R1707 Net-to-Gross Study (NTG) of Connecticut Residential New Construction

FINAL

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SUBMITTED TO:

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Connecticut Residential New Construction Net-to-Gross Study

The R1707 Connecticut Residential New Construction (RNC) Net-to-Gross (NTG) study assessed how the RNC program impacted the energy consumption of participant and non-participant homes. The study used a Delphi panel to develop a hypothetical scenario in which the program had been canceled at the end of 2011. The panelists estimated how much less efficient homes would have been without the program. The results were compared to the program's gross savings to estimate an overall NTG ratio based on panelists' feedback about single-family and multifamily home efficiency.

Methods

- Data from past baseline studies
- Delphi Panel of experts
- 2 rounds of responses
- Energy models & savings

Key Findings

Key measures affected by the program

Without the program, measures such as *duct leakage*, *air infiltration*, and *insulation installation quality* would have been much less efficient than their current levels. Insulation R-values would have been modestly less efficient, and mechanical system efficiencies would have only been marginally less efficient. Experts estimated that key measures would have been worse by the following amounts:

	Duct leakage	Air infiltration	Insulation installation	Average energy use	
PROGRAM	102%	44%	33%	10%	% worse
NON-PROGRAM	32%	22%	5%	11%	

Overall Net Impacts

Whole Program NTG

Panelist estimates yielded a NTG ratio of 1.56 for the program overall.

Free-ridership (FR) and Spillover (SO)

Moderate FR: 0.69
High non-participant SO: 1.25
Estimated penetration rates:
Single-family - 12%
Multifamily - 50%

Looking Forward

Panelists saw a strong future for the program, but gross savings may decrease as non-program baselines improve and lighting savings diminish.

Recommendations

1. Use the retrospective NTG value of 1.56. Value could drop in the future without big jumps in program efforts to stay ahead of steadily increasing non-program baselines.
2. Continue to promote the adoption of solar PV and net zero designs. Improve the efficiency requirements for the lowest program tier.
3. Continue to include code compliance as a part of the RNC program, and carefully track the outcomes of such efforts to claim impacts.

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Abstract

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

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

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

Panelists estimated that the program strongly improved duct leakage, air infiltration, and insulation installation quality in Connecticut homes; and modestly impacted insulation R-values and efficient lighting. Panelists described the program as only slightly affecting mechanical system efficiencies, and they saw limited impact on market adoption of solar PV and Net Zero designs. The program trains Connecticut market actors and requires panelists to meet advanced building practices; word-of-mouth helps spread these best practices from well-trained market actors, such as HERS raters and program builders, to those working on non-program homes.

The study recommends a single program NTG ratio of 1.56, including its single- and multifamily activities. The study found free-ridership (0.69) and substantial non-participant spillover (1.25). As non-program homes continue to gain in efficiency, the study recommends the program push for higher levels of performance to stay ahead of non-program homes that continue to rapidly increase in efficiency, as seen in the two most recent baseline studies.

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

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

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

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

Executive Summary

The R1707 Residential New Construction (RNC) Net-to-Gross (NTG) study, detailed in this report, carried out the following goals: (1) estimated savings and an overall NTG ratio for the Connecticut RNC program, (2) gained feedback about the program's impacts on solar PV adoption, Net Zero designs, lighting, and multifamily homes relative to single-family homes,[5] and (3) determined if future evaluations should adjust the savings baseline to include program home efficiency values.

The Connecticut RNC program offered by Eversource and United Illuminating (the Companies) provides financial incentives to builders and homeowners to encourage energy-efficient construction and calculates savings by comparing its program homes to a market baseline. As background, the 2017 Connecticut *Residential New Construction Program Baseline* study (R1602) updated the program's savings baseline based on findings from real-world homes.[6] This R1707 NTG study, a follow-up to the R1602 study, will allow the Companies to understand the net impacts the program may have had on new home construction in Connecticut.

R1707 used a Delphi Panel approach in which a panel of 13 RNC experts reviewed efficiency data on non-program homes from the 2017 and 2011[7] single-family RNC baseline studies, program home data from REM/Rate energy models, findings from a 2017 RNC program process evaluation,[8] a history of energy code changes in Connecticut, and a host of supporting documentation that enabled them to develop counterfactual estimates of energy consumption assuming the program had been cancelled at the end of 2011.

The panelists were RNC experts, including HERS providers,[9] a HERS rater, program builders, national program evaluators, RNC program managers outside Connecticut, and a Connecticut code official in a leadership role. Assessing their own familiarity with the topics, they considered themselves well-versed in the measure-level details they were asked to consider.

Panelists' estimates were used to create new REM/Rate energy simulation models representing this hypothetical scenario; the results were compared to the program's gross savings to calculate a retrospective NTG ratio for the single-family portion of the RNC program. The study used adjustment factors to estimate net impacts for the multifamily portion of the program. This study built on the methodology from the 2014 *Massachusetts RNC Net Impact Study.*[10]

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[5] The program groups buildings with four or fewer units with single-family attached and detached homes. However, when this study refers to single-family homes, it only includes single-family attached and detached and treats the rest as multifamily. This is because program REM/Rate files do not make distinctions between four- and five-unit buildings, and because the non-program baseline study only included single-family attached and detached homes.

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

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

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

[9] All HERS raters have a RESNET-accredited HERS Provider firm that conducts QA/QC reviews on the rater's work.

[10] https://goo.gl/8ADJA5. Using this approach, the NTG estimated for the 2011 MA Residential New Construction Program was 1.87 (between 1.37 and 2.36 at the 95% confidence level), including free-ridership of 0.53 and spillover

FINDINGS

Overall Net Impacts

In a hypothetical scenario where the program ceased to exist several years ago, Delphi panelists said that recently-built homes would have been substantially less efficient than they are now.

NTG Ratios. Perceiving substantial net impacts from the program, panelist estimates yielded a NTG ratio of 1.56 for the program overall, combining single-family and multifamily results that were analyzed separately (see Table 1).

- For single-family homes, a relatively high free-ridership rate of 0.68 is more than counterbalanced by an extremely high non-participant spillover rate of 2.33, yielding an estimated NTG ratio of 2.65.[11]
- Multifamily results, which are based on adjustment factors rather than measure-level estimates, show an estimated NTG ratio of 0.6.[12]
- The program has a low single-family penetration rate (13%), but a much higher multifamily rate (50%). This results in high non-participant spillover in single-family homes but much less opportunity for spillover in the multifamily market.

Table 1: Retrospective Net Savings and Net-to-Gross Ratios (MMBtu)

	Gross Savings (MMBtu)	Net Program Savings	Net Non-Program Savings	Free-Ridership	Non-Participant Spillover	Net-to-Gross
***Overall:** 1,654 program / 3,723 non-program homes*						
Low CI	38,349	12,030	44,505	0.66	0.91	1.22
Mid-Point	40,057	12,452	49,986	0.69	1.25	1.56
High CI	41,765	12,874	55,467	0.72	1.59	1.90
***Single-Family:** 376 program / 2,432 non-program homes*						
Low CI	17,093	5,372	33,705	0.63	1.71	2.02
Mid-Point	18,801	6,025	43,760	0.68	2.33	2.65
High CI	20,510	6,679	53,815	0.73	2.95	3.27
***Multifamily:** 1,278 program / 1,291 non-program homes*						
Low CI	20,158	6,157	5,846	0.68	0.27	0.56
Mid-Point	21,256	6,427	6,226	0.70	0.29	0.60
High CI	22,353	6,698	6,606	0.72	0.32	0.63

(mostly from non-program homes) of 1.39. The Delphi panelists said that the program had a particularly strong effect on air infiltration, duct leakage, lighting, insulation installation grades, and some heating system efficiencies.

[11] These values are heavily dependent on program penetration rates, which were approximated for this study due to inconsistencies between program tracking data and statewide CT Dashboard counts, as discussed in Appendix A.5.

[12] Panelists' detailed, measure-level estimates focused on single-family homes and this study lacked non-program multifamily energy models. Therefore, this study adjusted multifamily data to mimic the changes panelists described in the single-family market. This adjustment also included a minor qualitative adjustment, based on the panelists' estimates of the program's impacts on multifamily homes relative to single-family homes.

