Compared to What? An Alternative Strategy for Estimating Commercial and Industrial New Construction Baselines

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ABSTRACT

Determining the baseline for commercial and industrial (C&I) new construction program evaluations presents unique challenges. The new construction market is diverse and dynamic. Building practices and technologies vary widely from one project to the next and change rapidly over time. These characteristics make it difficult to conduct a comprehensive new construction baseline study to support estimation of program impacts. A common practice is to use the applicable energy code as baseline; however, experience demonstrates that this approach is not always accurate (Wright et al. 2000).

This paper presents an alternative baseline strategy that was developed for a recent impact evaluation of the New York State Research and Development Authority's C&I New Construction Program. This approach included calibrated simulation modeling for a sample of projects under three scenarios: 1) as-built, 2) energy code baseline and 3) project-specific baseline. The models were used to determine gross savings and modeled partial net savings[2] (MPN) which includes free ridership (FR) and inside spillover. MPN also uses surveys of multiple decision makers and triangulation of survey results.

The MPN method quantifies the energy use of the specific technologies intended to be installed in the building prior to program intervention. This accounts for deviations in baseline from code. MPN analysis allows evaluators to obtain and incorporate a level of detail that cannot be acquired through traditional FR survey techniques. This paper describes the evaluation design, implementation and results with a specific focus on the MPN methods and findings.

Introduction

Energy efficiency programs targeting the new construction market are typically designed to improve building energy efficiency over the minimum levels mandated in the applicable energy code. Many states lack the resources to rigorously enforce energy codes which could result in non-compliance (Stellberg et al. 2012). Market influences such as LEED[3] and building benchmarking requirements can drive the market to include building design solutions that are more efficient than code. It is widely understood that code is not necessarily an accurate representation of the levels of efficiency that would be achieved absent the involvement of the energy efficiency program.

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[1] Any opinions expressed, explicitly or implicitly, are those of the authors and do not necessarily represent those of the New York State Energy Research and Development Authority.
[2] This term uses "modeled" to indicate that the savings estimates are derived through energy modeling. The term "partial net" refers to the fact that this component of net savings includes only free-ridership and inside spillover impacts.
[3] Leadership in Energy and Environmental Design (LEED) currently offers up to 19 credits for energy cost reductions ranging to 48% relative to a code compliant building.

Impact evaluations of new construction programs need to determine the savings above what would have occurred absent the program's intervention through gross and net impact analysis. Therefore it is essential for new construction program evaluation methods to accurately account for baseline practices occurring in the market.

This paper describes the recent evaluation of New York State Research and Development Authority's (NYSERDA's) commercial and industrial (C&I) New Construction Program (NCP) using a new method designed to address these baseline issues. It provides an overview of NYSERDA's NCP, describes the evaluation approach and details the findings.

Background

NYSERDA has been operating its NCP since 2001. The program influences the adoption of energy efficient design approaches, LEED Certification and commissioning in new C&I buildings by providing technical assistance, energy modeling and incentives for whole building, custom and prescriptive measures. Using evaluation teams selected for their expertise in impact and process evaluations and market characterization studies, NYSERDA regularly conducts evaluations to assess performance and provide input to the NCP regarding the market and the program's impacts.

The impact evaluation covering NCP projects completed in 2007 and 2008 commenced in 2009 and was finalized in 2012. Due to the long development cycle associated with large C&I new construction projects, the projects completed in those years spanned numerous changes in program implementation. There were 236 completed projects with approximately 83 gigawatt hours of claimed electric savings. The NCP addressed a wide range of building types and end uses. Building end uses addressed by the program included envelope, HVAC[4], lighting, controls, residential appliances, domestic hot water, process and refrigeration. The program reported some natural gas impacts; however, natural gas savings were not a focus of the program at that time and the evaluation did not develop natural gas savings estimates at the program level.

Approach

The purpose of this impact evaluation was to establish rigorous and defensible estimates for the net electric energy and demand savings attributable to NYSERDA's NCP. Due to the complexity of the market, the diversity of project types and the variability of savings, a high level of rigor, including on-site measurement and verification (M&V) and calibrated modeling, was used to evaluate gross savings.

A new method, the modeled partial net (MPN) applied a high level or rigor to estimate the impacts of free ridership[5] (FR) and inside spillover[6] (ISO). This method employed multiple strategies to increase the validity and reliability of results including: surveys of multiple decision makers (owners and designers) for each project, inquiry regarding specific technologies in the respondent's building, triangulation of survey results by members of the evaluation team and modeling of the impacts by adjusting the gross savings model to reflect the counterfactual baseline energy use. The authors believe this approach is a significant improvement over standard impact evaluation techniques in estimating FR and ISO in new construction projects.

