CONNECTICUT ENERGY EFFICIENCY BOARD

Evaluation Studies and Results Abstracts for 2018

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

Connecticut Energy Efficiency Board Evaluation Committee

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January, 2020

Final Report

PREFACE FROM THE ENERGY EFFICIENCY BOARD 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 2018. Changes were made to streamline the delivery of this report so future reports will be delivered earlier. 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 Energy Efficiency Board Evaluation Committee:
Taren O'Connor, Office of Consumer Counsel, Chair
Michael Li, Department of Energy and Environmental Protection
Amy McLean Salls, Acadia Center

PREFACE FROM THE EVALUATION ADMINISTRATORS – OVERVIEW AND VERIFICATION OF THE 2018 EVALUATION OF CONNECTICUT'S ENERGY EFFICIENCY FUND ACTIVITIES

The evaluation efforts conducted in 2018 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 2018 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 2018 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.

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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 2016, is a team of experienced independent evaluators led by Skumatz Economic Research Associates (SERA) and includes Ralph Prahl and Associates, Cx Associates, LLC, Wirtshafter Associates, and Jacobson Energy Research, 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, Florida, Vermont, Massachusetts, and Rhode Island.

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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 the EEB 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; 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. The three-year 2019-2021 C&LM Plan budget is $714 million. The accompanying three-year evaluation budget is $7.9 million for all evaluation and related research studies. This is an evaluation percent of 1.1%, which represents a decrease compared to figures of 1.4% for 2016-18, 1.9% in 2013 and 2.1% in 2012.

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. These studies include:

- 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 the Energy Efficiency Board (EEB), 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 measurable after program interventions have occurred.

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 EEB, 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 programs 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 calendar year 2018. Findings and recommendations are summarized; links to the full reports are found at the end of each study description.
- **Chapter 3 – Studies in Progress** includes list of titles and objectives for other evaluation studies underway in the 2018 calendar year.

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

Figure 1: List of Studies Addressed in the 2018 Legislative Report (by category)
(R=Residential; C=Comm'l / Industrial)

COMPLETE 2018 (Chapter 2)	Report Status
R1614/1613. HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation	Complete
R1702/1710. Codes and Standards Assessment	Complete
R1707. Net-to-Gross Study for CT Residential New Construction	Complete
R1709. Connecticut Non-Energy Impacts Literature Review	Complete
C1630. Largest Savers Evaluation	Complete
C1641. Business and Energy Sustainability Program Impact Evaluation	Complete
IN PROGRESS IN 2018 (Listed in Chapter 3 – studies begun or underway in 2018 but have not yet produced draft results by end of year)	Report Status
R1617 Residential Ductless Heat Pumps / Cold Climate Heat Pump Measure Cost-effectiveness and Effects	In progress 2018
R1616/R1708 Residential Lighting Impact Saturation Study	In progress 2018
R1705 R1609 Multifamily Baseline and Weatherization Study	In progress 2018
R1706 Residential Appliance Saturation Survey	In progress 2018
R1603 Home Energy Solutions Impact Evaluation	In progress 2018
C1644 EO Baseline & NTG	In progress 2018
C1634 ECB Impact Evaluation	In progress 2018
C1635 EO Impact Evaluation	In progress 2018

The list of begun and on-going EM&V projects and their start dates were affected by last year's legislative budget diversion, leading to some gaps in guidance to the PSD and to program design, development, and evaluation. The Evaluation committee is working to try to make up some of these gaps, but it will take a few years to catch up, given budget constraints.

2. COMPLETED RESIDENTIAL STUDIES

R1614/R1613 CT HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation, Final Report

The report covers impact and process evaluation studies of the Connecticut Residential Upstream HVAC and Water Heating Program ("Upstream HVAC Program") and the impact evaluation of Heat Pump Water Heater Program. The Upstream HVAC Program offers rebates to distributors to encourage the installation of high efficiency space and water heating equipment and the Heat Pump Water Heater Program offers rebates to distributors and retailers.

This evaluation covered full analysis of five of the eight program measures, which account for over 75% or more of the program reported savings for natural gas and winter peak savings, about 60% of the electric energy savings and about 15% of the summer peak savings. The evaluated measures are boilers, furnaces, electrically commutated motor (ECM) furnace fans, heat pump water heaters (HPWH's), and boiler circulating pumps.[3] The analysis used several combinations of methods chosen to balance cost and accuracy. The analysis method and outcomes for each measure are presented in Table R-1.