> "A surge in market penetration, like in 2012 and 2014 … provide real spillover to non-program houses as crews are educated on methods and materials."
> – HERS Provider

Future Program Performance. Delphi panelists predicted a strong future for the program even though non-program baselines continue to improve, narrowing the gap between program and non-program homes. Panelists commonly cited lighting as a future weakness for the program, given the limited savings opportunities that remain in this transformed market. However, the NTG ratio remains similar (1.6) even if all gross and net lighting savings are removed from NTG calculations, resulting in lower savings overall but still a high NTG ratio.

Panelists identified trainings on code compliance and trainings about building practices as key activities driving future savings in non-program homes, which could result in non-participant spillover and be a key mechanism impacting the market in Connecticut. That said, as non-program homes' efficiency increases, maintaining a wide efficiency gap between program and non-program homes may be challenging in the future, and will likely depend on the program's ability to promote new efficiency measures or push to higher overall performance levels.

Single-Family Net Impacts

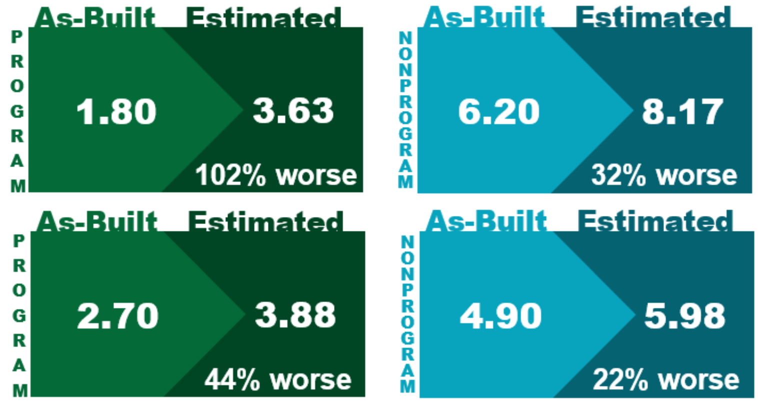
Panelists provided measure-level net impact estimates for single-family homes and identified substantial program impacts on duct leakage, air infiltration, and insulation installation quality in new homes – in and outside of the program.

HERS index values.[13] In program homes, HERS values would have been nearly 20% worse (higher) than they are in the real-world (58 vs. 49). Non-program HERS values would have been 8% worse than they are (HERS 77 rather than the real-world 71).[14] Without the program, panelists estimated that single-family program and non-program homes would have consumed about 10% and 11% more energy than they do now, respectively.

Key measures affected by program. Without the program, measures such as duct leakage, air infiltration, and insulation installation quality would have been much less efficient than their current levels. The following describes the panelists' estimates about what would have happened without the program – these outcomes are hypothetical, not certain. For more discussion of measure-level free-ridership and spillover, see Section 2.1.1.

[13] A HERS Index value is a standardized assessment of a home's energy-efficiency performance based on the home's construction and energy-using equipment. RESNET oversees the process of scoring homes using the HERS index. A score of 100 means the home is as efficient as the RESNET defined reference home, which is based on the 2006 IECC. A score of zero signifies that a home uses no more energy than it produces on site with renewable sources and a score of less than zero signifies that home produces more renewable energy on site than it consumes.

[14] The HERS Index values here are not directly comparable to the R1602 study results which reported an average HERS Index value of 69.8 for non-program homes and 48.2 for program homes. The R1602 study used REM/Rate version 14.2 while this study used version 15.4. Additionally, the averages in R1602 were weighted.



Ducts in program homes may have been twice as leaky, and one-third leakier in non-program homes (leakage to outside, CFM25 per 100 sq. ft. of conditioned floor area).

Air infiltration in program homes may have been 44% worse, and non-program 22% leakier (estimates of ACH50). As one national evaluator said, without the program, "leakage would increase in both groups due to lack of spillover effects."

Typical insulation installation quality may have been over one-third worse for walls, ceilings, and floors (but no more than 5% worse in non-program homes).

Insulation R-values may have been only modestly impacted. Average ceiling R-value in program homes may have been 13% lower (worse), and 7% lower in non-program homes.

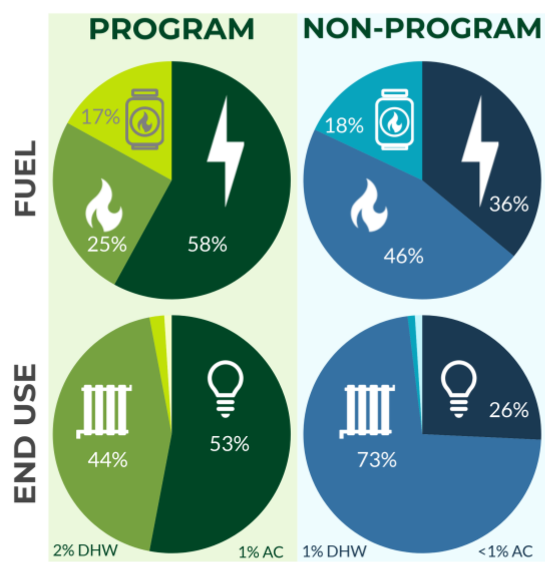
Heating, cooling, and water heating system rated efficiencies may have been marginally affected, but less efficient system types might have been installed.

Efficient lighting saturation may have been about 10% lower than current levels.

Solar PV adoption may have only been slightly affected – this scenario estimates 6% adoption, compared with the 8% of program and 7% of non-program homes that currently have solar panels installed. However, PV-readiness, particularly in program homes, would have been far less common (down from 94% to 50% in program homes) as it is a program requirement for higher-tier homes.

The number of **net zero designs** would likely have been about the same without the program; net zero homeowners and builders were reportedly driven by their own sustainability goals.

Net Savings by Fuel and End-Use. As shown at right, lighting (and by extension, electricity) represents over half of net savings in program homes, with space heating making up nearly all the rest. In non-program homes, nearly three-quarters of net savings comes from space heating, with lighting making up most of the remainder. Water heating and cooling are minor fractions of net savings overall.



Multifamily Net Impacts

Based on limited data, panelists characterized the program as delivering strong results in the multifamily market, but higher penetration rates yielded much lower spillover effects than in single-family homes.

Overall effectiveness in the multifamily market. Compared to single-family program homes, most panelists reported that the program achieves relatively similar efficiency results in multifamily homes. Without the program, this study estimates that multifamily program and non-program homes would have consumed about 7% and 8% more energy than they do now, respectively.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion. The Delphi panelists – experts involved in the RNC market as HERS providers, builders, non-Connecticut program managers, evaluators, and so forth – provided clear and thoughtful responses when describing the hypothetical scenario in which the Connecticut RNC program had not existed after 2011. They created a picture of an effective program that has had significant impacts on the Connecticut new construction market, particularly in terms of non-participant spillover, which resulted in large estimated net savings in non-program homes. This finding is consistent with the 2014 and on-going 2018 Massachusetts RNC studies, where separate groups of Delphi panelists reviewed program-specific information. All panelists came to results that showed similar programs resulting in large impacts on key measures such as air infiltration, duct leakage, and insulation installation quality, resulting in sizeable non-participant spillover impacts. There may be synergistic effects between the Connecticut program and other neighboring states, but Appendix B describes those other programs and provides information that supports the idea that the Connecticut impacts are due to the Connecticut program, rather than out-of-state efforts.

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

Rationale. This value is high compared to the 1.0 value currently used, but it reflects a holistic view of the single- and multifamily sides of the program and was informed by the market's change across two baseline studies, which showed significant improvements in building practices and the adoption of efficient lighting. The program has updated its baseline based on the R1602 baseline study results. Assuming similar levels of program activity, this will likely decrease the program's gross savings moving forward, given that non-program homes have become increasingly efficient over time.

This high NTG value is based on home-level savings estimates for the 2015 program year, where panelists estimated that without the program, homes would have consumed around 8% more energy than they actually do. However, the Companies should note that panelists assessed the program's impacts *as if the program had been gone for several years* – since 2011. Therefore, it will be important for the program to continue to drive program penetration – particularly on single-family homes – in order to increase gross savings values. In the absence of significant and planned attempts to further shift the new construction market and increase the efficiency of program homes in line with the amount of change seen from 2011 to 2015, the program should not expect a similarly high NTG value if it is evaluated several years from now.