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[4] Heating, Ventilation and Air Conditioning (HVAC)

[5] Free ridership (FR) refers to installed efficiency measures claimed by the program which are found not to be attributable to the program

[6] Inside spillover (ISO) refers to installed efficiency measures in participant projects that were not claimed by the program and were installed due to program influence. ISO tends to be small in new construction programs that treat the whole building.

In reality, there are two components to estimating what would have occurred without the program:

1. The influence of the program on the decision to install the efficient equipment
2. The actual efficiency of the alternative equipment that would have been installed in the absence of the program

Common methods to estimate FR and ISO based on self-reports ask respondents to estimate the efficiency level they would have achieved absent the program (Megdal et al. 2009). The simplifying assumption is made that participants can accurately estimate energy savings between 0% and 100% relative to a baseline that the project would have achieved in the absence of the program, that there is a measure that could achieve the estimated efficiency level (Peters and McRae 2008) and that the baseline practice is consistently known among respondents. In contrast, basing the evaluated net savings on specific technical data collected from multiple sources and the calculated project-specific baseline energy use creates a more nuanced assessment by analyzing the specific equipment and controls that were intended for the project prior to program participation. Thus, the MPN approach has the potential to provide better information than more typical strategies because the final estimate of net effects is based on an engineering estimate of the counterfactual baseline determined by modeling project specific technology inputs resulting in a more reliable estimate of net savings.

Evaluation Components

The NCP impact evaluation included the following major components:

1. Determination of project evaluated gross savings which included site-specific M&V of installed measures, modeled as-built annual energy use of the installed systems, calibrated to utility data where feasible and normalized to typical meteorological conditions; and modeling of code baseline energy use for the systems affected by the program
2. Determination of modeled partial net savings including in-depth interviews of participating owner and design firms, modeling project-specific baselines
3. A non-participant baseline survey which was compared to MPN findings for consistency
4. Determination of participant outside spillover (OSO) through survey data and review and use of OSO data from the prior evaluation
5. Determination of non-participant spillover (NPSO) through non-participant surveys
6. Pilot study of potential market effects not captured by spillover (SO)

The focus of this paper is primarily the modeled partial net savings analysis which is related to the gross savings analysis.

Methodology

The evaluated gross savings and modeled partial net savings were estimated for every project in the sample, and the results were aggregated to program totals using stratified ratio estimation. The following sections provide an overview of the sampling plan, measurement and verification and MPN methods.

Sampling

The sample was designed for estimating the realization rate[7] (RR) and MPN using stratified ratio estimation, resulting in an initial sample of 40 drawn from the 236 completed projects. The sample frame was divided into three strata according to the size of the program reported energy savings and

[7] Realization rate (RR) is the ratio of evaluated gross savings to program reported savings.

projects were randomly selected in each stratum. The sample stratification is shown in Table 1. Site-specific M&V was completed for 39 of the 40 projects in the sample[8].

Table 1. Summary of Sample Stratification

Size Stratum		Project Population	Projects in Sample	Projects Completed	Min. Project Savings (kWh/Year)	Max. Project Savings (kWh/Year)
0	Tiny (excluded)	100	0	0	0	48,777
1	Small	94	15	15	50,004	387,040
2	Medium	32	15	15	413,987	1,049,706
3	Large	10	10	9	1,056,600	17,602,951

Site-Specific Measurement and Verification

Site-specific M&V of the installed efficiency measures was the foundation of the NCP Impact Evaluation and supported the development of the three models: as-built, code compliant and project-specific baseline. The site-specific M&V was conducted to gather sufficient information to support a rigorous analysis of the program-supported measures installed in the M&V sample projects. This effort included M&V Planning, on-site investigation and metering and a rigorous quality assurance process.

M&V Plans were developed by the assigned review engineer (RE) based on program files, utility bills and building operator surveys. These plans guided the on-site work and detailed the analysis approach. The evaluation protocol typically resulted in detailed M&V for measures that accounted for at least 95% of kWh and 90% of demand savings for each project.

The REs conducted field inspections, interviewed participants regarding operational parameters, and performed metering for each site. They obtained site data such as as-built drawings, sequences of operation, and trend logs showing HVAC equipment operation from the building automation system (BAS). The evaluation protocol required the REs to validate BAS data through on-site metering.

