence and objectivity of Evaluation Measurement and Verification (EM&V). It is critical that the programs be evaluated, measured, and verified in ways that provide confidence to the public that savings are real and enable the Companies and EEB to use savings estimates and Evaluator's recommendations to improve and advance programs with full confidence.

1.1 Definition of Evaluation Types

There are many types of evaluation supported by EEF funding. Research studies assist regulators, policy makers, the EEB and program administrators to maintain excellent practices and develop new programming options to meet Connecticut's growing efficiency needs throughout program formation and evolution.

- Process Evaluations determine the efficacy of program procedures and measures. Process Evaluations assess the interactions between program services and procedures and the customers, contractors, and participating ancillary businesses. Process evaluation is essential to support development of improved program delivery, increased cost effectiveness and customer satisfaction.
- Impact Evaluations verify the magnitude of energy savings and the reasons for differences between projected and realized savings. The results and value of energy efficiency programs are reported to regulatory bodies, ISO-New England, Company management, and program planners and administrators. Many different types of impact studies may be completed including end-use metering, engineering modeling, billing analyses, participant interview, surveys and combinations of these.
- Market Assessments examine overall market conditions related to energy efficiency products and services, including current standard practices, average efficiency of equipment, consumer purchasing practices, and identification of market barriers. The assessments ascertain the extent to which efficiency programs are likely to influence customer adoption of measures and practices. Assessments are conducted to identify effective ways to influence key market players to take efficiency actions and increase the breadth and depth of the actions taken.
- Impact Support Studies (including measure effects / performance and methods studies) assess the adequacy of engineering methodologies and background assumptions, supporting the Program Savings Document (PSD) and providing the foundation against which evaluations will assess program performance. Methods studies address methodological issues and develop best practices for evaluation research.
- Baseline Studies provide direct impact support by assessing pre-conditions that will no longer be measureable after program interventions have occurred.
- Evaluation Protocols are produced within the Regional EM&V Forum to provide direction to states new to the evaluation process and to ensure consistency to all of the states within the Forum. Cost-effective regional evaluations are coordinated through the Forum. The EEB is an active participant in the EM&V Forum, providing leadership, quality control, data and funding to its efforts.

Collectively, these types of studies are sometimes referred to as Evaluation, Measurement and Verification (EM&V; defined at the top of the page). The evaluation process is a critical tool to measure energy savings, as well as other key attributes of each program, to allow optimum program design and careful management of consumer conservation funds. The various types of evaluation studies are

utilized to support ongoing improvement in program offerings and to measure the results of those programs. The audiences for evaluation include regulatory bodies, the regional electric system operator (ISO-New England), Company management and program planners and administrators, all of whom need the information to make decisions about program design and efficacy to enhance existing cost-effective programs and redesign program that are not cost-effective to make them successful. Evaluation research provides the basis for determining program direction or focus; increasing participation and savings; expanding the reach of programs, developing messaging more relevant to the non-participating customers where appropriate; reducing costs; and fine-tuning procedures.

1.2 Organization of the Report

The remainder of this report is organized in chapters, based on the current status of the study.

- **Chapter 2 - Completed Studies** includes descriptions, costs and summary results from completed studies that were filed in the last 12 months. Findings and recommendations are summarized; links to the full reports are found at the end of each study description.
- **Chapter 3 - On-going Studies / Draft Reports** includes study descriptions and costs for projects currently being completed. For most of these studies, reasonable estimates of completion dates can be provided as well.

1.3 Completed, and In-Progress Studies

Figure 1-1, summarizes the completed and in-progress and Regional EM&V studies addressed in this Evaluation Legislative Report. Each is described in more detail in subsequent chapters, as noted.

Figure 1-1: List of Studies Addressed in the 2014 Legislative Report (by category)
(R=Residential; C=Comm'l / Industrial)

COMPLETE 2014 (Chapter 2)	Report Status
C9. SBEA Impact Evaluation	Complete
C10. Small Business Data Mining Study	Complete
C12.Small Business Research Area Limited English and Low Income Barriers Project	Complete
C14.EO Impact and Process Evaluation	Complete
R2. CL&P Behavior (HER) Pilot Studies 2012 Yr. 2	Complete
R3. Regional Lighting Hours of Use	Complete
R5.Weatherization Baseline	Complete
R7.Ground Source Heat Pump Impact Evaluation & Market Assessment	Complete
R8.Central Air Conditioning Impact and Process	Complete
R15.Energy Potential Study for single-family existing homes	In progress
R16. HES/HES-IE Impact Evaluation	In progress
R48 Market Assessment for HES Measures	Complete
R67. LED Market Assessment and Lighting NTG	Complete
IN PROGRESS / DRAFT REPORTS (Chapter 3)	
C11. Barriers to C&I Program Participation with a Focus on Financing &Cancellations	In progress
C20. Energy Conscious Blueprint (ECB) Evaluation	In progress
R15.Energy Potential Study for single-family existing homes	In progress
R84 Consumer Electronics Potential	In progress
R86 LED Market Assessment and Lighting NTG	In Progress

2. COMPLETED STUDIES

2.1 Commercial

C9- Small Business Impact Study

Objective and Principle Outcomes:
The Connecticut Energy Efficiency Board (CT EEB) Evaluation Committee commissioned a study to evaluate the 2011 Small Business Energy Advantage (SBEA) Program sponsored by Connecticut Light & Power (CL&P) and United Illuminating (UI). The primary objectives of this study were to 1) develop SBEA Program level electric gross energy savings estimates targeted to achieve +/-10 precision at the 90% level of confidence, 2) develop SBEA Program electric energy demand savings coincident with summer on-peak and seasonal peak periods targeted to achieve +/-10 precision at the 80% level of confidence (to allow bidding into the capacity markets), and 3) provide inputs to update the current Program Savings Document (PSD) as appropriate with findings from the study, including metering results, installation results and other parameters.

Approach and Work Plan:
There were 1,696 customer sites that participated in the SBEA program from January 1– December 31, 2011. The two program sponsors combined for a total of 35,205,536 kWh saved in the 2011 Program Year, with lighting measures comprising the majority of electric savings (86%). Refrigeration and custom measures account for 7.6% and 3.1% of the 2011 Program Year electric savings, respectively.

The two primary evaluation activities undertaken in this effort include an engineering study with site-level measurement and verification (M&V) at 60 participating sites and a billing analysis. The engineering study in this evaluation was a measure level approach that was based upon gathering and analyzing site-level data from 60 statistically selected sites. This approach incorporated M&V activities, such as metering time of use or consumption of the measures installed in the businesses in the sample. This impact evaluation conducted a billing analysis in addition to the standard engineering M&V method. Billing analysis estimates the impacts of the SBEA Program through use of consumption data and using the tracking data as a statistical variable. We performed the billing to assess its ability to provide energy savings estimates for a small business program.

Results:
A total of 33,874 MWh of energy savings are estimated from 2011 SBEA Program activity based upon the on-site M&V approach. The realization rates associated with this estimate is be 96.2%, with a precision of ±7.8% at the 90% confidence interval. The summer on-peak and seasonal peak savings estimates are 6,093 and 6,187 kW, respectively. The precision on these estimates are ±8.6% at the 80% confidence level for summer on-peak and ±8.3% for seasonal. The winter on-peak savings estimate is 5,148 kW, with a precision of ±16.2% at the 80% confidence level. The winter seasonal peak savings estimate is 4,440 kW, with a precision of ±17.6% at the 80% confidence level.

The Connecticut PSD is the source of savings calculations and assumptions for tracking program savings. The PSD is constantly evolving to reflect new findings and studies in its calculations and parameters. While this study did not explicitly target the updating of the measures examined, we did review the

calculations for the four primary measures explored in this study (lighting, door heater controls, vendor heating controls, and evaporator fan motor replacement and evaporator fan controls) to assess opportunities to recommend changes based upon our findings, as summarized in the table below.

Figure 2-1: Measure Reviews for Program Savings Document Measure Type Reviewed Findings

Measure Type Reviewed	Findings	Conclusion
Lighting	Formula appropriately calculates energy and demand savings. Key inputs include self-reported hours of use, standard pre and post watts and COP assumption for interactive effects.	Formula exceeds industry standards as it includes interactive effects.
Door Heater Controls	Formula is standard and correct. Key inputs include number of units, site-specific voltage, and amperage and a power factor fixed at 1.	Formula is consistent with industry standards for calculating energy and demand savings. Power factor is valid for electric resistance loads. The annual hours are stipulated at 6,500 for coolers and 4,070 for freezers, which are reasonable based on the metering and observations of this study.
Vending Machine Controls	Formula is standard and correct. Key inputs include number of units, site-specific voltage, amperage, annual operating hours and a savings factor fixed at 45%.	Formula is consistent with industry standards for calculating energy and demand savings. The savings factor of 45% is appropriate, within expected engineering estimates and provides reasonable estimates of savings in light of the findings of this study.
Evaporator Fan Controls and Evaporator Fan Motor Replacement	Formula is standard and correct. Key inputs include number of units, fan motor kW, annual hours before and after control, and refrigeration efficiency.	Formula is consistent with industry standards for calculating savings. The annual hours are assumed to be 5,000 hours if controls are already in place or installed with replacement motors and 8,500 hours if controls are not present. We believe these to be reasonable based upon the findings from this study. Refrigeration efficiencies are stipulated at an ACOP of 2.03 for freezers and 2.69 for coolers, which are acceptable average efficiencies for refrigeration equipment of this nature.

Conclusions and Recommendations:

- Conclusion #1: Based upon the M&V impact results, it is apparent that the 2011 SBEA Program Generated significant energy and peak demand savings. The estimate of annual energy savings is 33,874 MWh and the seasonal summer peak demand savings is 6,093 kW.
- Conclusion #2: Based upon the M&V impact results, we conclude that the CT PSD used to develop the tracking estimates of savings is producing very reasonable estimates of SBEA energy and summer seasonal peak demand savings. The realization rate is 96.2% for energy and 89.9% for summer seasonal peak demand.

- Conclusion #3: We do not believe the SBEA Program is a good candidate for program level billing analyses given its current state due to uncertainty around the relationship between accounts and program treated spaces. The performance of another billing analysis on the SBEA Program should be undertaken only if the program administrators are fully confident that all billing data associated with each participant's treated area has been identified and available.
- Recommendation #3: To the extent the EEB desires a billing analysis as an evaluation method for the SBEA Program, we recommend that program vendors and implementers establish a system of ensuring the acquisition of all meters and accounts associated with each treated premise.
- Conclusion #4: In the M&V site work, when the PSD formulas were used to calculate summer demand and annual energy savings, the results were consistent with the estimates in the tracking system (99.6% and 98.2% realization rates, respectively). When the PSD formulas were used to calculate winter and connected demand savings, the results suggest that the tracking system estimates for these parameters are grossly underestimated (136.1% and 165.6% realization rates, respectively). There were three sites in the sample that had tracking winter demand savings estimates of zero. When the PSD formulas were applied, the total winter demand savings for these sites was 64.52 kW. Likewise, there were four instances where the tracking connected demand savings estimates were zero and the total PSD calculated value for these sites was 73.11 kW.
- Recommendation #4: Although we do not believe that connected demand or winter demand are important metrics for CT filing or ISO-NE FCM purposes, we recommend that the sponsors take steps to more closely follow the PSD in calculating these values in the tracking system.
- Conclusion #5: While the overall annual energy savings results were very good (96.2% realization rate), the interactive savings applied to lighting retrofits in the tracking system appear to be slightly overestimated; causing a 7.5% reduction in lighting savings. Some of this overestimation is due to applying the cooling credit to spaces that were not found to be cooled during the on-site visits. Additionally, a review of the PSD formula used to apply interactive savings to lighting retrofits found the cooling system COP (coefficient of performance) assumption to be less efficient than the COP of the units typically found on-site.
- Recommendation #5: We recommend that the cooling credit calculation only be applied to lighting retrofits that occur in spaces that are mechanically cooled. We also recommend that consideration be given to assuming an interactive COP that is more consistent with the cooling systems used in small businesses today. The current COP assumption of 2.4 is a dated assumption that is cited from an ASHRAE journal article from 1993. During the on-site visits, most of the cooling systems observed in the sample were packaged systems with estimated COP's of 2.9. As such, we recommend that consideration be made for adjusting the PSD COP assumption to 2.9 to calculate interactive savings for small business lighting retrofits that occur in cooled spaces. *With utility review and discussion this recommendation was withdrawn in the Evaluation Committee Letter in Response to Utility Comments. The PSD has algorithms for all commercial and industrial lighting retrofits and does not differentiate small business versus larger businesses. Given this, the 2013 PSD value of 3.5 is appropriate.*
- Conclusion #6: One of the larger adjustments experienced in the electric non-lighting realization rate was that of documentation adjustment. This adjustment had a negative 11.5% impact on the final savings result. The primary measures where the documentation adjustment was particularly problematic were electrically commutated motors and cooler curtains.
- Recommendation #6: We recommend that a renewed effort be undertaken to calculate savings for ECMs and cooler curtains per the PSD. We think such an effort would not need to be time

consuming and once established it would greatly improve the accuracy of tracked savings for these measures.

See full report at:
http://www.energizect.com/government-municipalities/sbea-impact-evaluation-c9-may-2014-2

C10- Small Business Data Mining Evaluation Study

Objectives and Priority Outcomes:

Connecticut Light & Power and United Illuminating offer the Small Business Energy Advantage (SBEA) Program that provides an energy audit and incentives to small business owners to improve the energy efficiency of their buildings. The program provides direct installation of lighting upgrades and controls, air conditioning equipment tune-ups, and automated controls for refrigeration equipment.

The objectives of the research were as follows.
- Assess the representation of various market sectors among the SBEA participants over the last five years, which sectors were underrepresented and which were missing.
- Determine how the market sector distribution of program participants compared to those of nonparticipants.
- Characterize the mix of measures installed in the program, including an examination of the nature and frequency at which measures beyond lighting were installed.
- Explore the levels of savings tracked by sector.

Approach and Work Plan:
The SBEA Data Mining Research aimed to help program administrators make more informed decisions about how to garner deeper and more comprehensive energy savings by examining what has and has not been accomplished through the SBEA from 2007 through 2012. The research consisted of analysis of the SBEA program databases and the utility customer databases to characterize the program and the participants, and compare the population of eligible customers to those who participated in the program.

Data- APPRISE requested a complete download of SBEA program data from CL&P and UI for projects that were undertaken between 2007 and 2012. The data received included information on program dates; project cost, incentives and financing; business type; measures installed; and usage and demand savings. APPRISE requested customer data from CL&P and UI to merge with the program data and to provide analysis of customers who were eligible and who did and did not participate in the SBEA. The data received included business type, usage, and demand.

Results:
Key findings from the program data analysis were as follows.
- *Projects*: From 2007 through 2012 there were nearly 6,300 CL&P SBEA projects installed and nearly 2,000 UI SBEA projects installed. The peak year for the SBEA installations was 2010 for CL&P and 2009 for UI.
- *Business Type*: The most common types of participants were offices, retail, auto-related, and restaurants, making up half of the projects.
- *Usage Intensity*: Restaurant and food establishments had the greatest energy usage intensity. While 74 percent of this facility type had over 30 kWh per square foot of facility space, other establishment types were most likely to use less than 10 kWh per square foot of space.
- *Demand*: Mean average demand was 31 kW, but 25 percent had average demand over 33 kW. College/school, manufacturing and restaurants/food participants were most likely to have average demand over 50 kW.

- *Contractors*: The top two contractors completed 25 percent of the SBEA jobs and the top six contractors completed more than half of the jobs. While 42 contractors participated, 15 completed fewer than 20 jobs each over the six years studied.
- *Measures:* While 72 percent of projects were lighting only, 16 percent had lighting and refrigeration measures installed, ten percent had lighting and custom measures installed, and three percent had lighting and cooling, heating, or domestic hot water measures installed.
- *Costs and Incentives*: Mean project costs were approximately $14,000 and incentives covered approximately 40 percent of the costs on average.
- *Financing*: Approximately 90 percent of the SBEA projects used financing. Colleges and schools were least likely to use program financing and government was also less likely to use financing than most of the other facility types.
- *Savings*: Projected average annual savings were 22,197 kWh per CL&P SBEA project and 18,899 kWh per UI SBEA project. Colleges/schools had the greatest mean savings by far, followed by the entertainment/gym category. Projects with other measures in addition to lighting had much higher savings.
- *Savings per Square Foot*: Higher savings for colleges and schools followed by entertainment and gym facilities was related to their larger facility size. Restaurant/food stores, parking, and retail establishments had the greatest savings per square foot.
- *Percent Savings:* Warehouses and parking facilities had the highest average savings as a percentage of pre-treatment usage.
- *Demand Reduction*: Mean annual kW savings in the program database were estimated as 5.7 kW per project. Colleges/schools had the greatest projected savings.

Participants and eligible customers were distributed similarly across business segments and corporate structures. Eligible customers had somewhat higher usage and demand than the post-program usage and demand of SBEA participants, but the differences were approximately equal to the projected reductions, indicating that these customers may have had similar usage and demand prior to program participation.

There were two primary findings of import from this research. The first is that the program appears to be doing a good job of serving all customer segments. SBEA participation is a very good representation of Connecticut businesses of this size (by kW usage). Therefore, there does not seem to be underserved business segments that need to be targeted and no change is recommended regarding a change of market target.

To target particular segments would move SBEA away from its equal level of service to the C&I customers. If greater savings or higher cost-effectiveness is desired and viewed as having greater value than providing services equally to the C&I customer segments, then targeting colleges/schools followed by entertainment/gym should aid these alternative goals as these sectors have the highest savings per participant and program dollar.

The second important finding from this independent third-party research is that SBEA participants appear to have on-average saved 24% off their prior demand usage. The SBEA program tracking data does not contain the participant's usage. Matching the billing data to the program data allowed an estimate of the average percent of demand savings expected from the program tracking estimates and customer usage.   Comparison of demand usage for the SBEA-eligible population to the SBEA

participants over the 2007-2012 period generally supports the program estimates of savings since the difference between the two groups is close to that savings level.[3]

There were a limited number of contractors who have worked on the program. The utilities have worked to develop these relationships and expand contractor reach in the program. Another potential avenue for increased participation is to increase the contractor participation base.

We have seen the analysis of contractor data by CL&P and the efforts to leverage detailed contractor knowledge to aid in obtaining more savings efficiently. Both program administrators (PAs) are working to expand their relationship with the SBEA contractors. We have no recommendation to change that.

Colleges/schools, followed by entertainment/gym had the greatest mean savings, and are good potential targets for the program to increase savings per participant or cost-effectiveness. The decision to target specific sectors for greater cost-effectiveness would reduce the close representativeness of the SBEA program seen in 2007-2012. The desire for greater cost-effectiveness may outweigh the desire to have the program exactly match its target population. Another alternative mentioned by the utilities during comments on the draft report is that colleges and schools may be better served by energy efficiency efforts other than SBEA.

Given the fact that 72 percent of projects were lighting only and that projects with measures in addition to lighting had much higher savings, increasing the percent of projects with additional measure categories appears to be one of the surest ways to increase program savings. But we know that the PAs have already been undertaking activities to obtain more savings from a broader number of measures in 2013 and 2014. We have no recommendation to change that.

This research study did not involve any new data collection. However, it did involve analysis of existing data that, in our experience, PAs do not usually undertake on their own. We would recommend that future research and evaluation activities have an initial task that involves interviews with PAs to ensure that the research is valuable to the PAs. Undertaking research that relies on data already available to the utilities and being undertaken for outside parties to either have knowledge from this data, or as analysis from an independent third-party, should be carefully assessed for its need and be very explicit about what information from the utility data needs to be produced or assessed by an independent third-party.

See full report at: http://www.energizect.com/government-municipalities/sbea-data-mining-c10-final-report

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[3] This also provides secondary support to the SBEA Impact Evaluation that found relatively high realization rates within the impact evaluation of the 2011 program year.