Table R-1: Summary of Evaluation Activities

Evaluation Activity	Determine Baseline	Determine Efficiency	Estimate Annual Load	Estimate kW Peak Reduction	Assess Reasons for Performance	NTGR/ Decision-Making	Process
Billing or AMI analysis			●●●	●			
In situ metering	●	●●●	●●●	●●	●●●		
Customer interviews	●				●●●	●●●	●●●●●
Market actor interviews	●●●●				●●●	●●●●●	●●●●●
Manufacturers' data	●●●●●	●●●●●					

• *Furnaces* • *Boilers* • *Circulator pump* • *HP Water Heater* • *ECM furnace fan*

The approach to estimating net savings utilized the self-report method and incorporated responses to program influence questions. Both the self-report and program influence questions were tied to the program's causal mechanisms on the market actors. NTGR estimates were developed for the three markets actors, i.e., customers, contractors and distributors, and the results were combined to reflect the relative contribution of the market actors to the decision-making process. Table A-2 presents a

[3] Ground source heat pumps, mini-splits, air source heat pumps, and central air conditioners were not evaluated. In aggregate, these measures account for less than 40% of the electric energy, less than 25% of the winter peak savings, and over 80% of the summer peak electric savings. These measures were not prioritized as previous impact evaluations for ground source heat pumps and central air conditioners were completed in June of 2014 and October of 2014, respectively. Natural gas water heaters were also not evaluated as they account for less than 10% of the natural gas energy savings.

summary of the evaluated gross and net savings by measure. Detailed recommendations for changes to the Program Savings Document are provided in the Executive Summary and in Section 8 of the full report.

Table R-2: Summary of Per Unit PSD and Evaluated Savings by Measure

Measure	2017 PSD Gross Savings	Realization Rate[1]	Evaluated Gross Savings[2]	NTGR[1,3]	Evaluated Net Savings
High Efficiency Furnace	14.1 MMBtu/year	74% +/-4%	10.4 MMBtu/year	62% +/-8%	6.4+/-0.9 MMBtu/year
High Efficiency Boiler	11.5 MMBtu/year	66%+/9%	7.6 MMBtu/year	56% +/-7%	4.3+/-0.8 MMBtu/year
ECM Boiler Circulating Pumps	285 kWh/year	24%+/-3%	68 kWh/year	69% +/-11%	47+/-9 kWh/year
	0.056 Seasonal Winter Peak kW	44%+/-5%	0.024 kW	69% +/-11%	0.017+/-0.003 kW
Furnace Fan	293 kWh/year	125%+/-7%	366 kWh/year[4]	62% +/-8%[5]	227+/-33 kWh/year
	0.090 Seasonal Winter Peak kW	131%+/-8%	0.118 kW	62% +/-8%[5]	0.073+/-0.010 kW
	0.072 Seasonal Summer Peak kW	90%+/-4%	0.065 kW	62% +/-8%[5]	0.040+/-0.006 kW
Heat Pump Water Heater[6]	2,112 kWh/year	54% +/- 6%	961 kWh/year	59% +/- 6%	567+/-85 kWh/year
	0.244 Seasonal Winter Peak kW	55% +/- 5%	0.134 kW	59% +/- 6%	0.079+/-0.012 kW
	0.185 Seasonal Summer Peak kW	95% +/- 7%	0.175 kW	59% +/- 6%	0.103+/-0.015 kW
	0 MMBtu/year	N/A	4.3 MMBtu/year	59% +/- 6%	2.5+/-0.3 MMBtu/year

[1] Confidence intervals are at the 80% confidence level and account for the sampling error at each stage of the calculation by incorporating the propagation of uncertainty.

[2] Gross evaluated savings are the PSD savings multiplied by the realization rate.

[3] NTGR = 1 – FR (Free rider rate) + SO (spillover).

[4] The furnace fan kWh savings include both winter (heating) and summer (cooling) savings. The summer savings are based on the assumption that approximately 60% of homes with furnaces also have central air conditioning. See Section 4.5 for more details.

[5] It was not possible to estimate the NTG for ECM furnace fans separately from furnaces. Only furnaces with ECM fans are eligible to receive a rebate through the program and ECM furnace fans are not a stand-alone measure. Thus, the NTGR for furnaces was applied to furnace fans.

[6] These savings reflect a blended baseline, accounting for replacements of electric and fossil fuel water heaters. Although the electric savings are lower, substantial fossil fuel MMBtu savings were added.

Recommendations

Improve Program Tracking: Issues with the data quality had substantial effects on the evaluation. In addition, it is critical to maintain a connection between the rebate and the location of the installation to allow for verification. Quality control procedures need to be strengthened to check the integrity of data required for verification and evaluation to the extent possible within the upstream program design.

Improve Communication about Rebate Processing: The satisfaction rating for distributors was substantially affected by low ratings for rebate processing, long lag time to receive the rebate and communication from the utilities. Program managers can improve communication to establish clear expectations with distributors around rebate requirements and timelines. [4]

Expand Contractor Training: Contractors expressed an interest in attending trainings offered by the utilities or third parties that increase their employees' technical knowledge of efficient products and familiarize them with program processes and requirements.

Encourage Distributors to Stock Replacement Parts: Contractors expressed concerns about equipment issues with the efficient equipment, such as problems finding replacement parts. Program staff can work with distributors to stock replacement parts and increase training to contractors on installation and maintenance concerns.

Conduct Further Research into the NTG for the Tiered Boiler Incentives: In 2017, the utilities made a change to the incentive structure for efficient boilers from a single incentive for all eligible boilers to a two-tiered system depending on the level of the boiler efficiency. As this evaluation covers program years 2014 through 2016, further investigation into the effects of this tiered incentive on the NTG is warranted.

[4] The utilities reported that since developing these findings, improvements have been made to the distributor rebate process.