The data collected on site was used along with metering and utility data to model the annual as-built energy use.

As-built Model & Utility Calibration

The Impact Evaluation Team conducted an analysis of the installed measures for each project in the sample using either full building energy modeling or custom, hourly, annualized (8760) spreadsheet analysis (Patil, Barbeiri & Azulay 2009) of the efficient equipment or systems. Computer simulation models or custom spreadsheet analyses were developed using data from the on-site and interview data, program files and where available, the original program models, which were updated to reflect as-built conditions. The analysis determined the annual energy use and the performance period demand of the installed equipment.

The models were calibrated at two levels. First, metered data from the sites was used to inform the models by calibrating the modeled energy use of major equipment, such as chillers and air handlers, to the actual metered energy use as measured on-site within given operating conditions. Secondly, calibration of whole building models to monthly utility data was completed following the protocols of International Performance Measurement and Verification Protocol Option D – Calibrated Simulation Modeling and ASHRAE Guideline 14-2002 Measurement of Energy and Demand Savings. The models

[8] One large project declined participation in the evaluation and was not replaced due to the fact it was in the census stratum.

were weather normalized to reflect the energy consumption for a typical meteorological year for the locale in which the site is located.

The result of this effort was an accurate model of the as-built building and/or measure which could then be modified to accurately estimate the consumption of baseline efficiency levels.

Code Baseline Model

The evaluators determined the code baseline efficiency levels for the measures. These code baseline measures were input to the calibrated as-built model on an iterative basis until the code baseline building model was achieved. For 8760 spreadsheet models, efficiency levels were adjusted to code levels and the spreadsheet analysis was run. Applicable baseline codes ranged from 1999 – 2004 New York Energy Conservation Codes depending on the time of the building permit for the projects in the sample.

The result of this step was a solid estimate of hourly energy use for the code compliant building or equipment.

Project-Specific Baseline Model

The purpose of the project-specific baseline model was to estimate the building energy use that would have occurred absent the program. The as-built model was modified to reflect the project-specific baseline for each project using the following process:

1. Project-specific baseline surveys were developed by customizing a survey template to investigate project design intent prior to engagement with the program. The surveys explored all areas addressed by the NCP, including design approach, whole building modeling, building envelope, lighting, HVAC, domestic hot water and appliances for multi-family, etc.
2. Using the customized surveys, REs trained in survey techniques interviewed the project owners and design team members to determine the technologies, control strategies and efficiency levels that would have been installed in the building absent the program.
3. Survey results were reviewed in a triangulation teleconference between the NCP evaluation lead, the attribution lead, and the RE. The purpose of the triangulation meetings was to ensure consistency in interpretation of interview responses across the entire evaluation. The outcome of this process was a list of project-specific baseline technologies, control strategies and equipment efficiencies.
4. These efficiency levels were input to the as-built models (methods described under Code Baseline Model) to develop a model of the project-specific baseline.
5. Traditional FR, ISO and OSO participant questions were also included in the survey. Responses were used for comparison with the aggregated FR and ISO findings in the program level modeled partial net analysis.

This method increases the reliability of responses by using several techniques outlined in the California *Guidelines for Estimating Net-To-Gross Ratios* (CPUC 2007). The surveys sought "factual and concrete information" such as the specific technologies planned for the building, rather than asking more generally about expected efficiency levels and program influence. Multiple decision makers (owners and designers) were queried and responses were compared by three separate members of the evaluation team to determine the most valid result. Savings were estimated using the calibrated model, adjusted to reflect the project-specific baseline energy use.

Modeled Partial Net Savings

The modeled partial net (MPN) savings reflect the savings attributable to the program for each project including FR and ISO impacts. The MPN savings is the difference between the as-built and project-specific baseline energy use, as shown in the following formula:

Modeled Partial Net Savings =
Energy use from project-specific baseline model - Energy use from as-built model

Additional surveys of non-participating building owners and design firms were conducted to investigate baseline practices regarding design approach, modeling and technology. This data was used to provide a reality check on the participant-reported project-specific baselines. The non-participant sample was drawn from new buildings that completed construction from 2004 to 2008[9] and that did not participate in the program. Owners and designers of the sampled buildings received a questionnaire prior to the survey, enabling them to research efficiency levels in their buildings and provide accurate input to the survey. The responses obtained from these surveys were compared to the findings from the participant project-specific baseline surveys to identify whether the project-specific baseline surveys were over or understating baseline practices relative to the market in general.