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C12- Small Business Energy Advantage (SBEA) Low Income and Limited English Business Owner Study

Objectives and Priority Outcomes:
The Connecticut (CT) Energy Efficiency Board would like to increase the participation of small businesses that are owned by low-income and limited English speaking proprietors in the SBEA Program. Many utilities, states and the federal government conduct programs that target low-income and limited English speaking residential customers. Much fewer have efforts to target business owners within this population. This is a unique research effort, not seen in other jurisdictions, to gather information that program planners may use to determine whether participation from this population can be increased at reasonable costs. The CT utilities have made efforts to reach out to these businesses and educate them about energy efficiency opportunities. However, little information is available on the population of these small business owners who are eligible to participate in the program. There is no information source on small businesses that fall into these categories.

The purpose of the research documented in this report was to provide information on the potential population of businesses that meet these criteria, assess whether community organizations can provide valuable guidance and support for obtaining program participation, and to provide a confidential document that furnishes information on organizations that are willing to facilitate participation. The information also includes the role the organizations may be willing to take to facilitate participation and the compensation that they would require to provide this assistance. The goal is to provide the utilities with contact information for organizations that may help the utilities increase participation by this group of customers.

The Small Business Energy Advantage (SBEA) program already includes an effort to reach low-income and limited English businesses. This report is not a process evaluation of these existing efforts. The goal of this market research was to provide market data that may enable greater participation by these targeted businesses.

Approach and Work Plan:
In-depth telephone interviews were conducted with Connecticut organizations that serve low-income small business owners or limited English speaking small business owners to characterize the targeted businesses and to assess whether and how the organizations could facilitate participation by these businesses. This report presents the findings from this research.

The research consisted of two phases of in-depth telephone interviews conducted with organizations that potentially had knowledge of low-income or limited English small business owners.
- *Phase I Research Pilot* – In-depth telephone interviews were conducted in June and July 2013 with seven (7) organizations that had knowledge of low-income or limited English speaking small business owners in CT. The goal of this research was to develop an understanding of the size of this market sector and to determine whether these business owners may be interested in the SBEA Program. These interviews also sought to identify the best methods of contacting the targeted business owners.
- *Phase II Research* – The first phase of the research affirmed that there was an opportunity to reach low-income and limited English customers in the SBEA, and provided support for the use of trusted contacts to provide program information to these customers. Therefore, the second round of research aimed to collect additional information from a much broader group of

Prepared by Skumatz Economic Research Associates (SERA), Apex Analytics, & AEC

organizations. Interviews were conducted in October and November 2013 with 28 organizations that had knowledge of low-income or limited English small business owners. The goal of these interviews was to develop a deeper understanding of this market sector and to determine whether and how the organizations that work with these small business owners would be willing to facilitate participation from these targeted organizations into the SBEA Program.

Results:
Phase I Research Findings
Key findings from the initial seven interviews were as follows.
- Respondents from all organizations felt that low-income and limited English business owners would potentially be interested in the SBEA Program.
- All of the respondents interviewed felt that there would be barriers to participation by these small business owners. The following barriers were identified.
  - Language/cultural barriers
  - Cost
  - Lack of trust
  - Lack of knowledge about the program
- The organizations reported that face-to-face interaction and contact through trusted local organizations would be the most effective methods of reaching these business owners.

Phase II Research Findings
The key findings from the additional in-depth interviews with contacts at 28 organizations were as follows.
- *Low-Income Small Business Owners* – Twenty-four of the organizations interviewed work with low-income small business owners. Key findings with respect to these business owners are summarized below.
  - The organizations indicated that retail businesses, restaurants, food stores, construction/contractor businesses, and small manufacturing businesses were the most common types of small businesses owned by low-income individuals.
  - All of the contacts who provided an estimate of the average number of employees of low-income small business owners indicated that the average is ten or fewer.
  - Most respondents estimated that a quarter or fewer of low-income small business proprietors own their business locations.
  - Most organizations interviewed felt that these small business owners would be interested in the program.
  - Cost, lack of knowledge, time, and trust were identified as primary barriers to program participation for this market sector.
- *Limited English Small Business Owners* – Twenty-one of the organizations interviewed work with limited English small business owners. Key findings with respect to these business owners are summarized below.
  - Spanish was identified by all but one organization as a primary language spoken by limited English speaking small business owners. Chinese, French, Portuguese, and Asian languages were also identified as common among these business owners.
  - Restaurants, retail stores, food stores, and salons were identified as common types of small businesses owned by limited English speaking individuals.
  - All of the contacts who provided an estimate of the average number of employees indicated that the average is ten or fewer.

- o Most organizations reported that a quarter or less of limited English speaking small business proprietors own their business locations.
- o Most organizations believed that all or most of these business owners would be eligible and interested in the program.
- o Language, cost, and lack of knowledge, time, and trust, were identified as the primary barriers to program participation for this market sector.
- *Program Facilitation* – The second round of interviews also explored whether the responding organizations might be willing to facilitate program participation by low income and limited English speaking small business owners. Key findings from this research were as follows.
  - o Twenty-one of the 28 organizations interviewed indicated that they would be willing to facilitate program participation.
  - o Most of those who were willing to assist indicated that they could distribute program information.
  - o Eleven indicated that they might be willing to provide business owner contact information to the utilities.
  - o Eleven contacts indicated that they might be willing to work through the process with business owners.
  - o Nine organizations reported that they would require some type of compensation for facilitating participation, and seven indicated that they would not need to be compensated for facilitating program participation.

See the full report at:
http://www.energizect.com/government-municipalities/c12-sbea-low-income-and-limited-english-small-business-study-final-repor-0

C14- Energy Opportunities Process and Impact Evaluation

Objectives and Principal Outcomes:
This report presents the outcomes of the evaluation of Connecticut's 2011 Energy Opportunities (EO) Program. The evaluation contractor team ("the evaluation team"), led by Energy Market Innovations (EMI), designed this evaluation in collaboration with the Connecticut Consultant to the Energy Efficiency Board (EEB) Evaluation Committee. During 2011, the Connecticut electric utilities United Illuminating (UI) and Connecticut Light & Power (CL&P) provided incentives for 1,329 projects, reporting an aggregate annual energy savings of 88 GWh. In addition, Southern Connecticut Gas (SCG), Connecticut Natural Gas (CNG), and Yankee Gas provided incentives to 38 customers for natural gas conservation measures and reported an aggregate annual savings of 4.2 million Therms. Projects incentivized through the EO Program consisted of commercial, industrial, and municipal customers willing to engage in retrofits of existing equipment that was operational with at least 25 percent of its useful life remaining. The EEB designated this study a priority as electric savings from the EO Program provide a large portion of the overall portfolio savings that are bid into the ISO New England (NEPOOL) Forward Capacity Market by these Connecticut utilities; however, the most recent impact evaluation is three years old, evaluating the 2008 program year. This study was conducted to provide more recent evaluation results.

The evaluation consisted of an impact and process evaluation. The overall objective of the impact evaluation was to estimate the energy saved by the program (both electricity and natural gas) and the reduction in electrical peak demand. The overall objective of the process evaluation was to identify how the EO Program could be improved so that it is better able to meet its goals.

The impact evaluation emphasized high impact measures that account for a majority of the program savings and therefore represented the greatest aggregate risk in regards to progress towards energy savings and demand reduction goals. The evaluation research achieved the overarching objectives outlined below.
- Evaluate the savings impact of lighting projects, non-lighting projects, and natural gas projects, including documenting detailed adjustment factors
- Calculate and recommend "forward-looking" overall realization rates using the 2013 Program Savings Document (PSD).
- Assess the accuracy of methods used by the engineering firms (vendors) in estimating savings for complex "custom" projects and recommend changes, if needed.

The objective of the process evaluation was to identify what is currently working well with the EO program and where improvements could be made so that the program is better able to meet its goals.
Approach and Work Plan- Impact Evaluation Methods:

To develop the *ex post* saving estimates, the evaluated savings estimate, the evaluation team used on-site measurement and verification (M&V) for a representative sample of projects as the primary method of data collection. This M&V included conducting project documentation "desk reviews;" selecting the appropriate International Performance Measurement and Verification Protocol (IPMVP) option given the available data and expected variability, and developing site-specific M&V plans based on the selected IPMVP option. Once the M&V plans were approved, field staff visited the site to conduct interviews, measure key assumed inputs, and meter long-term usage patterns. Using the collected data, the evaluation team in most cases developed hourly energy use models for the 8760 hours per year (referred to as an 8760 model) to extrapolate measured energy use from a limited measurement period

over the year. This provided estimates for both annual energy use and peak demand. These models incorporated all appropriate day-types. In many cases, regression models were also applied to energy and/or power use data with appropriate normalizing variables to estimate ex post savings. To complete the impact evaluation, the evaluation team first compared estimated *ex post* savings values to reported *ex ante* savings values (estimated savings prior to evaluation) to determine realization rates for each sample project. Next, the team weighted and aggregated these project-by-project realization rates to create an overall, program-level realization rate. Finally, the evaluation team calculated forward-looking realization rates using assumptions in the 2013 PSD, as opposed to the 2011 PSD. It should be noted that this evaluation does not present any recommendations to change the PSD for future years.

The realization rates are the most important output from impact evaluations for several reasons. These are:
1. An estimate of the evaluated savings can be obtained from either the year under evaluation or any more current year where the program's methodology for estimating savings has not changed substantially by multiplying the program's claimed/tracking system estimate of savings times the realization rate from the evaluation.
2. The realization rate provides information as to how well the program is estimating savings and when viewed by energy versus demand, measure or disaggregated by types of adjustment can point to areas where the program might want to investigate the method and assumptions used in estimating a project's savings and program savings claims.
3. Targeting the realization rate, rather than absolute savings estimates, reduces variability from size of facility or scope of measure such that sampling can be accomplished efficiently and impact evaluations cost far less than if the target were the savings estimate.

Approach and Work Plan - Process Evaluation Methods:
To complete the process evaluation, the evaluation team conducted a database review and interviews with key program staff, program participants, and vendors.
The evaluation team's database review included a detailed review of the program-tracking database, examining it for completeness and consistency in terms of project detail and contact information. In addition, the evaluation team completed qualitative in-depth interviews with 3 program staff, 41 EO program participants from the 2011 program year, and 19 participating vendors. These interviews explored how participants and vendors engaged with the program and each other. Interviewers specifically probed participants and respondents for information *Evaluation of the Energy Opportunities Program: Program Year 2011* ES-4 and feedback regarding comprehensive projects, alternative financing methods (*e.g.*, ESPC, utility-sponsored financing), strategic energy planning, and building benchmarking.

After completing the interviews, the evaluation team examined the collected data for key themes, using open coding techniques to analyze the interviews with program participants. As part of this process, the evaluation team identified key trends across interviews and from specific segment subgroups. Outcomes from this analysis were then categorized by their relationship to EO Program goals and evaluations objectives.

Impact Evaluation Results:
The EO program impact evaluation results presented in this report are based on a sample of 144 projects; 66 of these were lighting, 45 were non-lighting electric, and 33 were non-lighting gas.4 The tables in this section summarize the impact evaluation principal findings, comparing ex post (evaluated) savings estimates to ex ante (utility program tracking system) savings estimates for annual energy consumption, summer seasonal peak demand, and winter seasonal peak demand.

There were 36 non-lighting gas projects in the sample for which the evaluation team conducted on-site data collection. Billing data could not be retrieved for three of these projects, and due to the nature of these projects, reliable estimates could not be made without the billing data.

Figure 2-2 provides a summary of the annual energy savings for the 2011 Energy Opportunities program. The evaluation revealed that the program achieved an estimated 86,640 MWh of annual electric energy savings and 504,551 Therms of gas energy savings, as compared to 88,161 MWh and 603,045 Therms reported in aggregate for all EO programs by the Companies. The aggregate electric energy realization rate is 98% with relative precision of ±11% at the 90% confidence level, while the gas energy realization rate is 84%, with relative precision of ± 16%. Breaking down the electric savings, the energy realization rate is 89% ± 9% for lighting measures and 112% ± 16% for non-lighting measures. The forward-looking realization rates are also included, showing the realization rates if the *ex ante* calculations had been performed using the 2013 PSD. Only lighting realization rates changed, leading to a change for the overall electric realization rate. For annual energy savings, it is customary to target ±10% relative precision at the 90% confidence interval in Connecticut energy efficiency program evaluations. The impact evaluation for the 2011 Energy Opportunities program meets this target for lighting, but not for electric non-lighting, gas non-lighting, or electric overall. The precision of these impact findings is lower than the target as a result of high variability in site-specific realization rates, which were much higher than anticipated in the sample designs.

Figure 2-2: 2011 Energy Opportunities Program Annual Energy Savings

Sector	Units	Ex Ante	Ex Post	Realization Rate	Rel. Prec. (90% confidence)	Forward Looking Realization Rate
Lighting	MWh	52,261	46,269	89%	± 9%	93%
Non-Lighting	MWh	35,900	40,314	112%	± 16%	112%
Electric Total	MWh	88,161	86,584	98%	± 11%	101%
Gas	Therms	603,045	504,551	84%	± 16%	84%

Figure 2-3 presents a similar summary of summer peak demand impacts for electric projects only. These findings show that the program achieved an estimated 13.8 MW of summer peak demand savings compared to 10.8 MW aggregate reported in the Companies' tracking systems. The electric summer seasonal demand realization rate is 127% with a relative precision of ±17% at the 80% confidence level. The summer demand realization rate is 115% ± 9% for lighting measures and 168% ± 38% for non-lighting measures, at 80% confidence. The forward-looking realization rates are also included, showing the realization rates if the ex ante calculations had been performed using the 2013 PSD. Only lighting realization rates changed, leading to a change for the overall electric realization rate.

Figure 2-3: 2011 Energy Opportunities Summer Seasonal Demand Impacts (MW)

Sector	Ex Ante	Ex Post	Realization Rate	Rel. Prec. (80% confidence)	Forward Looking Realization Rate
Lighting	8.3	9.5	115%	± 9%	101%
Non-Lighting [a]	2.5	4.2	168%	± 38%	168%
Total	10.8	13.8	127%	± 17%	116%
a. Non-lighting precision bands are much wider than the M-MVDR objective of 10% at 80% confidence, primarily because of sites having missing or zero estimates for demand savings where savings were found by the evaluation. However, even at the low end of the range of expected values, the realization rate exceeds 100%.					

See full report at:
http://www.energizect.com/government-municipalities/energy-opportunities-impace-evaluation-final-report

2.2 Residential

R2- Evaluation of the Year 2 CL&P Pilot Customer Behavior Program

Objective and Priority Outcomes:
This report summarizes the results of a process evaluation and an impact evaluation of Year 2 of the Home Energy Reports (HERs) Pilot Program, implemented for Connecticut Light and Power (CL&P) by OPower. NMR Group, Inc. (NMR) and subcontractor Tetra Tech performed the evaluation activities. The objectives of the Year 2 Pilot Program evaluation stem from the program design and seek to understand whether responses to HERs vary for high-use and average-use customers and how long savings persist after high-use households stop receiving HERs.7 The detailed objectives include the following:

- Estimate the program-induced electricity savings for all households in the treatment group and for households in the following treatment sub-groups and time period:
  - *"Extension"* (high-use) treatment group recipients continued from Year 1
  - *"Expansion"* (average-use) treatment group added in Year 2 All-electric heat households
  - Summer and winter months
- Explore how long savings persisted after discontinued Year 1 households stop receiving reports
- Year 2 Process Assessment
  - Treatment Group Survey
  - "Average" customer focus groups

Program Design
CL&P and program implementer OPower administered a behavior pilot program for the purposes of achieving residential electricity savings, and providing value to their customers through the delivery of a two-page report. These reports present the treatment group with feedback on their electricity use and compare that use to a group of similar households referred to as "neighbors." They also provide lists of energy-saving tips that differ from year to year.

The implementer identified a study group of CL&P residential customers and then randomly assigned each of the study group households to either a treatment group that received HERs in the mail or to a control group that did not receive the HERs. The pilot program uses an "opt-out" design, where customers assigned to the treatment group automatically receive reports, but have the option to contact program representatives to opt-out of the HERs program if desired.

This report evaluates the second year of the HERs pilot program. In Year 2, CL&P and OPower sent HERs to two customer groups: 1) High-use Extension group comprising 8,000 Year 1 monthly treatment group households who received reports for another year, and 2) Expansion or average-use group comprising 10,000 newly selected households who all exhibited pre-program electricity use similar to the average CL&P customer (i.e., about 700 kWh per month).

Methods
The evaluation team used three different methods to inform the study objectives:
1. Telephone survey with high-use Extension and average-use Expansion households
2. Focus groups with average-use Expansion households8
3. Billing analysis of Year 1 households (high-use Extension and Discontinued) and Year 2 average-use Expansion households

Key Findings
Treatment Group Experiences
The telephone survey and focus group yielded the following critical findings.

- **Awareness of the program and readership of the HERs is high**. Over 90% of surveyed respondents in this opt-out program recalled receiving the reports, and at least one person read the whole report in more than one-half of households. Among households who at least skim the report, 65% looked at all of the reports they received. A small portion, less than one percent, of households ignored the report and did not read it at all. High-use Extension and average-use Expansion households displayed similar levels of awareness and readership.
- **Households maintain readership of the HERs over time**. Nearly three-quarters of households reported reading the reports at similar levels at the time of the survey as when they started receiving them. Among households that did change their readership, average-use Expansion households were more likely to read the reports at the time of the survey compared to the start of the program. High-use Extension households, if their readership changed, were slightly less likely to read the reports over time, although they have received the reports for a longer time period than the average use Expansion households.
- **Households find the HERs useful overall but no single element is most important**. About 75% of households felt that the information provided in the HERs was very or somewhat useful, but no single aspect of the reports stands out as especially useful. When asked to select the "most useful" information in the report, about one-third referred to the neighbor comparison; one-fifth cited the energy-saving tips as the most useful. Another 20% of respondents, however, indicated that no one aspect of the report is most useful. Average-use households held more positive views of the HERs than high-use households.
- **The HERs keep energy conservation "top of mind."** While survey respondents could not always identify how HERs prompted specific actions, survey respondents and focus group attendees acknowledged the reports made them think about their choices. Regularly receiving the HERs reminded households of the importance of energy conservation behaviors and shaped the framework in which they made decisions about equipment purchases or practices.
- **The HERs can make energy efficiency part of the household conversation.** Getting everyone in a household "on board" with efficient practices can be a significant challenge. Survey respondents explained that they have used the HERs as objective evidence of the household's energy use and to encourage more efficient behavior among other members of the home.
- **Households express frustration with the lack of specific recommendations or details on the underlying sources of their high consumption**. Qualitative responses to survey questions and focus group discussions pointed out that the reports and their comparisons identify a problem but do not provide a solution. Households state energy-saving tips are generic; they lack reactions or behaviors of each household member HERs fail to help households understand what appliances or practices in their homes are using the most electricity.
- **Average-use households hold more positive opinions about the program.** High-use households attribute more effects of the program to their actions. Average-use households rate the HER program higher on subjective measures—satisfaction, usefulness, likelihood of recommending the program to others, and perceived relevance and importance of the energy-saving tips.
- **Energy-saving behavior patterns differ for high-use and average-use households.** High-use households more often make home improvements or invest in new, energy efficient appliances or equipment. Average-use households are significantly more likely to practice energy-efficient habits, such as turning off lights, unplugging chargers, or using direct lighting. Two likely sources of these differences include: 1) That high-use households have received reports for a longer

period of time, and 2) That high-use households have higher incomes, on average, than average-use households so they may find it easier to afford purchasing new appliances and equipment.

- **Engagement with the program website is low.** Less than one-half of households are aware of the HER website and 7% have visited the website. Only a slightly higher percentage of households have visited the CL&P website to look for ways to save energy (12%). However, access to the Internet is not a significant barrier for most respondents: the overwhelming majority use email, make on-line purchases, or bank on-line. Rather, they are not aware of the program's on-line resources and lack a compelling reason to use them. Any program redesign that seeks to focus on web-based report delivery will need to combat a persistent lack of interest in using websites to learn about energy efficiency.
- **Households desire comparisons that are more transparent and standardized.** Survey respondents and focus group attendees feel the HERs would be more helpful for them if performance metrics compared their own usage over time rather than comparison with neighbors. Neighbor comparisons should be more clearly standardized, for example, by comparing households with the same number of occupants or itemized by type of equipment.

