

CONNECTICUT ENERGY EFFICIENCY BOARD

Evaluation Studies Completed and Underway in 2022

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



Connecticut Energy Efficiency Board Evaluation Committee
Prepared by the SERA Evaluation Administration Team:
Lisa Skumatz, Ralph Prah, Robert Wirtshafter, Peter Jacobs, Dakers Gowans,
Scott Pigg, Ryan Kroll

April 2023
FINAL

<Page left blank intentionally for dual sided printing>

PREFACE FROM THE EEB EVALUATION COMMITTEE

The Energy Efficiency Board (EEB) Evaluation Committee is pleased 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.

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

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 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

Kathy Fay, Neighborhood Housing Services of New Haven, Inc., Chair
Benjamin McMillan, Claire Sickinger, Kate Donatelli, DEEP
John (J.R.) Viglione, OCC

PREFACE FROM THE EVALUATION ADMINISTRATORS -- OVERVIEW AND VERIFICATION OF THE 2022 EVALUATION OF CONNECTICUT'S ENERGY EFFICIENCY FUND ACTIVITIES

The evaluation efforts conducted in 2022 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 the EEB's Evaluation Roadmap², which instituted policies to assure independence of the evaluation process.

The evaluations completed in 2022 add to the evaluation evidence of accomplishments from the use of Connecticut's Energy Efficiency Fund (CEEF).

The Evaluation Administrators (EA)³ verified that the 2022 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 CEEF are making reasonable energy efficiency achievements.

SERA Evaluation Administration Team

Lisa Skumatz, Skumatz Economic Research Associates, Inc. (SERA)
Ralph Prah, Independent Consultant
Bob Wirtshafter, Wirtshafter Associates
Peter Jacobs, BuildingMetrics, Inc.
Dakers Gowans, Left Fork Energy, Inc.
Scott Pigg, Independent Consultant
Ryan Kroll, Driftless Energy

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, and the evaluation activities provide objective evaluation and verification of program performance.

² https://energizect.com/sites/default/files/2022-02/CTEvalRoadmap_2021_fromDec2014Version_Approved092621_v16Final%20%281%29.pdf

³ The current Evaluation Administration Consultant, initially contracted in 2013, and most recently contracted in 2019, is a team of experienced independent evaluators led by Skumatz Economic Research Associates (SERA) and includes Ralph Prah Independent Consultant, Wirtshafter Associates, BuildingMetrics, Left Fork Energy, Driftless Energy, and Scott Pigg Independent Consultant. Each consultant on the team has between 30 and 45 years of experience in the field and has conducted work nationwide. The offices of these firms are located in Colorado, Florida, Wisconsin, Massachusetts, and New York.

Contents

PREFACE FROM THE EEB EVALUATION COMMITTEE	iii
PREFACE FROM THE EVALUATION ADMINISTRATORS -- OVERVIEW AND VERIFICATION OF THE 2022 EVALUATION OF CONNECTICUT'S ENERGY EFFICIENCY FUND ACTIVITIES	iv
1. INTRODUCTION	1
1.1 Definition of Evaluation Types	2
1.2 Organization of the Report	3
2. PROJECTS COMPLETED IN 2022	5
C1902A – Energy Conscious Blueprint (ECB) Net to Gross (NTG) and Baseline Study	5
C1902B - Energy Conscious Blueprint Baseline and Code Compliance Results	6
C2014A – C&I Lighting Saturation and Remaining Potential	6
R1965 - HP/HPWH Baseline and Potential Assessment / R2027 – Heat Pump and Heat Pump Water Heater Reliability Study	8
R2015 – Low Load Residential New Construction	9
R2120 – Appliance Recycling Impacts Study	10
X1931-4 New Measure for PSD – Advanced Lighting Controls (ALC), Phase 2	10
X1931- 5 Commercial Refrigeration Efficiency Update Study	11
X1932 – Evaluation of Demand Reduction (DR) Programs (UI & Eversource, All Sectors)	12
X1942A – Cross-Cutting Non-Energy Impacts Evaluation-Arrearage Results	13
X2001A – Measure Life Study / EUL Update – Residential Measures	15
X2022 – Evaluation of Customer Engagement, Education, and Workforce / Training Initiatives	16
3. STUDIES IN PROGRESS IN 2022	19
C1906 – Strategic Energy Management (SEM) Program Evaluation.	19
C2117 Persistence Study for Retrocommissioning Measures	20
C2203 – Agriculture Market and Baseline Assessment	20
C2201 – Commercial Baseline Study and Database Study	21
C2211 – BES – O&M – RetroCommissioning Impact and Process Evaluation	23
R1968 - RNC Baseline and Code Compliance (Phase 1)	25
R1982 - HVAC / DHW Performance & Potential Evaluation	25
R1983 HES & IE Process and NTG Evaluation and Impact Evaluation	25
R2029 – Single Family Weatherization Metric and Update	26
R2209 and R2215 RNC NTG and Impact Evaluation	27
R2213 – Delivered Fuel Savings Impacts — Methods & Attribution	27
R2246 - Residential Heat Pump Study	28
X1942B and C – Cross-Cutting Non-Energy Impacts Evaluation – Heat Pumps and Air Sealing Measures	29
X2001B – Measure Life Study / EUL Update – Commercial Measures	29
X1939-2 – Early Retirement Evaluation – Phase 2	30
C2230 – Heat Pump and Electrification Study	31
X2231 – Heat Pump and Electrification Study – Cross-Cutting	32
X2244 – Review Possible Shift from EE to GHG Policy Integration Goals and Metrics at the State Level	35

<Page left blank intentionally for dual sided printing>

LEGISLATIVE REPORT ON 2022 CT EEB EVALUATION PROJECTS

1. INTRODUCTION

The Connecticut Energy Efficiency Fund (CEEF) 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 CEEF programs are: administered appropriately and efficiently; comply with statutory requirements; 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 2022-24 C&LM Plan budget⁴ is \$708 million. The accompanying three-year evaluation budget is \$13.5⁵ million for all evaluation and related research studies. This represents an evaluation percent of 1.9%. This 2022-24 C&LM plan included a stabilization of a downward trend that had occurred between 2013 – 2021. During this period, the evaluation percentage of the C&LM plan declined from 2.1% to 1.16%, below industry standards. Connecticut's evaluation funding is now more commensurate with other states in the region and nationally.

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

⁴ <https://energizect.com/sites/default/files/documents/Final%202022%202024%20Plan%20030122.pdf>, filed March 1, 2022.

⁵ The budget for the Three-Year Evaluation Plan, passed by the EEB, is \$14.775 million, and includes a slightly higher budget than the current 3-year C&LM Plan.

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
- Equity issues

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 CEEF 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 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 and PSD Support Studies (including measure effects / performance, methods, and value studies) assess the adequacy of engineering methodologies and background assumptions, support and update values in the Program Savings Document (PSD) and provide the foundation against which evaluations will assess program performance. These studies also include

assessment and quantification of NEIs/NEBs and carbon reductions, and studies that address methodological issues and develop best practices for evaluation research.

- Baseline and Issue Studies provide direct impact support by assessing pre-conditions that will no longer be measurable after program interventions have occurred, or address emerging topics or issues.

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 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 and summary results from studies that were completed in calendar year 2022. 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 brief descriptions of study background and key outputs expected from each residential, commercial, and cross-cutting study that was underway – but not completed – in 2022.

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, highlighting objectives for all studies, and results for completed studies. In 2022, a total of 30 evaluation studies were either completed (12) or underway (18), as noted below.

Figure 1: List of Studies Addressed in the 2022 Legislative Report (by category)

(R=Residential; C=Commercial / Industrial, X=All/Both Sectors)

PROJECTS COMPLETED IN 2022

1. C1902A – Energy Conscious Blueprint (ECB) Net to Gross (NTG) and Baseline Study
2. C1902B - Energy Conscious Blueprint Baseline and Code Compliance Results
3. C2014A – C&I Lighting Saturation and Remaining Potential
4. R1965 - HP/HPWH Baseline and Potential Assessment / R2027 – Heat Pump and Heat Pump Water Heater Reliability Study
5. R2015 – Low Load Residential New Construction
6. R2120 – Appliance Recycling Impacts Study

7. X1931-4 New Measure for PSD – Advanced Lighting Controls (ALC), Phase 2
8. X1931- 5 Commercial Refrigeration Efficiency Update Study
9. X1932 – Evaluation of Demand Reduction (DR) Programs (UI & Eversource, All Sectors)
10. X1942A – Cross-Cutting Non-Energy Impacts Evaluation-Arrearage Results
11. X2001A – Measure Life Study / EUL Update – Residential Measures
12. X2022 – Evaluation of Customer Engagement, Education, and Workforce / Training Initiatives

STUDIES IN PROGRESS IN 2022

13. C1906 – Strategic Energy Management (SEM) Program Evaluation
14. C2117 Persistence Study for Retrocommissioning Measures
15. C2203 – Agriculture Market and Baseline Assessment
16. C2201 – Commercial Baseline Study and Database Study
17. C2211 – BES – O&M – RetroCommissioning Impact and Process Evaluation
18. R1968 - RNC Baseline and Code Compliance (Phase 1)
19. R1982 - HVAC / DHW Performance & Potential Evaluation
20. R1983 HES & IE Process and NTG Evaluation and Impact Evaluation
21. R2029 – Single Family Weatherization Metric and Update
22. R2209 and R2215 RNC NTG and Impact Evaluation
23. R2213 – Delivered Fuel Savings Impacts — Methods & Attribution
24. R2246 - Residential Heat Pump Study
25. X1942B and C – Cross-Cutting Non-Energy Impacts Evaluation – Heat Pumps and Air Sealing Measures
26. X2001B – Measure Life Study / EUL Update – Commercial Measures
27. X1939-2 – Early Retirement Evaluation – Phase 2
28. C2230 – Heat Pump and Electrification Study - Commercial
29. X2231 – Heat Pump and Electrification Study – Cross-Cutting
30. X2244 – Review Possible Shift from EE to GHG Policy Integration Goals and Metrics at the State Level

This EM&V project list represents a portion of the projects from the adopted 3-year plan. Additional studies in the three-year plan for 2022-2024 will begin during the remainder of the three-year period.

2. PROJECTS COMPLETED IN 2022

The following studies were completed and finalized in 2022. Note that study numbers beginning with C are commercial, R means residential, and X studies cross both residential and commercial sectors.