R1702-R1710 Codes and Standards Assessment, Final Report

This report estimates code compliance rates and potential savings from compliance enhancement for new single-family homes in Connecticut that were built at the end of the 2009 International Energy Conservation Code (IECC) cycle. The study also compares homes to the amended version of the 2012 IECC adopted in Connecticut (2012 IECC-CT). *The 2012 IECC-CT results represent minimum compliance rates (a floor) and maximum potential savings (a ceiling) as the homes used for this assessment were built prior to the adoption of the 2012 IECC-CT (under the 2009 IECC).*

Statewide compliance with the 2009 IECC (as defined in the footnote[5]) is 91% – 97% for program homes and 90% for non-program homes. Compliance with the 2009 IECC among non-program homes notably lags behind program home compliance in terms of ceiling, frame floor, wall, and foundation wall insulation. Statewide compliance is estimated to be between 79% and 86% when compared to the 2012 IECC-CT. The 79% compliance rate represents a compliance floor under a business-as-usual scenario where building practices remain the same even in the face of new code requirements. The 86% compliance rate is an adjusted calculation based on results seen in Massachusetts for homes built at the end of the 2009 IECC cycle and the beginning of the 2012 IECC cycle. Using the same compliance methodology, the 2012 IECC- CT compliance rates are comparable to rates that were recently developed in Massachusetts (86%) and Rhode Island (83%) for 2012 IECC compliance.[6]

The gross technical potential savings available from code compliance enhancement (i.e., bringing all non-compliant measures up to prescriptive code requirement levels) are 17% over the mean MMBtu consumption for the 2009 IECC (6% for the small subset of program homes and 17% for non-program homes), and are estimated to be between 20% and 33% for the 2012 IECC-CT. The 33% savings potential under the 2012 IECC-CT represent a ceiling under the business-as-usual scenario, while the 20% savings are adjusted using the 2009 IECC and 2012 IECC Massachusetts results previously mentioned. This study projects that air leakage and duct leakage measures have the largest opportunity for compliance enhancement savings under the 2012 IECC-CT.

In addition to Connecticut compliance and potential savings results, this report documents examples of code compliance enhancement programs in other jurisdictions. There are a few code compliance enhancement programs throughout the country (e.g., Massachusetts, Rhode Island, and California), which exemplify ways to design, implement, and evaluate code enhancement programs.

Up to this point, many states have focused on code compliance enhancement as opposed to advocating for more stringent energy codes or pushing for more aggressive equipment standards. While this study focuses on code compliance rates, code enhancement potential, and code enhancement programs, it should be noted that there are other avenues available for saving energy in this research area.

[5] This study followed the MA-REC methodology (also recently employed in Massachusetts and Rhode Island), which uses REM/Rate energy models to calculate compliance rates. Using the MA-REC approach, homes are scored based on their energy performance relative to a hypothetical counterpart home built to prescriptive code requirements.

[6] All compliance rates in this study were calculated using the MA-REC compliance methodology

R1707 Net-To-Gross Study for Connecticut Residential New Construction, Final Report

The R1707 Residential New Construction (RNC) Net-to-Gross (NTG) study describes how the RNC program in Connecticut has impacted the energy consumption of participant and nonparticipant homes and will inform Connecticut's Program Savings Document, which does not currently have an adjusted net-to-gross (NTG) ratio for the RNC program. The study was designed to (1) estimate savings and an overall NTG ratio for the RNC program; (2) gain feedback on the program's impacts on the efficiency of multifamily homes relative to single-family homes, and on the adoption of solar PV, Net Zero designs, and efficient lighting; and (3) assess whether future evaluations should adjust the savings baseline to include the efficiency values of program homes to account for free-ridership in the program.[7]

The study used a Delphi panel approach, in which a panel of 13 RNC experts reviewed (1) efficiency data on non-program homes from the 2017[8] and 2011[9] single-family RNC baseline studies, (2) program home efficiency data, (3) findings from a 2017 RNC program process evaluation[10], and (4) a host of supporting documentation about the Connecticut RNC program and market. This information enabled them to develop estimates of measure-level building practices for 2009 IECC homes built around 2015 in a hypothetical scenario where the RNC program had been cancelled at the end of 2011.

These estimates were used to create REM/Rate energy simulation models representing this hypothetical scenario. The results were compared to the program's gross savings to estimate a NTG ratio for the single-family portion of the RNC program. Savings estimates were calculated for multifamily homes using adjustment factors based on consumption differences between single- and multifamily program homes and qualitative panelist responses.

Panelists estimated that the program strongly improved duct leakage, air infiltration, and insulation installation quality in Connecticut homes; and modestly impacted insulation R-values and efficient lighting. Panelists described the program as only slightly affecting mechanical system efficiencies, and they saw limited impact on market adoption of solar PV and Net Zero designs.

The program trains Connecticut market actors and requires panelists to meet advanced building practices; word-of-mouth helps spread these best practices from well-trained market actors, such as HERS raters and program builders, to those working on non-program homes. The study recommends a single program NTG ratio of 1.56, including its single- and multifamily activities. The study found free-ridership (0.69) and substantial non-participant spillover (1.25). As non-program homes continue to gain in efficiency, the study recommends the program push for higher levels of performance to stay ahead of non-program homes that continue to rapidly increase in efficiency, as seen in the two most recent baseline studies.