Electricity Savings Attributable to the Program
- The billing analysis suggests that Year 2 treatment households achieved electricity savings of about 1.82%; this translates into 0.64 kWh per day or 233 kWh per year for each household, or 4,254 MWh across the entire program
- As expected, the analyses revealed that the percentage of electricity savings differed significantly between high-use Extension households and average-use Expansion households, with high-use Extension households saving about 2.31% and average-use Expansion households
- About 1.17%10. Note that the electricity savings achieved by the high-use Extension group in Year 2 were comparable to those achieved by all Year 1 monthly report recipients—of which they are a subset—in the Year 1 study (i.e., 2.17%), suggesting that savings remain relatively constant over time in households with prolonged program exposure.
- Due to a mixture of preprogram electricity use and differences in achieved savings, the high-use Extension households saved an average of 433 kWh per year (3,487 MWh program savings), while the average Expansion household saved 96 kWh per year (977 MWh program savings). A Wald test (see discussion in Appendix A) concludes that the two models differ significantly.

The team also explored savings for various sub-groups. These results suggest the following:
- Households with the highest use in the Year 2 treatment group (i.e., the highest users within the high-use Extension group) achieved a greater percentage of savings (2.49%) than typical high-use households (2.34%).
- High-use Extension households who did not pay the all-electric rate (these customers have all electric appliances in the home) saved more (2.71%) than those households that did pay the all-electric rate (1.27%)—a shift from the Year 1 findings likely explained by the characteristics of the Extension sample compared to the whole Year 1 sample.
- Finally average-use expansion households paying the all-electric rate saved more (1.29%) than average-use Expansion households not paying this rate (1.16%). A Wald test confirms that each pair of models differs significantly.

Persistence of Savings
The team also examined how long savings persist after treatment households stop receiving report. They explored savings persistence through two types of analyses:

1. Persistence of savings among high-use Extension households between their last Year 1 report and their first Year 2 report (six months)—what the team refers to as the "hiatus" period
2. Persistence of savings for all permanently discontinued Year 1 households.

The results of the first analysis indicate that the high-use Extension sample continued to achieve savings comparable to their Year 1 savings (1.97% during Year 1 and 2.17% during the hiatus) during the entire hiatus period. Monthly variations in savings, which ranged from 2.04% to 2.32%, reflect natural fluctuations in electricity use.

The results of the second analysis point to continued electricity savings for the discontinued treatment sub-groups from Year 1; note that implementer assigned the discontinued sub-groups, not the evaluation team Overall, the discontinued monthly group saved about 3.70% during Year 2 of the program while the persistence and quarterly groups saved about 1.86% and 2.06% respectively. However, the team cautions that the characteristics of the discontinued monthly treatment group may have inflated its estimated savings. Given the stability in savings for the persistence and quarterly groups as well as the High-use Extension group during the hiatus period, the team believes that it is more likely that the discontinued monthly group also achieved savings in the 2.0% range over the entire time period. Looking at the persistence of electricity savings for each month after the cessation of reports, the results suggest that households that received reports for a year—either monthly or quarterly— still regularly exhibited statistically significant savings 15 months after receiving their first report, although the savings appeared to be diminishing over time. In contrast, households that received monthly reports for only eight months in Year 1 not only saw savings diminish, but they also tended to become non-significant over time.

Ratio of Program Expenditures to Savings
The team obtained the Year 1 and Year 2 budgets to calculate ratios of program expenditures to savings for Year 1 and Year 2 of the program that covers the period when the participants were receiving reports as well as the ratios of program expenditures for saving that also encompasses a year of persistence savings. The computations show that cost per kWh savings was between two and three cents for the high use customer groups, and about 13 cents for the "average" use customers.

Conclusions and Recommendations
CL&P and OPower designed the Year 2 study to determine whether the HERs program model achieves the same percentage of savings for the average CL&P residential electricity customer as it does for the high-use customers. The analyses in this report suggest the following conclusions regarding this issue:

- Savings: The program design achieves statistically significant savings (1.82%) for both high-use and average-use customers, but high-use households achieve statistically higher percent savings (2.31%) than average-use households (1.17%).
- Lower savings for "average" use households: Differences in pre-program electricity use and the percent savings means that CL&P can expect high-use households to achieve 350% more electricity savings as measured in kWh than average-use households.
- Persistence: The analyses also demonstrate that high-use treatment households from the Year 1 study group continued to save electricity long after they stopped receiving reports. Households demonstrated average savings of about 2% through July 2013, a period of 15 months for the discontinued monthly and quarterly treatment groups and almost two years for the discontinued persistence treatment group.
- Ratio of Expenditures and Savings: Computing the ratio of expenditures to electricity savings showed that the program achieves a more desirable ratio when focusing on high energy use

households. This finding draws into question whether the ratio of expenditures to savings would be adequately high if CL&P opened the program to all households.

- Demand Savings: Calculating the demand savings based on MA inputs gave evidence that high-use expansion households likely had demand savings around 428 kW and that average-use extension households likely had demand savings between 273 kW and 73 kW.

These critical findings on electricity savings, persistence of savings, reactions to reports, and use of the website lead to the following recommendations:

Recommendation 1: Given the strong evidence for program savings during the treatment period and well after the cessation of reports, the team recommends that CL&P calculate program savings for* high-use households *to include the savings achieved during treatment period plus another 2.0% for at least one year after the households stop receiving reports. The evidence actually supports claiming savings for 15 months to two years after report cessation, but the team recommends the more conservative period of a year due to the pattern of diminishing savings over time. Still, the team recognizes that a strong argument can be made for extending the period beyond one year after the cessation of reports for customers that will no longer be involved in the program, and CL&P and the EEB should consider the strengths and weaknesses of a longer persistence period when calculating program savings. *This recommendation applies only to high-use households; research planned for 2014 will provide more insights into the persistence of savings for average-use households.*

Recommendation 2: The HERs program results in lower (i.e. more desirable) expenditures to savings ratios for high-use households than for average-use households. This suggests that expanding the program to all households may not achieve desirable expenditures to savings ratios. However, additional program goals may justify expansion to all households. The team stresses that the program will remain the most cost effective if it targets high-use households, but this creates social equity concerns, as these households tend to be wealthier and enjoy higher socioeconomic status than the typical CL&P customer.

Recommendation 3: Future evaluations should be responsible for developing their own control group for estimating savings from the program. The implementer selects the treatment and control groups, and the team stresses that the data point to random allocation of these groups. Yet, the random allocation cannot be confirmed or tested with certainty. The evaluation design and independence could be improved if the evaluators compared estimates of electricity savings based on the implementer control group and an evaluator selected control group that matched the treatment group. The team notes, however, that the matching process can sometimes be quite involved and require somewhat substantial resources to carry out.

Recommendation 4: Given its integral role in inducing energy-saving behavior, the neighbor comparison should remain a critical component of the program design. However, CL&P and OPower should also *consider* revising the report to make the definition of "neighbors" more prominent. In short, perhaps CL&P and OPower could experiment with ways of continuing to promote the competitive spirit created by the neighbor comparison in a way that is more conducive to positive customer relations.

Recommendation 5: CL&P should be hesitant to move to a web-based design unless they have a strong plan in place to convince households to visit the website initially and then to continue to engage the website on a regular basis. The most difficult component of a web-based program design will likely be convincing households to visit the website and create an account. The team anticipates that the

program would need to move from an "opt-out" to an "opt-in" design *unless CL&P already has email addresses for substantial numbers of its residential customers*. The need for email addresses reflects the reality of the current design—the papers reports have not induced use of the website, so it is unlikely that a "welcome letter" will work any better. In contrast, the ability to follow an embedded email link could increase use of the website. If CL&P lacks large numbers of email addresses for its residential customers, an opt-in design could take advantage of social media to encourage interested households to sign-up at the website. Finally, a web- or email-based approach would almost certainly be cost effective, but the biased sample could result in electricity savings that differ radically from the current program design. In short, the savings reported here could not be generalized to a web- or email-based design, be that design opt-in or opt-out.

See the full report at: http://www.energizect.com/government-municipalities/evaluation-year-2-clp-pilot-customer-behavior-pgm-r2-final-report-8-8-14

R3- Regional Hours of Use (HOU) Study

Objectives and Priority Outcomes:
The purpose of this study was to provide updated information to the Connecticut Energy Efficiency Board, the Massachusetts Program Administrators (Cape Light Compact, National Grid Massachusetts, Northeast Utilities, and Unitil), National Grid Rhode Island, and the New York State Energy Research and Development Authority (NYSERDA) (hereafter "the Sponsors") to assist in the calculations of demand and energy savings for lighting programs. Specifically, this report presents load shapes, coincidence factors (CFs), and daily hours of use (HOU).
Following are the principal tasks completed as part of this project:
- Sample design
- Recruitment
- Onsite data collection
- Analysis and reporting

To help control costs, the study took advantage of previously planned lighting saturation studies in New York and Massachusetts; the results of the saturation studies are presented under separate cover. To complement the Base Study, NYSERDA also funded an oversample of high-rise households in Manhattan. In addition, this study leveraged data collected as part of two additional concurrent studies: the *Massachusetts Low-Income HOU Study* (conducted by Cadmus) and the *National Grid New York EnergyWise Study* (conducted by DNV GL). NMR, Cadmus, and DNV GL coordinated the development of protocols and methods to ensure comparable data.

Methodology
Sample Design, Recruitment and Onsite Visits
For this evaluation, the Team collected data through onsite visits to 848 homes located throughout Connecticut, Massachusetts, New York (excluding Nassau and Suffolk Counties), and Rhode Island. All sites required two visits. During the first visit, the Team collected detailed lighting inventory data and installed time-of-use light meters (loggers). The second visit consisted of removing loggers installed during the first visit. In New York, NYSERDA funded the inclusion of an additional oversample of high-rise homes located in Manhattan in order to determine if high-rise households in densely populated New York City behave differently in terms of lighting usage. The Team offered all potential study participants incentives that varied by area and study.

Sample Attrition, Data Cleaning, and Treatment of Outliers
Altogether, over 5,730 loggers were installed between December 2012 and March 2013. Logger installations were timed to be as close to the winter solstice as practical, given project constraints and the impact of storms. Logger retrieval began in June 2013 and continued through August 2013. The greatest number of loggers was deployed between February and July 2013 (six months). A substantial number of loggers (greater than 1,500) was deployed in each month from December 2012 through July 2013 Attrition due to customers moving, damage to loggers, and lost loggers reduced the sample about 4%.

The Team was very careful in identifying and removing loggers with HOU values that might be considered outliers. In addition, the Team implemented quality assurance and control procedures during logger installation and removal that reduced errors associated with loggers recording incorrect. Removing outliers and data cleaning reduced the number of loggers included in the final analysis to

4,642. Of the 4,642 loggers included in the final analysis, 84% were installed for at least 121 days and 31% of the loggers were installed for at least 151 days. On average loggers were installed for 143 days.

For information on Coefficient of Variation and Weighting see Sections 2.4 and 2.5 of the main report, respectively.

HOU Modeling
Developing HOU estimates consisted of three modeling steps:
- Creating annual datasets
- Adjusting HOU estimates
- Applying a hierarchical model
A summary of each modeling steps is as follows.

Creating Annual Datasets. Since each logger was installed for only a portion of the year the Team had to annualize the data. To annualize the data the Team fit a sinusoid model to each logger. The Team fitted separate weekend and weekday models for each logger. For any loggers not conforming well to the sinusoid model, the analysts took steps to prepare annualized estimates based on average daily usage.
Adjusting HOU Estimates. Using the annualized estimates, the Team performed a weighted regression analysis to estimate the adjusted HOU for each room in each area of the study. In this step, only loggers for each individual area were used to develop area-specific estimates, and all loggers were used to develop estimates for the overall region. Based on outputs from this model, it was clear that Connecticut, Massachusetts, Rhode Island, and Upstate New York all had comparable usage patterns and that usage patterns for Downstate New York were significantly different.
Applying a Hierarchical Model. Due to the similar use patterns in four of the areas (CT, MA, Upstate NY, and RI), the Team sought a way to leverage data from each of these areas to refine area-specific estimates. To accomplish this, the Team fit a multi-level hierarchical model. The advantage of this type of modeling approach is the ability to use information from all four areas to help inform area-specific estimates. In a hierarchical model, the observations specific to an area form the basis of the estimates for that area, while observations from outside that area also inform and help refine the area-specific estimates. The hierarchal model is particularly beneficial for areas where fewer loggers were installed, thereby providing more refined (tighter precision and adjusted means) HOU estimates compared to individual models fit to each area separately.

Throughout this report, eight separate area estimates are presented—five produced by the hierarchical model and three produced by separate standalone models. For the sake of clarity, the team presents below a brief overview of the data informing each of the estimates, and the reader may find it helpful to refer to this overview when reading the summary of results that follows:

Hierarchical Models
Connecticut (CT): The 549 loggers from Connecticut inform the core of Connecticut estimates. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Massachusetts, Rhode Island, and Upstate New York.
Massachusetts (MA): The 2,175 loggers from Massachusetts inform the core of Massachusetts estimates. The core estimates were then refined through a hierarchical model that draws upon all loggers installed in Connecticut, Rhode Island, and Upstate New York.

Rhode Island (RI): The 232 loggers from Rhode Island inform the core of Rhode Island estimates. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Connecticut, Massachusetts, and Upstate New York.

Upstate New York (UNY): The 721 loggers from Upstate New York inform the core of Upstate New York estimates. This includes the 299 loggers from the National Grid *EnergyWise* Study. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Connecticut, Massachusetts, and Rhode Island.

Overall Excluding Downstate New York (Overall): A product of the hierarchical model described in Section 2.6.3, the Overall estimates collapse the modeled data from the four areas described above. The 3,677 loggers from Connecticut, Massachusetts, Rhode Island, and Upstate New York make up the core of Overall estimate. As with the other estimates above, the Overall estimate excludes all loggers from Downstate New York (including Manhattan).

Standalone Models
Manhattan (MHT): The 544 loggers from Manhattan inform the Manhattan estimates.
Downstate New York (DNY): A product of a standalone model (as described in Section 2.6.3), the 965 loggers from Downstate New York, including the 544 loggers from Manhattan, inform the Downstate New York estimates.

NYSERDA Service Area (NYSERDA): The 1,686 loggers from New York—the 721 loggers from Upstate New York and the 965 loggers from Downstate New York (including the 544 loggers from Manhattan)—inform the NYSERDA Overall estimates.

Derivation of Load Curves: As with the HOU modeling, since each logger was installed for only a portion of the year—between five and nine months—the Team had to annualize the data to generate a full year of monthly load curves for the eight geographies included in the study.

HOU Analysis Results
When the Team began to analyze HOU across areas, it became apparent that the HOU estimates for Connecticut, Massachusetts, Rhode Island, and Upstate New York were all very similar and that the estimates for Manhattan, Downstate New York, and NYSERDA (a combination of Upstate and Downstate New York) diverged from the other areas. The similarity of Connecticut, Massachusetts, Rhode Island, and Upstate New York justified their use in a hierarchical model that did *not* include the divergent areas of Manhattan or Downstate New York.

To simplify the discussion, the Team will first compare the four similar areas informed by the hierarchical model and then discuss the NYSERDA area standalone models. Each of the five estimates from the hierarchical model is statistically similar to the others. Estimates for Manhattan and Downstate New York are statistically higher compared to the other models.

HOU Analysis Results – Hierarchical Models: All Bulbs
The Team found no significant differences in HOU estimates at the household level between any of the areas included in the hierarchical models. Even at the room level, only nine significant differences exist—discussed in detail in Section 3.2.1 of the full report —out of 80 comparisons between the five sets of estimates obtained from the hierarchical model. It is important to note that none of the areas are significantly different from each other at the household level, and even at the room level only one significant difference exists between the Overall model and any of the four areas included in the Overall model.

Further, the Team examined HOU estimates in these four areas by the following eight categories of home type and income levels:

- Single-Family Households (SF), Multifamily Households (MF), Low-Income Households (LI), Non-Low-Income Households (NLI), Low-Income Single-Family Households (LI SF), Low-Income Multifamily Households (LI MF), Non-Low-Income Single-Family Households (NLI SF), Non-Low-Income Multifamily Households (NLI MF)

The team then compared models for each category within an individual area. Across the eight categories within a specific area there were only four significant differences. The Team also compared each of the eight categories across the five areas. Across the areas, there were only three significant differences among the five areas. With such minor differences in HOU estimates across Connecticut, Massachusetts, Rhode Island, and Upstate New York and with relatively few differences at the home type and income level, *the Team recommends that the Sponsors consider adopting the HOU room-by-room estimates from the overall hierarchical model for all households regardless of income or home type*.

Figure 2-3: HOU Estimates by Area and Room – All Bulbs

Room	CT	MA	RI	UNY	Overall
Bedroom	2.6 (2.2, 3.1)	2.0 (1.8, 2.3)	2.6 (2.0, 3.3)	1.7 (1.3, 2.1)	2.1 (1.9, 2.3)
Bathroom	1.5 (1.1, 2.0)	1.8 (1.5, 2.0)	1.2 (0.6, 1.8)	1.9 (1.5, 2.4)	1.7 (1.5, 1.9)
Kitchen	4.6 (4.0, 5.1)	4.0 (3.7, 4.3)	3.8 (3.0, 4.5)	4.1 (3.7, 4.6)	4.1 (3.9, 4.3)
Living Space	3.8 (3.3, 4.3)	3.3 (3.0, 3.6)	3.4 (2.7, 4.2)	3.1 (2.6, 3.5)	3.3 (3.1, 3.6)
Dining Room	3.2 (2.6, 3.9)	2.7 (2.3, 3.1)	3.5 (2.6, 4.6)	2.5 (1.9, 3.1)	2.8 (2.5, 3.1)
Exterior	6.0 (5.6, 6.5)	5.5 (5.2, 5.8)	6.6 (6.0, 7.1)	5.5 (5.1, 5.8)	5.6 (5.3, 5.9)
Other	1.7 (1.4, 2.0)	1.7 (1.5, 1.9)	1.6 (1.2, 2.0)	1.7 (1.4, 2.0)	1.7 (1.6, 1.9)
Overall	2.8 (2.7, 3.0)	2.7 (2.6, 2.8)	2.6 (2.3, 2.9)	2.6 (2.4, 2.8)	2.7 (2.6, 2.8)

Inefficient versus Efficient Bulbs HOU

While the Team did not find many significant differences between areas, home types, and income types, it did uncover significant differences comparing HOU by bulb efficiency. HOU estimates for efficient bulbs are significantly higher than HOU estimates for inefficient bulbs within each of the eight individual models. Estimates for inefficient and efficient bulbs across the five sets of estimates obtained from the hierarchical model, are all statistically similar, meaning that use of inefficient bulbs does not vary much across the areas, and neither does use of efficient bulbs.

The differences in bulb efficiencies may be evidence supporting one of three competing theories put forth by some lighting program implementers and evaluators about how households use efficient bulbs. The first theory, differential socket selection, is that households select higher-use locations for their high-efficiency light bulbs. The second theory, shifting usage, holds that a household installs an efficient bulb in a socket and then begins to use that socket in lieu of sockets containing inefficient bulbs. The third theory, increased usage, asserts that snapback occurs—using an efficient product more than the non-efficient one it replaced. However, this evaluation did not collect any data to determine which of these three theories is correct, or the proportion of the difference between efficient and inefficient HOU that is attributable to each type of behavior. In the absence of clear evidence supporting one theory over the others, the Team suggests assuming that the difference between efficient and all-bulb HOU is caused equally by the behavior posited by all three theories, with each accounting for one-third of the total difference between efficient and all-bulb HOU. The team thinks it would be reasonable for residential lighting programs to claim savings based on two of the three theories—differential socket selection and shifting usage—and reduce savings based on the third theory, increased usage (snapback).

Therefore, the Team recommends adjusting efficient HOU by subtracting one-third of the difference between efficient and all-bulb HOU.

See the full report for Tables showing the HOU by area for efficient bulbs both adjusted and unadjusted for snapback.