C1902A – Energy Conscious Blueprint (ECB) Net to Gross (NTG) and Baseline Study

The C1902A evaluation included measurement of Net-to-Gross (NTG) ratios for the Energize CT Commercial Midstream HVAC & Water Heating and Commercial Foodservice & Laboratory Programs. Through these programs, the Connecticut Electric and Gas Companies (the Companies) offer distributor incentives for high-efficiency electric and natural gas commercial HVAC and water heating equipment, and dealer incentives for commercial kitchen equipment, including freezers, fryers, griddles, and refrigerators. The stated objective of the midstream offerings is to influence the stocking and selling practices of distributors and dealers by offering instant discounts at the point of sale and increasing contractor and customer demand for high efficiency equipment.

The evaluation team used self-reported data obtained through interviews with distributors and surveys of HVAC & Water Heating program contractors and end-use Foodservice customers to estimate savings attributable to the Energize CT programs and determine NTG ratios to apply in the Connecticut Program Savings Document (PSD). The team also conducted a market review based on participating distributor interview responses and program tracking data, as well as a focused process review to identify program improvements to increase attributable savings. This report accompanies a broader review of Connecticut’s Energy Conscious Blueprint (ECB) Program, which offers incentives for new construction, major renovation, and new (or end-of useful-life replacement) equipment projects.

Based on the findings of the review, the team identified several recommendations to better reflect Midstream Program attributable savings and help increase attributable savings going forward. As shown in the table below, these include updated PSD values and several program improvements.

Evaluation Objective	Recommendation
Determine NTG ratios for the Midstream Programs	Update the Connecticut PSD with the NTG values from this study—specifically 68% for the HVAC & Water Heating program and 81% for the Foodservice & Laboratory program
Identify improvements to increase attributable savings	Adjust measure offerings for spray valves and furnaces to reduce free-ridership and increase attributable program savings
Identify improvements to increase attributable savings	Increase oversight of the rebate passthrough requirement
Identify participation barriers	Increase program marketing targeting end-users, including sustainability departments at large or institutional customers
Identify participation barriers	Consider streamlining pre-approvals and payment processing, particularly for large projects
Identify improvements to increase attributable savings	Consider directing certain interested customers to the downstream rebate program

C1902B - Energy Conscious Blueprint Baseline and Code Compliance Results

This report provides results for the C1902B Energy Conscious Blueprint Baseline and Code Compliance study. This study includes four primary components—baseline measurement, ECB NTG analysis, code compliance research, and midstream non-lighting NTG analysis. This report only covers results for the baseline and code compliance components, and is based on data collected only from non-participants. This study:

- characterizes measure-level baseline values for true new construction and replacement on failure.
- documents current code compliance
- gathers data to support future evaluation and attribution of savings for code compliance and development efforts.

The study includes a literature review; collection of data related to equipment efficiency and building construction using the construction drawings obtained through Dodge data set; interviews with manufacturers, distributors, general contractors, architects, energy modelers, and code officials; and an assessment of building compliance using COMcheck.

The recommendations from this study include updating the following baselines in the Program Savings Document (PSD):

Recommendations
Apply a lighting adjustment factor of 40% better than IECC 2015 and 20% better than IECC 2021 (2022 PSD) across the buildings.
Minimum cooling efficiency of 15 SEER for DX systems with size < 65,000 Btu/h.
Minimum cooling efficiency of 12 SEER for DX systems for sizes >= 65,000 Btu/h and <135,000 Btu/h.
Minimum cooling efficiency of 14 SEER for split unitary systems with size < 65,000 Btu/h.
Minimum cooling efficiency of 10.2 EER for split heat pump systems with size < 65,000 Btu/h.
Minimum cooling efficiency of 12.1 EER for multi-split variable refrigerant flow (VRF) systems with heat recovery for sizes >= 135,000 Btu/h and <=240,000 Btu/h.
Minimum HT heating efficiency of 3.7 COP for multi-split variable refrigerant flow (VRF) systems with heat recovery for sizes >= 135,000 Btu/h and <=240,000 Btu/h.
Minimum LT heating efficiency of 2.9 COP for multi-split variable refrigerant flow (VRF) systems with heat recovery for sizes >= 135,000 Btu/h and <=240,000 Btu/h.
Minimum cooling efficiency of 10.3 EER for multi-split variable refrigerant flow (VRF) systems with heat recovery for sizes >= 240,000 Btu/h.
Minimum LT heating efficiency of 2.2 COP for multi-split variable refrigerant flow (VRF) systems with heat recovery for sizes >= 240,000 Btu/h.
Minimum gas water heater efficiency of 95%.

C2014A – C&I Lighting Saturation and Remaining Potential

As part of the Connecticut C2014 Commercial and Industrial (C&I) Lighting Saturation and Remaining Potential Study, DNV investigated savings opportunities around three key lighting-related themes: TLED to LED luminaire conversions, adding enhanced lighting controls capabilities to existing LEDs, and commissioning. The results of these investigations are based on interviews with five lighting experts and additional data from research conducted in Connecticut and similar jurisdictions.

In general, there is no perfect solution for replacing the declining C&I lighting program savings. As the natural adoption of LED technology continues to increase, there are a few strategic areas that program administrators should consider. At this point in the market transformation, program administrators should continue to shift the focus from the traditional TLED market towards the more advanced LED luminaires with lighting controls. It is very challenging to add advanced control capabilities after installation, so it's essential to encourage the adoption and accurate commissioning of advanced technologies. The following summarizes the key market insights around the three topics:

TLED to LED Luminaire Conversions

Market Insight 1: The natural adoption of standard TLEDs has reached or is close to the peak of the market, and the price of TLEDs has decreased from historical rates to a point where there is now minimal opportunity for programs to generate significant savings moving forward. However, there may still be pockets of customer segments where TLED incentives can transform the market and deliver benefits, like in EJs. Programs incentives for controllable technologies, like networked TLEDs or LED luminaires with advanced or networked controls, are still needed to push customers towards controllable technologies to mitigate the impacts of stranded savings.

Market Insight 2: Since many customers are satisfied with the performance of the TLEDs and there is some uncertainty around what types of situations or conditions where it would be cost-effective to replace TLEDs with LED luminaires, the opportunity for a targeted TLED replacement program is likely minimal. However, there may be some situations where replacing a TLED with LLCs or luminaires with NLC may be cost-effective, but more work is needed to understand the benefit-cost ratio and customer willingness-to-pay for these types of projects.

Adding Controls to Existing LED Systems

Market Insight 3: it's challenging, although not impossible, to add controls after LEDs are already installed. For older TLED systems, this is especially challenging. For newer LED luminaires installed without controls, it may be easier to install controls after a project is completed, especially given the technology improvements and new DLC standards for luminaires. Given these challenges, it's important to incentivize controls capabilities as part of the initial install/project.

Commissioning Advanced Controls

Market Insight 4: Savings from lighting controls systems are dependent on the installation and appropriate commissioning, which is dependent both on the space type and usage patterns. Pre-commissioned fixtures will have some savings, but don't necessarily maximize the savings opportunity. Continued contractor training is an important tool for ensuring that these fixtures are commissioned accurately. Tracking the specific controls capabilities of installed fixtures, and to what extent they are being deployed correctly, can help inform future program design to maximize savings.

Market Insight 5: due to the limited uptake to date associated with networked lighting controls, there is likely limited opportunity to pursue a program solely targeting retro-commissioning networked lighting systems. However, ensuring that commissioning efforts aimed at Integrated fixtures with Room-Based Controls, LLCs, and NLCs will help capture the full measure potential. While the opportunity for retro-commissioning networked lighting controls is small, there is likely more opportunity associated with retro-commissioning programs that focus on non-networked LLCs and fixtures with integrated controls. As networked systems gain market share, there could be an opportunity down the road to increase savings through a targeted retro-commissioning program.

As part of this study effort, DNV previously forecasted the saturation, market share, and trend in net program savings associated with the ambient linear submarket using a stock turnover model. These forecasts were used as the future baselines to calculate recommended adjusted measure lives (AMLs).

In addition to this report, DNV delivered a set of recommendations on the savings factors and measure lives for new residential and commercial Advanced Lighting Controls (ALC) measures as part of the Connecticut X1931-4 ALC evaluation study. The interviews with lighting experts that supported the Connecticut X1931-4 ALC savings estimations were also used to support the market opportunities presented in this report. DNV will also be conducting customer surveys to estimate net-to-gross (NTG) ratios as part of the C2014 study to help understand where lighting programs have a higher influence in continuing to transform the C&I lighting market in Connecticut. Program Administrators have already provided DNV with data to support this effort, and a report will be available later with these results.

R1965 - HP/HPWH Baseline and Potential Assessment / R2027 – Heat Pump and Heat Pump Water Heater Reliability Study

This report provides results for the R1965 Heat Pump/Heat Pump Water Heater Baseline and Market Characterization and R2027 HP/HPWH Reliability studies. This combined study characterizes the markets for residential-sized mini-split heat pumps (MSHP), central, ducted air source heat pumps (CASHP), ground source heat pumps (GSHP), and heat pump water heaters (HPWH) (R1965) and assesses system reliability (R2027). The study informs the EnergizeCT programs, which provide support and incentives for the installation of high-efficiency heat pumps.

The study estimates the number of heat pumps installed in Connecticut by type, configuration, and efficiency, including the portion incentivized by the programs (2017 to 2019). It gathers market actor feedback about heat pumps, recommendation and stocking practices, and market trends. The study describes the prevalence of different configurations, pre-existing conditions, installation challenges, and baseline scenarios. The study describes end-user maintenance costs, satisfaction, pre-existing conditions, and what market actors might have installed without program support. The study includes a literature review; market sizing using HARDI shipment data from D+R and other data sets; interviews with manufacturers, distributors, and installers; web surveys with installers and end-users; and an assessment of customer cost-effectiveness.

Key takeaways include:

- the Connecticut market is poised to take off with continued program intervention; market actors are interested in and comfortable with heat pumps, with some gaps that can be overcome;
- end-users report high levels of reliability and satisfaction;
- Connecticut has underperformed relative to neighboring states in terms of installation volumes and efficiency;
- and opportunities exist to boost heat pump usage and installation rates in the state.