This evaluation and the high NTG value reflect substantial lighting savings. Given the rapidly changing lighting market, these savings are not guaranteed in the future. However, by completely removing lighting savings from the results of this study – so as to envision a scenario where the program did not claim lighting savings – the overall NTG ratio happens to remain similar, around 1.6. Of course, even if the program had a strong NTG ratio without lighting savings, this large multiplier would be being applied to a smaller gross savings value.

One suggestion to help the Companies move down this path in the face of advancing baselines is for them to identify and track market effects – effects that do seem to be present but are hard to measure without clear indicators and metrics of progress. Setting clear goals for market transformation may help the program better plan its activities and track progress. Examples of metrics that could be used to point toward market effects over time include closely tracking program penetration, training attendance, training influence on market actors, and the size of the HERS rater market.

Recommendation. *Continue to promote the adoption of solar PV and net zero designs and improve the efficiency requirements for the lowest program tier.*

*Rationale***.** The program appears to have had only a small impact on the adoption of solar PV, but by incorporating it and solar-readiness into program design criteria, the program better prepares builders to meet the increasingly high levels of performance. In the face of ever-improving baselines, the program needs to strongly focus on higher performance homes. As one evaluator on the panel noted when thinking about the program's future, "low-hanging fruit may have been captured" already, requiring the program to push to higher levels of performance. The R1602 study found that non-program homes had average HERS scores that met the lowest tier of the program, indicating that this tier should change. In fact, the Companies have reported that they have recently removed this lower performance tier from the program.

Recommendation. *Continue to include code compliance as a part of the RNC program, and carefully track the outcomes of such efforts.*

*Rationale***.** Teasing apart the impacts of a code compliance enhancement program from a complementary RNC program is complicated and likely unnecessary, given that they go hand in hand. By not only tracking participation in trainings, which the program appears to do, but by also using surveys and interviews to evaluate the effectiveness of those trainings, future RNC impact evaluations (and Delphi panels) can better account for those impacts.

Recommendation. *Continue to exclude program homes from the savings baseline and use evaluation methods that account for free-ridership.*

*Rationale***.** The program clearly has free-ridership, but also substantial spillover. By including program homes in the savings baseline to account for free-ridership, the program would still need a methodology by which they can account for spillover. The program should rightfully be judged by both metrics.

Recommendation. *Continue to improve program tracking databases.*

*Rationale***.** The Companies are working to improve their program tracking databases, based on the results of the R1602 study. Given that this study largely leveraged data requests from the R1602 study, this evaluation was not able to take advantage of any progress that might have been made on that front. Given the importance of obtaining accurate program penetration values for such NTG studies –for example, in this study, program tracking data conflicted with the CT Statewide Dashboard[15] penetration numbers – high quality program data will be critical for future evaluations.

[15] https://ctenergydashboard.com/Public/PublicHome.aspx

Section 1 Introduction and Methodology

This study was commissioned by Eversource and United Illuminating Company (the Companies) and the Connecticut Energy Efficiency Board (EEB) as a Net-to-Gross (NTG) study of the Connecticut Residential New Construction (RNC) program. The study used a Delphi Panel method similar to that used in NMR's 2014 *Massachusetts Residential New Construction Net Impact Study,*[16] whereby informed experts assessed the program's effectiveness by providing measure-level estimates of how new homes might have been built in the absence of the RNC program.

This study built on the results of the most recent Connecticut RNC baseline studies, the 2011 RNC baseline, a study of homes built under the 2006 International Energy Conservation Code (IECC) and the 2017 R1602 study, which included homes built under the 2009 IECC.[17,18] This study focuses on homes from the R1602 study, built from 2014 to 2016.

1.1 Program Background

1.1.1 Program Description

The Connecticut RNC program provides financial incentives to builders to offset some of the cost of building to a higher level of energy efficiency than required by code. It also provides some training and marketing assistance. Historically, the program has offered prescriptive and performance-based incentive options for builders, allowing them to choose the participation path that best fits their needs.

In 2014, the program began replacing its prescriptive rebate offering with a tiered-incentive system dependent on home performance as measured by the HERS Index,[19] and by 2016 the program stopped offering prescriptive rebates entirely. The program also includes bonus incentives for homes that qualify for energy-efficiency certifications and designations, such as ENERGY STAR. In 2017, the program made additional programmatic design changes, such as adding a new, higher performance designation (Tier 4) for homes achieving HERS Indices of 0.

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[16] http://ma-eeac.org/wordpress/wp-content/uploads/Residential-New-Construction-Net-Impacts-Report-1-27-14.pdf. Using this approach, the NTG estimated for the 2011 Massachusetts Residential New Construction Program was 1.87 (between 1.37 and 2.36 at the 95% confidence level), including free-ridership of 0.53 and spillover (mostly from non-program homes) of 1.39. The Delphi panelists said that the program had a particularly strong effect on air infiltration, duct leakage, lighting, insulation installation grades, and some heating system efficiencies.

[17] NMR Group. "Connecticut 2011 Baseline Study of Single-Family Residential New Construction," available at: https://www.energizect.com/sites/default/files/ConnecticutNewResidentialConstructionBaseline-10-1-12_0.pdf.

[18] NMR Group. "R1602 Residential New Construction Program Baseline Study," available at: https://www.energizect.com/sites/default/files/R1602_Residential%20New%20Construction%20Baseline%20Study_Final%20Report_12.5.17.pdf.

[19] The HERS index is nationally recognized rating system through which a home's energy efficiency is measured. The index scores range from below zero to well above 100. At the time the index was created, a standard new home would have a rating of 100. A home with a score of 70 would be 30% more energy-efficient than home with a score of 100 while a home with a score of 130 would be 30% less energy-efficient.

Table 2 shows the program's incentive structure.

Table 2: RNC Program Incentive Structure (2015 - 2017)

Performance Level		Single-family	Dwelling Type Single-family Attached	Multifamily (5 units or more)
HERS Rating Path **Tier**	**HERS Index**	**Rebate Amount (per project)**		
Tier 1	70-61	$3,000	$2,000	$1,500
Tier 2[1]	60-51	$4,000	$2,500	$2,000
Tier 3[1]	< = 50	$4,500	$3,000	$2,500
	Each point < 50[2]	+$50	+$40	+$25
Tier 4[1]	0 (2017+) [2]	$7,000	$5,000	$3,750
Bonus Incentives **Certifications**	**Program Year**	**Rebate Amount (per certification)[3]**		
ENERGY STAR	2015 – 2016	$750	$250 per unit	$250 per unit
	2017+	$500	$250 per unit	$250 per unit
DOE Zero Energy Ready Home	2015 – 2016	$500	$250 per unit	$250 per unit
	2017+	$750	$250 per unit	$250 per unit
LEED for Homes National Green Building Standard (NGBS) Passive House		$500	$250 per unit	$250 per unit

Sources: 2015, 2016, and 2017 program application forms.
[1] Must meet the Connecticut version of the Zero Energy Ready Home PV-Ready Checklist.
[2] Must reach a HERS Index value of 50 before renewables are added to the project.
[3] Up to two certifications per home.

1.2 Evaluation Goals

This RNC NTG study was designed to build on Connecticut's investment in past baseline studies to help the EEB and program sponsors understand how the RNC program has impacted the energy consumption of program and non-program homes, and inform the Program Savings Document, which does not currently have an adjusted NTG ratio for the RNC program.

The objectives of this project were as follows:

1. Estimate savings and an overall NTG ratio for the low-rise, residential RNC program;
2. Gain feedback via a short battery of questions about the program's impacts on the adoption of solar PV, Net Zero designs, and efficient lighting, as well as the efficiency of multifamily homes relative to single-family homes; and
3. Make an assessment about whether future evaluations should adjust the R1602 UDRH baseline to include the efficiency values of program homes.

1.3 Evaluation Methodology

1.3.1 Delphi Panel Principles

The Delphi approach is an interactive and iterative process that relies on a panel of experts to develop a group judgment, often by obtaining responses via multiple rounds of questions. The Delphi technique is based on the principle that structured, closed-ended responses from experts, informed by the responses from their peers, may lead to more accurate results than unstructured responses without the benefit of that iterative feedback.[20]

1.3.2 Delphi Panel Selection

The study recruited panelists with expertise in the new construction market, program implementation, and program evaluation. The final panelists, described in Table 3, were recruited from a list of candidates compiled by the evaluation team and approved by the EA team. Only three of the thirteen experts were participants in the Connecticut RNC program, so as to avoid having results skewed by respondents with a vested interest in the program's existence. The final 13 panelists who participated were each provided a $500 incentive.