Findings

The impact evaluation findings included evaluated gross, modeled partial net and net electric and demand savings (including participant outside spillover and non-participant spillover). The following provides an overview of the gross findings and explores the modeled partial net findings in more depth.

Evaluated Gross Savings

The evaluation found the gross savings realization rates to be 71% for electric savings and 52% for demand savings. The evaluators conducted an in-depth measure-level review for each project to understand the reasons for the realization rates and identified a number of issues that resulted in differences between reported and evaluated savings. To determine the pervasiveness of these issues, the results of the project-level analyses were analyzed by project size, project type and measure types.

As the first step in this process, the evaluators calculated realization rates for small, medium and large strata projects. As shown in Table 2, the large projects were found to have the lowest realization rate. Large projects tend to be more complex and changes in operation have a larger impact on savings.

Table 2. kWh Realization Rates by Size Category

Size Stratum		Projects in Population	Projects in Sample	Stratum RR
1	Small	94	15	0.94
2	Medium	32	15	0.74
3	Large	10	9	0.57

NYSERDA uses three tracks for the NCP – whole building, custom measure analysis and prescriptive. The program combined prescriptive measures with custom and with whole building

[9] 2004-2008 non-participant population was used in order to ensure adequate sample frame. These projects had similar code baselines to the participant projects.

analysis resulting in projects with a blended approach. In order to investigate the impact of project type on savings realization, *post hoc* stratification was conducted by grouping the projects into two categories: 30 whole building and custom projects constituted one group and 9 prescriptive projects comprised the second group. This analysis indicated an un-weighted RR of 72% for the whole building and custom projects and 92% for the prescriptive-only projects.

The evaluators also looked at the drivers that resulted in the measures with the largest differences between the program reported and evaluated gross savings. The driver with the greatest impact on lower realized savings was facilities and systems operating differently than expected during the design phase. This is not uncommon for new construction because the program savings analyses are necessarily based on assumptions regarding building occupancy. Actual operations often changes significantly from design to occupancy. The majority of custom and whole building projects included prescriptive measures as well, some of which had low RRs at the measure level. The evaluation found that in these cases, prescriptive savings were often significantly over estimated because the program method of combining custom and prescriptive savings did not adequately capture the interactive effects between the measures.

Modeled Partial Net Savings

The results of the MPN analysis indicate that free ridership is high for this program and inside spillover is quite low. The modeled partial net ratio (MPNR) is the ratio of MPN to evaluated gross savings.

$$Modeled\ Partial\ Net\ Savings\ Rate\ (MPNR) = {}^{Modeled\ Partial\ Net\ Savings}/_{Evaluated\ Gross\ Savings}$$

The MPNR reflects the proportion of the gross savings that can be attributed to the program. A low value of the MPNR indicates high FR. The MPNR was calculated using ratio estimation, comparing the evaluated gross savings to the evaluated net savings for each project in the participant sample. The result of this analysis is the percent of savings that can be attributed to the program, and the combined FR and ISO were estimated by subtracting this value from unity.

$$Modeled\ Partial\ Net\ Savings\ Rate\ (MPNR) = (1\text{-}FR+ISO)$$

The MPNR is lower for large projects and higher for medium and smaller projects, as shown in Table 3. This result is most likely related to the greater complexity of, and higher costs involved with, the large projects. The complexity of these projects requires a higher level of knowledge of buildings systems by the design team; design professionals with this more sophisticated expertise are more likely to be aware of energy efficiency options and how to implement them. In addition the cost per square foot budgets for larger, more complex projects are often higher than for smaller projects with simple systems. These larger budgets tend to support the costs of more efficient, higher performing buildings from the beginning of the project.

Table 3. Modeled Partial Net Savings

Size Stratum		Projects in Population	Projects in Sample	Evaluated Gross Savings (kWh)	Modeled Partial Net Savings (kWh)	MPNR (1-FR+ISO)	Combined FR & ISO Rate
1	Small	94	15	17,402,332	7,970,249	0.46	0.54
2	Medium	32	15	17,513,394	6,522,605	0.37	0.63

3	Large	10	9	21,663,068	3,582,621	0.17	0.83
Not sampled		46	0	2,471,105	2,471,105		0.0
Overall				59,049,899	20,546,580	0.35	0.65
Absolute Precision of Partial Net Evaluated Savings							7.3%
Relative Precision of Partial Net Evaluated Savings							18.0%