R1707 PSD Recommendations: R1707 recommendations for the PSD, included adjusting the NTG value for prospective planning purposes.

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[7] This study built on the 2014 Massachusetts RNC Net Impact Study. The NTGR for the 2011 MA RNC program was 1.87, including free-ridership of 0.53 and spillover of 1.39. Panelists said that the program had a strong effect on air and duct leakage, lighting, insulation installation grades, and heating system efficiencies. goo.gl/rXxuJd

[8] R1602 Residential New Construction Program Baseline Study, NMR Group; December 2017: https://goo.gl/JPgqTv.

[9] CT 2011 Baseline Study of Single-Family Residential New Construction, NMR Group, et al; 2012: https://goo.gl/M5P2DY.

[10] R1602 Residential New Construction Program – Process Evaluation, NMR Group; 2017: https://goo.gl/WA5oh4.

Recommendation. Use the retrospective NTG value of 1.56 for prospective program planning purposes. In addition, plan to conduct another similar study to assess NTG in the future but expect a decrease in the NTG value if program-eligibility criteria do not advance dramatically.

R1709 Connecticut Non-Energy Impacts Literature Review, Final Report

This study assessed how the Connecticut EEB may incorporate valuation of Non-Energy Impacts (NEIs) into their evaluations and their cost- effectiveness analyses. This report provides a review of the literature on NEIs.

Energy efficiency programs lead to substantial benefits beyond the energy and demand savings they achieve. These NEIs are important to understand and measure to effectively market the program to potential participants. NEIs are also important to accurately conduct the benefit-cost analysis for the energy efficiency investments.

This literature review addresses the challenge in this research area where studies point to previous studies (and those studies point to previous studies) that do not provide adequate documentation of the research methodology used to estimate the NEIs. This report provides a rigorous examination of the past studies to assess the specific models used and assumptions made.

This study includes NEI research that was completed in 2000 or later *with original research and calculation* of NEI values. While there are hundreds of reports that cover the NEI topic, many of those reports are dated and most do not calculate benefits that are specific to the program and jurisdiction studied. Many reports are literature reviews and even of those that do quantify the benefits, they usually utilize estimates that were previously calculated in prior studies.

Additionally, more NEI research is needed to assess the findings summarized in this report and to further estimate the impact of energy efficiency on NEIs. Because the findings may be used in cost-effectiveness tests and impact the level of energy efficiency investments, it is critical to conduct additional studies that provide verification or refutation of these results. Such studies need to be clear about the methodology used, assumptions made, data sources employed, and limitations of the analyses.

NEIs are real and they can be significant. While it can be challenging to estimate and monetize these benefits, it is important to do so. Connecticut should use the information in this report as a starting point to assess the potential range of benefits that can be achieved, how to prioritize NEI research, and where adjustments should be made to cost-effectiveness testing. Additional steps in this research project include development of a database to provide easier comparison of methods and results, and assessment and implementation of adjustments to those estimates that allow for better application to Connecticut's energy efficiency programs.

3. Completed Commercial Studies

C1630: Largest Savers Evaluation, Final Report

This report covers an impact evaluation of the projects with the most energy savings in the CT C&I Energy Conservation Blueprint (ECB) and Energy Opportunities (EO) for program years 2013-2015 and discusses observed trends and their potential impact on future evaluation planning. The study addresses two objectives:

1. Evaluate the energy and peak demand savings impacts for a census of the largest projects supported by the Energize CT initiative.

2. Provide stakeholders with findings that are relevant and useful to potentially reducing future evaluation costs.

The study used a new method, avoided cost of energy, to quantify impacts of electric and gas measures with common units. It then selected the top 35 projects in terms of avoided cost impact over the program period under study. The evaluators provided on site measurement and verification for 34 of the 35 sites using high rigor methods for the largest measure(s) at each site and using low rigor for the remaining measures. The study developed realization rates for the projects to complete Objective 1.

The study recognized that these largest savers were key contributors to program savings, had complex and numerous measures, and were drivers of the realization rates for many commercial programs. The study provides information for future evaluations regarding observed sources of variance between ex ante and ex post savings and suggests strategies to minimize that variance. Also, the study provides information useful to refinements in the PSD and the manner in which computations of savings are developed.

This study found that realization rates (RR), including high and low rigor measures, were as follows:

- ECB electric energy RR: 90%
- ECB summer demand RR: 92%
- ECB gas RR: 92%
- EO electric energy RR: 76%
- ECB summer demand RR: 96%
- ECB gas RR: 76%

Because the sample size is small, inference from the results should be done with caution. The study also found that realization rates and coefficients of variation continue to be strong for lighting measures but show more variance and generally lower RRs for non-lighting measures. The study also found that the relatively high coefficients of variation found in prior studies persists, indicating that reducing sample sizes for C&I Impact Evaluations going forward is not recommended until the programs implement processes to reduce variances and evaluations prove such approaches have the intended result.