Table 3: Panel Composition

Expert Type	Target	Achieved
Efficiency Consultants and Builders	6	5 *2 HERS providers* *2 program builders[1]* *1 program HERS rater[1]*
National Evaluation Experts	4	3
Non-CT RNC Program Managers/Implementers	2	4
CT Code Officials	2	1
Other (regulators, etc.)	1	--
Total	**15**	**13**

[1]Program participants; potential source of bias.

1.3.3 Delphi Panel Process

Panelists were given detailed background information about the Connecticut RNC program and the RNC market and then participated in two rounds of questions about the RNC program's measure-level impacts. In the second round, panelists reviewed the aggregated initial responses of their fellow panelists, and were given the opportunity to revise their initial, first round responses

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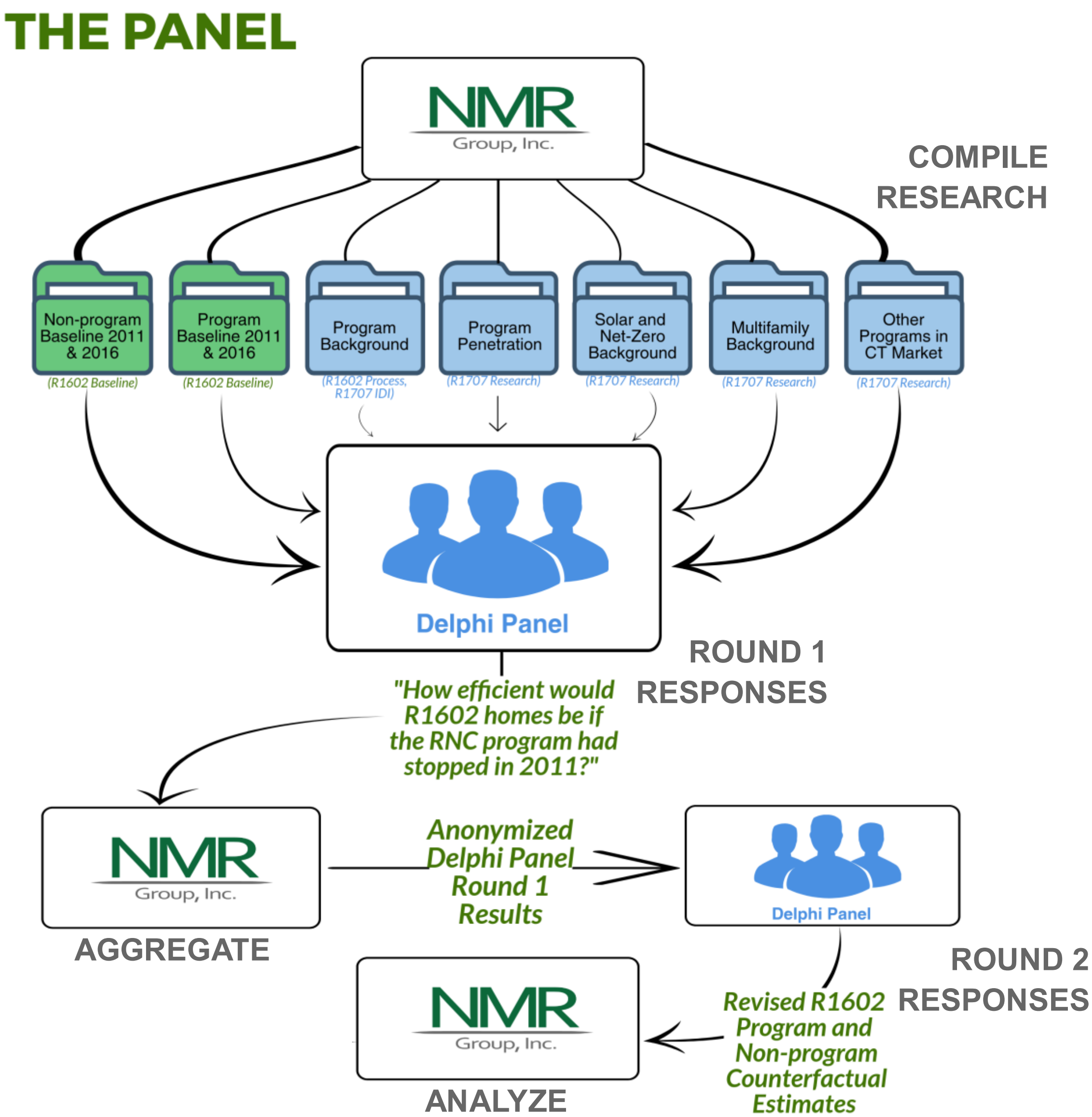
[20] See: (A) Hsu, C. and B.A. Sandford. (2007). ―The Delphi technique: making sense of consensus. ‖ Practical Assessment, Research & Evaluation. 12(10): 1-8; (B) Linstone, H. A., & Turoff, M. (1975). The Delphi Method: Techniques and Applications. Reading, MA: Addison-Wesley Publishing Company; (C) Ludwig, B. (1997). Predicting the future: Have you considered using the Delphi methodology? Journal of Extension, 35 (5), 1-4. Retrieved August 25, 2010 from http://www.joe.org/joe/1997october/tt2.ht

considering the rationales their colleagues provided. The revised Round 2 responses formed the basis of the study's NTG estimate.

Figure 1 describes this study's Delphi Panel process. More detail on this method is available in Appendix A.

Figure 1: The Delphi Panel Process



**R1602 is the baseline study completed in 2017.*

Round 1 of the Panel

In Round I, panelists were shown extensive background information[21] about the Connecticut RNC market, including:

- RNC program activities, requirements, and market penetration
- Code changes from the 2006 IECC to the 2009 IECC
- Key findings from NMR's 2017 RNC program process evaluation[22]
- Solar PV adoption rates and available incentives
- Other energy-efficiency interventions in the Connecticut market
- Changes in efficiency across time (e.g., shell measures, HVAC, domestic hot water, air infiltration, duct leakage, windows, efficient lighting saturation, etc.), based on the past two Connecticut baseline studies. Table 4 describes the samples of homes that were included in those two baseline studies and summarized for panelists.

Table 4: Baseline Study Results Used to Inform Delphi Panel Questionnaire

Data Source	Program REM/Rate Files	Non-Program On-Sites	Applicable Code
2011 RNC Baseline Study	367 SF, 67 MF	69 SF	2006 IECC
2017 R1602 RNC Baseline Study	198 SF, 165 MF	70 SF	2009 IECC

The panelists then reviewed a questionnaire that detailed measure-level efficiency values for two samples of homes, mostly built around 2015: 70 sampled, single-family non-program homes included in the recent R1602 Connecticut RNC baseline study (subject to the 2009 IECC) and 70 sampled program homes built around the same time as the sampled non-program homes.[23] Panelists estimated what the measure-level efficiency values would have been for those same homes, *if the RNC program had ended on December 31, 2011*.

Panelists also provided assessments of their relative familiarity or expertise on a given topic and finally, the panelists answered a battery of qualitative questions about the program's effect on the multifamily market and the program's future.

Round 2 of the Panel

In the second round, the panelists reviewed the mean and anonymized individual responses of their fellow experts. They were shown the measure-level rationales provided by each person, alongside each respondent's profession and the relative confidence they had in their own

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[21] For detailed descriptions of the background information see Appendix A.1.1.1.
[22] https://goo.gl/WA5oh4
[23] Based on REM/Rate files from program homes completed in 2015.

expertise on that topic. [24] Panelists could then decide to adjust their original response or keep it unchanged; the questionnaire also displayed how much their counterfactual estimates differed from the as-built, measure-level efficiency averages. Appendix E describes which measures were revised the most in round two.

1.3.4 Energy Models and Retrospective Savings Calculations

The as-built REM/Rate models of the sampled program (n=70) and non-program single-family homes (n=70) were adjusted at the measure-level to reflect the Delphi panelists' estimates.[25] These altered models served as the energy models for the hypothetical, estimated scenario wherein the program had ceased to exist for roughly six years prior. The difference in consumption between the as-built models and the models of the hypothetical homes resulted in per-home net savings estimates, while the difference in consumption between the program's User Defined Reference Home (*UDRH* – the baseline against which the program claims savings for program homes) and each program home resulted in an estimate of home-level gross savings.