Figure 2-4: HOU by Area Adjusted for Snapback

Room	CT	MA	RI	UNY	Overall
Bedroom	2.8 (2.4, 3.1) bdefg	2.2 (2.0, 2.4) acfgh	2.9 (2.4, 3.4) bdefg	2.0 (1.7, 2.3) acfgh	2.3 (2.1, 2.5) acfgh
Bathroom	1.7 (1.3, 2.0) fgh	2.0 (1.8, 2.3) fgh	1.6 (1.1, 2.1) fgh	2.1 (1.7, 2.4) fgh	2.0 (1.8, 2.1) fgh
Kitchen	4.7 (4.3, 5.1) bfgh	4.2 (3.9, 4.4) afgh	4.1 (3.5, 4.6) fgh	4.3 (3.9, 4.6) fgh	4.2 (4.1, 4.4) fgh
Living Space	3.9 (3.5, 4.3) dg	3.5 (3.3, 3.7) fgh	3.6 (3.0, 4.2) fg	3.2 (2.9, 3.6) afgh	3.5 (3.4, 3.7) fgh
Dining Room	3.4 (2.9, 3.9) fg	3.0 (2.6, 3.3) fgh	3.8 (3.0, 4.6) df	2.8 (2.3, 3.2) cfgh	3.0 (2.8, 3.3) fgh
Exterior	6.5 (6.0, 6.9) bdegh	5.7 (5.5, 6.0) acg	6.7 (6.2, 7.2) bdegh	5.7 (5.3, 6.0) ac	5.8 (5.6, 6.1) acg
Other	1.9 (1.7, 2.1) fgh	1.9 (1.7, 2.0) fgh	1.7 (1.4, 2.0) fgh	1.9 (1.7, 2.1) fgh	1.9 (1.8, 2.0) fgh
Household	3.0 (2.8, 3.2) fgh	2.9 (2.8, 3.0) fgh	2.9 (2.7, 3.1) fgh	2.8 (2.7, 3.0) fgh	2.9 (2.8, 3.0) fgh

[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Load Shape Analysis
The Team developed hourly load shapes by month for each area based on logger data collected for the study. The Team also calculated coincidence factors (CFs) in two ways for each area:
1) Using the data that informed the monthly load shapes for the three New England states included in the study, the Team calculated CFs during the New England Independent System Operator (ISO-NE) summer and winter on-peak and Seasonal Peak hours. According to ISO-NE, the winter on-peak hours are during non-holiday weekdays from 5:00 to 7:00 PM. The summer on-peak hours are during non-holiday weekdays from 1:00 to 5:00 PM.
2) The Team also prepared estimates based on peak data from the two Independent system Operators covering the area of the Sponsors.
   a. Estimates were based on ISO-NE's 2013 Seasonal Peak Data for Connecticut, Massachusetts, and Rhode Island. According to the ISO-NE Seasonal Peak Data Summary, in 2013 the winter peak period occurred on January 24, 2013 at the hour ending 19 and the summer peak hour occurred on July 19, 2013 at the hour ending 17.
   b. The Team prepared estimates based on the NYISO's peak hour. Based on NYISO actual load data for 2013, the peak occurred on July 7, 2013 at the hour ending 19.

Figure 2-5 displays one load curve as a visual accompaniment to the data presented in Figure 2-5.

Prepared by Skumatz Economic Research Associates (SERA), Apex Analytics, & AEC

As with HOU estimates, the team recommends that the Sponsors consider adopting the Overall load curve and resulting coincidence factors across Connecticut, Massachusetts, Rhode Island, and Upstate New York. In addition, unlike with HOU estimates, the all bulb and efficient bulb coincidence factors are statistically similar for the Overall model and as such there is no need to adopt an all bulb estimate and a separate efficient specific estimate. *Turning to Downstate New York and Manhattan, the Team recommends that NYSERDA adopt the Downstate New York model to represent Downstate New York and Manhattan as the two models are statistically similar.* Results in Table ES-7 are presented as *mean (90% CI)*. The Team leaves it up to the Sponsors to decide when it is appropriate to use the winter and summer peak period estimates versus the ISO specific peak hour estimates.

Figure 2-4: Overall Load Curve for Summer and Winter (Weekday) – All Bulbs
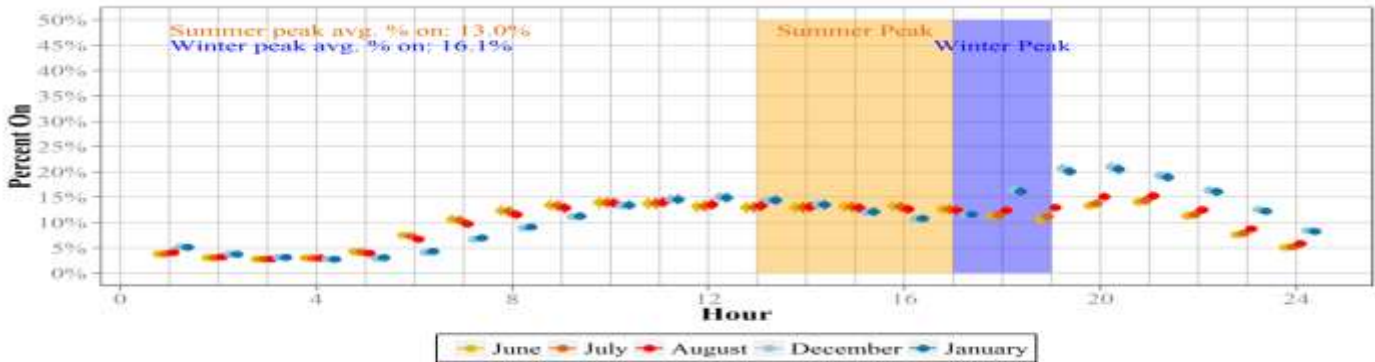
Figure 2-5: Peak Period Coincidence Factors and Confidence Intervals – All Bulbs

Region	Winter Peak Period Dec. & Jan. (5PM-7PM)	Summer Peak Period June, July and August (1 PM-5PM)	ISO-NE Seasonal Peak Hour (Winter) January 24, 2013 Hour Ending 19	ISO-NE Seasonal Peak Hour (Summer) January 24, 2013 Hour Ending 17	NYSO Peak Hour July 7, 2013 Hour Ending 19
CT	17% (15%, 19%)	16% (13%, 18%)	22% (19%, 24%)	16% (13%, 18%)	n/a
MA	16% (15%, 17%)	12% (11%, 14%)	19% (18%, 20%)	12% (10%, 13%)	n/a
RI	16% (13%, 19%)	19% (15%, 24%)	19% (16%, 22%)	17% (13%, 21%)	n/a
UNY	14%(11%,16%)	11% (9%, 13%)	n/a	n/a	9% (8%, 11%)
Overall	16% (15%, 17%)	13% (12%, 14%)	20% (19%, 21%)	13% (12%, 15%)	n/a

Considerations

Consider Adopting the Overall model HOU and coincidence factors for CT, MA, RI, and Upstate New York

With such minor differences in HOU estimates across Connecticut, Massachusetts, Rhode Island, and Upstate New York and with relatively few differences at the home type and income level, the Team recommends that the Sponsors consider adopting the HOU room-by-room estimates from the Overall hierarchical model for all households in these four areas. The Overall model has the greatest level of precision owing to the larger sample sizes and is statistically similar to each of the individual area models on a room-by-room basis and by each of the eight categories of home type and income. By adopting room-by-room estimates, the Sponsors will have the flexibility to apply separate estimates based on specific program data. For example, if direct install program data include room type, the Sponsors can apply estimates for specific room types.

Further, room-by-room estimates provide the ability to update and revise HOU estimates periodically for upstream programs based on room-level socket saturation. For example, if saturation data indicate that saturation is increasing more quickly in kitchens relative to other room types, this would results in an increase to household HOU.

Consider Adopting Two Models for NYSERDA Area
Given the divergence of the Upstate New York model from both the Downstate and even the NYSERDA area model, NYSERDA should consider using the Overall hierarchical model (i.e., the four area model discussed above) for Upstate and the stand-alone Downstate New York for Downstate New York and Manhattan. NYSERDA may also want to consider whether or not higher lighting operating hours and coincidence factors among Downstate households may justify programmatic differences for Upstate and Downstate, such as higher incentives in the latter.

See full report at: https://app.box.com/s/o1f3bhbunib2av2wiblu

R5- Weatherization Baseline Study

Objectives and Principle Outcomes-
The primary objective of this study is to determine the percentage of single-family residential units in Connecticut that currently meet the weatherization standard. The weatherization standard allows for compliance to be assessed using either a prescriptive path or a performance path; the evaluation team assessed compliance with single-family residential units using both approaches. Although, Public Act 11-9 encompasses multifamily residential units as well as single-family units, at the request of DEEP and the EEB, NMR did not include multifamily units in this study (approximately 36% of all units), and all results are for single-family residential units only. The study included both single-family detached (i.e., stand-alone) and single-family attached (e.g., duplex or townhouse) homes, which together represent approximately 64% of all housing units in Connecticut. NMR worked with Home Energy Solutions (HES) vendors to collect the information necessary to estimate baseline weatherization conditions; this report collectively refers to NMR and the vendors as "the Team" or "the evaluators."

- Secondary research objectives in this report include the following:
  - Detail what percentage of single-family homes with various characteristics (e.g., low income vs. non-low income, fuel oil vs. natural gas heated homes, etc.) fall above and below the weatherization threshold.
  - Characterize the weatherization-related features of single-family homes in Connecticut.
  - Detail the characteristics of homes' thermal envelopes (wall insulation, ceiling insulation, air infiltration, duct leakage, etc.), including visually inspecting homes' thermal envelopes using infrared cameras.
  - Detail the characteristics of homes' heating, cooling, and water heating equipment.
  - Detail the characteristics of other energy-related features (e.g., appliances).
  - The findings detailing the characteristics of homes' thermal envelopes, mechanical systems, and other energy-related features can be found in the main body of this report.

Approach and Work Plan-
The study involved on-site visits to 180 single-family homes across the state. The Team assessed compliance with the weatherization standard using both the *prescriptive* and *performance* paths described in the memorandum issued by the EEB on June 10, 2012.1

Figure 2-6: Weatherization Prescriptive Checklist and Performance Modeling Inputs

Building Element	Prescriptive Requirements and Modeling Inputs for Performance Approach
Above Grade Walls	R-11
Flat Ceilings	R-30
Cathedral Ceilings	R-19
Unconditioned Basements & Crawlspaces	Floor separating basement from conditioned space above is uninsulated to R-13
Conditioned Basements & Crawlspaces	Interior walls fully insulated to R-5
Slab on Grade	R-5 four feet below grade; assume to proper depth if present
Windows	U-0.50 (Double pane or single pane with storm)
Air leakages	9 ACH @ 50 Pascals based on HES program data
Duct Leakage for ducts outside conditioned space	16 CFM @ 25 Pascals per 100 sq. ft. of conditioned space based on HES program data

Building Element	Prescriptive Requirements and Modeling Inputs for Performance Approach
Duct Insulation: Unconditioned Basements	R-2
Duct Insulation: Unconditioned Attics and Crawlspaces	R-4.2

Sampling Plan

The study focused exclusively on single-family homes, both detached (stand-alone homes) and attached (side-by-side duplexes and townhouses that have a wall dividing them from attic to basement and that pay utilities separately). Multifamily units were excluded from the study due to the complexity of including them in the evaluation. The evaluators relied on a disproportionately stratified design that aimed to achieve 10% sampling error or better at the 90% confidence level across all of Connecticut and also for several subgroups of interest. This level of precision means that one can be 90% confident that the results are a reasonably (±10% or less) accurate description of all the single-family homes in Connecticut. The Team based all precisions on a coefficient of variation of 0.5.7

Weatherization Assessment

The Team assessed compliance with the weatherization standard by using the performance approach subject to the definition laid out by the EEB for the purposes of this project (see Appendix L). 8 This document states that in order to comply with the performance-based approach, a home must demonstrate modeled energy usage that is equal to or less than the same home built to the criteria listed in Table ES-2. As shown, all of the items listed in the weatherization standard are related to the building envelope. The EEB and DEEP excluded mechanical equipment from the standard for the following reasons: it can be difficult to induce early retirement, mechanical equipment is covered through non-weatherization related program activities, and much of the mechanical equipment currently in use will be replaced with new equipment by 2030, when compliance with the standard is expected to be 80%.

Results-

The evaluation determined 26% of the sampled homes (with a confidence interval of 21% to 31%) comply with the weatherization standard's performance path. Only 5% of the sampled homes comply with all applicable prescriptive requirements. Other highlights from the study include the following:

- Newer homes are significantly more likely than older homes to comply with the standard. Homes built in 2000 or later have a compliance rate of 87%, while homes built in 1939 or earlier have a compliance rate of 7%. This relationship is so strong that targeting homes built prior to 1980 would provide the most effective way of increasing the percentage of weatherized homes.
- Non-low-income homes (29% compliance) are significantly more likely than low-income homes (15% compliance) to comply with the standard. However, due to their small numbers (18% of all single-family homes in the state), targeting low-income homes will not yield large increases in the number of weatherized homes, though it will improve quality of life. That said, targeting older homes will capture many low-income residences as well.
- Compliant homes exceed the standard (when comparing the heating and cooling energy consumption of the "as built" model to the prescriptive weatherization model) by an average of 13%, while non-compliant homes fall below the standard by an average of 48%.
- Compliance with the individual measures listed in the standard ranged from a low of 15% (floors over unconditioned basements) to a high of 82% (windows). The three prescriptive components

- with the lowest compliance rates are floors over unconditioned basements (15%), flat ceilings (34%), and air leakage (39%).
- Compliant homes have a significantly lower average HERS index (score of 96) than noncompliant homes (score of 127). A lower HERS index indicates a more efficient home.
- Among the 180 homes visited as part of this study, 9% (16 homes) have asbestos or vermiculite present and an additional 4% (seven homes) have mold present.
- As-built homes have an average energy consumption, for heating and cooling end uses, of 125.7 MMBtu and average costs of $3,393, while weatherized homes have an average energy consumption of 100.4 MMBtu and costs of $2,784. These differences result in a 20% decrease for energy consumption and an 18% decrease for energy costs when comparing weatherized homes to as-built homes. Based on the findings of the evaluation, the Team identified the following conclusions and recommendations related to the weatherization standard.
- The current weatherization standard does not address multifamily buildings, which account for approximately 36% of housing units in the State of Connecticut. The Team recommends that the EEB develop a weatherization standard and assess baseline compliance for multifamily buildings.
- Classifying basements as "conditioned" or "unconditioned" can be challenging and can have a significant impact on the compliance of homes with the weatherization standard. The Team recommends that the EEB consider the economic and energy impacts of basement insulation retrofits and adjust the weatherization standard accordingly.
- It is nearly impossible for an auditor to verify the presence, type, and R-value of slab insulation in existing homes. The Team recommends that the EEB consider removing the slab insulation requirement that exists in the current draft weatherization standard.
- Compliance is high for certain measures (e.g, 82% for windows and 81% for attic duct insulation) and low for others (15% for frame floor over unconditioned basements and 34% for flat ceiling insulation). The Team recommends that the EEB review the current standard definition and consider revisions to the efficiency levels required by the standard based on the study results.
- The current standard only addresses frame floor insulation over unconditioned basements and excludes other frame floor locations. The current standard does not address rim joist insulation. The Team recommends that the EEB consider adding details to the current standard that address all frame floor locations that are located over unconditioned space. Similarly, the EEB should consider adding a requirement to the standard that addresses rim joists.

Overview of Weatherization Results

Overall, 26% of the sampled homes (with a 90% confidence interval of 21% to 31%9) comply with weatherization standard. Non-low-income homes (29%) are much more likely to comply with the standard than are low-income homes (15%). Similarly, the 16 homes heated primarily by electricity (50%) are much more likely than homes heated by natural gas (22%) and homes heated by oil and other fuels (25%) to be compliant with the standard.

The bullets below highlight the key findings discussed in the rest of the executive summary.
- Newer homes are significantly more likely than older homes to comply with the standard. For example, homes built in 2000 or later have a compliance rate of 87%, while homes built in 1939 or earlier have a compliance rate of 7% (Table ES-6).
- Non-low-income homes (29% compliance) are significantly more likely than low-income homes (15% compliance) to comply with the standard.

- On average, compliant homes exceed the standard (when comparing the heating and cooling energy consumption of the "as built" model to the prescriptive weatherization model) by 13%, while non-compliant homes fall below the standard by 48% (Figure ES-2).
- Just 5% of the sampled homes comply with all applicable prescriptive requirements (Figure ES-3).
- Compliance with the individual measures listed in the standard ranged from 15% (floors over unconditioned basements) to 82% (windows) (Figure ES-3). The three prescriptive components with the lowest compliance rates are floors over unconditioned basements (15%), flat ceilings (34%), and air leakage (39%).
- Six measures show statistically significant differences in average efficiency when comparing compliant homes to non-compliant homes (Table ES-7). These measures include:
    - Conditioned to ambient wall insulation – R-15.1 vs. R-7.6
    - Flat ceiling insulation – R-32.5 vs. R-17.2
    - Conditioned to unconditioned basement frame floor insulation – R-9.9 vs. R-2.6
    - Conditioned to garage frame floor insulation – R-22.4 vs. R-13.2
    - Air infiltration – 6.6 ACH50 vs. 13.2 ACH50
    - Duct leakage to the outside – 13.7 CFM25/100 sq. ft. vs. 19.8 CFM25/100 sq. ft.
- Compliant homes have a significantly lower (better) average HERS index (score of 96) than non-compliant homes (score of 127) (Figure ES-4). Advanced statistical modeling (see Appendix K for details) also revealed that older homes— particularly those that do not heat with electricity and have not taken part in HES—provide the
- Greatest opportunity to move the state closer to achieving 80% weatherization. Although the study found that low-income homes were less likely to meet the standard than non-low-income homes, status as a low-income home was not a defining characteristic of non-weatherized homes. Targeting older homes for weatherization would capture many low-income homes and improve quality of life, but targeting low-income homes would not lead to large increases in the number of weatherized homes.

Conclusions and Recommendations

The following conclusions and recommendations are focused on possible ways to increase performance-based compliance with the current weatherization standard; some of the recommendations overlap but each stems from a unique conclusion of the baseline study.

Weatherization Standard

Conclusion: The current weatherization standard does not address multifamily buildings, which account for approximately 36% of the housing units in the State of Connecticut.

Recommendation: The EEB should develop a weatherization standard specific to multifamily buildings. After a multifamily standard has been developed, the EEB should consider conducting a weatherization baseline assessment of the multifamily housing stock in Connecticut.

Conclusion: Classifying basements as "conditioned" or "unconditioned" can be challenging in existing homes and as a result is often left to the discretion of the auditor. The final classification can have a significant impact on the compliance of homes with the weatherization standard as multiple measures address basement insulation and the designation of a basement as "conditioned" or "unconditioned" influences the results of diagnostic tests (i.e., air and duct leakage tests).

Recommendation: The EEB should consider the best way to address basements in the weatherization standard. The current standard suggests that homeowners should insulate the

frame floor separating a conditioned first floor from an unconditioned basement. In some cases, this suggestion may be contradictory to sound building science; there may be limited cost-effective savings from insulation retrofits in these cases as the temperature change is typically not that dramatic between a first floor and a basement. Moreover, insulation installation in these applications can be challenging due to wiring, plumbing penetrations, and access stairways. Finally, accurately defining a basement as conditioned or not influences the results of air and duct leakage testing which are components of the weatherization standard.

Conclusion: It is nearly impossible for an auditor to verify the presence, type, and R-value of slab insulation in existing homes.

> *Recommendation:* The EEB should consider removing the slab insulation requirement that exists in the current draft weatherization standard. The majority of homes in the State are older homes that likely lack documentation on the presence and level of slab insulation. As a result, any assessment of slab insulation, when addressing progress towards the 80% weatherization requirement, will likely be based on general assumptions as opposed to visual verification.

Conclusion: Compliance is high for certain measures (e.g, 82% for windows and 81% for attic duct insulation) and low for others (15% for frame floor over unconditioned basements and 34% for flat ceiling insulation).

> *Recommendation:* The EEB should review the current standard definition and consider revisions to the efficiency levels required by the standard based on the study results. Although the EEB should review the entire standard, the Team suggests paying particular attention to basements and frame floors. The information provided in the main body of the report will assist this review and potential revision.