The overall MPNR for kWh is 0.35, resulting in a combined FR and ISO rate of 65%. The absolute and relative precision of the partial net evaluation savings are 7% and 18%, respectively. MPNR for kWh and kW were each derived from the models; therefore the values differed as expected.

$$(MPNR) = (1\text{-}FR+ISO)$$
$$(MPNRkWh)\ \ 0.35 = (1\text{-}0.66+0.01)$$
$$(MPNRkW)\ \ 0.46 = (1\text{-}0.55+0.01)$$

The participant surveys used to determine the project-specific baseline also included traditional self-report free ridership questions. Because of the survey length, ranging from 25 – 45 minutes, not all survey respondents completed the traditional free ridership portion of the interview. Comparing the results from the MPNR analysis and traditional FR findings at the project level provides some insights regarding the limitations of traditional FR methods.

In prior evaluations and in the traditional self-report battery included in this evaluation, free ridership was estimated by asking participants about the proportion of the project savings that can be attributed to the program. Thus, the resulting percentages vary between 0% and 100%. The more detailed, project-specific approach used in this evaluation suggests that reality is far more complex. In some cases, the inquiry into the participants' plans prior to enrolling in the program indicated that the buildings as planned would not have met code resulting in an MPNR greater than 100% since the code baseline was used in the gross savings analysis. In other cases, the findings indicated that the buildings had planned systems that would have used less electricity if the project had not gone through the program[10], resulting in a negative MPNR. Table 4 shows the upper and lower bounds of the self report and MPNR methods.

Table 4. Comparison of MPNR and FR Bounds

Bounds	Lower	Upper
Self Report FR	0%	100%
MPNR	-14%	303%

There were three projects with an MPNR greater than 100%. In these projects the savings attributed to the measures influenced by the program were larger than the gross savings which were compared to the energy code baseline (in other words the project-specific baseline was less efficient than code). These savings could not have been captured using traditional FR methods.

In three other cases, the MPNR method resulted in a negative multiplier for net savings. This means that the project, absent the program, would have used less electric energy. These projects included heat recovery ventilation or fuel switch measures which were attributed to the program. Because heat recovery does not include an enthalpy component (which saves cooling energy), the increased fan energy, which is necessary to overcome the static pressure penalty of the heat exchanger, is not offset by electric cooling savings. In the case of fuel switching, the participants reported that

[10] The projects with a negative electric MPNR included significant natural gas savings and overall had positive total energy savings (net positive MBTU savings including electric and gas impacts). Because the evaluation scope did not include establishing a RR for natural gas, only the electric impacts were aggregated to the program level.

absent the program, they would have installed gas heating systems in lieu of a heat pump system. In all cases these measures had positive net energy savings but they increased electric use over the baseline systems.

Another issue with traditional FR surveys is that respondents are required to estimate a percent of savings achieved in any given project due to a measure or combination of measures. The comparison between modeled partial net savings calculated based on self-report baseline technologies to the same respondent's estimates of percent savings they would have achieved absent the program shows some significant issues in the traditional FR approach. Table 5 provides an overview of the differences at the project level.

Table 5. Comparison of MPNR and Traditional FR Savings

Difference Between MPNR & FR Rates (MPNR-FR)	Project Qty	Additional Project Savings Attribution with Traditional FR
NA[11]	12	No FR self-reports
0-20 pt difference	10	~264 kWh
21-50 pt difference	13	~848 kWh
> 50 pt difference	4	~4,530 kWh

An example of the issue associated with participants' inability to estimate savings attributable to planned measures can be seen in one project with two measures (project 12 in Figure 1). The first measure involved installation of variable speed drives (VSDs) on ventilation fans which were reported to be planned for the project prior to program intervention. The other measure was a ventilation heat recovery system which was fully attributed to the program. Because the VSDs were determined to be free riders, the MPNR analysis showed no savings for the drives. The heat recovery system had negative electric savings due to fan energy impacts[12]. In response to the FR questions, the participants estimated that they would have achieved half of the savings absent the program, inaccurately attributing 50% of the realized electric savings to the heat exchangers.