Net savings from program home models informed free-ridership values (i.e., the amount of savings that would have been achieved by program homes even without program participation). Net savings from the non-program home models was used to calculate *spillover* (i.e., the amount of savings in non-program homes that would not have been achieved without the program). The average home-level savings values from the sampled REM/Rate energy models were then scaled up to represent the population of program and non-program homes.

A net to gross ratio of savings was then calculated using the following equation:

$$1 - Free\ Ridership + Spillover = Net\ to\ Gross\ Ratio$$

Figure 2 displays the calculations in more detail. For a full discussion of the modeling and calculation methods see Appendices A.2 and A.3.

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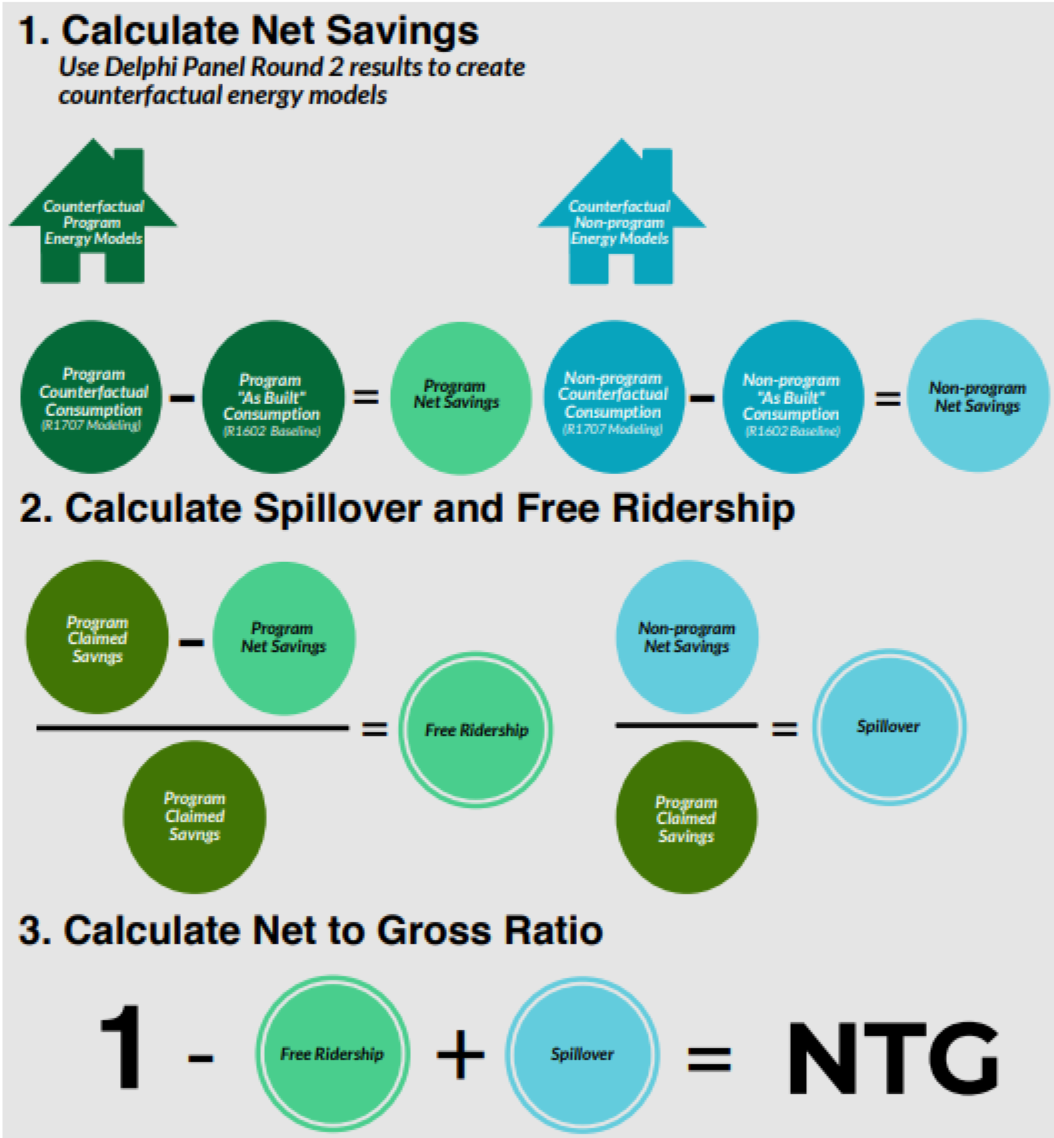
[24] See Appendix F for detail about the panelists' familiarity assessments. Overall, panelists were quite familiar with the topics addressed in the survey, but these familiarity assessments gave panelists the opportunity to give more or less weight to a fellow panelist's rationale.

[25] Two different counterfactual energy models were created for each sampled home (280 in total). The consumption values of both models were averaged together to create a more robust counterfactual estimate.

Figure 2: Net-to-Gross Ratio Calculation



1.3.4.1 Lighting

The RNC program does not use REM/Rate to quantify lighting savings for program homes, instead utilizing a formula from the Connecticut Program Savings Document that calculates savings based on the wattage of the bulb and the room type in which a bulb is located.[26] This study replicated that approach to the extent possible, relying on bulb counts for non-program homes from the R1602 baseline study, Eversource tracking data for program home bulb counts, and wattage estimates from NMR's 2017-18 RLPNC 179 Lighting Market Assessment Study.

[26] https://www.energizect.com/sites/default/files/2017%20CT%20Program%20Savings%20Document_Final.pdf (Lighting can be found beginning on page 114.)

1.3.4.2 Multifamily Homes

This study leveraged the results of previous Connecticut studies, but there has not been a recent RNC baseline study in Connecticut for multifamily homes. Accordingly, multifamily results were handled separately, using available data. While single-family results are speculative in that panelists provided estimates of a hypothetical scenario, readers should be advised that the results from the multifamily analyses could be considered more so, as the panelists did not make measure level multifamily estimates, and non-program data was based on artificial data sets – this process is described in more detail in Appendix A.3.3. Gross savings from program multifamily units were calculated following the same approach as single-family program units, as the study had access to program REM/Rate files for multifamily homes.

Adjustment factors were used to estimate net savings for multifamily homes, and also to create a fictional dataset of non-program multifamily home consumption values in order to estimate non-program impacts. Adjustment factors were applied to consumption values from program multifamily REM/Rate files and took into account the fact that multifamily units tended to have less savings associated with them than larger single-family units, and that the panelists provided qualitative assessments of the program's effectiveness on the multifamily market relative to the single-family market. See Appendix A.3.3 for more detail.

Throughout the study, *multifamily* refers to any home with multiple units that did *not* meet the U.S. Census definition of a single-family attached home or detached home, which includes detached homes or an attached home that has walls extending from ground to the roof, separate utilities for each unit, and no unit above or below the other. If a home did not meet these criteria, then it was considered multifamily. This definition is different from that of the program, which applies single-family incentives to units in buildings with four or fewer units. The U.S Census definition was used over the program's incentive structure because the REM/Rate files for program participants, the only source of measure-level data for multifamily homes, did not distinguish between units in buildings with four or less units and units in buildings with five or more units, and because the non-program baseline study only included that subset of single-family homes.

Section 2 Delphi Panel Findings

The Delphi panelists were asked to review how recently-built homes were actually constructed based on the results of baseline studies in Connecticut, and then to consider how those same homes *would have been built* had the program been discontinued at the end of 2011. This section describes the changes estimated by the panelists at the measure-level for the hypothetical scenario wherein the program had been cancelled.[27] The Delphi panel questionnaire focused on measure-level details for single-family homes, and separately asked limited questions about multifamily homes. The responses provide insight on the program's impact on each measure, including discussions of free-ridership and spillover.