Conclusion: The current standard only addresses frame floor insulation over unconditioned basements and excludes frame floors located over other unconditioned spaces such as garages and ambient conditions. Additionally, the current standard does not address rim joist insulation which is an important component of building envelopes.

> *Recommendation:* The EEB should consider adding details to the current standard that address all frame floor locations that are located over unconditioned space (e.g. conditioned to garage frame floor locations, conditioned to ambient frame floor locations, etc.). Similarly, the EEB should consider adding a requirement to the standard that addresses rim joists.

Program Opportunities

Conclusion: Statistical modeling (Appendix K) reveals that participation in the HES program, the age of homes, and whether homes are heated primarily by electricity are the most significant predictors of whether or not homes meet the weatherization standard. Of these three, the age of home serves as the strongest predictor of weatherization status.

> *Recommendation:* The HES program should target non-electrically heated homes built prior to 1980, regardless of household income. The program should prioritize those homes that have not yet taken part in the program.20 Targeting non-electrically heated homes is the best way to increase state-level compliance with the weatherization standard, but HES should continue to pursue energy saving opportunities (e.g., heat pumps replacing electric resistance heat) in the electrically heated homes that do take part in the program even if these opportunities will not greatly increase compliance with the weatherization standard. The current study suggests that a greater proportion of electrically heated homes already meets the weatherization standard, so serving them will not move forward state-level compliance; however, adoption of electric-efficiency measures in electrically heated homes will meet the other critical objectives of increasing electricity and demand savings in Connecticut.

Conclusion: One out of every five homes (20%) that heat primarily with natural gas have uninsulated exterior walls.

> ***Recommendation:*** The Companies should ensure that HES vendors are discussing wall insulation upgrades with homeowners, particularly in homes with uninsulated wall cavities. The Companies may want to consider whether the current incentive and financing options adequately induce adoption of wall insulation upgrades by households with by natural gas.2

Conclusion: Air leakage, flat ceiling insulation, and conditioned to ambient wall insulation are significantly less efficient in performance-based non-compliant homes than in compliant homes.

> ***Recommendation:*** The Companies should continue to focus on air infiltration reductions during initial HES visits and continue to have HES vendors offer flat ceiling and wall insulation upgrades where applicable. Likewise, the Companies may want to consider whether the current incentive and financing options adequately induce adoption of these measures.

Conclusion: Inadequate basement insulation—primarily conditioned to unconditioned basement frame floor insulation—and foundation wall insulation are contributing factors to the low performance-based compliance with the weatherization standard.

> ***Recommendation:*** Increasing basement insulation, specifically conditioned to unconditioned basement frame floor insulation, will likely increase compliance with the *current* weatherization standard. The Companies could consider increasing the focus on basement insulation during initial HES visits and encourage homeowners to insulate their basement at either the foundation walls or the frame floor if increasing compliance with the current standard definition is a priority22.

Conclusion: The use of infrared cameras would help vendors with their retrofit efforts, particularly when it comes to air sealing.

> ***Recommendation:*** The Companies should consider requiring and/or recommending that HES vendors utilize infrared cameras during HES visits. The use of these cameras would likely increase air infiltration reductions and help increase compliance with the weatherization standard.

Other

Conclusion: Among the 180 homes visited as part of this study, 9% (16 homes) have asbestos or vermiculite present and an additional 4% (7 homes) have mold present.

> ***Recommendation:*** The Companies previously helped address these issues through the healthy homes initiative and health impact assessments. The Companies should continue to work with other agencies to address these issues. The EEB and DEEP may also want to consider the appropriateness of offering financing to HES households and HES-IE landlords and rebates to HES-IE homeowners to fund abatement of these problems with the understanding the recipient would then adopt more energy-savings measures such as insulation or air sealing. It is the opinion of the evaluation team that meeting the 80% weatherization requirement by 2030 without increasing the efficiency of homes with these concerns will be difficult.

Conclusion: The labor required to fully populate a REM/Rate model is significant. REM/Rate requires users to perform intensive area and volume calculations in order to properly populate the model. Additionally, REM/Rate accounts for more variables than many other software options. The result is a thorough and accurate energy consumption estimate for any given model (and the option to analyze a large selection of data).

> ***Recommendation:*** The EEB should consider the pros and cons of various software options for assessing compliance using the performance-based approach. REM/Rate is a robust modeling tool that produces accurate energy consumption estimates, but it may not be a viable software option if the EEB expects HES vendors to calculate the

weatherization status for HES participating homes. Other options such as the DOE Home Energy Score software or a customized spreadsheet based model may be more applicable. There would undoubtedly be a tradeoff of time/cost vs. accuracy should a less robust model be adopted, but these tradeoffs are something the Team believes the EEB should consider.

See full report:
http://www.energizect.com/sites/default/files/R5-Connecticut%20Weatherization%20Baseline%20Assessment-FINAL%2006-04-14.pdf

R7- Connecticut Ground Source Heat Pump Impact Evaluation & Market Assessment

NMR and its partner, DNV GL, (henceforth referred to as the evaluation team) performed an evaluation of the Connecticut Residential Geothermal Heat Pump Program and a market assessment of residential ground source heat pumps (GSHPs) in Connecticut.

Objectives and Principle Outcomes

The GSHP program, administered by the Connecticut Energy Financing and Investment Authority (CEFIA) and the Connecticut Energy Efficiency Fund (CEEF), has provided incentives since 2009 to homeowners and businesses that install qualifying GSHPs. We refer to the two programs collectively as "the GSHP program." In April 2012, CEFIA exhausted their American Recovery and Reinvestment Act (ARRA) funding for the GSHP program and discontinued incentives, although CEEF continues to offer incentives. Residential customers of Connecticut Light & Power and United Illuminating were required to apply for both CEFIA and CEEF incentives while the CEFIA program was active. It is important to note that homeowners could also receive 30% of the total project cost in federal tax credits.

The objectives of the study include the following:

- To quantify energy and peak demand savings of the Connecticut GSHP program
- To quantify improvements in air quality
- To assess the GSHP program for potential improvements
- To assess the market for GSHPs in Connecticut

The following tasks were undertaken in order to address these objectives.

- Short-term on-site metering at 40 participating homes, including 21 existing homes and 19 new construction homes
  - Long-term on-site metering at a subset of 10 homes
- Assessment of system design including analysis of Manual J sizing as well as field and loop sizing.
- Analysis of energy and demand savings using DOE-2 energy models
- Analysis of emission reductions
- Telephone surveys with 100 participating customers
- In-depth telephone interviews with 10 participating contractors

Approach and Work Plan

The evaluation team utilized the data collected from the 40 on-site homes to develop two prototype DOE-2 energy models: one for existing homes and one for new construction. The CEFIA program and the CEEF program each assume that their incentives influence different components of the project and, consequently, they assume different baseline scenarios. The CEFIA incentive encouraged an upgrade to a standard GSHP system, while the CEEF incentive encouraged an upgrade to a high efficiency GSHP . Each of the two prototype homes were analyzed using two baseline scenarios, as described below:

- CEFIA baseline: This scenario represents the baseline conditions assumed by CEFIA for its portion of the GSHP program, which include a typical AC unit plus an oil hot water boiler. CEFIA analyzed emission savings for program planning purposes, but did not claim any savings.
- CEEF baseline: This scenario represents the baseline conditions assumed by CEEF for its portion of the GSHP program—an ENERGY STAR Tier 1 water-to-air GSHP system. The CEEF program claims the energy savings that exceed this baseline level.

The upgrade scenario for each baseline was the same—the as-observed participating program home.

Key Findings:

Gross Energy and Demand Savings

- **For a typical existing home, the gross annual savings for CEFIA include over 800 gallons of oil in conjunction with increased electricity usage of about 6,500 kWh.** During heating mode, the electricity consumption increases because the baseline oil boiler used a relatively small amount of electricity for the circulating pump, burner motor, and controls in comparison to the GSHP system. A similar rationale applies to the cooling mode as well; a central air conditioning system does not include pumps, which contributes to negative cooling savings. Peak CEFIA demand savings per home are estimated to be 0.66 kW in the summer and -2.9 kW in the winter.
- **The gross annual electricity savings for CEEF is about 2,200 kWh for a typical existing home.** Peak demand savings per home are estimated to be 0.34 kW in summer and 0.5 kW in winter.
- **Similar to an existing home, the CEFIA savings for a typical new home include substantial oil savings, but negative electricity savings.** Annual electricity usage increased by about 6,500 kWh, though oil usage decreased by over 700 gallons. In addition, peak demand savings per home are estimated to be 1.13 kW in the summer and -2.9 kW in the winter.
- **Gross annual CEEF electricity savings are about 3,700 kWh for a typical new home.** Peak demand savings per home are estimated to be 0.48 kW in summer and 0.90 kW in winter.
- **Overall, each program home yields annual gross savings of between 79,000 to over 90,000 thousand British thermal units (MBTUs) for CEFIA and nearly 7,500 to over 12,500 MBTUs for CEEF.** All of the CEFIA energy savings result from reduced oil usage, while all of the CEEF energy savings result from reduced electricity usage. Except for the cooling mode of the CEFIA option, the annual energy savings are all positive.
- **The evaluated electricity savings exceed the CEEF program tracking system estimates.** The CEEF realization rate for annual electricity savings is 1.52 for existing homes and 3.53 for new construction. The evaluation team did conduct a high-level review of the savings estimates. Based upon this review, it appears that the GSHP hours of operation assumed in the CEEF tracking system were lower than those observed in the field by the evaluation team.

Gross Air Quality Improvements
- The average program home yielded emission savings of between 8,000 and 11,000 pounds per year for CEFIA, entirely due to carbon savings from reduced heating oil usage.
- The CEFIA program tracking data overestimated the annual CO_2 emissions, yielding a realization rate of 0.48 and 0.33 for existing homes and new construction, respectively. For NO_2, the DOE-2 models estimated an increase in emissions rather than the decrease indicated by the CEFIA data, resulting in a realization rate of -0.57 and -0.45 for existing homes and new construction.

Program Influence
The homeowner surveys revealed the following findings regarding the influence of the GSHP program.
- **Program Net-to-Gross (NTG) ratios are modest**. The evaluation team estimated NTG ratios and found the following results.
    - The average overall NTG ratio for all participants, including all incentives (CEEF, CEFIA, and federal tax credit), is 0.71.
    - As might be expected, average overall NTG ratios are higher for those that received federal tax credits (0.75) than those that did not (0.53). In addition, the CEFIA and CEEF NTG ratios are lower for participants who received tax credits (0.25 and 0.16, respectively) than for the participants who did not (0.33 and 0.20, respectively) because, without the federal tax credit, CEFIA and CEEF represent all of the available incentives.

- o The CEFIA NTG ratios are higher than CEEF NTG ratios for both retrofit and new construction projects. This difference probably reflects the notable difference in incentive sizes.
- o Overall NTG ratios are lower for new construction projects (0.63) than for retrofit projects (0.77). This is likely because owners of existing homes must *choose* to replace their existing equipment, whereas owners of new homes *must* install a new heating system, regardless of program incentives.
- **The relative amounts of the incentives, the high cost of the GSHP systems, and the high incomes of participants may all contribute to the modest NTG ratios.** The evaluation team believes that there are three primary reasons why the CEFIA and CEEF NTG values are fairly low.
  - o CEFIA and CEEF NTG values among tax credit recipients are lower than those among non-recipients likely due to the fact that, on average, federal tax credits are nearly double the combined sum of CEFIA and CEEF incentives. As a result, the incentives may decline in importance when juxtaposed with the much larger tax credits.
  - o The evaluation team estimates that, on average, CEFIA incentives may represent between 11% and 13% of the total installation cost, and CEEF incentives may represent 3% to 4% of the total installation cost. When rebates represent relatively small shares of total project costs—especially among very expensive projects—they likely do not carry great importance in the decision to install.
  - o Program participants have considerably higher incomes than typical residents in Connecticut: nearly three-quarters of homeowner respondents (72%) report annual incomes of $100,000 or greater, whereas only one-third of households in Connecticut (33%) have incomes of $100,000 or greater. If homeowners have the financial resources to install equipment without incentives, the importance of the incentives may be lower than otherwise. In addition, it is likely that the purchase of most new homes was financed, thus further reducing the cost barrier for a GSHP system for this market segment.
  - o While contractors were not specifically asked about program attribution, their feedback tends to support the findings of the homeowner survey. Five of the ten interviewed contractors asserted, unprompted, that the program incentives have been a crucial element in customers' final decision to install a GSHP system, especially in combination with the federal tax credit. Three contractors noted that the disappearance of the CEFIA incentive slowed down their business.

Net Energy Savings
For several reasons, we recommend applying the overall NTG ratio, rather than the NTG ratio for each individual incentive, to estimate net savings. First, homeowners are most likely to collectively consider the aggregate impact of all three incentives rather than any single incentive. In addition, the CEEF baseline accounts for only a portion of the overall savings, whereas the NTG ratios were estimated for the entire GSHP system as a whole, which further complicates the calculation. Because CEFIA does not claim any savings from the GSHP program, we only estimate net savings for the CEEF program.

System Sizing & Performance
- **Ground source heat pumps are sized to meet homes' largest space conditioning requirements.** In Connecticut, the dominant residential space conditioning requirement is for heating. System sizing analysis focuses on determining if the units were properly sized to meet the heating loads.

- **The systems, on average, are slightly oversized for heating loads.** According to the Manual J calculations, the sampled participant homes had an average heating sizing ratio of 1.21 for newly constructed homes and 1.24 for existing homes, both of which slightly exceed standard practice. However, 11 of the 21 existing homes and 9 of the 17 newly constructed homes exceeded a heating sizing ratio of 1.20.
- **The systems appear to be performing somewhat below the manufacturer-rated efficiencies.** The calculated field/rated performance ratio is 85% for existing homes and 91% for newly constructed homes.
- **However, the field-rated capacities of the systems appear to meet manufacturer ratings**. The calculated field/rated capacity ratio is 99% for existing homes and 102% for newly constructed.
- **The recovery fields for the GSHP loops appear to be sized correctly.** Determining the ratio of the heating capacities to the manufacturer-rated heat extraction rates revealed that three (8%) of the 38 sites were below 0.90 (with the lowest at 0.83), while 14 sites (34%) had ratios greater than 1.10, and the overall average for all sites was 1.12. In addition, an analysis performed in the DOE-2 models also indicated that the size of the recovery fields relative to the size of the ground loop was adequate. The calculated return water temperatures from the ground loop wells were consistent with those expected of properly performing deep well ground coupled systems during both the heating and cooling modes of operation.

Program Processes and Participation

The contractor interviews and homeowner surveys revealed the following findings regarding participation in the GSHP program.

- **Contractors play an important part in disseminating program information to homeowners.** Homeowners most commonly first learn about the GSHP program through their contractors (39% of respondents). In addition, most contractor interviewees report actively marketing the GSHP program.
- **Participation drivers**. Nearly all homeowner survey respondents (94%) reported that they participated in the GSHP program in order to receive the program rebate. This finding is corroborated by the contractors, as nine of ten interviewees believe that homeowners participate in the program solely for the rebate. However, 6% of homeowners reported participating for the Verification of Installed Performance (VIP) report, and another 6% cite the stamp of approval or certification. In light of the moderate NTG ratios found above, this suggests that, while most customers participate in the program for the incentive, some would have installed a GSHP in the absence of the program incentive.
- **Homeowners are generally satisfied with the GSHP program and their new GSHP systems.** Homeowners provided average satisfaction ratings of 9.4 out of 10 for the new GSHP systems themselves and 9.1 for their participation in the program.
- **Contractors are somewhat satisfied with the GSHP program.** On average, the ten contractors rated their overall satisfaction with the program as 6 out of 10. Many contractors consider it "a good program," and three interviewees emphasized that they would like the CEFIA incentives to return. They commended the program on its effective distribution of incentives and the demeanor and diligence of program staff.
- **Contractor participation requirements are reasonable**. Contractors largely believe that the program requirements regarding their eligibility—such as expectations regarding licensing, accreditation, insurance, and references—are reasonable.

The contractor interviews and homeowner surveys revealed the following findings regarding the processes of the GSHP program.

- **The VIP report yields a mixed response**. Some contractors (four of ten) believe that the technical details required by the VIP report are generally valuable to both perform and verify. In addition, the VIP report has changed the way some contractors (four of ten) are checking their installations. While some contractors find the VIP requirements reassuring, others find VIP reporting to be time consuming and frustrating. In particular, they believe that their VIP reports have been rejected because program staff considered that the reports' data reflected that the systems were *too* efficient, program staff believed the formulas in the worksheet were incorrect, or program staff did not know how to interpret the data if they did not meet the staff's expectations. In some instances, contractors report altering their practices to make systems *less* efficient in order to meet program requirements. This feedback likely refers to the VIP requirement that systems perform within 15% of AHRI-rated efficiency and capacity levels. Some contractors recommend that the program adjust its specifications to accept projects where the systems achieve greater efficiency than the VIP report allows.
- **Contractors unanimously report using Manual J to determine system size, as required by the GSHP program.** Some contractors find that customers often want systems that are larger than necessary, but they try to steer homeowners toward more appropriate systems that will properly and efficiently heat and cool their homes.
- **Contractors believe program staff require more technical knowledge.** Despite some contractors' praise for program staff, others are troubled by their perception that program staff appear to have little technical knowledge and training regarding GSHP systems. They would advise the program to focus on staff training and development around geothermal technology and require that the inspectors obtain more rigorous licensing accreditations.
- **Other program complaints include paperwork, funding, and coordination.** Contractors list other frustrations, including: (1) too much program paperwork, (2) CEFIA mismanaged its waning program funds, (3) hassles in dealing with the review and involvement of the State Historic Preservation Office,5 and (4) insufficient coordination of program administration between CEFIA and CEEF.
- **The program does not appear to be overlooking any savings opportunities**. According to five of the ten contractors interviewed, the program is not missing any savings opportunities in program homes. They underscore the relevance of Home Energy Solutions (HES) testing requirements for existing homes because it is inefficient to install a GSHP in a home with inadequate insulation and air sealing. The other five contractors believe the program might be missing savings opportunities because the rigorous HES efficiency standards and project pre-approval requirements may discourage participants, the ineligibility of open loop GSHP systems, and the lack of a requirement for desuperheaters.
- **Program eligibility does not appear to influence system efficiency levels**. Contractor interviewees indicated that the program eligibility requirements for the GSHP systems do not influence the efficiency levels of the heat pumps they sell. Interviewees explained that they only offer eligible systems to their customers, regardless of the program. Most contractors believe that the program requirements for home eligibility, such as HES testing, are reasonable.
- **Few program-eligible GSHPs appear to be installed outside of the program.** Some contractor interviewees report installing systems during the program period that did not receive rebates because they were ineligible due to the home failing to meet energy efficiency requirements as well as installations beginning before receiving program approval. Only one interviewee has been involved in projects that *qualified* for the program yet had not participated—this

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contractor found that a small number of customers chose not to go through the program in order to receive a larger federal tax credit.

- **The GSHP program appears to have improved the building shell efficiency of only a portion of the participating homes, according to homeowners.** Eighty percent of the owners of newly constructed homes believe that their homes would have likely met ENERGY STAR standards if the GSHP program had not required them to do so. In addition, two-thirds (64%) of owners of existing homes think they would have likely made the upgrades required to pass the HES requirements if the program did not require it.

Market Assessment

The contractor interviews and homeowner surveys revealed the following findings regarding the market for GSHPs in Connecticut.

- **Contractors perceive a large opportunity for residential GSHPs in Connecticut.** Contractors interviewed see tremendous opportunity for installing GSHPs in Connecticut, estimating that about one-half of existing homes (51%) and nearly all newly constructed homes (96%) are good candidates. They explained that most newly constructed homes have adequate weatherization and land available to install GSHPs, whereas fewer existing homes are good candidates because of limited insulation, leaky air sealing, and the greater likelihood of an existing connection to natural gas service.