PSD-Related Recommendations - C1630 Largest Savers study advised:

- create standard calculators for measures already in the PSD to increase efficiency and consistency (calculators are currently custom built for each project).
- improve documentation of custom projects including baseline documentation and retention of executable energy models
- improve consistency regarding the application of the PSD
- improve data management and retention

C1641: Business and Energy Sustainability Program Impact Evaluation, Final Report

This study conducted an impact evaluation of the Business & Energy Sustainability suite of programs (BES, or "the programs"), comprised of the following four commercial and industrial (C&I) programs: the Operations & Maintenance Services (O&M) program, the Retro-Commissioning (RCx) program, the Process Reengineering for Increased Manufacturing Efficiency (PRIME) program, and the Business Sustainability Challenge (BSC). Program stakeholders, including the EEB and the program administrators (PAs), prioritized this evaluation, as the O&M, RCx, and BSC programs have not been evaluated since 2012, and PRIME since 2007.

The following were the primary objectives of the impact evaluation:

1. Develop electric and natural gas energy savings estimates targeted to achieve ±10% relative precision at the 90% level of confidence for the BES suite of programs.
2. Develop program-level electric demand savings coincident with summer and winter on- peak and seasonal peak periods for the BES suite of programs, targeted to achieve ±10% relative precision at the 80% level of confidence.
3. Provide recommendations to support future iterations of the Connecticut Program Savings Document (PSD) as appropriate with measure-level findings from the study.
4. Estimate the non-energy impacts from the sampled projects.
5. Provide forward-looking realization rates that incorporate the most recent measure-level updates from the 2018 Connecticut PSD.

Program Descriptions

The BES suite of programs encompasses four former stand-alone programs, which each address sustainable practices, energy savings, and/or process improvements at C&I facilities. Brief descriptions of the four BES programs are provided below. Detailed descriptions of these programs are provided in Section 2 of this report.

1. **The Operations and Maintenance Services (O&M) Program** provides financial and technical assistance for electrical and thermal efficiency improvements through operational changes and repairs instead of capital investments.
2. **The Retro-Commissioning (RCx) Program** works with customers to identify malfunctions and inefficiencies in building management systems (BMSs) that cause unnecessarily high energy use. The RCx program focuses primarily on low-cost heating, ventilating, and air-conditioning (HVAC) and control improvements among existing energy-using systems.
3. **The Process Reengineering for Increased Manufacturing Efficiency (PRIME) Program** makes lean manufacturing training available to all manufacturing customers throughout the state, offering technical and financial assistance to apply lean techniques to their manufacturing processes.
4. **The Business Sustainability Challenge (BSC) Program** provides training and education to participating businesses to improve their strategic energy management practices. The program works with the participating facility to develop a plan and timeline for implementing the sustainability strategy, leveraging benefits from other efficiency programs and external tools as needed. No savings were claimed through this program during the evaluation timeframe.

therefore, the BSC program is not addressed in forthcoming sections of this report.

The evaluation studied 2015 program activity which included, 136 UI and Eversource electric and gas energy efficiency projects delivered via the BES suite of programs, which accounted for a combined total of 9,037,272 kWh and 41,714 MMBtu saved.

Study Methods

ERS determined the evaluation results through an engineering assessment of 81 statistically sampled BES projects incentivized in 2015. Project-level analyses and measurement and verification (M&V) reports were developed for each sampled project. A key metric from each project assessment is the realization rate (RR), or the ratio of project-level evaluated savings to reported savings. The 81 project-level RRs were combined in a statistical expansion analysis leading to the program-level RRs summarized in the next section.

Results

Table C-3 provides the overall impact evaluation results for the BES projects claiming electric savings during program year 2015. Please note that PRIME projects, by design, do not claim peak demand savings, thereby making calculation of RRs impossible.

Table C-3. Comparison of BES Reported and Evaluated Savings: Electric Projects

Program	Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision[1]
PRIME	Annual energy savings (kWh)	2,187,794	1,180,245	0.54	29.4%
	Summer seasonal demand savings (kW)	0.0	38.9	N/A	N/A
	Winter seasonal demand savings (kW)	0.0	38.9	N/A	N/A
O&M	Annual energy savings (kWh)	2,004,007	1,589,436	0.79	18.1%
	Summer seasonal demand savings (kW)	74.1	141.8	1.91	28.67%
	Winter seasonal demand savings (kW)	45.6	117.7	2.58	21.1%
RCx	Annual energy savings (kWh)	4,845,471	5,092,974	1.05	6.9%
	Summer seasonal demand savings (kW)	505.8	636.2	1.26	17.4%
	Winter seasonal demand savings (kW)	251.6	440.4	1.75	4.6%
Total	**Annual energy savings (kWh)**	**9,037,272**	**7,987,201**	**0.88**	**8.7%**
	Summer seasonal demand savings (kW)	**579.9**	**832.0**	**1.43**	**14.3%**
	Winter seasonal demand savings (kW)	**297.2**	**586.3**	**1.97**	**5.7%**

[1] At 90% confidence interval for energy savings (kWh and MMBtu) and at 80% confidence interval for demand savings (kW)

Table C-4 provides the impact evaluation results by program for the BES projects claiming natural gas savings during the 2015 program year.