Key Findings about Single-Family Homes

- If the program had ceased to exist, panelists said that non-program homes would have been somewhat less efficient than they actually are, and that program homes would have been much less efficient than they actually are in the real world. Panelists described program elements (training, program requirements, etc.) impacting market actor behavior and spillover impacts from other market actors' interactions with those who have worked with the program.
- Panelists estimated that the program had the greatest impact on duct leakage and air infiltration, indicating little free-ridership and relatively high levels of spillover for those measures. These same measures were highlighted by builders and HERS raters in the R1602 process evaluation; the R1702 codes and standards study also identified these as important factors in determining the actual energy consumption of a project.
- The panelists' estimated duct leakage for program homes built without the program was 102% worse than the real-world value. The estimated non-program value was 32% worse.
- The estimated air infiltration value for program homes was 44% worse than the real-world value. The estimated non-program value was 22% worse.
- Panelists consistently estimated that the mean insulation installation quality (grade) would be 35% to 41% worse in program homes without the program but only up to 5% worse in non-program homes.[28]
- Panelists estimated there would have been minimal differences in heating, cooling, and water heating efficiency ratings without the program, but that the program might have slightly increased the penetration of system types such as ground-source heat pumps, ductless mini-

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[27] Because the program promotes above-code construction, panelists were asked to assumption that if the Program had been discontinued, homes' efficiency at the measure level would have either stayed the same or gotten worse. In other words, it would be illogical to assert that by removing a program that promotes efficient building, homes' efficiency would increase.

[28] RESNET defines the insulation installation standards for HERS ratings. REM/Rate models take insulation grade into account; homes with better quality insulation installations will perform better (lower consumption values and better HERS Index values) than homes with worse installation grades. A summary of the technical requirements for these insulation grades are defined as follows:

- Grade I: Negligible void areas, compression or incomplete fill ≤ 2%, fitted neatly around obstructions
- Grade II: Void areas ≤ 2%, compression or incomplete fill ≤ 10%
- Grade III: Void areas ≤ 5%

splits, and heat-pump water heaters in homes (factors that were not able to be incorporated into this study's modeling efforts).

- Panelists thought that slightly fewer homes would have installed solar PV without the program (down from 8% of program homes and 7% of non-program homes to 6% of homes overall). PV-readiness would be less common, particularly among program homes (down from 94% to 50% – it is currently a program requirement for higher-tier homes), and down from about one-third to one-fourth of non-program homes.[29]
- Panelists thought that the number of true ZNE homes would be about the same without the program as ZNE homeowners and builders are driven by factors outside the program, such as personal beliefs in sustainability.

Key Findings about Multifamily Homes

- Compared to single-family program homes, the panel said that the program achieves similar or slightly better efficiency results in multifamily homes overall. Panelists offered rationales such as large design teams in multifamily homes have significant professional expertise and adopt new building strategies from the program effectively, and multifamily residents have little leverage to request efficiency, meaning that builders who do participate are driven by the program rather than being free riders who would have built efficiently regardless.
- Compared to single-family non-program homes, panelists said the program was similarly or slightly less effective at impacting the multifamily non-program market. Panelists cited multifamily builders' greater sensitivity to marginal increases in material costs paired with split incentives reducing the motivation to build efficiently. Others described the program as more geared towards the single-family market in terms of its marketing and interaction with decision makers. Conversely, two panelists felt that the smaller number of multifamily builders would facilitate knowledge transfer and thus increase spill over.
- Panelist opinion was split on the program's effectiveness (on program homes) for some key measures. Air leakage and duct leakage were cited most often (four votes) as measures where the program was less effective in multifamily homes; however, air leakage received an equal number of *more effective* votes and duct leakage received three *more effective* votes.
- For non-program multifamily homes, the program was cited as being the least effective at driving domestic hot water system efficiency relative to the single-family market.

[29] The R1602 study did not cover PV-readiness. Panelists here estimated both the real-world and the counterfactual values.

2.1 SINGLE-FAMILY

2.1.1 Panelists' Overall Comments about Program Impacts

> Program "builders will continue to improve as they learn to tweak their construction choices and techniques." – Non-CT RNC Program Manager

Panelists provided rationales for their estimates about what the Connecticut market would look like in the absence of the program. Panelists described a program that drove participating builders to meet high standards and that indirectly influenced non-program market actors to improve their practices (spillover) based on indirect contact with the program, program trainings, and the general improvement in knowledge that comes from interacting with trained contractors and HERS raters.

> The "program is continually driving innovation and more efficient homes, in particular with the … $50/extra HERS point below 50."
> – Non-CT RNC Program Manager

> **"If there is no program, there is no training and no spillover."**
> – HERS Provider

> "As the program continues and touches more builders and sub-contractors its influence on non-program homes will increase."
> – Non-CT RNC Program Manager

Program penetration was noted by some panelists as an important variable in determining the amount of spillover impacts that would be attributable to the program.

> "A surge in market penetration, like in 2012 and 2014 … provide real spillover to non-program houses as crews are educated on methods and materials."
> – HERS Provider

> "The program's market penetration has been erratic 2014-2016. The more the program is successful in increasing market penetration, the more impact I think it will have on non-program home[s]."
> - National Evaluator

> The "program has a residual effect on non-program homes and may help influence overall efficiency … even in non-program homes; … The effectiveness of the program may be better measured by reducing the percentage of non-program homes built in Connecticut altogether - move them right over into the program homes column."
> –Program Builder

2.1.2 All Measure-Level Findings

Table 5 and Table 6 compare the mean measure-level efficiency values estimated by the Delphi panelists for homes built in the absence of the program with values from real-world program and non-program homes.[30] These results were leveraged to create energy models for the counterfactual scenario in which the program had been discontinued (see A.2 for more detail).

As a reminder, the percentage change from as-built values to the estimated *Without Program* values does not reflect that measure's impact on consumption as that was determined through energy models.[31] That said, the 2018 *Codes and Standards Assessment for Connecticut* (R1702) quantified the relative energy consumption of each measure.[32] That study found that window U-values had the greatest impact on consumption, followed by air leakage, wall insulation R-value and grade, and duct leakage.

In Table 5, high *percent worse* values indicate that panelists estimated that the program had a *large impact on that measure* in program homes.[33] Low percentages indicate that the program had little effect (due to free-ridership or an efficient market baseline). Panelists described large program impacts on duct leakage, air infiltration, and shell measure insulation grades, and little impact on insulation R-values and window U-values (potentially a future opportunity given the importance of windows in terms of energy consumption according to the R1702 study). The measures most influenced by the program all have stated requirements in the program application[34] and eligibility materials,[35] which could have helped drive the program's impact on those measures. The R1602 process evaluation supported this finding, noting that these explicit requirements resulted in HERS raters and program trainings focusing on those measures. In turn, this focus helps to explain the program's impact on these measures.

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[30] Panelists were shown real-world data from the worst-performing 25% of homes, the middle 50% of homes, and the top 25% of homes. Panelists could alter the percentage of homes that would be in these low, medium, and higher-efficiency bins, as well as the average efficiency value within each bin; these new values were used to create a new overall weighted mean that took the altered distributions for each measure into account.

[31] For example, a 20% change in R-value does not directly equate to a 20% change in consumption. Additionally, a given change in R-value would have a different impact on consumption depending on the baseline starting point, hence the need to rely on energy models to determine impacts.

[32] https://www.energizect.com/sites/default/files/R1702-R1710_CodesStandards_Final%20Report_6.29.18_0.pdf

[33] In the estimated (counterfactual) scenario, *program homes* refers to the same group of homes that participated in the program and assumes they would still have been built without the program. Without the program, the estimated efficiency values for the program home group could be more efficient than the as-built non-program homes – this would indicate that panelists expected that program builders naturally build more efficiently than non-program builders.