- **However, contractors' expectations vary for Connecticut's GSHP market in the coming years.** Some contractor interviewees noted that the availability of variable speed compressors is increasing GSHP efficiency, though others expect that advances in GSHP efficiency will plateau over the next few years. Some interviewees anticipate installations will decrease or flatten in the coming years given the disappearance of federal tax credits in 2017, yet others believe sales will increase due to growing awareness. Further, some contractors predict that system prices will increase due to improved efficiency, while others think prices will remain relatively stable.

- **Participants are primarily motivated to install GSHPs due to energy concerns**. The primary motivations of homeowner survey respondents to install GSHPs include the desire to save energy (36%), reduce energy costs (23%), and help the environment/reduce their carbon footprint (21%). Contractor responses underscore these motivations—they find that customers are primarily motivated to install GSHPs in order to save on operating costs. However, contractors noted other motivators as well, including homeowners' concerns for the environment, federal tax credit funding opportunities, and the increasing price of oil and propane.

- **More than one-half of participants had concerns about installing a GSHP, primarily regarding reliability.** Fifty-three percent of homeowner survey respondents reported that they had concerns prior to installing a GSHP; most commonly (53%), they cited concerns about reliability. Contractors explained that homeowners often express confusion and skepticism around the function and reliability of the systems. However, all ten contractors said that the upfront cost is generally the largest barrier preventing homeowners from installing GSHPs. Both homeowners and contractors referenced the inconveniences of installation; for example, owners of existing homes are concerned with disrupting their landscaping and interior décor.

- **Word of mouth is the most common method of learning about GSHPs.** Homeowner survey respondents are most likely to first learn about GSHPs through word of mouth (35%). Contractors also reported that word of mouth is a major component of their marketing strategy. Contractors said they also conduct active marketing at various events and through professional networks.

- **Homeowner respondents find the level of energy efficiency of their new GSHPs to be notably high**. On average, participants rated the efficiency of their new GSHP system as 9.0 out of 10. In comparison, respondents who conducted retrofit projects believe their old systems were only somewhat efficient, having an average rating of 5.0.
- **Survey respondents feel comfortable in their homes now that the GSHP is installed.** On average, they rated their level of comfort as 9.5 out of 10. On the contrary, owners of existing homes, on average, were less comfortable in their homes prior to the installation of the GSHPs, rating their previous comfort level as 6.8.

Discussion and Recommendations

Participating customers provided universally positive feedback about the program, while participating contractors had mixed reactions. However, several contractors would like to see the CEFIA incentives return, noting that their GSHP sales have decreased since CEFIA funding was exhausted. The evaluation identified several issues to consider for the CEFIA incentive, if it returns, and the CEEF incentive, which is still offered for existing homes.

- Several participating contractors believe that the program staff and inspectors are not sufficiently knowledgeable about GSHP systems to perform their duties in an effective manner. However, it is unclear whether the contractors were referring to CEFIA or CEEF program staff. Based on feedback provided by CL&P and UI, it appears that some CEEF program staff are certified by the International Ground Source Heat Pump Association. Nonetheless, consider advanced training in GSHP design, installation, and performance for program staff, particularly if the CEFIA incentive returns.
- Several contractors believe that the VIP reporting requirements are not sufficiently adaptable to allow for the unique conditions that may exist in some homes. In particular, some contractors reported that their systems exceeded allowable efficiency levels. Therefore, consider redesigning the VIP spreadsheet to allow for more flexibility.
- Some contractors noted that effective coordination between CEFIA and CEEF was sometimes lacking. If the CEFIA incentive returns in the future, consider ways in which the program could be offered more seamlessly to both contractors and customers.
- If funding becomes available, consider reintroducing the CEFIA incentive in 2017 after the federal tax credit expires on December 31, 2016. At that point, demand for GSHPs may have peaked as customers rush to install systems before the tax credit expires. However, customer demand for GSHPs may drop substantially in 2017 unless the federal tax credit is extended or the system costs have declined such that the GSHP market is more sustainable.
- If the CEFIA incentive is offered again in the future, consider revising the CEFIA baseline assumptions to accommodate those participants who would choose a natural gas or propane heating system (for new construction in particular) in the absence of the GSHP program.

See full report at: http://www.energizect.com/government-municipalities/ground-source-heat-pump-impact-evaluation-and-market-assessment-r7-final

R8- Central AC Impact Evaluation & Market Research

Objective and Principle Outcomes

The Connecticut Energy Efficiency Board (EEB) requested that the evaluation team comprising NMR Group, Inc., and DNV GL perform a comprehensive central air conditioning (CAC) impact evaluation as well as market research to identify methods to better induce early replacement of CAC units among program participants.

The primary goal of the impact evaluation was to determine the program electric energy savings as well as summer on-peak and seasonal peak demand savings. In addition, the EEB, Connecticut Light and Power (CL&P), and the United Illuminating Company (UI, the latter two collectively referred to as the Companies) were interested in the provision of information on the performance and conditions observed around the installed CAC units, including load shapes; a characterization of CAC units as installed (including size, airflow, and rated efficiency); and a determination of whether new replacement units are properly sized for the homes in which they were installed. The CAC units of interest are those installed using rebates provided by the Connecticut Energy Efficiency Fund, both those that went through the Home Energy Solutions (HES) program and those that did not.

Approach and Work Plan:

To achieve these research goals, the evaluation team performed sampling and selection of 92 onsite visits, including long-term post-installation monitoring during the cooling seasons of 2012 and 2013. The visits included data collection on the areas served in order to support Manual J calculations, when appropriate, as well as true flow diagnostic testing. Regression modeling was applied to the field-collected data to project measure savings, determine peak period impacts, and develop measure load shapes. The final estimates of savings are derived from the on-site data, including the observed EER,[2] SEER,[3] capacity (tons), and metering.

Key Findings:

Impact Evaluation

The energy and peak demand impact portion of this study was designed to provide program savings estimates through the use of an M&V data-driven per-unit savings estimate. It was also designed to help the Companies and EEB improve on forward-looking calculations through recommendations to the Program Savings Document. The bullets below capture our conclusions and recommendations in this regard.

- The overall statewide Annual Savings factor (ASF4), which is an input to the calculation of savings in the PSD, is 362.0 kWh/ton, with an accompanying precision of ±11% at the 90% confidence interval. This value is based upon the calculation of energy savings using EER and is statistically the same as the current Program Savings Document Assumption of 357.6 kWh/ton. The calculated ASF using SEER results is 362.0 kWh/ton and is also statistically the same as the PSD assumption.
- The seasonal and on-peak Demand Savings Factors (DSFs), also PSD formula inputs, are 0.45 kW/ton and 0.24 kW/ton, respectively, each with precisions better than ±7% at the 80% confidence interval. The study's seasonal DSF estimate of 0.45 is statistically lower than the current PSD assumption of 0.591. (The PSD does not contain an on-peak DSF.)
- The overall statewide per-unit average annual savings estimate is 178.7 kWh/unit. The statewide per-unit average annual savings estimates for lost opportunity and retrofit events are 148.3 kWh/unit and 390.7 kWh/unit, respectively. The overall statewide per unit average summer seasonal peak demand savings estimate is 0.22 kW/unit. The statewide per-unit

average summer seasonal peak demand savings estimate for lost opportunity and retrofit events are 0.21 kW/unit and 0.34 kW/unit, respectively.

- Overall, the incentives provided for CAC installations appear to be generating significant levels of savings. This study estimates 1,147 MWh of energy savings associated with 2011 and 2012 CAC installations, with a realization rate of 98.2% when compared to the raw tracking data. We estimate 1.405 MW of summer seasonal demand savings with a realization rate of 85.9%. Using the PSD assumed free ridership rates of 26% for UI and 42% for CL&P and no spillover savings, the overall net energy savings impact estimate is 725.4 MWh, and the overall net seasonal peak demand savings estimate is 0.877 MW.
- There was inconsistent adherence to the PSD in the tracking systems. When compared to the revised tracking data (tracking that has been corrected to better reflect PSD formulas), the realization rates for kWh and summer peak demand are 124.3% and 77.1%, respectively. For Lost Opportunity, the realization rates are 95.0% for kWh and 79.9% for seasonal peak demand. For Retrofit, the realization rates are 129.5% for kWh and 69.0% for seasonal peak demand. The energy realization rate is moderately high for energy savings due to higher usage than assumed in the PSD, generally higher unit sizes observed on-site than captured in the tracking system, and the application of incorrect baselines in some tracking estimates. The realization rate around the summer seasonal result is lower, primarily due to a reduction in the seasonal demand factor as compared to the PSD.
- The team found that 11% of inspected installed CAC systems were either oversized (4%) or undersized (7%) when compared to Manual J. Although the sample of units assessed in this manner was a subset of overall installations visited, we consider these results to be reasonable since there is some contractor judgment in determining the final unit size based on the nature of the ductwork observed, home shading, and home tightness, among other factors. Although we note that roughly three in ten units in the sizing assessment had ratios of calculated load to installed capacity of between 125% and 150%, overall, we conclude that equipment sizing is a low-level issue and does not cause substantial inefficiencies in the central air conditioning systems replaced under the Connecticut programs.
- Unit efficiencies appear to be consistently tracked and accurate in the tracking system. Unit sizes, however, were noted not to be accurately tracked in a consistent manner.
- The assessment of unit air flow resulted in 49% of units having air flow at or below 350 CFM/ton. However, due to some uncertainty over whether all measurements were taken with blowers at full speed, the team believes that these lower measurements are not likely to significantly affect the efficiency of the program-installed units.

Market Research
The study team also conducted market research among program participants in order to identify methods to better induce early replacement of CAC units among program participants. Note that the evaluation team was told that the Companies follow a rule of thumb that any CAC more than 10 years old that is still functioning qualifies as an early replacement.

To achieve this objective, the study explored a variety of questions in an effort to understand what factors customers consider when deciding to replace their CAC, with particular emphasis on the role of standard and early replacement rebates, energy efficiency, information provided by HES vendors, and the advice of installation contractors. The team also included questions about Quality Installation, as this approach provides additional opportunities for rebates among households replacing CAC.

The survey focused on three groups of PY2011 HES participants: those who were recommended CAC replacement as part of the HES audit and

1. Obtained only a standard, $250 CAC rebate (n=70)
2. Obtained a $500 rebate ($250 standard CAC rebate plus $250 "Early Replacement" rebate) (n=70)
3. Were recommended CAC but did not obtain a rebate (n=100, of which 27 replaced CAC without a rebate and 73 did not replace their CAC)

The market research yielded the following key findings:

- Despite the fact that the Companies offer substantial rebates meant to induce early replacement, having an inefficient but working CAC unit is a substantial barrier to replacement, particularly considering the cost of replacement, even with substantial rebates. About one-fifth of participants who replaced their CAC with an early replacement rebate reported that their "old unit broke down." If these units were truly not functioning, then the HES program did not actually achieve any early savings from the replacement.
- The rebate was not one of the primary factors considered in the decision to replace a CAC (only about 5% of respondents volunteered it as a factor that was considered), but rebates were important in the decision to replace an existing CAC system *with a high efficiency ENERGY STAR®-qualified model* (76% of rebate users said it was somewhat or very important). The rebates played a more important role in decision making for early replacement rebate users than for standard rebate users.
- Only 15 respondents used program-supported low-interest financing to replace their CAC, but 13 of them said the loan was somewhat or very important to their decision to replace the unit.
- Participants who obtained an early replacement rebate were much more likely than other participant groups—especially those who did not replace their CAC—to say that they were aware they could receive a rebate before the audit or before the survey call. However, they were no more likely than those who received a standard rebate to say that they had had plans to replace their CAC equipment before the audit.
- Participants rely more strongly on the advice and opinions of installation contractors than on those of HES vendors when deciding whether to replace the CAC and with which equipment.
- Of those who did not replace their CAC despite the recommendation, one-quarter plan to do so within the next five years.
- The data suggest that as much as four-fifths of participants who did not replace their CAC might have qualified for an early replacement rebate had they replaced their CAC.
- Participants who did not use the rebate to replace a CAC suggested that the HES vendors provide more information that explains the benefits of early replacement and perform follow-up calls to encourage following through with audit recommendations.
- There is opportunity to increase participant awareness and use of Quality Installation & Verification.

Conclusions / Recommendations

Based on the impact findings, the Companies or EEB may wish to do the following:

- Consider the use of SEER in the PSD to calculate energy savings for this measure, but continue to use EER for peak demand savings. SEER better reflects the average of the EER over the range of operating conditions that would be seen over the course of a year, while EER is more representative of performance at the peak condition being estimated.
- Consider the use of the seasonal peak DSF (0.45) in lieu of the PSD assumption of 0.59.

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- Re-examine the manner in which tracking savings are calculated to ensure adherence to the PSD. Notable items in this regard include ensuring use of the proper baseline when calculating tracking savings, ensuring proper crediting of all savings associated with retrofit events, and not dividing lifetime savings by measure life to estimate annual savings.
- Re-examine the method being used to gather and input CAC unit sizes (tons) and EERs in the tracking system to ensure accuracy and comprehensiveness. One idea in this regard might be to accompany each rebate application with model specification sheets from the AHRI database to ensure proper coding and backup.
- Consider changing the term Annual Savings Factor (ASF) in the current PSD to reflect the fact that it is more of a Usage Factor. This term will make it more consistent with how it is used in the savings formula.

Based on the market research findings, in planning for future program marketing and encouraging early replacement of CAC, the Companies or EEB may wish to do the following:
- Better emphasize, and effectively communicate, the size and types of CAC rebates available to HES participants. One participant noted, "[They] should say up front about [the] $500 rebate."
- In program-related communications, emphasize the benefits of replacing systems before they break down, even if the system does not appear to be that old.
- Consider the means through which the program is marketed and how the program could bring CAC replacement rebates to the attention of participants earlier in the process. Currently, participants are most likely to learn about CAC replacement rebates from the HES vendor, followed by the utility website and a contractor. In order to reach the target audience with rebate information sooner in the program process, thus improving the likelihood of early CAC replacement, the Companies or EEB may wish to consider exploring other approaches for getting the word out about the availability of substantial rebates for CAC replacement and other residential measures earlier in the participation process. For example, immediately upon receiving an application, prior to approving it, the Companies could automatically send the applicant an eye-catching email or hardcopy mailing with information about the benefits of early CAC replacement and quality installation. There could be a "countdown" of periodic emails or mailings about the program from the point of application to the actual visit.
- While the energy auditor clearly plays an important role in participant decision making, most participants reported that the installation contractor was even more important. The Companies or EEB may want to help foster closer relationships between HES vendors and CAC installation contractors to increase the likelihood that customers who obtain an audit will follow through with replacing their CAC with high efficiency equipment.
- Continue to make financing available for CAC replacement. While only 16% of participants took advantage of financing, its availability mattered a great deal to the majority of these customers.
- Although measuring free ridership was not an objective of this study, the findings suggest that users of the early replacement rebate were more likely to have been aware of the rebate prior to their HES audit—pointing to free ridership. However, users of the early replacement rebate were no more likely than standard rebate users to report having prior plans to install CAC equipment—suggesting free ridership is not higher among this group. It may be worthwhile for the EEB to take these factors into consideration when measuring CAC free ridership for early replacement rebate users in the future.
- In light of the findings in this report and the recent Massachusetts Cool Smart evaluation, the Companies may wish to reconsider the decision to discontinue the early replacement rebate. If the Companies decide to reinstate the early retirement rebate, it may be worthwhile to have

vendors explore the condition of the unit replaced. This information would enable the Companies to develop an algorithm to better categorize respondents regarding early replacement versus replacement on breakdown, understand the differences in their thinking and decision making, and avoid the potential for free ridership.

- The Companies may wish to consider some of the recommendations made by participants to encourage other customers to replace their CAC equipment. For example, given the customer bias against replacing equipment that still functions, the utilities could find ways to ensure that when HES vendors recommend replacing CAC, they always provide information on costs and savings and the logic of replacing older but still-functioning units with new units of higher efficiency. Another option is that they follow up with participants after the audit to encourage them to pursue recommended measures.

- The Quality Installation option could be better supported. HES participant awareness of this option was low. The anecdotal evidence offered by participants in open-ended questions suggests that there are substantial challenges to the implementation of the Quality Installation option, not the least of which is a shortage of qualified technicians. If the Companies wish to garner additional CAC savings by increasing the rate of Quality Installation of CAC in their service territories, they may first need to assess how to increase the number of qualified technicians in their service territories.

The Full report can be found at: https://app.box.com/s/5c9766jgry0am6s7r6b5

R15- Single Family Potential Study- 2013

This report contains findings of a residential Potential Savings Study, for single-family homes, which NMR (from here on referred to as "the Team") conducted on behalf of the Connecticut Energy Efficiency Board (EEB). The following descriptions detail each of the four critical study components. See Section **Error! Reference source not found.** for details on the methodology, which vary for each study component.

- **Technical Potential Savings:** The total amount of energy savings that are technically feasible over a ten-year period from 2013 to 2022. These estimates *do not* take into account the cost-effectiveness of home energy upgrades. These estimates assume all measure upgrades are applied immediately.
- **Cost-Effective Potential Savings[4]:** The amount of energy savings that are technically feasible and cost-effective to achieve over a ten-year period from 2013 to 2022.
- **Achievable Potential Savings:** The amount of energy savings that are technically feasible, cost-effective, and achievable through over a ten-year period from 2013 to 2022. These estimates also take into account the likelihood of energy upgrade adoption and the evolution of codes and standards.
- **Fuel Switching Potential Savings:** The potential impacts that result from converting the heating and water heating equipment in single-family homes currently using oil, propane, biomass, or electric heating to either (a) natural gas space heating and water heating equipment, or (b) electric heat pump space heating and water heating equipment.

Figure 2-7 presents a summary of the savings associated with technical, cost-effective, and achievable potential. As shown, fuel oil is responsible for the majority of savings (using the fuel neutral metric of

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[4] Many of the measures considered for the potential study are not currently incentivized by the Companies and as a result they cannot be screened for cost-effectiveness using the Utility Cost Test. For this reason, the Total Resource Cost test was used to determine whether or not measures were cost-effective.

MMBtu) in each of the potential analyses. This is primarily due to the fact that fuel oil is the most prevalent heating fuel among single-family homes in Connecticut.[5]

Figure 2-7: Ten-Year (2013-2022) Aggregate Savings by Fuel Type

(Base: All SF homes, weighted to the population)
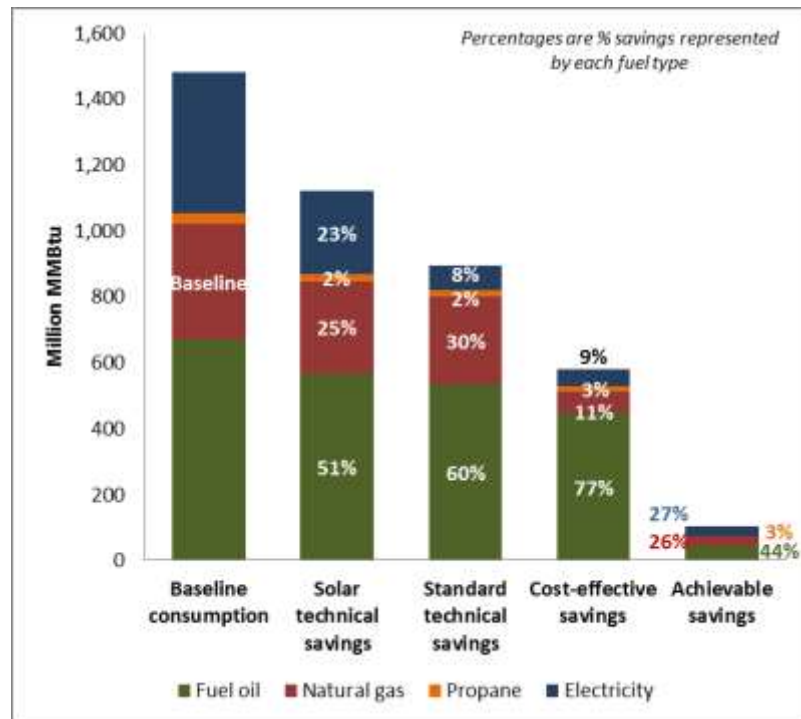
The following conclusions and recommendations were identified as part of this evaluation. Conclusions and recommendations are presented for the potential study (i.e., technical, cost-effective, and achievable) and fuel switching analyses separately as these results should be considered independent of one another.