Overall, heat pumps made up around 14% of HVAC system sales between 2017 and 2019. Relative to CASHPs and GSHPs, MSHPs dominate the heat pump market, but installations were flat from 2013 to 2019 (between 4,200 and 5,700 units annually), even as they climbed in neighboring states, particularly from 2017 to 2018 when Connecticut's program budgets were reduced. Most MSHPs are installed as supplemental systems, but multi-zone configurations are popular. CASHP sales are only half that of

MSHPs; GSHPs are installed in extremely small volumes. The HPWH market has been small and relatively flat but is a particularly compelling and cost-effective option for homes with failed electric-resistance or oil-fired water heaters.

Connecticut installers with heat pump experience saw heat pumps as available, reliable, and in-demand, indicating a strong market outlook, though some concerns about cold-weather performance remain. Those installers recommend them often and report that their customers accept the recommendation more than half the time. End-users confirmed high levels of reliability and satisfaction in the first few years of ownership.

R2015 – Low Load Residential New Construction

Connecticut’s energy efficiency program for residential new construction is in a state of transition. Industry standard practice has approached efficiency levels historically promoted by Energize Connecticut, leading the program administrators, advisors, and regulators to consider whether a structural shift is needed as part of a program update and how the next generation of residential new construction programs should be designed. Concurrently, state policy has shifted toward greater interest in decarbonization, and the Connecticut Department of Energy and Environmental Protection (DEEP) has directed the investor to shift the program to an all-- owned utilities that administer Energize Connecticut electric program. This study was designed to identify best practices among leading residential new construction programs outside Connecticut, help define what the next generation of residential new construction programs in the state may encompass, and provide actionable insights and input for ongoing program planning. This work is based on interviews and secondary reviews of best practices among leading programs outside Connecticut.

Overall study recommendations address a need to upgrade program tiers and incentives; increase the share of program efforts designed to transform the market rather than just influence participating structures; futureproof program homes by preparing them for a more dynamic grid that accommodates dynamic pricing, demand response, and distributed energy resources; integrate state policy, codes and standards, and program activities to a greater degree; and adjust governance of the program a bit to encourage and allow for an updated program focus. Immediate priorities for Energize Connecticut and DEEP are a shift of the program design to an all electric offering that achieves electrification for residential new construction.

This report includes a section that lays out how study recommendations apply to a program redesign focused on all electric homes. Recommendations for the program design include a tightening of efficiency standards from current levels, increases in current bonus incentives for all electric offerings, and broader market transformation activities. The report discusses the implications of rapid and slower transition time frames and how program approaches would differ between an all-encompassing all electric program offering and one that shifts rebates to all-- electric homes but continues to engage market actors who are not yet ready to shift all end uses to electric. This section also highlights the role policy, energy codes, comprehensive energy planning, and regulatory program oversight play in the transition. The report includes recommendations that Comprehensive Energy Strategy set the framework for the program’s role, that Energize Connecticut and energy codes work together in a complementary fashion, that DEEP’s oversight of the program align utility incentives with state policy shifts and ensure that measurement of program impacts allow for market transformation efforts.

R2120 – Appliance Recycling Impacts Study

The R2120 Appliance Recycling Study had the following objectives:

- To estimate gross and net energy savings resulting from the recycling of refrigerators and freezers through the Energize Connecticut Appliance Recycling Program in 2020
- What participants think they would have done with the appliances at various incentives levels (including having to pay to have the unit removed)
- The importance of incentives relative to other benefits, including the reclamation of refrigerants and other materials, energy savings, and ease of removal
- To estimate the amount of materials reclaimed from appliances recycled in 2020 that could be attributed to program activity

The study makes the following recommendations:

- The study recommends that the utilities adopt the PSD updates listed below:
 - **Refrigerators:** Gross Savings = 932 kWh, Realization Rate = 0.90, NTG Ratio = 0.37
 - **Freezers:** Gross Savings = 760 kWh, Realization Rates = 0.83, NTG Ratio = 0.38
- The program should keep the incentive at \$30 but also offer special offers at higher incentive levels.
- Should the program decide to permanently raise incentives, the NTG ratio should be raised to match those in Massachusetts and Rhode Island: 46% for refrigerators and 50% for freezers.
- Although the program does not currently account for non-energy impacts, the study suggests that 40% of the materials reclaimed or recycled can be directly attributed to program efforts.

To arrive at these recommendations, the study found the following:

Program Savings: Gross savings are comparable between Connecticut and Massachusetts, but the NTG ratio is lower in Connecticut than in Massachusetts. This may reflect the lower incentive paid in Connecticut (\$30 to \$60) compared to Massachusetts (\$75). The gross savings and realization rate estimates reflected the application of recent study results from Massachusetts to the characteristics of appliances recycled in Connecticut in 2020. The study calculated net savings based on survey responses of Connecticut participants. Incentives: The study results did not provide clear guidance on the optimal incentive level. Many participants seemed willing to take part without an incentive. However, the program convinced more people to get rid of a unit they would have otherwise kept when they temporarily offered a \$60 incentive over the typical \$30 one. Attribution of Recycled Materials: Survey responses from Connecticut participants suggest that the program caused 40% of the total amount of materials reclaimed and recycled by the program. The program reclaims ozone-depleting refrigerants and other hazardous materials. It also recycles glass, plastic, and metals contained in recycled appliances. Yet, some of the appliances would likely have been recycled outside of the program. Therefore, the program should only claim the portion of materials it directly causes to be recycled.

X1931-4 New Measure for PSD – Advanced Lighting Controls (ALC), Phase 2

The objectives of this study are to update, where necessary, and enhance the technical basis of the savings factors and measure lives for new residential and commercial Advanced Lighting Controls (ALC) measures adopted in phase 1. The results are to be incorporated into the 2023 Connecticut Program Savings Document (CT PSD). In Phase 1 of this study, these new measures were developed through a literature review, discussions with experts, and program administrator (PA) interviews. In this second

phase of the study, in-depth interviews with market actors and industry experts, as well as a review of program custom project files, have been used to inform conclusions.

The three measures developed as part of phase 1 were:

1. Commercial Interior Lighting Controls (including networked lighting controls (NLC), luminaire-level lighting controls (LLLC), the combination of high-end trim with daylight dimming or occupancy sensors, dual occupancy and daylight controls, high-end trim, daylight dimming, and occupancy sensors),
2. Residential Connected LED Lighting, and
3. Residential Occupancy Sensors.

DNV interviewed five industry experts and four market actors, and reviewed 12 custom NLC project files from Eversource Energy and United Illuminating Co. In addition, the study team reviewed the methodology used in the DLC study, which is the basis for the advanced lighting controls' savings assumptions.

The study found a large variance in responses from interviews and a large variance in potential savings from reviewed custom project files. This variability in the custom project data and interview responses highlights the need for a more in-depth study of advanced lighting controls. The variance and nuances produced by the research also made clear the need to better understand the LLLC product and its installation when attributing energy savings.

The research team proposes maintaining all measure savings factors defined in Phase 1, apart from LLLCs and adding one. The team also proposes that LLLCs be more specific, requiring proof of networking and commissioning. The team proposes adding a new measure category, Integrated Fixtures with Room-Based Controls. This measure is for those LLLCs that are not networked or networked but not commissioned. LLLCs (those networked and commissioned) will maintain the 49% savings factor identified in Phase 1, and the Integrated Fixture with Room Based controls will adopt a 38% savings factor. This 38% savings factor is the highest savings factor for controls that are not networked. The distinction between these two is important, as the networking and proper installation of LLLCs has consequences on their saving potential. Those LLLCs sold through the upstream/midstream programs will be assigned a 38% savings factor, as verification of commissioning and networking at point of sale is currently not feasible. This memorandum provides distinct savings factors for each.

X1931- 5 Commercial Refrigeration Efficiency Update Study

As part of the ongoing project X1931 CT Program Savings Document (PSD) Review and Update, the Connecticut Energy Efficiency Board (EEB) Evaluation Administrators commissioned DNV to update the average coefficient of performance (ACOP) efficiency values of commercial refrigeration equipment for use in the PSD.

This report presents the methods and results of research to quantify ACOP efficiency values that represent commercial cooler and freezer refrigeration systems in Connecticut. The PSD uses the ACOP efficiency value to estimate annual energy impacts of measures that include refrigerator LED lighting, evaporator fan controls, evaporator fan motor replacement, and door heater controls.

We recommend that the next versions of the PSD replace the preexisting average coefficient of performance efficiency values with the values presented in this study: 1.88 and 3.35 for commercial

freezers and coolers, respectively. In parallel with the PSD update, we recommend updates to associated savings calculators and tracking systems to incorporate ACOP values based on this study.

X1932 – Evaluation of Demand Reduction (DR) Programs (UI & Eversource, All Sectors)

The X1932 Demand Response EM&V Support Study explored Connecticut’s demand response (DR) programs. The study reviewed three programs from the United Illuminating demand response portfolio, including two residential and one commercial program, as well as one residential Eversource program not examined as part of a multi-state DR evaluation.⁶ In addition to producing impact estimates for these programs, the goal of the study was to assess the appropriateness of methods and ensure alignment with program design and evaluation goals. The study had three fundamental findings:

- Evaluations based on advanced metering infrastructure (AMI) data require fewer assumptions and produce more robust load impact estimates than analysis of telemetry from connected devices.
- Baseline methods that are well-documented improve replicability and transparency.
- Connecticut would benefit from standard processes to regularly estimate DR program impacts, report results, and incorporate those impacts into planning.

The study also includes recommendations based on the four evaluated programs, as well as overarching recommendations for how these DR programs may provide value to the grid and the implications of incorporating DR programs into the Program Savings Document (PSD):

Recommendation	Smart Savers Rewards	Wi-Fi HPWH	C&I Auto DR	Wi-Fi AC	Value of DR	PSD Implications
Revisit the connected load assumption.	P					
Ensure all enrolled devices are dispatched.	P	P		P		
Use AMI where available	P	P	P	P		P
Target less efficient equipment that has coincident loads.		P				
Use same-day event notification, after the adjustment period.			P			
Establish a load predictability requirement.			P			
Incentivize participants to inform the program of planned load decreases.			P			
Modify the adjustment window if pre-event changes are deployed.	P	P	P	P		P
Implement a clear settlement baseline methodology that is consistently applied.	P	P	P	P		P
Track the association between device and utility account/meter number.	P	P				
Make curtailment algorithms more aggressive.				P		
Assess data quality prior to including device manufacturers in the program.	P	P		P		

Assess the possibility of utilizing other cost-effectiveness tests.						P
Consider bidding DR resources into the ISO-NE marketplace.	P	P	P	P	P	
Define standard reporting methods/criteria for quantifying the value of DR.	P	P	P	P	P	P

X1942A – Cross-Cutting Non-Energy Impacts Evaluation-Arrearage Results

Purpose

As part of the broader X1942 Non-Energy Impacts (NEIs) study, the NMR study team conducted an analysis to quantify and monetize NEIs that accrue to utilities in the form of financial savings from increased bill affordability and reduced arrears for income-eligible energy conservation/weatherization program participants. The study also attempted to quantify a limited set of complementary NEIs that accrue to the participants. The analysis used electric and gas customer data from Eversource and United Illuminating (UI), Southern Connecticut Gas (SCG) and Connecticut Natural Gas (CNG) on arrearages and shutoffs for participants in the EnergizeCT Home Energy Solutions - Income Eligible (HES-IE) program.⁷ This report, which will become a section in the broader X1942 study report, discusses the results from this analysis and presents the pertinent NEIs the study was able to monetize with the data available.