[34] https://goo.gl/5KRNKd

[35] https://goo.gl/4XViKi

Table 5: Program Home Energy Efficiency Values Estimated by Delphi Panelists

Measure	Program Homes		
	As-Built	Without Program	Percent Worse
HERS Index Value	***48.7***	***57.8***	***19%***
Duct Leakage to Outside (CFM 25/ 100 sqft CFA)	1.80	3.63	102%
Air Infiltration (ACH50)	2.70	3.88	44%
Cathedral Ceiling Insulation Average Grade	1.03	1.45	41%
Frame Floor Insulation Average Grade	1.20	1.65	38%
Flat Ceiling Insulation Average Grade	1.03	1.40	36%
Wall Insulation Average Grade	1.07	1.45	36%
Cond. Foundation Wall Insulation Average Grade	1.10	1.48	35%
Cond. Foundation Wall Insulation R-Value	14.9	12.6	16%
Flat Ceiling Insulation R-Value	44.1	38.5	13%
Percent of Sockets with Efficient Lighting (%)	97%	87%	10%
Frame Floor Insulation R-Value	27.1	25.1	7%
Cathedral Ceiling Insulation R-Value	38.9	36.2	7%
Wall Insulation R-Value	21.9	20.6	6%
Window U-Value	0.29	0.30	3%
Heating Equipment			
Air Source Heat Pump & Ductless Minisplit HSPF	10.0	9.5	5%
Gas/Propane Furnace AFUE	94.7	93.4	1%
Ground Source Heat Pump COP	4.1	4.1	1%
Gas/Propane Boiler AFUE	93.8	93.2	1%
Oil Boiler AFUE	86.5	86.5	0%
Cooling Equipment			
Ground Source Heat Pump EER	24.4	23.2	5%
Central Air-Split SEER	14.4	13.9	3%
Air Source Heat Pump & Ductless Minisplit SEER	18.9	18.5	2%
Domestic Hot Water Equipment			
Gas/Propane Conventional Storage EF	0.72	0.69	4%
Gas/Propane Instantaneous (Tankless) EF	0.94	0.93	1%
Heat Pump Storage EF	2.60	2.58	1%
Electric Conventional Storage EF	0.91	0.91	0%
All Fuels Indirect Fired EF	0.86	0.86	0%
Ground Source Heat Pump EF	2.56	2.56	0%
Oil Conventional Storage	0.55	0.55	0%
Electric Instantaneous (Tankless) EF	0.97	0.97	0%

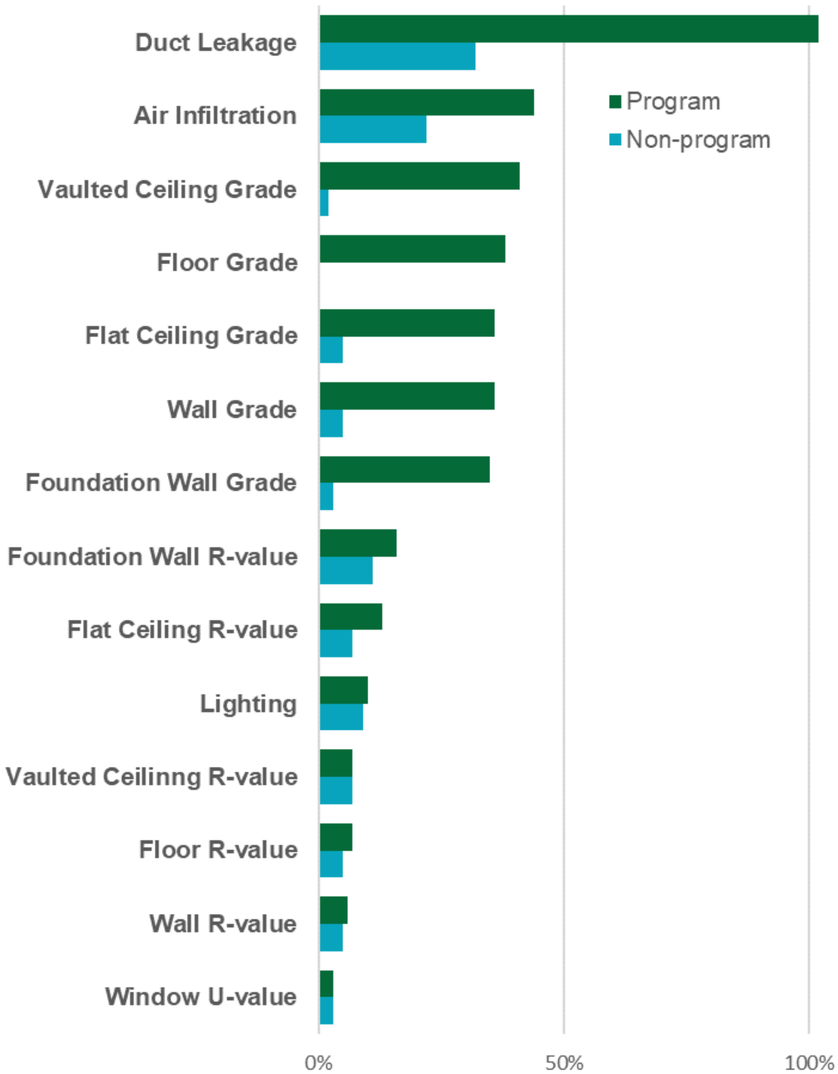
In Table 6, high *percent worse* values indicate that the program had a large impact on that measure in *non-participant* homes (spillover); low values suggest little spillover. In non-program homes, the largest impacts were on duct leakage and air infiltration; there were smaller impacts on shell measure insulation grades and R-values.

Table 6: Non-Program Home Energy Efficiency Values Estimated by Delphi Panelists

Measure	Non-Program Homes		
	As-Built	Without Program	Percent Worse
HERS Index Value	***71.3***	***76.8***	***8%***
Duct Leakage to Outside (CFM 25/ 100 sqft CFA)	6.20	8.17	32%
Air Infiltration (ACH50)	4.90	5.98	22%
Cond. Foundation Wall Insulation R-Value	10.90	9.68	11%
Frame Floor Insulation R-Value	25.7	23.4	9%
Percent of Sockets with Efficient Lighting (%)	58%	53%	9%
Cathedral Ceiling Insulation R-Value	36.5	33.7	8%
Flat Ceiling Insulation R-Value	35.1	32.6	7%
Flat Ceiling Insulation Average Grade	1.85	1.95	5%
Wall Insulation R-Value	20.8	19.7	5%
Wall Insulation Average Grade	1.84	1.93	5%
Window U-Value	0.30	0.31	3%
Cond. Foundation Wall Insulation Average Grade	1.85	1.90	3%
Cathedral Ceiling Insulation Average Grade	2.04	2.09	2%
Frame Floor Insulation Average Grade	2.53	2.54	<1%
Heating Equipment			
Air Source Heat Pump & Ductless Minisplit HSPF	10.5	10.3	2%
Gas/Propane Boiler AFUE	92.7	91.7	1%
Gas/Propane Furnace AFUE	93.7	92.8	1%
Ground Source Heat Pump COP	4.0	4.0	0%
Oil Boiler AFUE	NA	NA	NA
Cooling Equipment			
Air Source Heat Pump & Ductless Minisplit SEER	22.3	21.2	5%
Ground Source Heat Pump EER	17.8	17.5	2%
Central Air-Split SEER	14.0	13.9	1%
Domestic Hot Water Equipment			
Heat Pump Storage EF	3.05	2.94	4%
Gas/Propane Conventional Storage EF	0.65	0.63	3%
Gas/Propane Instantaneous (Tankless) EF	0.94	0.92	2%
Electric Conventional Storage EF	0.92	0.92	0%
All Fuels Indirect Fired EF	0.83	0.83	0%
Ground Source Heat Pump EF	NA	NA	NA
Oil Conventional Storage	NA	NA	NA
Electric Instantaneous (Tankless) EF	NA	NA	NA

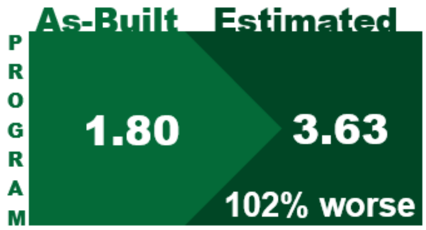
Figure 3 shows the decrease in efficiency between the as-built and estimated scenarios for selected measures. This is the *percent worse* values from Table 5 and Table 6, above. Duct leakage and air infiltration have the highest reduction in efficiency between the as-built and estimated scenarios for both program and non-program homes.

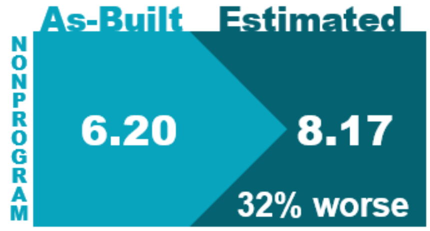
Figure 3: Decrease in Efficiency Between As-Built and Estimated Scenarios



2.1.3 Duct Leakage

Panelists provided estimates for duct leakage to outside per 100 square feet of conditioned area. The panelists estimated that the program had substantial influence on the Connecticut RNC market in terms of reducing duct leakage. They estimated that in the absence of the program, duct leakage would have a larger drop in efficiency from the as-built values than any other measure. If the program did not exist, panelists estimated that ducts would be 102% leakier in program homes – twice as leaky as they currently are. Panelists estimated that non-program homes would be about one-third leakier (32% worse).