Technical, Cost-Effective, and Achievable Potential

Conclusions

- Of the 43 measures considered in this study, ductless mini-split heat pumps have the largest technical potential for energy savings (in terms of MMBtu, see **Error! Reference source not found.**). This is due to the high efficiency of the units, the fact that they can displace a high percentage of a home's heating load, and the versatility of the technology to be installed in any home.
- Fifteen out of the 43 measures considered have an average benefit/cost ratio that is greater than one when using the Total Resource Cost (TRC) test (**Error! Reference source not found.** and **Error! Reference source not found.**). Of these 15 measures, all but foundation wall insulation and water heater tank wrap insulation are currently incentivized through the HES and HES-IE

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[5] Of the 180 homes audited for this study, 111 were primarily heated by fuel oil.

programs. These results indicate that the HES and HES-IE programs are already targeting the majority of cost-effective measures through their incentive efforts.

- o Air sealing, duct sealing, ceiling insulation, and wall insulation are all key measures that are incentivized by HES and HES-IE with mean benefit/cost ratios that are greater than one.
- Ductless mini-split heat pumps and heat pump water heaters are two emerging technologies that have an average benefit/cost ratio that is greater than one when using the TRC test (**Error! Reference source not found.**). Current market penetration for these measures is extremely low (see Section **Error! Reference source not found.**), indicating there are significant cost-effective savings opportunities associated with these technologies moving forward.
- Achievable potential, which accounts for the likelihood of energy upgrade adoption as well as codes and standards, shows that fuel oil (7%), natural gas (8%), propane (10%), and electricity (7%) all have a savings potential between 7% and 10% of baseline consumption over the ten-year period assessed in the analysis.

Recommendations

- The Companies should consider adding foundation wall insulation and hot water heater tank wrap insulation to their list of incentivized retrofit measures.
- The Companies should continue to provide incentives for ductless mini-splits and heat pump water heaters; the Companies may want to consider increasing current incentive levels to increase the market penetration as the potential savings from these measures are substantial (see Section **Error! Reference source not found.**).
- The Companies should review their savings calculations and cost-effectiveness screening processes to ensure that known changes to codes and standards are incorporated.

Fuel Switching

Conclusion

- Under the upgrade case, assuming program incentives are available for high efficiency equipment, fuel switching has the potential to decrease fuel oil consumption by 21% and propane consumption by 18% if conversions take place at 25% of potential single-family homes. These percentages are only slightly higher than the 19% of savings for fuel oil and 15% of savings for propane under the base case scenario with 25% uptake in fuel switching. Similar increases are reflected at the 50%, 75%, and 100% conversion levels.

Recommendations

- Potential fuel oil and propane savings from fuel switching are significant. The Companies should consider the best ways to promote fuel switching among single-family homes in Connecticut.
- Incentives designed to influence homeowners to fuel switch, thereby increasing the overall rate of fuel conversions, will have a more significant impact than incentives for high efficiency equipment once a fuel switch has already taken place. The Companies should consider offering an incentive for fuel switching if reducing fuel oil and propane consumption is a goal moving forward.

See full report at: http://www.energizect.com/government-municipalities/single-family-potential-study-r15-review-draft-9-5-14

R16- HES/HES-IE- Impact Evaluation and Effective Useful Life Study

Objectives and Priority Outcomes:
The Connecticut Energy Efficiency Board (EEB) requires an impact evaluation of the Home Energy Services (HES) and Home Energy Services-Income Eligible (HES-IE) programs offered by the following Connecticut utilities: Connecticut Light & Power (CL&P), The United Illuminating Company (UI), Connecticut Natural Gas (CNG), Southern Connecticut Gas (SCG), and Yankee Gas Services Company (YGS). The impact evaluation sought to provide evaluated estimates of energy and demand savings associated with measures installed through these programs. The NMR Group and Cadmus, its subcontractor (collectively referred to as the Evaluation Team), conducted this evaluation.

The results have been provided in two volumes, each focusing on a different approach for evaluating the impacts for the program year 2011 HES and HES-IE programs:

- *Volume 1* provides the results of a whole-house billing analysis that estimates average participant (household-level) electric and natural gas impacts.
- *Volume 2* includes a measure-level impact evaluation, providing estimates of per-unit savings for measures offered through the HES and HES-IE programs and using an array of evaluation tasks, such as billing analysis, calibrated simulation modeling, and engineering analyses. Volume 2 also includes a whole-house billing analysis that estimates the electric and gas energy impacts for two of four HES-IE subprograms.

Both methods are considered industry "best practices", and both provide valuable information for Connecticut's programs.

Approach and Work Plan:

- **Whole-house billing analysis** is a statistical analysis (using fixed-effects regression models) providing household-level savings estimates. This analysis used data from participating households that had sufficient billing data both prior to and after participation. Whole house billing analyses are used around the nation to provide best practice results for estimating savings impacts and associated realization rates for a variety of energy-efficiency programs, in particular whole-house programs. The Evaluation Team performed the whole-house billing analysis for HES and HES-IE (in Volume 1), including two CL&P-specific subprograms (i.e., SP1 and SP4) (included in Volume 2).
- **Measure-level analysis** uses a multiple-method approach to identify the best estimates of energy savings for individual measures. The analysis used fixed-effects, savings regression models and two engineering analysis approaches (addressing measures with and without interaction effects) to estimate measure-specific savings for the most common fuel types (e.g., electric, natural gas, propane, and heating oil). The measure-based evaluation and realization rates provide specific information to refine PSD savings calculations. The results of the measure-level analysis for HES and HES-IE are include in Volume 2., with the exception of two CL&P-specific HES-IE subprograms (i.e., SP1 and SP4), which were addressed using a whole-house billing analysis (also presented in this volume).

The realization rates resulting from the different analytical approaches used in Volume 1 and Volume 2 are presented below. The differences in the realization rates for each type program (HES vs. HES-IE) and each type of savings (electric vs. gas) is largely due to slight differences in the measure distributions between the sample of households included in whole-house billing analysis and the program populations as reflected in the program tracking data. For HES-IE, there are also some differences related to differences in the treatment of HES-IE subprograms.

Figure 2-8. Comparison of Realization Rates by Report Volume

	Electric Savings		Gas Savings	
Program	Volume 1*	Volume 2**	Volume 1*	Volume 2**
HES	117%	111%	58%	64%
HES-IE	82%	79%	50%	55%

* Volume 1 realization rates for HES-IE present an average that includes model realization rates for SP2 and SP3, proxy realization rates for SP1 (based on building- and utility-specific models), and excludes SP4.

** Volume 2 realization rates for HES-IE present an average that includes measure-level impacts for HES-IE SP2 and SP3 and whole-house impacts for SP1 and SP4.

Recommendations

The Evaluation Team recommends using whole-house billing analysis realization rates for estimating electric savings and measure-level realization rates for estimating gas savings, with the exception of HES-IE SP1 and SP4 for which whole-house billing analysis realization rates are all that are available. The combined report will present findings from both analytical approaches.

The Evaluation Team has developed several recommendations related to improved data management as well as several measure-specific recommendations. These recommendations address challenges that arose in working with utility billing and program tracking data throughout this study, and have been based on the impact evaluation findings and assessment of results.

Data Management

Some additional suggestions follow for improvements in data management. These adjustments will not only benefit evaluation efforts; they will provide valuable data to inform the future delivery of these programs:

- ***Measure-specific inputs require better tracking within the utility program tracking systems*** to calculate savings based on Program Savings Documentation (PSD) algorithms. In many cases, the tracking system did not provide the details used for these calculations (e.g., windows, no baseline or efficient unit descriptions or installed square footage).

  - Many challenges arose in identifying measure names/descriptions and, in some cases, disaggregating a category into specific measures for energy-savings calculations (e.g., appliances, insulation).

- ***Consistency should increase between utility tracking systems*** for programs and measures, particularly if the programs continue to be reported and evaluated jointly across gas and electric utilities.

  - Align terminologies, such as: discrete measure categories (including subcategories and descriptions, as necessary); measure input values (e.g., efficiency levels); program and subprogram names; and building/household/equipment characteristics.

- Consistently collect household/equipment characteristics that feed into detailed savings calculations (such as building types, heating fuels, and heating and cooling equipment).
- Integrate database QA protocols to ensure consistency within projects:
  - For example, the value of conditioned square footage from an initial home audit should match reported conditioned square footage collected in subsequent visits for follow-on measure installations; in some instances, audit data reported conflicting information for individual participants.
- Ensure fields are populated consistently with standardized values: many differences occurred within and across utility data regarding the methods for defining or describing measures; unpopulated fields (blanks) could be appropriately replaced with values such as "n/a" or a quantity of zero.

- **QA check information by project**. Specifically for insulation, QA checks should determine whether installed square footage quantities surpass reasonable values relative to a reported, total, conditioned floor area. Additionally, checks could ensure fuel-specific savings calculated for a project remain consistent with information provided for that site regarding heating and water heating fuel, and the presence and/or type of cooling equipment.

- **Improved tracking of project data for multifamily buildings.** Reporting should be consistent at the unit level. The Evaluation Team observed that tracking data and billing data could not always be directly mapped. Billing data often were presented at the facility level, while measure data often were presented at the unit level; a unique identifier to link these data sources should help to resolve this issue. If program tracking data can maintain consistency for multifamily participants in recording information at the unit level, this unique identifier for multifamily units should be present in the billing data to facilitate integration.

- **Improve the ability to easily export program tracking data** for specific programs in isolation. In some cases, challenges emerged in identifying measures attributed to HES and HES-IE programs (versus other energy-efficiency programs). In several cases, lacking a program identifier, the Evaluation Team had to identify program-attributed measures using measure descriptions and rebate levels. Recommended actions include creating a data dictionary for existing variables and always adding a variable description when including new fields/values to the dataset.

- **Ensure program tracking of both electric and gas account numbers.** This would facilitate accessibility and connections to other databases, using account numbers as unique identifiers (e.g., billing and transaction data). Alternatively, another unique identifier currently utilized by utilities could possibly better facilitate this process.

Measure-Specific

Ductless Heat Pumps
Based on measure-level and whole-house findings, *ex ante* savings estimates for ductless heat pumps overestimated actual savings and did not account for scaled-down savings, which could relate to take-back effects or the accuracy of baseline assumptions (e.g., some level of continued baseboard heating or increased cooling loads). More detailed analysis should be performed, specific to this measure, for HES

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Prepared by Skumatz Economic Research Associates (SERA), Apex Analytics, & AEC

and HES-IE participants (and could include other programs offering ductless heat pumps in Connecticut). Region-specific research would help clarify discrepancies between current planning estimates and evaluated savings, refine assumptions regarding baseline conditions, and identify key inputs that the current algorithm does not account for.

Faucet Aerators
Based on the engineering review and benchmarking performed on the faucet aerator measure, the savings algorithms and inputs used for the energy-savings calculation should be adjusted to incorporate a drain factor and to use the water heater recovery efficiency rather than the energy factor.

Showerhead
Much like faucet aerators (above), the utility should use the water heater recovery efficiency rather than the energy factor when determining energy savings for showerheads.

Pipe Insulation
The Evaluation Team recommends setting a maximum linear feet of pipe insulation to be used in calculating savings for this measure (i.e., approximately six feet of pipe insulation per water heater).

Window AC
Utilities should ensure that window AC replacements installed through the program meet minimum efficiency requirements, and claimed savings should account for the installed efficiency collected through tracking data (rather than assuming a constant installed efficiency from the PSD). As discussed, the Evaluation Team found, in many cases, that installed units proved less efficient than the CEER Tier 1 or Tier 1 levels,
See full report at:

- http://www.energizect.com/government-municipalities/2014-hes-impact-evaluation-volume-1-review-draft
- http://www.energizect.com/government-municipalities/heshes-ie-impact-evaluation-r16-vol-2-review-draft-6-5-14

R48- HES Additional Measure Review- 2014

Objective and Priority Outcomes:
The 2014-2016 EEB Program Evaluation Plan calls for the completion in 2014 of a "Market Assessment/Literature Review/Performance Evaluation for Incorporation of High Performance Measures into HES/Res Programs." The primary objective of this study is to identify cost-effective measures from the Potential Study to understand the drivers and barriers to integrating these measures into existing HES programs.

Approach and Work Plan:
The study drew upon the R15 Potential Study, which includes a component to assess the cost effectiveness of measures that may results in savings for the HES program. The study considers key components such as enhanced shell measures, high efficiency mechanical equipment, high efficiency appliances, and increased efficient lighting saturation and address savings for natural gas, fuel oil, and electricity.
Based on the findings of the Potential Study, the evaluation team identified the best candidates for cost-effective potential savings among measures or efficiency levels currently not incentivized by the program. The four measures identified were wifi-thermostats, foundation wall insulation, water heater tank-wrap, and solar assisted hot water systems. The team then performed an internet-based search to learn more about the drivers and barriers to adding these measures to program offerings, most likely through HES and HES-IE. Where applicable, the internet search also touched on the experiences that other programs have had with promoting these measures, both within HES-like programs as well as stand-alone programs (including incentive, financing, and education-based programs). The team reported the results, as well as some preliminary insights into ways in which these measures could be incorporated into the Connecticut Energy Efficiency Fund program offerings (or the reasons not to do so).

Recommendations:
This study recommends that Companies incentivize water heater tank wrap insulation and consider incentivizing Wi-Fi thermostats moving forward.

- **Wi-Fi Thermostats**- "Smart" thermostats allow occupants to adjust their thermostat to set points remotely. This technology could enable homeowners to change their behavior in ways that could potentially lower energy consumption. This product was not included in the potential study and was added here at request of EEB Evaluation Consultant.
    - Market Drivers- Alerts, and other monitoring features, self-adjusting ability tailored to occupant's behavioral patterns, and possible Smart grid integration.
    - Market Barriers- Upfront cost; the average unit cost is around $200. Wi-Fi, Access. Contractor labor may be needed. Security and Privacy concerns.
    - Recommendation- Companies should consider offering an incentive for WI-FI Thermostats that does not exceed $100. Pilot studies in MA and NH both showed savings from Wi-Fi thermostats and both states offer such an incentive. This measure was not screened for cost effectiveness.
- **Foundation Wall Insulation**- 34% of CT homes with foundation walls in conditioned space have un-insulated foundation walls, this indicates a significant opportunity for foundation wall

insulation improvements in existing single-family homes in the state. This measure has a B/C ratio of 1.56. Few companies incentivize this measure.

- o Market Drivers- Various installation options, creation of a more comfortable space.
- o Market Barriers- Moisture problems- it can create or magnify moisture problems and can create mold/mildew programs. Cost could be a factor as well, as the cost from this measure may be higher than the cost of insulating other building components.
- o Recommendation- Companies should consider the pros and cons of providing incentives for foundation wall insulation. Potential liability from unintended moisture problems may preclude this upgrades inclusion in the HES and HES-IE program. Nevertheless, incentivizing this type of installation is likely to provide cost-effective energy savings and increase compliance with the current weatherization standard.

- **Water-Heater Tank Wrap Installation**- A low cost retrofit, tank wrap has been shown to produce cost-effective savings for older storage tank water heaters. The recent potential study suggests this measure on average is cost effective when self-installed (B/C of 6.93) or when installed by a contractor (B/C 1.83).
  - o Market Drivers- Cost- insulation is easy to procure relatively cheap and can be found in most hardware stores for around $25. Can be self-installed.
  - o Market Barriers- Increasing R-Value of New storage tanks, this measure is likely not cost effective on newer tanks. Self-installation challenges
  - o Recommendation- Companies should directly install tank wrap insulation through the HES and HES-IE programs in homes with older water storage tanks. U.S. DOE proposes installing external insulation when the internal water heater insulation is less than R-24. HES and HES-IE vendors should identify the existing R-Value for water heater tanks during site visits and install tank wrap insulation where applicable.

- **Solar Assisted Hot water Systems**
  - o These systems use solar panels to collect the sun's thermal energy and heat water for domestic use. CT currently offers financing for solar thermal installations but does not offer any additional incentives. There are federal tax credits available for solar thermal installations which reduce the costs for homeowner though the up-front cost can still be quite expensive. They have a B/C ratio of 0.85.
    - ▪ Drivers- Federal Tax Credits, State-level incentives.
    - ▪ Barriers- Lack of awareness, Competitive high efficiency water heaters- can outperform some solar heaters and are typically cheaper.
    - ▪ Recommendation- Companies' should continue to focus incentive efforts on heat pump water heaters, and high efficiency gas water heater

See full report at: http://www.energizect.com/about/eeboard/evaluationreports

R67- Lighting Interactive Effects Study

Objectives and Principal Outcomes

Lighting has been one of the most important contributors to savings from Connecticut programs, but lighting has interactive effects with other installed measures (especially heating/ventilation/air-conditioning, or HVAC), complicating evaluation and attribution. Interactive effects are examined for most lighting programs now around the country, but have not been estimated specifically for Connecticut residential programs. This research works to enhance the reliability of estimates of savings from this measure going forward. The study will leverage:

- significant work that has already been conducted to collect market penetrations of various HVAC technologies, building shell characteristics, and run times for both the lighting and HVAC measures impacted,
- existing building simulation modeling work to estimate interactive effects, and
- estimates of the interactive effect savings impacts from lighting measures on other measure savings.

Approach and Work Plan

The project will research, quantify and develop an approach to the interactive savings effects of reduced wattage of common residential light measures using methodologies explored and demonstrated in other studies. Using information on prototypical homes already available and accepted engineering methods, the project focuses on developing, if possible, a common set of interactive factors for demand and energy savings based on typical HVAC systems. The research will focus on market penetrations of various HVAC technologies, building shell characteristics, and run times for both the lighting and HVAC measures impacted.

Summary of Results

Compact fluorescent light bulbs (CFLs) and light-emitting diodes (LEDs) emit substantially less heat than incandescent bulbs because they convert a much larger percentage of the energy used into light. For this reason, replacing incandescent bulbs with more efficient bulbs results in a small but real impact on the amount of energy consumed by heating, ventilation, and air-conditioning (HVAC) systems. This is referred to as *interactive effects* (IE). Failure to take these interactive effects into account can lead to inaccurate estimation of savings from lighting retrofits. NMR conducted four separate analyses as part of this study to measure interactive effects in Connecticut residential units. Figure 2-9 summarizes the results of each IE factor analysis. Precision estimates describe variation among the IE factors only.

Figure 2-9: Interactive Effects Factors Summary

Factor	Number of Sites	Average IE Factor	Precision at the 90% Confidence Level	
			Number	Percent
Electric energy IE factor	180	1.04	± 0.013	± 1%
Electric demand IE factor	180	1.05	± 0.003	± <1%
Heating fuel IE factor	180	1,902	± 38	± 2%
Gas takeback factor	48	0.56	± 0.024	± 4%

Each analysis calculates a different factor with which lighting retrofit savings can be adjusted to account for the changes in heating and cooling usage that result from the installation of efficient lighting.

REM/Rate™ energy models initially developed for the Connecticut Weatherization Baseline Assessment were used to simulate these interactive effects.

The electric energy analysis results in an average electric IE factor of 1.04. This means that an efficient lighting retrofit in the average Connecticut home will result in 104% of the electric energy savings attributable to the efficient bulbs alone due to interactive effects.

Concurrently, the same retrofit will result in a heating IE factor of 1,902 BTU/kWh. This means that for every kWh saved in lighting, 1,902 BTU in additional annual heating usage will result, on average. This translates to about 0.07 MMBtu annually per bulb, or 1.8 MMBtu annually from a 25-bulb retrofit (the maximum number of efficient bulbs installed through the Home Energy Solutions (HES) program). The heating IE factor applies only to homes that heat with a fuel other than electricity, because heating system interactive effects for electric-heated homes are captured in the electric IE factors.

The analysis also results in a gas takeback factor of 0.56. This means that for the average gas-heated home in Connecticut, 56% of the energy saved by installing more efficient bulbs is negated by the increase in gas heating requirements. The gas takeback factor is essentially the same as the heating IE factor, except that it is unitless and applies only to gas homes. Because it equates electricity and gas, it is best viewed as a way to contextualize interactive effects rather than measure them. It is included in this study because it is a common method of describing interactive effects for gas-heated homes.