Background

The 2018 Connecticut Non-Energy Impacts Literature Review study (R1709) identified and recommended a few key areas for additional research and estimation. With respect to NEIs that accrue to utilities, these key areas included affordability impacts and arrearage impacts estimated through an analysis of data on customer balances, arrearages, collection actions, and pertinent utility costs.

Utilities can realize several NEIs from their low-income energy-efficiency programs in the form of financial savings. Energy-efficient technologies installed by energy-efficiency programs often result in reduced energy bills for participants, which can decrease the likelihood that customers experience difficulties paying their utility bills. In turn, utilities realize financial savings through reduced costs associated with arrearages and late payments, uncollectible bills and bad debt write-offs, service terminations and reconnections, bill-related customer calls, and the bill collections process. In addition, utilities may realize savings from their efficiency programs due to a reduction in safety-related emergency calls and reductions in energy use that is eligible for a rate discount. If utilities offer rate discounts to low-income customers that are subsidized by other ratepayers, energy-efficiency programs that reduce the amount of energy consumed by low-income customers can decrease the quantity of energy sold at the discounted rate.

In addition, energy efficiency program participants could also realize several financial savings NEIs such as avoided reconnect fees and avoided collection calls from increased affordability and reduced arrears.

⁷ For income eligible customers, HES-IE program provides no cost in-home assessment and energy conservation/weatherization services such as blower door guided air sealing, insulation, and energy-efficient heating and cooling equipment. The study excluded participants that received an in-home assessment but had not completed any energy conservation measures.

Goal

The goal of this part of the X1942 study was to quantify and monetize the following NEIs from increased affordability and reduced arrears that accrue either to the utility or the participants.

- Reduced arrearage carrying cost (utility NEI)
- Reduced bad debt write-off (utility NEI)
- Fewer shutoffs and reconnects (utility NEI)
- Avoided reconnect fees (participant NEI)
- Fewer notices (utility NEI)
- Fewer collections calls (utility and participant NEI)
- Fewer safety-related emergency calls (utility and participant NEI)
- Reduced quantity of energy sold at the discounted rate (utility NEI)

Summary of Results

Table 1 presents the NEIs that the study was able to quantify and monetize with the data available. The utilities did not systematically track notices, collection calls, and safety-related emergency calls, so they could not provide the data needed to quantify the NEIs related to notices and calls. The utility and participant NEIs related to shutoffs and reconnects were \$0 because the net change in the number of shutoffs for participants from pre- to post-treatment period was not found to be statistically significant for either of the utilities or statewide. The NEI associated with reduced quantity of energy sold at the discounted rate was not applicable because neither of the utilities offered rate discounts to their low-income customers.

Table 1 also provides a comparison of the monetized NEIs in this study to the range of NEI values found in the literature from weatherization programs. Currently, none of these NEIs are included in Appendix Six (Non-Energy Impacts) in Connecticut’s Program Savings Document (PSD) for use in the Total Resource Cost Test.

The NEI values presented in Table 1 are annual values, which are expected to last through the life of the energy conservation/weatherization measures through by the HES-IE program.⁸

Table 1: Summary of Monetized NEIs – Annual NEI per Participant

NEI	Connecticut			NEI Values from Weatherization Programs in the Literature*		
	Eversource	UI	Statewide	Low	High	Typical
Reduced Arrearage Carrying Cost (Utility)	\$0.38	\$0.50	\$0.41	\$1.50	\$4.00	\$2.50
Reduced Bad Debt Write-off (Utility)	\$3.14	\$3.61	\$3.31	\$0.50	\$3.75	\$1.75
Fewer shutoffs and reconnects (Utility)	\$0	\$0	\$0	\$0.10	\$3.65	\$0.65
Avoided reconnect fees (Participant)	\$0	\$0	\$0	\$0.21	\$7.00	\$1.60
Reduced quantity of energy sold at the discounted rate (Utility)	N/A	N/A	N/A	\$3.00	\$25.00	\$13.00
TOTAL	\$3.52	\$4.11	\$3.72	\$5.31	\$43.40	\$19.50

*Source: Northeast Energy Efficiency Partnerships. (2017). Non-Energy Impacts Approaches and Values: an Examination of the Northeast, Mid-Atlantic, and Beyond. Table 20.

⁸ Per Connecticut PSD, measure lives for envelope/weatherization measures range from 15 to 25 years.

X2001A – Measure Life Study / EUL Update – Residential Measures

The X2001A Measure Life/EUL Update Study involves the update of the effective useful life (EUL) and remaining useful life (RUL) values for key residential measures offered through Connecticut’s energy efficiency programs. The objectives of this study were to identify high priority EULs to update, apply an efficient, quick, and cost-effective approach, and to update the EUL and RUL values for those key measures.

This report presents the results for the prioritized residential measures. Using a survey-based methodology, the Evaluation Team gathered information about survival of six residential measures installed through Connecticut’s energy efficiency programs from 2011-2019. In line with industry standard practice, the team used a parametric survival analysis approach to estimate the “survival” function of each equipment type to develop estimates of its effective useful life (EUL) and remaining useful life (RUL).

Based on the primary research conducted in this study, the Evaluation Team made the following recommendations:

Recommendation Category	Recommendation
Effective Useful Life (EUL) - Values	<ol style="list-style-type: none"> 1. Update the EUL values in the Program Savings Document (PSD) for the measure types with adequate precision levels. Use recommended values of 20 years for air source heat pumps, 17 years for ductless heat pumps, 15 years for heat pump water heaters, and 25 years for central air conditioners. We recommend continuing to use the values in the PSD for natural gas furnaces and insulation, as the estimates for these measures did not meet the study’s precision threshold. 2. Conduct additional research on natural gas furnaces and insulation to develop EUL estimates with better precision that can be used to update the PSD in the future.
Remaining useful life (RUL)	<ol style="list-style-type: none"> 3. Where practical, programs should document the age of the replaced equipment at a site-specific level and use the RUL values in Appendix B for air source heat pumps, ductless heat pumps, heat pump water heaters, and central air conditioners when calculating retirement savings. 4. Where the age of the existing equipment cannot be determined, programs should use the recommended values in this study. 5. For natural gas furnaces and other measures without an RUL specified in the PSD, continue to use the industry standard practice of 1/3 of the EUL.
EUL Study Methodology	<ol style="list-style-type: none"> 6. Consider conducting future EUL research similar to this for measures that meet the criteria of high levels of participation, large contributions to Connecticut’s energy efficiency portfolio, and are able to be easily observed and self-reported by participants. 7. Conduct future research on the measures included in this study, as new cohorts of participants can be added to this data to bolster these results.

Recommendation Category	Recommendation
	8. Consider using the combination of respondent-provided photographs and follow-up interviews for other evaluations and studies where additional verification may be desired but site visits are too costly.

X2022 – Evaluation of Customer Engagement, Education, and Workforce / Training Initiatives

This report includes the findings and recommendations of the evaluation of the 2019 – 2021 Energize Connecticut (EnergizeCT) education, workforce development, and community and customer engagement efforts, grouped under the following initiatives: “Educate the Students,” “Educate the Workforce,” “Educate the Public,” and “Customer Engagement.” For this evaluation, ILLUME (referred to as the team or the evaluation team) conducted a review of EnergizeCT initiative activities, a review of best practices from other similar utility programs and initiatives around the country, and primary research on several targeted initiatives to refine our findings.

Through these activities, the evaluation team identified best practices for education, engagement, and workforce development initiatives, and identified areas where the Connecticut programs could better align with best practices. The team also identified areas and initiatives where the current programs are in alignment with industry best practices. Many of the recommendations included in the report are focused on program design and ensuring that the program goals are reflected in the design of the program and the activities conducted as part of the program. The evaluation team found that in many cases, either the initiative goals were lacking, for example, the goals did not relate to energy savings or behavior changes likely to result in energy savings, or the activities did not line up with the goals, for example, a goal of expanding the workforce, but an activity of only marketing trainings to those individuals already on the distribution list.

The cross-cutting recommendations presented in the report include the following:

- Initiatives need strong, action-oriented goals focused on changing behaviors and practices: Program goals need to be well defined, specific, and outline what the program is meant to accomplish. Most evaluated initiatives lack action-oriented goals focused on changing behavior or practices.
- Initiatives should specify the outcomes they are trying to achieve to ensure program designs match goals: Outlining program outcomes is a vital process to ensure program activities link up with the goals stated for the program. With few exceptions, the Connecticut Education and Engagement initiatives do not have outcomes that link activities to goals.
- Initiatives need to ensure activities conducted directly inform the initiative outcomes and goals. Across initiatives, the activities being conducted do not uniformly and consistently support the stated goals of the program. In many cases, the activities are in line with the goals, but they do not robustly support the goals nor are they sufficient to create behavior change.
- Initiatives should link goals and outcomes to potential energy savings: Because they are using Public Goods funds that could be used instead to fund more resource acquisition activities, they need to qualitatively produce benefits commensurate with those achieved by resource

acquisition programs. Accordingly, for education and outreach programs to be justified they need to lead to actions that save energy. There is currently no way to link program activities to energy savings.

- Initiatives need to incorporate continuous improvement mechanisms into program design: Since non-resource programs are not evaluated with the same frequency as resource programs, setting up continuous improvement mechanisms is vital to ensure each initiative is operating as intended and performing well. Currently, some initiatives collect information from trainers, teachers, and attendees, but this is conducted in an ad hoc fashion and is not tracked.

The full report includes findings for each program initiative in addition to the recommendations listed below.