Table C-4. Comparison of BES Reported and Evaluated Savings: Natural Gas Projects

Program	Total Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)	Evaluated Gross RR[1]	Relative Precision
O&M	33,252	23,265	0.70	10.0%

RCx	8,463	7,579	0.90	0.0%
Total	**41,714**	**30,716**	**0.74**	**7.9%**

[1] Evaluated gross RRs are calculated based on ex-ante savings that reflect the PSD algorithms at the time of project implementation (2015). The steam trap measure's savings algorithm has since been updated in the current CT PSD (2018). Therefore, evaluators calculated a forward-looking RR (FRR) that reflects the current steam trap savings algorithm. The O&M gas FRR of 0.94 should be applied by the program moving forward, as further explained in Section 4.6.

Conclusions and Recommendations

The PRIME, O&M, and RCx programs were estimated to have generated significant savings, achieving 88% of the ex-ante reported electric energy savings and 74% of the ex-ante reported natural gas savings. The primary drivers of the lower- than-anticipated evaluated energy savings include the following: changes in site-specific operation or production levels, differences in calculation methodologies, removal or failure of previously repaired equipment, and differences in pre-project (baseline) and operating conditions. The O&M and RCx programs achieved significantly higher summer and winter peak demand savings than initially reported. Evaluators found a total of 6 O&M projects that did not claim peak demand savings but were confirmed to produce positive peak demand savings, as well as two RCx electric projects with significant differences between the equipment load profiles estimated by the applicant and measured by the evaluators. These differences primarily led to the high RRs for summer and winter peak demand savings.

Overall, the evaluators found that the programs' savings claims were reasonable, relying on the Connecticut PSD when possible (e.g., steam traps and lean manufacturing) or involving site- specific analysis when warranted (e.g., RCx projects). Many of the key contributors to the RRs involved facility- or equipment-specific operation that could not be precisely predicted by vendors a year or more in advance.

The evaluation team identified nine forward-looking recommendations to improve program effectiveness and savings estimations:

1. The BES PAs should apply the evaluation RRs to PRIME and RCx projects moving forward, barring any significant changes in program design, measure offerings, or customers. Additionally, the PAs should apply the evaluation RR to electric O&M projects moving forward; however, the PAs should prospectively apply the forward-looking RR (FRR) of 0.94 to gas O&M projects.[11] The evaluators assessed changes in the PSD from the 2015 version to present (2018) and found that, of the measures addressed by the PSD and featured in this evaluation, only the steam trap measure has undergone changes that result in an FRR considerably higher than the evaluation RR. The evaluators found no such changes for electric measures, as summarized in Section 4.6.
2. Each BES program should implement pre- and post-project inspections and possible metering to more comprehensively document baseline conditions and most up-to-date facility operations. For PRIME projects, the standard practice involves a 90-day review of facility operations, compared to the savings assumptions calculated at the time of project implementation. This 90-day true-up is

[11] The current version of the PSD (2018) recommends two mutually exclusive approaches to calculating steam trap savings—Napier and Grashof. Without knowing which of these approaches will be utilized by the program to estimate steam trap savings, an explicit FRR cannot be calculated. Evaluators therefore recommend an FRR of 0.94 for gas O&M projects based on an assumption that the PAs will follow this report's Recommendation #9 and use only the PSD's Grashof algorithm to calculate steam trap savings moving forward. If Recommendation #9 is not adopted, an alternative FRR must be calculated.

highly valuable for realistic savings claims but could not always be found for sampled PRIME projects in the project files supplied by the utility to the evaluator. Based on the project documentation provided by program staff, the evaluators could not confirm if the 90-day review occurred for 32% of the sampled PRIME projects. The kWh RR for these projects were 43% lower than projects with 90-day review documentation available to the evaluators. While pre- and post-project inspections are standard practice for RCx and O&M programs, the evaluators were unable to obtain the relevant inspection documentation for 42% of the sampled RCx and O&M projects. The kWh and natural gas RRs for these projects were 36% and 9% lower, respectively, then projects with relevant inspection documentation confirmed by the evaluators. In order to reduce uncertainty in savings claims, the RCx and O&M programs should more frequently include pre- and post-project metering, particularly for the largest or most complex projects, in the calculation of reported savings and subsequent incentive amounts.