See full report at: http://www.energizect.com/government-municipalities/residential-lighting-interactive-effects-2nd-review-draft-11-10-14

3. STUDIES IN PROGRESS (Draft Reports)

3.1 Commercial

C20- Energy Conscious Blueprint Program Process Evaluation

Objective and Priority Outcomes:
The objective of the Energy Conscious Blueprint (ECB) program is "to maximize electric and natural gas energy savings for 'lost opportunity' projects, at the time of initial construction/major renovation, or when equipment needs to be replaced or added." The ECB program seeks to accomplish this by working with new construction trade allies to raise awareness of energy efficient technologies and whole-building design practices and assist these allies in illustrating the benefits of energy efficiency during initial construction to property developers and owners. The program also provides incentives to building owners for incorporating energy efficient equipment into building design or for using energy efficient equipment to replace equipment at the end of its usable life.

The objectives of this evaluation were to assess the program's effectiveness in reaching its target market, assess participant and vendor satisfaction with the program, and identify barriers that could inhibit the program from achieving its goals.

Approach and Work Plan:
During the sample period from April 2013 to April 2014, program participants achieved over 136,000 mmBTU in annual energy savings from 420 projects and 751 individual measures. New construction projects accounted for one quarter of projects and 37% of energy savings in the period. Process, lighting, and heating measures comprised the majority of ECB program savings, while cooling measures comprised the greatest number of measures. Heating, process, and lighting measures had the greatest average per-measure savings.
The process evaluation was based on analysis of program tracking data, surveys of 70 program participants, 13 program dropouts, and 41 vendors working with the program, and interviews with 10 non-participating customers or "rejecters." The process evaluation also included web usability testing with 18 vendors and participants to assess how the website meets the needs of program stakeholders.

Results:
Results from the process evaluation indicated that the ECB program is functioning smoothly for participants and vendors. Participants in particular demonstrated high satisfaction with the program. Vendors partnering with the program appear to drive most equipment replacement projects through their marketing efforts, while utility and program staff appear to be the impetus behind many new construction and major renovation projects. Many vendors rely on the ECB program for a quarter or more of their business, and some requested additional support and greater responsiveness from program staff.
Customers rely on utility and program staff to learn how to participate, and vendors rely on utility and program staff to answer questions. Participating customers, dropout customers, and participating vendors all identified financial factors—lack of access to capital and financing—as barriers to completing projects. Participants consult the utility websites to learn more information about the program but do not use it to figure out next steps to participate in the program. Participating vendors typically use the website to look up incentive information. The findings from web usability sessions indicate that although there is useful information on the Connecticut Light & Power and United Illuminating websites, it is challenging for both vendors and customers to find this information.

Recommendations:
Based on the findings of the process evaluation, the evaluation team proposes the following recommendations:

- Promote awareness of financing sources and consider expanding financing options. Dropout customers, participating customers, and vendors consistently identified financial factors as potential barriers to program participation. While some options are available for project financing these options could be more effectively communicated or expanded.
- Dedicate additional resources and/or develop tools to support vendors. Vendors play a key role in promoting these programs, and while most vendors reported being satisfied they also indicated ways in which they desire more support from the utilities.
- Increase outreach efforts to individuals involved with new construction projects. Awareness of the ECB program is low among some building owners, project managers, architects, and developers involved with new construction, and performing outreach to these parties, though time intensive, could help increase the number of new construction participants.
- Consider providing improved signposting that enables more effective webpage scanning. Both vendors and customers requested a more intuitive organizational structure for the website that used common program description titles so that they can quickly locate the information they need.
- Implement changes to program tracking database to improve program evaluability and project tracking for staff. Based on the work conducting the process evaluation, the evaluation team proposes a number of changes or additions to the program tracking database to facilitate the tracking of performance indicators and to improve evaluability.

C11- Barriers to Commercial and Industrial Program Participation with a Focus on Financing and Cancellations

Objective and Priority Outcomes:
The Connecticut Energy Efficiency Fund (CEEF) supports programs and initiatives to advance energy efficiency. Connecticut Light & Power and United Illuminating administer and fund the electric programs. Connecticut Natural Gas, Southern Connecticut Gas, and Yankee Gas fund gas programs from conservation charges on the natural gas bills. The programs provide financial incentives and/or financing mechanisms, information, technical assistance, tools, and educational services to encourage businesses to undertake energy efficiency investments. Utilities and state programs around the country have often fallen short of their participation goals for these programs because numerous challenges and barriers are faced in obtaining business sector participation. This report provides a summary of commercial and industrial (C&I) market research that was undertaken to better understand the specific barriers and challenges faced by program nonparticipants and program dropouts in Connecticut and to understand the potential opportunities for increasing participation.

Approach and Work Plan:
The population of interest was segmented into several groups to meet the goal of understanding the characteristics and issues faced by the various market segments. Program nonparticipants in the following market segments were sampled for the study, where small was defined as average demand of 10 to 200 kW and large was defined as average demand greater than 200 kW.

- Small nonparticipating manufacturing businesses

- Large nonparticipating manufacturing businesses
- Small nonparticipating general market businesses
- Large nonparticipating general market businesses

Program dropouts were divided into two groups for the study.
- Small dropout businesses
- Large dropout businesses

The surveys focused on the following research areas.
- Business Characteristics – business type and building ownership issues
- Decision Making – process and responsibilities for investment decisions
- Information and Awareness – how respondents learn about energy efficiency and knowledge of CT's energy efficiency programs
- Investments – criteria for energy efficiency investment decisions
- Financing – importance of financing and interest in potential financing vehicles
- Barriers and Opportunities – barriers to undertaking efficiency investments and offerings that may increase the likelihood of participation

Because of the low response rates and small sample sizes, this study does not provide definitive conclusions, but rather provides a range of options and a qualitative understanding of the barriers and opportunities faced in these market segments.

Results:
One of the key goals of this research study was to identify the barriers to participating in the C&I energy efficiency programs and the factors that may enable customers to participate. Program nonparticipants and dropouts were asked to rate the barriers on a scale of 1 to 5 where 1 represents "not a barrier at all" and 5 means "a very significant barrier". The research found that most nonparticipants and dropouts (ranging from 65 percent to 85 percent of the six groups) rated two or more of the following issues as a 4 or a 5 on the scale indicating that it was a significant or very significant barrier.

- Lack of awareness of opportunities for efficiency
- Lack of credible information on efficient alternatives
- Lack of staff resources (*e.g.,* time) for implementation
- Lack of capital for investment
- Absence of acceptable financing mechanisms
- Lack of confidence in energy/cost savings claims
- Lack of availability or longer-delivery times for efficiency measures
- Perception that efficiency delivers less on other values, (*e.g.*, production, comfort)
- Competing priorities taking precedence
- Lack of credit quality
- Do not plan on staying long enough in the property
- Inability to share capital costs of energy improvements with tenants
- Other specified by respondent

Program nonparticipants and dropouts were most likely to face logistical barriers including a lack of staff resources, a lack of availability of efficiency measures, not planning to stay in the property, and

competing priorities taking precedence. Over 75 percent of most of the groups rated at least one of these barriers as significant or very significant.

This is a challenge for the program because these barriers are more difficult for the program to address. However, additional information and technical assistance may be a potential means to help overcome such barriers for some of these businesses. For example, lack of staff resources may be addressed by providing a turnkey solution. Not planning to stay in the current location may potentially be addressed if the program provides specific information on the expected payback time for the investment or providing broader information and offering of Connecticut's Commercial Property Assessed Clean Energy (C-PACE). The C-PACE program allows building owners to finance qualifying energy efficiency and clean energy improvements through a voluntary assessment on their property tax bill. Property owners pay for the improvements over time through this additional charge on their property tax bill and the repayment obligation transfers to the next owner if the property is sold. A third potential option for some of the businesses with competing priorities is to reassess the relative value of energy efficiency with greater information on non-energy impacts for their type of business, information on payback that might be better than they had assumed, or information on other potential combinations of program services.

When asked about factors that would encourage the company to consider an energy efficiency project in the future, both nonparticipants and dropouts were most likely to report factors that could potentially be addressed with information on the payback of the energy efficiency measures, including the reduced energy bills, reduced maintenance cost, and the return on the investment. The majority of these customers identified at least one of these factors as something that would encourage the investment.

Nonparticipants and dropouts were also asked about specific program offerings that would make them significantly more likely to take energy efficiency actions. Most of the respondents identified at least two programmatic opportunities that would make them significantly more likely to take action.

However, many of those who stated that they would be very likely to take action on energy efficiency if one of these offerings were available had barriers that the energy efficiency programs are unlikely to address. These significant barriers were as follows.
• Lack of staff resources (*e.g.*, time) for implementation
• Competing priorities taking precedence
• Do not plan on staying long enough in the property
• Inability to share capital costs of energy improvements with tenants

A much lower percentage of customers stated they would be likely to improve energy efficiency but did not have one or more of the four barriers listed. For example, while 57 percent of small manufacturing customers stated that zero or low-interest loans would make them more likely to take on energy efficiency improvements, only three percent stated this and did not have any of those four barriers. In general, financing did not appear to be a key solution for the barriers. The majority of nonparticipants stated that financing was only of moderate or lower importance in their decision to move forward with an energy efficiency project. At least one quarter of each nonparticipant group except small manufacturing (13 percent) stated that they were not interested in outside financing.

Key findings from this analysis were that most nonparticipants and dropouts have more than one barrier preventing them from undertaking energy efficiency projects. The barriers were most likely to be logistical, which make it difficult for the utility to provide assistance to help customers. There were several opportunities to encourage participation. Most nonparticipants and dropouts named at least one factor that would encourage the company to consider an energy efficiency project in the future, and most nonparticipants and dropouts selected two or more of the programmatic options that would make it significantly more likely for the business to take action on energy efficiency opportunities. The most important factors were information on investment payback and programmatic financial and informational support. However, it is important to understand that these businesses may still face significant challenges to energy efficiency.

3.2 Residential

R84- Consumer Electronics and Potential Study

Objectives and Principal Outcomes
Consumer electronics are a growing industry and account for an increasingly greater proportion of residential electricity load. The project examines the market for consumer electrics to determine program savings/impact potential and identify future program offerings and enhancements. This evaluation will be a two-step process. First, the evaluation will examine available literature and perform in-depth interviews to scope what primary research, if any is needed. The study then may include a saturation study to determine detailed program savings potential for consumer electronics and identify best practices for such programs.

Approach and Work Plan
This area changes very quickly, so scope and budget will need to be carefully crafted; the project could focus on specific measures or focus on limited aspects of the range of questions related to these measures. Project design elements may include in-depth interviews with manufacturers, retailers, internet and cable service providers, other program managers, and others associated with the defined measures (potentially televisions, computers, power strips, and related peripheral devices or other appliances), depending on the ultimate scope of the project.
In order to identify the potential for a residential customer electronics program in Connecticut, NMR Group, Inc. (NMR) conducted a literature review for the Energy Efficiency Board (EEB). To this end, NMR researched literature published between 2012 and 2014 and used this information to estimate potential energy savings associated with consumer electronics measures. In addition to reporting these findings, this report contextualizes the savings measures within the confines of market barriers that might affect willingness to participate, market trends that might increase chances of free ridership, and saturation rates that might limit the technical potential for a program to make an impact in the territory.

Many of the findings suggest that the EEB may benefit from commissioning a more detailed consumer electronics potential study in the future. Ideally, a future study would provide greater detail on both program and energy savings potential through one of the following methods: 1) qualitative research involving activities such as in-depth interviews; 2) quantitative research, potentially using surveys with market actors, performing home site visits, or conducting secondary data analyses, if possible; or 3) both types of research.

Recommendations

NMR focused on a number of measures that could yield reasonably high per-unit or per-household energy savings for the top five energy-consuming consumer electronics products. For each product category, the team found at least one measure that could be implemented in the near term. Some of the most promising measures and NMR's suggested considerations and recommendations related to these measures are as follows:

- **Televisions (TVs).** The team estimated that replacing older installed TV models with new "best-in-class" models could offer sizable savings over the installed base. Depending on size, upgrading to new ENERGY STAR® Most Efficient TVs could offer 38% savings in UEC when compared to standard new TV models. If the EEB wishes to address TVs through a consumer electronics program, it might consider investigating the potential of offering TV recycling programs and incentives based on labels and recognition programs directed at end-users, retailers, and distributors. Because of high ENERGY STAR market penetration, it may be preferable that models eligible for program incentives meet efficiency levels greater than ENERGY STAR's minimum specifications or leverage ENERGY STAR's Most Efficient list, which recognizes the highest efficiency TVs.

- **Set-top boxes (STBs).** The following two measures for reducing STB energy consumption stand out as potential near-term measures that do not require partnerships with groups like manufacturers or media service providers and appear realistic to implement: 1) Reconfiguring high-consuming multi-room STB configurations by replacing the non-primary devices with low-power thin-client devices that have the same functionality could potentially reduce annual UEC of those non-primary units by 52%; 2) Selecting ENERGY STAR models could offer savings of 45% over standard models.[6] NMR concludes that addressing STBs through end-user incentives, however, may be inappropriate due to certain market dynamics. First, on top of already high ENERGY STAR market penetration, an important voluntary agreement signed by media service providers will likely result in even higher market penetration of ENERGY STAR models. Second, consumers may not be able to opt for energy-efficient STB models or engage in energy savings behaviors due to the level of control that media service providers have over STB model selection and time spent in off modes.

- **Personal Computers (PCs).** NMR found that optimizing power management settings for the installed base of desktop PCs could possibly result in savings of 144 kWh/year among installed desktop PCs and, if successfully implemented in all households where the measure is not already implemented, it could have the technical potential to save 43.4 GWh/year in Connecticut as a whole.[7] If the EEB were to use this intervention, it might like to use consumer education campaigns on optimizing power management and/or use direct-installation efforts, perhaps as part of a home energy audit visit for another program. However, some factors, such as decreasing desktop PC sales and increasing efficiency of laptop PCs, could present diminishing

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[6] If the Companies have interest in pursuing this further, a potential next step could be to conduct interviews with media service providers operating in Connecticut to learn about the types of devices that they currently offer or provide.

[7] The team emphasizes that achieving participation in 100% of households without the measure already implemented is an unrealistic scenario.

opportunities to claiming sizable program savings and achieving adequate participation rates for a PC program.

- **Network Equipment.** Replacing the installed base of network equipment[8] with high efficiency equipment may generate notable savings (34%). Running equipment recycling opportunities and offering incentives based on labeling and recognition programs directed at end-users, retailers, and distributors could facilitate implementing this measure. Additional research characterizing common configurations and household usage patterns would offer further insight into savings opportunities at the household and state levels; further research on network equipment market trends would also be essential.

- **Video Game Consoles (Game Consoles).** NMR advises against offering incentives for the purchase and sale of energy-efficient models of game consoles. Program efforts targeting game consoles may quickly become obsolete, in part because there are few game console models and manufacturers; even if one manufacturer increases the efficiency of its only model, program efforts to incentivize the purchase of energy-efficient models could result in easy free ridership. As a near-term effort, game console efficiency might be addressed through consumer education campaigns. For example, measures to decrease the consumption of game consoles, such as disabling connected standby, could provide savings of up to 100 kWh/year.

In addition to the measures listed above, it may be worth further exploring the savings opportunities that advanced power strips (APSs) (also known as smart strips) could offer for each of these product categories. One study found that households could save 346 kWh/year, on average, by using highly sophisticated APSs with their home entertainment equipment.[9]

NMR urges the EEB to take several influential factors into account in the process of considering or designing a consumer electronics program. First, while a measure might technically be able to reduce a product's energy consumption, it may be challenging to implement the measure given market dynamics. For example, the measure may have a limited appeal to market actors or may quickly become obsolete because of expected market changes. Additionally, the EEB should keep abreast of changes in voluntary specifications and standards and factor them into any program-planning processes to reduce possibilities of free ridership and redundancy, increase savings opportunities, and streamline programs by leveraging specification structures. Researching these types of factors and staying informed could help drive decisions about which product categories to address and which measures are needed to address them.

Another essential area of future research may include a characterization of the consumer electronics equipment currently installed in Connecticut homes. The EEB may find it useful to conduct a saturation study in Connecticut like the one NMR conducted in Massachusetts[10] to help determine the technical potential savings for implementing measures that are estimated to yield high per-unit or per-household

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[8] Residential network equipment generally refers to two primary equipment types: 1) broadband access devices, which connect subscribers with high-speed internet, and 2) local area network (LAN) devices, such as routers, that allow consumer electronics within the household to communicate with each other.

[9] For more details, see http://www.nyserda.ny.gov/-/media/Files/EERP/Residential/Energy-Efficient-and-ENERGY-STAR-Products/Power-Management-Research-Report.pdf.

[10] In 2012, NMR conducted a consumer electronics saturation study for Massachusetts Program Administrators. For more details, see http://ma-eeac.org/wordpress/wp-content/uploads/Massachesetts-Residentail-Retail-Products_Consumer-Electronics-Saturation.pdf.

energy savings. This quantitative research could involve telephone surveys with customers or home site visits to collect data on characteristics like the number and types of units installed or in use in Connecticut homes.[11]

While this report did not conduct direct research on program implementation methods, the EEB may wish to examine the program models currently employed by other program administrators if it wishes to move forward with consumer electronics. For example, one program in New York uses a direct installation method with APSs that it has found to be successful. Other program administrators have also been offering direct incentive opportunities. It is in the evaluation team's opinion that any program planning efforts in Connecticut would benefit from learning about the efforts of other programs.

R86- Connecticut Residential LED Market Assessment and Lighting Net-to-Gross

This report summarizes the tasks completed to assess the Connecticut (CT) residential lighting market for light emitting diodes (LEDs) and to estimate net-to-gross (NTG) ratios for CFLs and LEDs for the Upstream Lighting Program. The study discusses the evaluation methods used, the key research findings and takeaways, and the resulting NTG ratios estimated from relevant approaches. It also presents a discussion of the relative strengths and limitations of these approaches in order to assist the Energy Efficiency Board (EEB) and Companies in determining the final NTG ratio to apply to the program and assessing program revisions for the 2016 to 2018 program cycle.

Study objectives and Approaches

The main objectives of the R86 LED Market Assessment and NTG Study were to understand consumer reactions to varying efficient bulb types and the Energy Independence and Security Act (EISA), to assess the residential LED market by describing current conditions and exploring future conditions, and to estimate NTG ratios for CFLs and LEDs. Figure 3-1 provides a brief overview of the evaluation activities, which will be fleshed out in the body of the report.

Figure 3-1: Evaluation Overview

Activity	Summary of Approach
Demand Elasticity Modeling	Estimated the price elasticity of program lighting products with an assessment of sales without the program's incentive, thus providing a net-of-freeridership estimate.
POS Data Modeling (n=44 states)	Modeled the CT program's impact on CFL and LED sales using sales data for 44 states over 5 years, along with lighting program and demographic data. Predicted bulb sales in the presence and absence of program activity to develop NTG ratios.
Examination of CT socket saturation trends (n = 95 in 2009, 100 in 2012, and 90 in 2013)	Used 2012 and 2013 CT saturation data to assess saturation trends, comparing those to MA and NYSERDA. 2014 MA data informed likely CT saturation rates. Reporting of this task combined with comparison area research.

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[11] A research effort involving home site visits could potentially be performed in conjunction with another study that involves collecting data on household characteristics through home site visits, such as a socket saturation study.

Activity	Summary of Approach
Supplier Interviews (n = 12 manufacturers, 3 high-level retail buyers)	Interviewed 12 lighting manufacturers and suppliers and 3 high-level retail buyers. Gained their insights into the LED market, predictions for the future market, satisfaction with the CT program, and estimation program impact yielding NTG estimates.
Contribution to regional comparison area data collection (n= 78 in GA, 67 in KS)	Onsite visits in Georgia and Kansas demonstrated saturation and purchase rates in areas with less program activity. Helped to identify the impact of program activity on the energy-efficient bulb market.
Overall report	Summary report focuses on the key findings and recommendations across tasks.

Findings

The findings of the research in progress will be provided in the future.