Workforce Development

Evaluation Recommendations:

1. Develop Goals, Outcomes, and associated Activities to expand and enhance the Contractor Base. These goals should also focus on developing behavior change in the contractor base with an aim to generate energy savings.
2. Develop Course series that cover breadth and Depth of key topics and use adult learning principles.
3. Develop metrics to accurately track progress towards energy saving and behavior change and codify current tracking standards. Ensure these metrics link to outcomes and show how goals are being achieved.
4. Increase diversity of participants within trainings.
5. Create training marketing/recruitment strategy.
6. Provide additional resources for attendees.

Green STEP

Evaluation Recommendations:

1. Identify overlap and Gaps between Green STEP activities and CTECS core curriculum and activities and adjust Green STEP to fill those gaps and enhance what CTECS is already doing related to Clean Energy.
2. Increase funding for new E-Houses and updates to current E-Houses.
3. Create a tool Lending Library.
4. Create magnet programs by investing more heavily in a limited number of schools.
5. Integrate milestones and tracking of metrics that link to behavior changes leading to energy savings into the program processes.

eesmarts

Recommendations:

1. Establish program goals and outcomes that tie to energy savings. Develop metrics to accurately track progress towards energy saving and behavior change and codify current tracking standards. Ensure these metrics link to outcomes and show how goals are being achieved.
2. Create a connection with families to expand the reach of the program and enable data tracking.
3. Leverage known behavior-change strategies to motivate energy saving.
4. Build collaboration between all school staff into Program Processes.
5. Expand multiple training approaches.
6. Establish state-wide goals but focus locally to ensure diverse and equitable participation.

7. Use other funding streams (not rate-payer dollars) to support this program.

Community Partnerships

This evaluation is still in progress as the program partners only recently began their activities. The evaluation team plans to conduct interviews with the municipal and community partners in Q3 2022 and will circulate a memo to update this report with findings based on those interviews.

Recommendations:

1. Review pre-and post-intervention data and coordinate with evaluations of other Energy Efficiency programs to assess impact.
2. Track longitudinal metrics to understand progress over time.
3. Consider using metrics from the E3 report (Goals 2 and 3) to identify priority communities to reach.
4. Ensure that key determinants of success are aligned with best practices.
5. In future program cycles, engage with community partners to understand whether offerings align with community needs and whether any gaps exist.

Customer Engagement

Recommendations:

1. Define the specific outcomes the sub-initiatives aim to achieve and how these fit into the broader customer engagement strategy.
2. Define metrics for the sub-initiatives that capture customer behavior change as well as engagement.
3. Include emotional appeals in the messaging of website widgets and monthly insights emails.
4. Track metrics for the sub-initiative.

3. STUDIES IN PROGRESS IN 2022

The following studies had kick-offs in 2021 or 2022 and were still in progress at the end of 2022. Note that study numbers beginning with C are commercial, R means residential, and X studies cross both residential and commercial sectors.

C1906 – Strategic Energy Management (SEM) Program Evaluation.

This report will present the process evaluation findings, conclusions, and recommendations for the Strategic Energy Management (SEM) program evaluation in Connecticut.

Program overview

The SEM program in Connecticut is an initiative of the Business and Energy Sustainability (BES) suite of programs that target outreach and assistance to the C&I market to make continuous energy efficiency improvements to their buildings.⁹ The Connecticut utilities, Eversource and United Illumination (UI)/Avangrid, revamped SEM program offerings in 2019 with a focus on how to better recruit new participants and claim energy savings under the 2019–2021 Conservation & Load Management (C&LM) Plan. In the 2022–2024 C&LM plan, the utilities have expanded upon the prior goals to integrate the benchmarking initiatives and optimize efforts in claiming energy savings in the form of collaborative training sessions with SEM providers, engineering reviewers, and internal evaluation staff.

Process evaluation goals

Due to the historical low participation levels, the program selected new vendors in June 2022 through a formal RFP process and put forth more requirements on the SEM providers for outreach support to procure customers and cohorts. This process evaluation had two main goals. The first was to assess prior and revised SEM program processes to help program staff and determine whether the revised processes are set up for success. This included assessment of program design, implementation, customer awareness, and program communication. It also included identification of barriers to participation (which was prioritized due to low participant enrollment) and energy savings, as well as how to overcome these barriers. Finally, to assess processes and outcomes, the process evaluation sought to understand program influence to date. The second overarching goal was to develop recommendations on future research topics.

Methodology and approach

The DNV evaluation team (“team”) first reviewed program documentation, including a sample presentation, other marketing collateral, templates of the letter of intent, regression modeling agreement, SEM implementation agreement, program/operations manuals, and M&V plans. This review informed the development of program staff interviews and assessment of program design against identified best practices.

The team fielded in-depth interviews (IDIs) to gather perspectives about the SEM program from different program actors: program staff and implementers, participants, partial participants, and non-

⁹ The other programs in the suite are Process Re-engineering for Increased Manufacturing Efficiency (PRIME), Operations & Maintenance (O&M) and Retro-commissioning (RCx).

participants. Partial participants are defined as customers that applied for the program and/or started participating in the program but dropped out at some stage prior to implementing projects and receiving an incentive.

The DNV evaluation team interviewed seven program staff and implementers, three participants, and one partial participant. The team reached out to nonparticipants as well (i.e., those who were contacted by members of the program team but opted not to participate in the program) for an interview. However, none agreed to participate in an interview. SEM program staff provided contact information for implementers, participants, partial participants, and nonparticipants to DNV. The team attempted to recruit contacts via email as a primary method of communication, followed by two phone calls after three email attempts were exhausted and SEM program staff were notified of the outreach. The team used phone and video conferencing as the medium for conducting the interviews.

Findings, conclusions, and recommendations

The team investigated seven topic areas during the interviews. The seven topics were:

- Barriers to participation
- Data collection
- Non-routine events (NREs) and adjustments
- Modeling strategies and goodness of fit
- Top down vs. bottom-up savings calculations
- Effectiveness of training
- Successful program elements

The team also compared findings from this study with findings from a recent literature review and in-depth interviews with SEM stakeholders and experts across the country to examine process evaluation findings against SEM best practices. Findings from this study were documented in the SEM Best Practices Report provided to the CT EEB in Q2 of 2021.

The final report will include conclusions and recommendations from the research.

C2117 Persistence Study for Retrocommissioning Measures

This study is focused on understanding the persistence of RCx measures, to provide updated values for the PSD. The last CT study was published in 2013 covering PY 2008-2010 and only covered persistence of treated air compressor leaks. This study will conduct a literature search, staff interviews, and program tracking analyses to:

1. summarize findings by measure from other regional and national studies and
2. prioritize Energize CT RCx measures for an in-depth persistence evaluation and
3. develop defensible, recommended values for the CT PSD.

C2203 – Agriculture Market and Baseline Assessment

According to the CT Department of Agriculture, “Connecticut may be one of the country’s smaller states, but its agricultural impact is substantial. With a total of 5,521 farms, Connecticut’s ag industry

contributes approximately \$4 billion to the state's economy each year and provides approximately 22,000 jobs. However, current CT C&LM programs have had a minor focus on the Agricultural sector.

The C2203 Agriculture Market and Baseline Assessment study will utilize a combination of sources, including utility customer data, the CT Open Data portal, and tax records to develop an estimate of the total quantities and energy consumptions of agricultural market segments, including cannabis and indoor agriculture, poultry and egg production, dairy cattle and milk production, outdoor agriculture, and others. This data will be supplemented with data collected through 330 customer surveys, 75 site inspections, and 40 market actor interviews to identify market baselines and potentials for key technologies and recommended program concepts and delivery strategies.

The initial market segmentation is expected to be completed March 2023 with the primary data collection, baseline analysis, and reporting being completed December 2023.

C2201 – Commercial Baseline Study and Database Study

Project Background:

This study provides a representative baseline for building characteristics and equipment efficiency in the C&I sector. The study will be used for program planning, identifying efficiency gaps and opportunities, and making projections of current to future potential saturations for selected equipment types. The study will provide key inputs to Efficiency Potential studies and provide support for refining building prototype simulation models used to estimate measure energy savings parameters in the CT PSD. The study will also inform program planning and policy development.

Research Objectives:

- Existing building stock characteristics segmented by building type and vintage¹⁰. Characteristics to include (including crosstabs where practicable):
 - Building size (SF), age and number of stories
 - Occupancy schedules
 - Exterior opaque envelope characteristics (construction type, insulation levels)
 - Fenestration type (number of panes, frame type, glazing treatments such as tint and low-e). Fenestration area as a fraction of total exterior wall area.
 - Interior lighting. Saturation and vintage of lighting system types (fluorescent, HID, LED, etc.) and associated lighting power density (W/SF)
 - Interior lighting controls. Saturation of lighting control types (occupancy sensors, daylighting controls, networked controls, etc.) as a fraction of connected interior lighting load
 - Exterior lighting. Saturation and vintage of lighting system types (fluorescent, HID, LED, etc.) and controls.

¹⁰ Prototypical building models used in the CT PSD include assembly, auto repair, dormitory, hospital, light industrial, lodging – hotel, lodging – motel, office – large, office – small, religious worship, restaurant – fast food, restaurant – full service, retail – big box, retail – small, retail – large, school – community college, school – post secondary, school – primary, school – secondary, and warehouse.

- HVAC system type and vintage saturation (packaged rooftop, split system, window/wall unit, central VAV system, central CAV system, multizone system etc.)
 - Cooling equipment and vintage saturation (direct expansion (DX) system, air cooled chiller, water cooled chiller etc.)
 - Cooling equipment efficiency (EER or COP) and age by equipment type and size
 - Cooling equipment capacity (SF/ton)
 - Heating equipment saturation (furnace, hot water boiler, steam boiler, heat pump, district heating, RTU, etc.) by fuel type
 - Heating equipment efficiency (AFUE, thermal efficiency, COP) and age by equipment type and size
 - Heating equipment capacity (Btu/hr-SF)
 - Pumping system type saturation (chilled water (CHW), hot water (HW), condensing water (CW))
 - Pumping system connected load (kW/ton for CHW and CW, kW/kBtuh for HW)
 - VFD penetration in ventilation and pumping systems
 - HVAC system controls saturation (standard thermostat, smart thermostats, energy management systems, time clocks)
 - Service hot water system type saturation (central tank type water heater, HW boiler, distributed storage type water heaters, heat pump water heaters, instantaneous water heaters) by fuel type
 - Service hot water equipment efficiency (Energy factor, thermal efficiency, COP) and age by equipment type and size
 - Service hot water equipment capacity (Btu/hr-SF)
 - Onsite power generation (cogeneration, solar thermal, PV) in terms of installed capacity per SF of building
 - Refrigeration system data (refrigerated casework type, temperature (Low, medium, high) and linear feet, walk in coolers/freezer square feet and temperature, number of refrigerated vending machines, number and size of laboratory refrigerators and freezers), compressor plant type (dedicated compressor or rack system) and size (tons) and heat rejection equipment type (air cooled, evaporative)
 - Commercial kitchen data (type and linear feet of vent hoods, makeup air source, number of commercial dishwashers, number type and fuel source of fryers, warming cabinets, broilers, ovens, etc.)
 - Data centers and server room data (square feet of conditioned data center/server room space, number of servers)
 - Air compressors (quantity, type [reciprocating, screw or centrifugal], horsepower, and hours of use), and compressed air storage in gallons
- Existing building stock energy consumption (site energy/SF) by fuel type segmented by building type and vintage.