3. The evaluators believe that the BES programs are best suited as a cost-effective gateway to build relationships with Connecticut commercial and industrial customers that may lead to additional capital improvement projects down the road. However, among the sampled RCx projects, the evaluators identified multiple instances of equipment replacements or add-ons, such as variable frequency drives. Among the twelve sampled electric O&M projects, five involved the upgrade to more efficient lighting systems. The evaluators recommend that the CT EEB and utilities more carefully reassess if such equipment replacement or add-on measures should be classified as O&M or RCx improvements. The BES programs should collaborate more closely with other Connecticut commercial and industrial programs that can offer complementary capital improvement measures at facilities participating in BES programs.
4. The BES programs' vendors should more comprehensively train the staff of participating facilities to maintain the implemented operational improvements. For example, the evaluators found that the poorest-performing RCx projects involved facility staff who were unaware of the controls improvements and the process of restoring them if overridden. The PRIME program sponsors five-day lean manufacturing events, but the program should follow up with similar supplementary training at the 90-day review to ensure that facility staff members become experts on optimizing the operation of the equipment used every day. The evaluators recommend that the closeout process for PRIME, O&M, and RCx projects is supplemented to include "handoff" paperwork and best practices documentation before incentive payout, in order to maximize the savings persistence of the incented improvements.
5. BES programs should more frequently consider peak demand savings, as some do not. The PRIME program does not consider peak demand impacts in site-specific savings estimations. However, the evaluators found that 3 of the 28 sampled PRIME electric projects caused a total of 38.9 kW savings.
6. The BES PAs should more carefully organize and archive relevant project files such as pre- and post-installation inspection reports, pre-project trended or metered data, and vendor analysis spreadsheets. For 27% of the sampled projects, the evaluators encountered difficulties in obtaining these relevant files, requiring three separate data request submittals that spanned 5 months and delayed evaluation activities for an estimated 6 months. Project files are often not stored in a central depository but on individual computers. The evaluators recommend that the utilities adopt a more comprehensive method to digitally archive all relevant project files. These systems will provide more transparency and will allow the utilities to more quickly and cost-effectively deliver project files in future evaluations.
7. For the PRIME program, the evaluators recommend that the lean manufacturing savings algorithm is updated with evaluation results on load dependence factors. The evaluators recommend that the existing load dependence factors for constant loads (65% as recommended in the current PSD), time-dependent loads (20%), and time- and production-dependent loads (15%) are updated to

reflect evaluated values of 41%, 41%, and 18%, respectively. The evaluated results reflect weighted averages among the sample of 28 projects completed in 2015.

8. The PRIME program, like other BES programs, offers an attractive, low-cost gateway for industrial customers to become more familiar with efficiency offerings in Connecticut. Eversource has indicated that 8 of 12 PRIME participants in 2015 went on to complete additional energy efficiency projects through other C&I programs. The evaluators recommend that the utilities continually revisit the PRIME benefits and costs, examining in particular if PRIME participants are more likely to engage other C&I programs as a result of their experience with PRIME, to ensure that the program is contributing towards overall C&I portfolio cost-effectiveness.
9. The current version of the PSD (2018) recommends two mutually exclusive approaches to calculating steam trap savings—Napier and Grashof—each of which generally reflect the evaluator's savings approach based on recent Massachusetts research on actual steam trap performance through analysis of utility data[12]. Evaluators believe that the condensate return factor of 0.45 currently recommended in the PSD's Napier algorithm is appropriate for low-pressure steam systems (5 psig or below), as it accounts for the overstatement in flow in the Grashof-based equation. However, for steam system pressures over 5 psig, evaluators believe that the Grashof method is most appropriate, as the 0.45 condensate return factor will result in overestimated savings using the Napier approach. Therefore, to simplify steam trap savings calculation moving forward, the evaluators recommend that the PAs use only the PSD's Grashof algorithm.

PSD-Related Recommendations

- The BES PAs should apply the evaluation RRs listed above to PRIME and RCx projects moving forward, barring any significant changes in program design, measure offerings, or customers. Additionally, the PAs should apply the evaluation RR to electric O&M projects moving forward; however, the PAs should apply the forward-looking realization rate of 0.94 to gas O&M projects. The evaluators assessed changes in the PSD from the 2015 version to present (2018) and found that, of the measures addressed by the PSD and featured in this evaluation, only the steam trap measure has undergone changes that result in an forward -looking realization rate considerably higher than the evaluation RR. The evaluators found no such changes for electric measures.
- To simplify steam trap savings calculation moving forward, the evaluators recommend that the PAs use only the PSD's Grashof algorithm

[12] "Steam Trap Evaluation Phase 2 by ERS for Massachusetts (MA) Program Administrators and Energy Efficiency Advisory Council," March 18, 2017.

3. STUDIES IN PROGRESS

No additional studies that were underway in 2018 produced draft reports within calendar year 2018. The following studies had kick-offs in 2018 and are in progress:

- R1603 – Home Energy Savers / HES-Income-Eligible Impact Evaluation ($323,000 budget). This impact evaluation uses a billing analysis to estimate savings (kWh, kW, and gas), realization rate and NTG information for the HES and HES-IE programs, and an examination of the underlying reasons for realization rate results that differ from 100%. These programs are responsible for the largest budget and some of the largest electric and gas energy savings for the residential sector, and are to be evaluated within each CT 3-year planning cycle. The Home Energy Solutions (HES) and Home Energy Solutions – Income Eligible (HES-IE) programs are Connecticut's largest residential energy efficiency programs, serving tens of thousands of customers per year with audits, direct installations, and rebates for a variety of energy-saving measures. This impact evaluation covers program years 2015 and 2016. The previous HES/HES-IE impact evaluation was conducted for program year 2011. The HES program serves both single-family and multifamily homes throughout market rate and low-income market segments. The measures installed through the HES program range from easy-to-install measures, such as DHW pipe insulation, light bulbs, and faucet aerators, to larger, more technical measures, including insulation and heating, ventilation or air conditioning (HVAC) equipment replacements and other measures. Note, the program includes substantial lighting savings, which is important for ISO-NE. The program's initial results show substantial gas and electric savings, in range with savings seen for similar programs in the Northeast. The outcomes include updated PSD results on savings and realization rates, and inputs to program planning. The study also includes an examination of sources of realization rate differences, exploration of differences from earlier studies and results, and context analysis (comparison to past and to results from other similar programs for best practices implications for design and analysis).