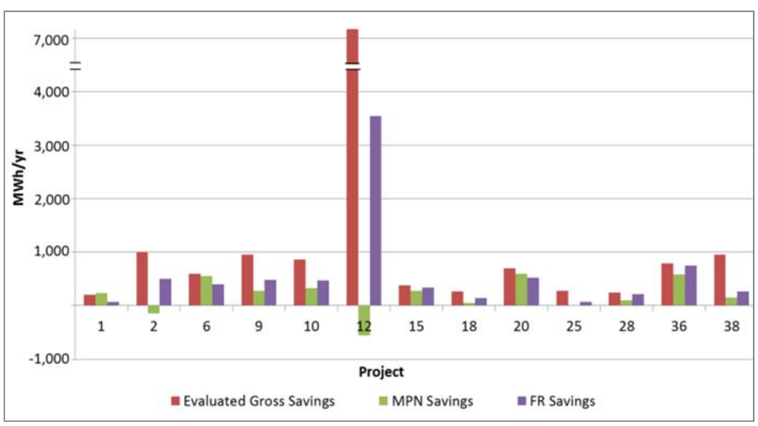

Figure 1. Project Level Comparison of MPN and FR Based Savings[13]

[11] Some projects had only MPN estimates due to survey length the REs were unable to administer the traditional FR questions.
[12] It is not the intent of the authors to convey that heat recovery or energy recovery measures result only in energy penalties. Because this program and evaluation did not focus on fossil fuel, the net BTU savings of the equipment was not included in the final evaluation. The authors analyzed the benefits of heat and energy recovery and therefore are able to characterize them as efficiency measures with significant net BTU savings when all fuels are considered.
[13] Figure shows selected projects with significant deviations between MPN and FR results.

Lighting was another area where the MPNR approach improved the accuracy of results. Basing the project-specific baseline analysis on particular technologies allowed the REs to develop a solid estimate of the project-specific baseline lighting power density (LPD) that would have been achieved with the originally planned lighting technologies. These baselines did not typically coincide with the energy code allowed LPD, in some cases they were more efficient and in other cases less efficient than code. These baselines were then modeled using the actual building operating characteristics to determine the annual energy use of the planned system. The quantification of a range of practices, above and below code, and the analysis of the energy consumption for those practices are strengths of the MPN approach for new construction. MPN accounts for better than code and below code baselines and accurately estimates the energy impacts for those practices.

Additional baseline surveys were administered to over 150 non-participant owners and designers of buildings that were built in 2004 and 2008 and did not receive program incentives. The findings from those surveys indicated that non-participants had a significant rate of adoption of above code energy efficiency measures and green building practices including whole building modeling, LEED participation, improved building envelope (white roofs, lower than code U-value of windows and above code R-value of wall and roof assemblies), improved HVAC systems, higher efficiency equipment and variable air volume systems, adoption of energy efficient lighting technologies and controls, and use of energy star appliances in apartment buildings. This information was compared to the project-specific baseline efficiency levels. This qualitative validation showed consistency between the levels of efficiency installed in existing buildings as reported by non-participants and the planned efficiency levels absent the program that were reported by participants in the MPN surveys.

The authors recognize that both the MPN and non-participant baseline surveys relied on self-reports which can be biased. However, the technological focus on the inquiry and the consistency in reporting across participants and non-participants leads the authors to believe that this approach increases the accuracy of the results. Future evaluation using the modeled partial net method should include use of quantitative data such as building plans to validate responses (CPUC 2007).

Conclusions

The single most critical component of a new construction program impact evaluation is determining the baseline. Savings from new buildings are difficult to estimate due to the inherent uncertainty in defining baseline construction practices and development of an accurate new construction baseline through market research is expensive and would require constant updates. The innovative approach used in this evaluation is believed to have provided a more thorough and accurate participant baseline assessment.

The MPN approach provided a highly nuanced method to determine the savings that can be attributed to the program. In traditional, survey-based self-reports, participants who indicate they installed the measure due to the program are surveyed to determine the likelihood and savings relative to code or "standard practice" that the project would have achieved on a percent basis absent the program. However, it may be infeasible for a percent efficiency to have been attained for a new construction end use. Through the project-specific baseline, it was possible to determine the actual equipment that would have been installed in the absence of the program and accurately model the energy consumption of that equipment. The high FR that resulted from this approach suggests that there is a greater level of complexity in the relationship between standard practice, the code baseline and efficient measures installed through the program than can be easily addressed in a standard net-to-gross telephone survey. While the MPN approach does rely on self-report of design and construction practices, it asks specifically about technology rather than savings and seeks information from both the owners and designers associated with the projects. This focus on gathering specific factual information from multiple sources is expected to result in more accurate responses. The responses were qualitatively corroborated by the baseline surveys. Finally, savings estimates were developed using rigorous engineering methods. The authors believe this combination of methods provided improved estimates of partial net savings attributable to the program.

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