Study Approach:

The study is being conducted as a combination of secondary data analysis, market actor interviews, web-based building characteristics surveys, telephone surveys, virtual onsite surveys and in-person onsite surveys will likely be required. Bidders will discuss the following

specific methodological issues in their proposal: (a) how their proposed mix of data collection methods has been affected by their experience with various forms of general population data collection in the commercial sector since the onset of the pandemic; (b) their assessment of the current potential for methods other than onsite surveys to accurately capture various specific types of building and equipment characteristics data; and (c) the potential for their proposed methods to provide granular information regarding the characteristics of specific non-lighting equipment types. Key activities include:

- Provide a sample design strategy, including sample frame identification, segmentation strategy and target sample statistics
- Provide a normalization scheme for each of the research objectives above (result/SF, result/ton, result/kBtuh, etc.)
- Provide data crosstabs where practicable. For example, equipment efficiency by type, building type, vintage and capacity.
- Data collection is being conducted at a higher level of building type aggregation but a method to project the study results into the standard commercial building types in the PSD will be described.
- To the extent possible, results on lighting saturation are being integrated with recent CT lighting market share data to provide an overall picture of the commercial lighting market in CT.
- Issues / special considerations are commercial baseline study data, which are traditionally collected by onsite surveys. The COVID-19 pandemic has made onsite data collection problematic. The project team is evaluating best approaches.

Project Deliverables:

- Interim report on sample design
- Interim report on survey instrument design.
- Interim report on data analysis.
- Final report meeting research objectives stated above
- Project database with sample weights.

C2211 – BES – O&M – RetroCommissioning Impact and Process Evaluation

Project Background:

This study will provide impact estimates and a process evaluation for the Operation and Maintenance (O&M) and Retro-Commissioning (RCx) components of the Business and Energy Sustainability (BES) umbrella. Strategic Energy Management (SEM) is currently the subject of a process and impact evaluation study (C1906) and is excluded from this project. Impact evaluation results must meet or exceed best practices and the requirements of the New England Independent System Operator (NEISO) Forward Capacity Market (FCM). Process results must provide guidance on the efficiency and effectiveness of the program operation compared to expectations and to similar offerings in other jurisdictions. The last evaluation study for BES/O&M – RCx was C1641 completed in 2018.

Research Objectives:

- Estimate gross energy savings and winter/summer demand savings in compliance with NEISO FCM rules. Estimates are needed by each BES component and for BES overall.
- Provide retrospective and prospective realization rates for energy and demand savings; the prospective values will be included in the PSD.
- Assess the accuracy of savings estimation methods used by PAs and vendors, identify changes where needed.
- Compare outcomes of BES to similar initiatives offered in other jurisdictions with particular attention to neighboring states. Performance metrics include but are not limited to relative savings, cost-effectiveness, penetration by sector and customer type.
- Compare operational structure and efficiency to similar initiatives in other jurisdictions, with an emphasis on neighboring states. Identify improvement opportunities.
- Identify underserved sectors/customer types/businesses that offer opportunities for additional savings.
- Measure customer experience and satisfaction with program operations based on participant and near-participant surveys. Identify improvement opportunities.

Study Approach:

Site specific M&V data will be required for the impact portion of this study. Ex-post savings will be supported with information from metering, EMS trends, maintenance logs, nameplate, spot measurements. RCx pre- and post-intervention data will be reviewed. Facility operators will be interviewed for operating parameters including past and current schedules, and set points.

Surveys and interviews of participants, vendors, implementers are being used to collect data for the process evaluation. Analysis tools, data records, and the PSD are being reviewed for adherence to accepted engineering methods. Program structure, success, gaps and other performance parameters are being compared to 3 or more similar offerings in neighboring and similar jurisdictions. The team is working to develop protocols that can use virtual or contactless data collection approaches. Strategies including engaging site personnel or building operators to take photos or videos of targeted equipment, or engaging HVAC service companies that maintain the building for equipment inventories and nameplate data are being investigated. In addition, strategies that reserve onsite surveys for high value sample points are being used, as well as alternative strategies for how to handle lighting vs. non-lighting measures.

Project Deliverables:

- Interim report on approach, data needs, and data collection plans.
- Interim report on sample design.
- Interim report on M&V plans, survey design, survey instruments.
- Interim report on data analysis and first draft findings.
- Final report meeting research objectives stated above, including recommendations.
- Project database with sample weights.

R1968 - RNC Baseline and Code Compliance (Phase 1)

Residential new construction (RNC) baseline studies are typically conducted one year after a code change. This allows the study to capture some homes built at the end of the old code and some at the beginning of the new code. For a number of reasons, this type of study is becoming harder and more expensive to accomplish: difficulty in unbiased recruitment of non-participant homes, difficulty in measuring energy efficiency differences after construction is completed, and difficulty in parsing out program and code effects. The study will gather data on code compliance, baseline, and may provide information related to industry standard practice (ISP) in new construction.

R1982 - HVAC / DHW Performance & Potential Evaluation

This project is focused on obtaining up-to-date performance measurements for two emerging technologies: mini-split heat pumps and heat pump water heaters. This project has installed metering equipment in 150 homes in Connecticut to provide detailed energy use and load shapes for prevalent HVAC and DHW equipment types. This data will update the PSD values for efficiency, annual use, seasonal peak and off-peak loads.

The project has installed end-use metering equipment on major energy-consuming equipment in 150 single-family homes across Connecticut. Emphasis will be on selecting homes with heat pumps or heat pump water heaters, though the sampling plan includes homes that have furnaces, boilers, or other types of water heaters. Meters will remain in place for at least one year so that data from summer and winter periods will be collected. When possible, other large electric equipment is metered. Together this project will update baseline and efficiency assumptions in the PSD. It will also provide better load shape data for use in demand-response studies and as inputs to the New England ISO.

R1983 HES & IE Process and NTG Evaluation and Impact Evaluation

This project is conducting a comprehensive process evaluation and impact evaluation of the single-family portions of the Home Energy Solutions (HES) programs and HES-IE (income-eligible) program. The HES and HES/IE Programs are the biggest programs in Connecticut's residential portfolio. The process evaluation focuses on program process and efficiency, document and performance review and a substantial customer profiling / data mining effort. The impact evaluation quantifies gross and net savings, NTG, and realization rates at the end use and measure level – with a drill-down on drivers for unexpected results.

The process component uses document review, interviews, and hundreds of surveys to examine: workforce needs, marketing and customer /engagement, recruitment, program delivery, quality assurance and vendor performance, vendor business models and viability, costs assessment, data collection and management, the role of financing including coordination with the Green Bank, and customer satisfaction. The program tracking database review is examining: performance, performance by contractor and utility (and possibly region or other factors), backlogs, percent with deeper measures, and other statistics.

The data-centric residential market assessment / customer profiling effort is examining what areas and customer types have been served by the residential efforts and where opportunities lie to improve participation, assess equity issues, and inform program refinement, with results stratified by renters, low and moderate- income households, households that have limited English proficiency, distressed areas, and other subgroups.

The impact evaluation is very important to Connecticut's update of the PSD values for this program and uses surveys and statistical analysis to provide measure- and end-use related consumption, savings and realization rates, and includes a detailed drill-down of drivers for the results. A comparison to recently-completed work using Recurve will also be conducted.

The major parts of the project are expected to be completed by Summer 2021, with additional research results delivered in late 2021 and early 2022.

R2029 – Single Family Weatherization Metric and Update

This study's goal is to develop and estimate a quantitative indicator of progress toward the Legislature's Weatherization Goal that can be estimated and reviewed on a regular periodic basis, be reasonably inexpensive to measure, and reflect the progress over time. The goal is to leverage available secondary data, potentially from the HES / HES-IE program and from CT participants in the national Weatherization Assistance Program (WAP) to create this metric.

In 2011, the CT legislature established a goal of having 80% of homes weatherized by 2030; however, the legislature was mute on the definition of weatherization. The 2014 R5 Study developed housing "types" and inspected 180 homes to assess the performance of homes relative to EEB's draft weatherization standard. The weatherization definition used was based on presence of various measures on-site, some of which could be validated on-site, and some of which ultimately could not be inspected in a practical / reliable way. The study found a significant shortfall in meeting the goal, but also cost a great deal to conduct, so it is not a feasible source for frequent updates monitoring progress. This analysis relies on a "desk study" approach rather than a primary data study with on-site data collection.

These findings are out of date at this point, but a progress metric toward the Legislative goal of 80% Residential Weatherization is a priority to DEEP. This study is tasked with:

- Identifying one or more feasible, workable, replicable weatherization definitions, with recommendations for best metric
- Quantification of the metric based on readily-available data to be reviewed by EM&V, DEEP and potentially a public process,
- Revisions as needed, and instructions (and data sources) for implementation of the metric into the future, and
- Coordinating with / supporting DEEP on aspects of the public process.

Researchable Questions:

- What progress is being made toward the 80% weatherization goal? How much progress is still needed?

- Is this a workable definition for “weatherization”? What other definitions may be appropriate and/or feasible and measurable? Can this (or another reasonably-feasible) method be used to track progress going forward in-between larger field inspection-based studies of weatherization progress?