- R1706 – Residential Appliance Saturation Survey ($250,000 budget). This study uses a combination of web surveys and on-site work to provide a comprehensive characterization of residential customer households within the State of Connecticut. The study includes characterization of CT households in terms of occupant demographics, appliances, consumer electronics, lighting, shell characteristics, HVAC, water heating, and fuel types. The study is coordinated with two concurrent on-site studies, and includes recruitment for the lighting and multifamily baseline visits for these studies. The results of the project include detailed baseline results that will serve multiple residential evaluation projects going forward, and market information for program planning. The project also includes a detailed database for use in planning and baseline work going forward.
- R1616/R1708 – Residential Lighting Impact Saturation Study ($375,000 budget). This study is focused on the upstream lighting program, and seeks to estimate on-site saturation by room type, delta watts from panelists, in-service rates, market-adoption model, effective measure life; adjustment to the 2013 hours of use. The study involves on-site Saturation Visits, including new (first-time) visited households and panel (return-visit) households. The study also develops CT

Market Adoption Models (MAM)s for Standard A-line and Reflector lamps, yielding estimates of delta watts for LEDs and CFLs supported by the Utilities in upstream and direct-install programs in 2016. To maximize the usefulness of the on-site work, this study's sampling, fielding, and data collection is coordinated with the R1706 Residential Appliance Saturation Survey (RASS) study described above.

- R1705/R1609 – Multi-family Baseline and Weatherization Study ($396,000 budget). The Multifamily Baseline and Weatherization Study is intended to estimate the number of multifamily units in the state, provide baseline information on the energy and household characteristics of the households, assess each unit's compliance to the residential weatherization standard, and estimate the savings potential of converting current equipment to more efficient alternatives offered by utility programs. The study is closely coordinated with the Residential Appliance Saturation Survey (RASS) described above.

- R1617 Residential Ductless Heat Pumps / Cold Climate Heat Pump Measure Cost-effectiveness and Effects ($150,000). This study is focused on providing updated information on DHP savings and other information for the range of scenarios in which DHPs are installed in the residential sector. This information is useful for planning and PSD purposes and provides more forwardly-useful market-relevant information on DHP savings than the existing impact results based on limited CT pilot tests of the technology. The study involves defining pre/post-DHP baseline installation scenarios leveraging past studies; assessing likelihood of purchase / participation and responsiveness to price and other factors; estimating costs and savings for each scenario based on secondary data drawing on past studies and available secondary baseline, evaluation, and manufacturer data; and developing electric and fossil fuel savings for installation scenarios. The project also delivers a model to estimate savings from the range of installation scenarios analyzed.

- C1644 – Energy Opportunities (EO) Net-To-Gross (NTG) Study ($200,000 budget). This study conducts an analysis of program attribution for the custom and prescriptive components of the Energy Opportunities Program. Specifically, its main outcomes include net-to-gross (NTG) ratios, spillover, and free-ridership values for the gas and electric EO program as a whole and major gas and electric end-uses as well as the upstream LED lighting component. The project is expected to survey more than 90 customers (some surveyed for more than one end-use), as well as smaller samples of upstream stakeholders, design professionals / vendors, and lighting distributors.

- C1634 – Energy Conscious Blueprint (ECB) Impact Evaluation ($1.2 million budget). This study collects primary data from Energy Conscious Blueprint program participants to analyze program impacts. Outcomes include updated gross savings realizations rates for the program for electric demand reduction and electric and natural gas energy savings. The study (electric & gas) includes on site measurement and verification for a statistically valid representative sample of participant sites to evaluate program gross savings estimates. The sampling quota consists of 285 unique energy efficiency measures (228 electric, 57 gas). While most customers were only sampled for a specific measure, some customers were selected that have multiple primary measures from the sample. About 220 unique sites are expected to be visited. The study

focuses on important end use groups, examines new construction, and provides realization rates for at least five electric and two gas end use groups, and develops other data (potentially hours of use, etc.) that will support future updates to the PSD.

- C1635 – Energy Opportunities (EO) Impact Evaluation ($1.635 million budget). This study is an impact evaluation of the EO program, including gas and electric installations. The study's objectives are to evaluate program-level energy and demand savings estimates and realization rates for electric and natural gas measures; evaluate the LED component of the upstream lighting program to provide savings parameter assumptions (i.e., delta watts, hours of use) to inform/refine future savings estimates; and provide PSD savings parameter including realization rates and PSD parameter updates where available. This impact evaluation is expected to include 149 C&I gas and electric downstream sites and a possible additional sample for the upstream lighting program of about 95 site visits, for a total of 244 sites.