R2209 and R2215 RNC NTG and Impact Evaluation

R2209 and R2215 were expected to be updates of earlier studies on the NTG and savings estimates for the Residential New Construction (RNC) Program. The normal sequence that each of these studies is updated every three years. The R2209 project was intended to measure the NTG impacts of the RNC program for participants in 2022. R2215 was expected to measure impacts using 2024 participants. However, delays in the introduction of the new code and the the new code release delayed R2209. In addition, the State’s direction to require that RNC only cover all-electric homes changed the need for a retrospective look at the previous incarnation of the RNC program.

The combined study uses a Delphi panel and interviews with program implementers and builders to estimate the baseline conditions and prospective NTG values for the new all-electric RNC program (which is just being finalized). The study includes a high priority on the need by implementers for baseline assumptions for program homes. Therefore, the contractor interviews are being done on an accelerated schedule to provide data to the Delphi Panel. The Delphi Panel will then provide prospective NTG and program baseline estimates for the program. The impact analysis is scheduled for late 2024 as part of this combined evaluation study.

R2213 – Delivered Fuel Savings Impacts — Methods & Attribution

Connecticut households rely heavily on delivered fuels for home heating. Energize Connecticut programs serve such households, but verifying savings remains difficult because, unlike electricity and natural gas, no consistent billing data exist for delivered fuels. The central question that this study seeks to answer is to address how best to estimate the delivered fuel savings achieved by energy efficiency programs and relevant measures and end uses in Connecticut. The study objectives include:

- Identify industry best practices in estimating attributable delivered fuel savings at program, end-use, and measure levels for residential and commercial programs.
- Identify methods for estimating gross direct program savings of delivered fuels, including weatherization measures and heat pumps displacing delivered fuel systems.
- Develop methods for better integrating delivered-fuel savings into new residential and commercial vendor / audit tools
- Produce results that can inform fuel switching programs, incentives policy changes, or greenhouse gases (GHG) policies that Connecticut has or may adopt.

The study will conduct a literature review, undertake interviews with subject matter experts and conduct sensitivity analysis to assess the degree to which changing current practices would have a significant impact on estimated energy savings and GHG emissions estimates. The final report will provide recommendations for how best to measure delivered-fuel impacts and integrate these into program tracking and GHG accounting.

The study was launched in December 2022 and is expected to be completed by the end of 2023.

R2246 - Residential Heat Pump Study

This study conducted jointly between Connecticut and Massachusetts is metering the usage and performance of heat pumps in homes. The study will install sufficient metering equipment in more than 170 homes across the two states that have installed heat pumps designed to fully or partially heat the home.

The residential heat pump (HP) study objectives are as follows:

- Perform field monitoring to assess the actual heating and cooling performance and usage of the latest generation of residential heat pumps being supported by the programs
- Perform field monitoring of baseline HVAC technologies as available and appropriate, estimate baseline (and program-reduced for partial displacement installations) HVAC consumption across all fuel categories
- Analyze and quantify gross baselines for residential heat pumps to derive gross measure impacts
- This study will provide the PAs with typical performance curves, load shapes, and de-rate factors for central and mini-split HP installations in Connecticut and Massachusetts, typical electric consumption of heat pump equipment in heating and cooling seasons, and measure impacts that represent the range of heat pump installations through the existing homes heat pump program offerings.

Key research Questions include:

1. What is the difference between rated and operational performance of heat pump systems, and what is the performance and delivered capacity of heat pumps down to low outdoor air temperatures?
2. What is the usage and peak demand of heat pumps in Connecticut during both heating and cooling seasons?
3. What is the overall delivered fuel savings and electric consumption increase due to central and mini-split heat pump installation for partial and full-displacement scenarios?
4. Can installed heat pumps meet the full heating loads of the homes during the coldest days?
5. For partial displacement systems, what type of control sequences are employed, and what settings and setpoints are contractors or customers programming?
6. What are the distributions of gross baseline heating/cooling systems for measure installations?
7. What fraction of total load across the cooling and heating season is being met by the heat pump? What causes homes to have a higher or lower fraction?
8. For partial displacement systems, when are backup HVAC systems being used? What is the primary driver for the backup HVAC system being used? What improvements could be made to increase the displacement fraction?

In the fall of 2022, metering equipment was installed in homes. A preliminary report on the first winter's metering will be released this spring. In addition, the metering of an additional 135 homes in both CT and MA will be installed this spring.

X1942B and C – Cross-Cutting Non-Energy Impacts Evaluation – Heat Pumps and Air Sealing Measures

Non-energy impacts (NEIs) are the effects, beyond energy savings, that energy efficiency program measures deliver to participants (comfort, productivity, etc.), utilities (T&D, bill payment improvements, etc.), and regional customers beyond participants (called “societal”, including emissions reductions, job creation, etc.). A traditional benefit-cost or cost-effectiveness test would include all benefits divided by all costs associated with the perspective of the “test”, but utility C/E tests have traditionally included only direct energy savings in the numerator, omitting indirect, harder-to-measure NEIs.

CT has been reviewing its cost effectiveness tests (C/E), and has been undertaking work consistent with the National Standard Practice Manual (NSPM) to review policy and options related to their C/E test, its perspective, and the potential role of various types of non-energy impact values in the revised test. Currently, only a limited set of NEIs are include in CT’s cost-effectiveness test.

This study will provide data and information to support review / revision work of CT cost-effectiveness test, and is designed to provide NEI results that can be included in updated C/E calculations as possible after CT’s C/E policy is updated. Previous work was completed on arrearages; these studies focus on Heat Pump NEIs and NEIs for the HES and HES-IE air sealing measures.

The project is not a literature review; instead, it is data-focused, including substantial CT-based primary research. The study will provide quantitative estimates of high priority NEIs that can support revisions to cost-effectiveness tests, enhance the low income and other NEBs in PSD Appendix 6, and also identify next NEI research priorities.

The methods to be used are best practice, resulting in NEIs that are defensible, derived using transparent procedures, and not be perceived as a coming from a “black box”.

Researchable Questions / Objectives:

- Identify and implement cost-effective, efficient, state of the art estimates of NEIs to address priorities for CT.
- Support policy and cost-effectiveness direction development, and answer issues addressed in the Order by expanding the coverage of NEIs in Appendix 6 of the PSD (from the current low-income NEBs, HES NEIs, and C&I BES NEIs).

As mentioned, these projects involve detailed survey work, and calculation of NEIs associated with measures installed in the HES / HES-IE program, and Heat pump measures. Additional efforts were completed in 2022 (described above), including an arrearage analysis, designed to allow quantification of the payment and financial benefits associated with CT’s low-income program.

X2001B – Measure Life Study / EUL Update – Commercial Measures

The measure lifetimes / EULs in the CT PSD are a key part of the cost-effectiveness calculations for measures and programs. However, the numbers in the PSD are very aged (>20 years), have been adopted / adapted from other locations (many without statistical underpinnings), and have not been updated to today's technologies or CT's conditions. Defensible numbers are not available from literature; new surveys and statistical work are needed to support improved values.

Research Objectives: The research objectives for this two-part project are to provide statistically-defensible, updated, CT-appropriate EULs for several major Residential and C/I measures. Residential measure research was completed in 2022; the commercial measure work was underway in 2022. The selection of measures is prioritized based on savings, program importance, age, measure importance, and ability to conduct analytical / quantitative work that will meet budget (e.g., HVAC, DHW, but excluding lighting).

Researchable Questions:

- What are the highest priority EULs to address? Which can this study provide quantitative information for?
- How can the study be designed to use best (well-known) practices for EUL studies, but also leverage the fact that many years of participants can be surveyed in one sample to reduce cost and improve efficiency? For which measures can this work or not work? Can a template be developed and applied to future CT residential and commercial EUL studies?
- What are updated values for EULs for a set of priority residential and commercial EULs?

Methods:

The study is being conducted using the basic long-recognized statistical approaches for EULs – but can be conducted more efficiently than traditional studies that look at one program year, and later conduct follow-up surveys to identify later, longer-term failures. Instead, this study uses the fact that programs have been offering many of the same types of measures for many years, and if multiple cohorts / vintages of participants receiving measures are surveyed now (including those installed more than 10 years ago down through recent-year participants), no follow-up studies are needed to identify long-period failures. This approach should save time and money, and lead to reliable estimates of updated measure lifetimes.

X1939-2 – Early Retirement Evaluation – Phase 2

This is an evaluation of early retirement programs in CT. In addition to evaluating the CT programs directly, it also includes secondary research and interviews on other programs throughout the country to provide program design and process guidance. Phase 1 of the project was completed in 2021.

The second phase of this evaluation is intended to be an impact evaluation of the early retirement programs that have been released in CT. At the start of the Phase 2 effort, four early retirement programs have been launched: two rounds of chiller programs, both targeting larger chillers (600+ tons); a boiler program; and a rooftop unit program. These programs have been competitive bid programs that accept applications from individual customers or implementers. The participation numbers for each of the Early Retirement programs follows:

- 2019 Chiller Program - 4
- 2020 Chiller Program - 1

- 2020 Boiler Program - 1
- 2020 RTU Program - 11

Twenty total projects have been awarded through these four programs. Savings have not been claimed for any of these programs yet. At the time of completion of the Phase 1 report the projects are just being installed for the first chiller program that was released in 2019. The original evaluation plan laid out tasks including sample design, desk reviews, and customer interviews. The primary reason the review included desk reviews was that the key information to be reviewed for incented projects in these programs was program eligibility, measure event type, and baselines. Going on-site to measure equipment performance is not nearly as valuable to the program as evaluators confirming the program eligibility and reviewing the preponderance of evidence collected for completeness and program qualification.

With the current status of the programs, the evaluation team is conduct follow undertaking desk reviews and customer interviews for all 20 of the awarded projects to date. This can provide near-real-time feedback to the early retirement program implementers as well as the EA team as to how the decision and documentation process is going so far. Despite not having claimed savings yet, this can provide an estimate of what the desk reviewed realization rate would be for these projects. The evaluation team believes this will provide more immediate value to the program implementers than waiting for more participation prior to evaluating. The team can then re-assess the plan moving forward once that review is complete.

In order to complete this review, the evaluation team will need to request program data for the projects that have been approved to date. Examples of the requested files may include but will not be limited to:

- Project application, savings calculations, individual site reports, photos, M&V data if applicable, project invoices
- Possibly billing data if determined it would be valuable for any of the individual programs.

C2230 – Heat Pump and Electrification Study

The purpose of the Commercial Heat Pump and Electrification Study is to characterize the commercial heat pump (HP) and heat pump water heater (HPWH) markets in Connecticut (CT). Study objectives are as follows:

1. Identify pathways for all-electric new construction
2. Assess existing building retrofit opportunities and compare savings and cost based on various equipment parameters
3. Refine savings estimation methods
4. Analyse attribution and baseline
5. Support the commercial heat pump pilot

Heat pump equipment applications in commercial buildings cover a wide range of equipment types. The study will address HVAC heat pump technologies as follows:

- Ductless Air Source Heat Pump (mini split)
- Ductless Air Source Heat Pump (multi-split)
- Variable Refrigerant Flow (VRF) Heat Pump Systems
- Ducted Air Source Heat Pumps
- Geothermal/Ground Source Heat Pump
- Water Loop Heat Pumps
- Air-to-Water Heat Pumps
- Water-to-Water Heat Pumps

Additionally, the study will cover heat pump water heater technologies as follows:

- Standalone heat pump water heaters in three size ranges (<= 40 gall., 40 to 55 gall., >55 gall)
- Component based heat pump water heaters

The project objectives will be met through a combination of data collection and analysis techniques as follows:

1. Utility Program Staff Interviews & Document Review
2. All-Electric Program Best Practices Review
3. New Construction Market Actor Interviews
4. Heat Pump Supplier Interviews
5. Heat Pump Equipment Cost Research
6. Utility Program Participant Surveys
7. Utility Program Participant Project Application Reviews

The study will rely on the concurrent C2201 Commercial Baseline Study to define common HVAC and water heater system types and fuels in the commercial sector and will coordinate with the concurrent X2231 Cross-cutting Heat Pump & Electrification study to address areas of common interest.

X2231 – Heat Pump and Electrification Study – Cross-Cutting

In order to complete this review, the evaluation team will need to request program data for the projects that have been approved to date. Examples of the requested files may include but will not be limited to:

- Project application, savings calculations, individual site reports, photos, M&V data if applicable, project invoices
- Possibly billing data if determined it would be valuable for any of the individual programs.

Beneficial Electrification. The American Council for an Energy-Efficient Economy defines beneficial electrification strategies as those providing three forms of societal benefits: reduced energy consumption, lower consumer costs, and reduced greenhouse gas emissions (GHGs).¹¹

In keeping with this definition, this study will focus on identifying programmatic best practices and market opportunities to promote high-efficiency electrification measures that result in installing the best electric available option. For example, replacing a 95% annual fuel utilization efficiency (AFUE) condensing natural gas furnace with baseboard electric radiant heating, but it's not *beneficial* electrification.

¹¹ American Council for an Energy-Efficient Economy (ACEEE), Beneficial Electrification and Energy Efficiency Policy, <https://www.aceee.org/sites/default/files/electrification-dc.pdf>.

Research objectives

- **Illuminate best practices** regarding fossil fuel to electric conversion and program design efforts in both existing and new buildings. Determine the value of integrated controls that would control both an existing/remaining heating system and the heat pump.
- **Identify and characterize new and emerging target measures** to help support electrification efforts in both the residential and the commercial sectors. For the commercial sector, this should cover all major existing building heating, ventilation, and air-conditioning (HVAC) systems where a heat pump and/or variable refrigerant flow (VRF) system is feasible, including heat pump rooftop units (RTUs) and dedicated outdoor air systems or heat pump systems.
- **Analyze the technical, economic, and market potential** for beneficial electrification in Connecticut.

Research outputs

- **A characterization of existing conditions in Connecticut** related to beneficial electrification, inclusive of building stock, equipment saturations, technology maturity, and demand- and supply-side market actor readiness.
- **A detailing of electrification measures** (about the technology, relevant applications, strengths and weaknesses, market availability) for consideration in Connecticut.
- **A summary of programmatic and policy best practices** for promoting beneficial electrification observed outside of Connecticut that can inform efforts within the state.
- **An estimate of the market potential** associated with identified electrification measures (for which sufficient data exists to support modeling) in Connecticut.
- **A list of specific programmatic and/or policy recommendations** for realizing the qualitative identified and quantitatively modeled electrification potential; recommendations will be actionable, specific to Connecticut’s existing conditions, and observe best practices.

This study is one of three concurrent, complementary studies in Connecticut exploring electrification in general and heat pumps specifically. Table 1 lists these three studies, study numbers, the evaluation teams responsible, and the primary focus of each study.

Table 1: Relevant Heat Pump Studies

Name	#	Lead Firm	Primary Focus
Residential Heat Pump Study	R2246	Guidehouse	Metering, baseline, and attribution
Commercial Heat Pump & Electrification Study	C2230	DNV	New Construction and retrofit pathways, cost, performance, and savings
Cross-Cutting Heat Pump & Electrification Study	X2231	Cadeo	Program best practices, market study on emerging heat pump measures, potential analysis

The teams leading these studies coordinated while developing their scopes of work and will meet monthly throughout the duration of all three studies to maximize the value of these concurrent efforts and avoid redundancy.

Project Approach

The electrification of buildings through greater heat pump deployment and other electrification measures is a cornerstone of the mitigation strategy to reduce greenhouse gases as stated in the Governor’s Council on Climate Change.¹² In line with the decarbonization priority of the Conservation & Load Management Plan,¹³ increased programmatic support is crucial to reduce GHG emissions from the building sector.

To achieve Connecticut’s target of reducing GHG emission 80% below 2001 levels by 2050, programs need more detailed market intelligence on how and where to focus their efforts. Under the heat pump and electrification assessment, the Cadeo team will complete the tasks shown below.

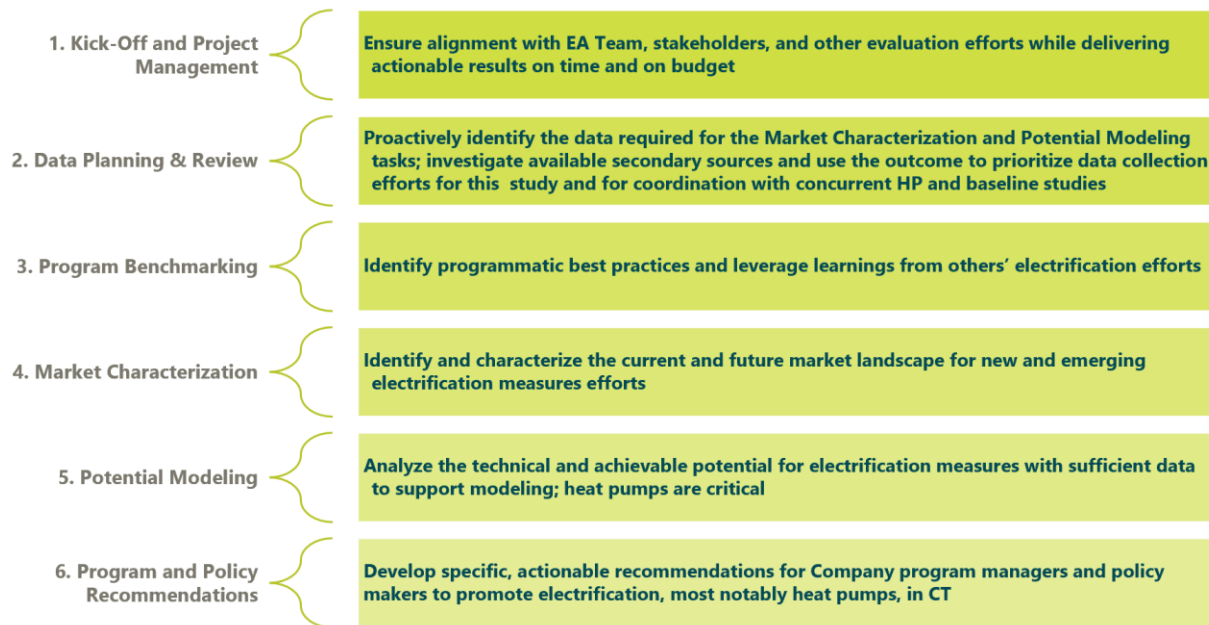


Figure 1: Project Tasks

Error! Reference source not found. Table 2 shows how each activity under the scope of work informs the research outputs.

Table 2: Activities and Research Outputs

¹² Connecticut Department of Energy and Environmental Protection, *Building a Low Carbon Future for Connecticut*, Recommendations from the Governor’s Council on Climate Change, December 2018, <https://portal.ct.gov/-/media/DEEP/climatechange/publications/BuildingaLowCarbonFutureforCTGC3Recommendationspdf.pdf>.

¹³ <https://portal.ct.gov/DEEP/Energy/Conservation-and-Load-Management/Conservation-and-Load-Management>

	Characterize Existing Conditions	Identify Electrification Measures	Identify Best Practices	Estimate Market Potential	Provide Recommendations
Data Planning & Review	X				
Program Benchmarking		X	X		X
Market Characterization	X	X	X	X	
Potentials Modeling	X	X		X	X
Program and Policy Recommendations	X	X	X	X	X

X2244 – Review Possible Shift from EE to GHG Policy Integration Goals and Metrics at the State Level

Project Background:

The State of Connecticut is considering a strategic transition from an EE focus to GHG metrics and focus for program goals and design, and seeks information on options, rationale, and experience in other locations to inform its consideration of this issue.

Research Objectives:

The State is interested in an exploration of the various options for this strategic shift and associated revised goals, including:

- rationales for identified GHG policies, goals, and metric options.
- advantages / disadvantages / tradeoffs assessments
- transitions issues, disruptions, and implementation experience
- best practices
- directions, progress, status, implications, and results / experience in other leading states.
- Potential effects on programs, workforce, customers, stakeholders.

Methods:

The study is being conducted as a secondary data effort. Key efforts include conducting a detailed literature review and interviews with subject matter expert (SME) and officials / stakeholders in Massachusetts and other leading states to identify the best practices and understand the experience and advantages / disadvantages related to this type of strategic change.

The study is conducting at least a high-level review of legal or other barriers to this change. This will require review of some Connecticut documents and interviews with relevant Connecticut stakeholders.

Deliverables:

The study's outputs will include a draft and final report, and presentation that include:

- Listing and information on other jurisdictions that are using some or all of the approaches
- Specific, detailed tables and analyses of the options, benefits, and experience.
- Implications for programs, savings, and effects on programs, workforce, and stakeholders.
- Information about barriers or opportunities, given the Connecticut regulatory situation.
- Recommendations on one or more specific options, best practices and supporting information (metrics, data collection, etc.), as well as a summary of the needed next steps for implementing recommended strategic changes.