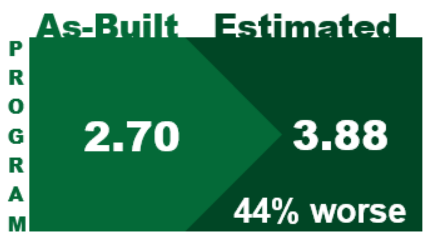


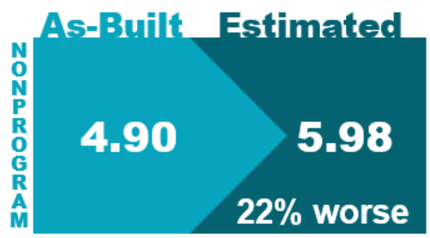


"In the absence of the incentives/program, I'm assuming houses would be tracking with non-program (code compliant) testing. There will still be some 'innovators' who will implement better installation techniques - but significantly reduced numbers. Non-program homes will be worse as well because the practices and training have a spill-over effect on non-program homes."
– HERS Provider

2.1.4 Air Infiltration

Panelists said that in the absence of the program, program homes would have been 44% leakier and non-program homes would have been 22% leakier, based on ACH50 estimates.





"[The] absence of the program would result in lesser efforts to meet higher thresholds and would result in poorer air infiltration performance in both categories (program and non-program). Part of this would be due to lower awareness by the building community and the public in general."
– Program Builder

2.1.5 Insulation

Panelists provided estimates for how shell insulation R-values would have changed in the absence of the program, and how insulation installation quality would have changed, based on the grade assessments used by HERS raters. Grade I indicates a high-quality installation, Grade II is a typical or fair installation, and Grade III is a relatively poor installation (within limits). As with

R-values, the energy impacts from insulation grade changes were calculated using energy modeling.[36]

An average insulation grade value (the mean grade across all homes in a sample), was calculated for each shell measure. In the absence of the program, panelists estimated that the average insulation grade for each shell measure would be between 35% and 41% worse in program homes but only marginally worse in non-program homes.[37]

Panelists estimated that R-values would be slightly worse for both program and non-program homes; most significantly, the R-value of flat ceilings would be 13% worse in program homes and the R-value of conditioned foundation walls would be 16% worse in program homes.

> "The program is having a very apparent impact on insulation grades that definitely spills over to the NPH [non-program homes]. I attribute this to training of participating contractors, then knowledge spread to the general market. PH [program home] insulation levels are being driven by the tiers and bonus incentives of the program, with a small number of the highest performers likely to have done so without the program anyways. NPH are trying to remain competitive in the general market so are seeing some uptick in their insulation levels due to pressure by the program. In the absence of the program from 2011-2016, gains in insulation values would be reduced, but backsliding lower than 2011 levels, particularly amongst PH, will be minimized. For walls, builders are adjusting to the 2009 IECC code requirements more so than responding to the program for insulation levels, so I changed their values relatively little. Again, the big difference is the quality, even for walls."
> – Non-CT RNC Program Manager

2.1.5.1 Walls

Panelists estimated that without the program, the R-values of walls would be 6% worse in program homes and 5% worse in non-program homes.

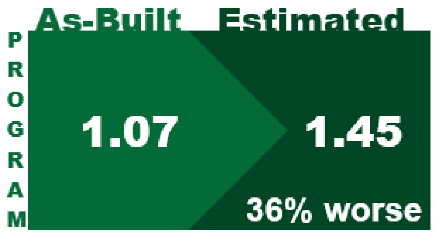
Grade I is a high-quality installation and Grade III is a low-quality installation – average values closer to one indicate better performance. Insulation installation quality would be 36% worse in program homes and 5% worse in non-program homes.

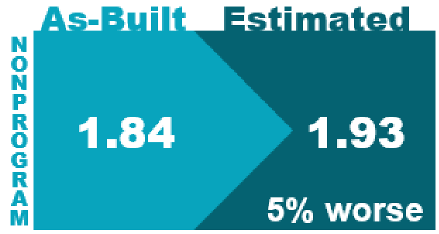
[36]RESNET defines the insulation installation standards for HERS ratings. REM/Rate models take insulation grade into account; homes with better quality insulation installations will perform better (lower consumption values, and better HERS Index values) than homes with worse installation grades. A summary of the technical requirements for these insulation grades are defined as follows:

- Grade I: Negligible void areas, compression or incomplete fill ≤ 2%, fitted neatly around obstructions
- Grade II: Void areas ≤ 2%, compression or incomplete fill ≤ 10%
- Grade III: Void areas ≤ 5%

[37] For a more detailed discussion on the methods used to estimate insulation grade see Appendix A.3.

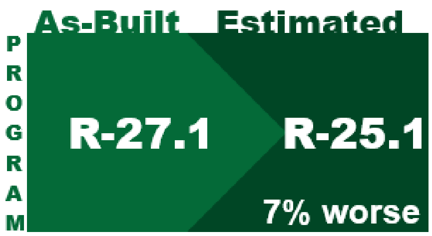
NMR Group, Inc.

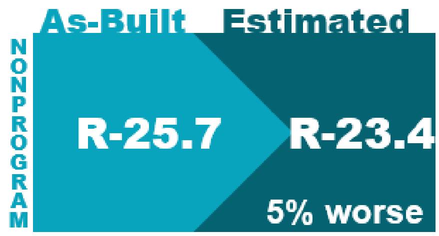




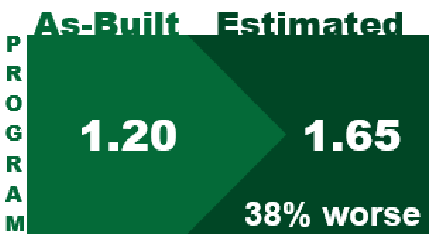
2.1.5.2 Frame Floor (Over Unconditioned Basements)

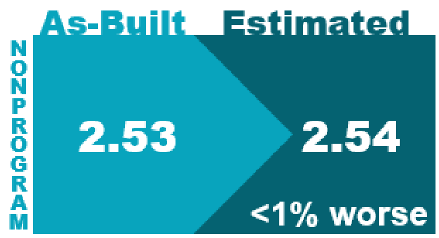
Panelists estimated that the R-values of frame floors would be 7% worse in program homes and 5% worse in non-program homes.





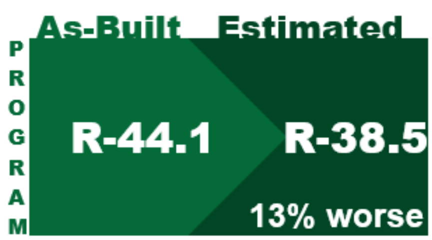
Insulation grade would be 38% worse in program homes and a bit less than 1% worse in non-program homes.

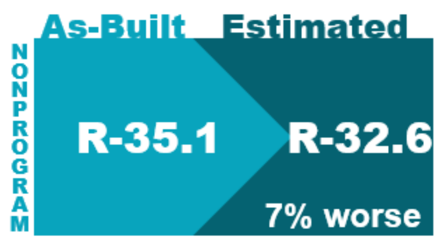




2.1.5.3 Flat Ceilings (Attics)

Panelists estimated that without the program, the R-values of flat ceilings would be 13% worse in program homes and 7% worse in non-program homes.



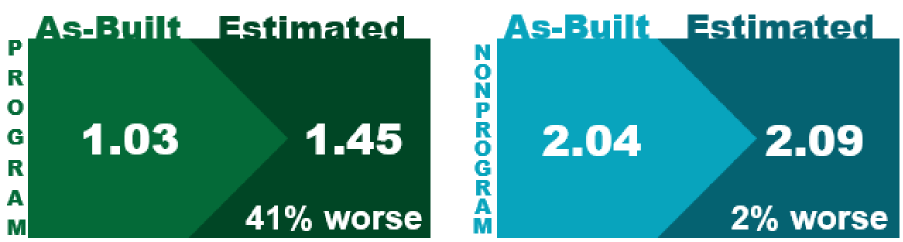


Attic insulation grade would be 36% worse in program homes and 5% worse in non-program homes.

2.1.5.4 Vaulted Ceilings

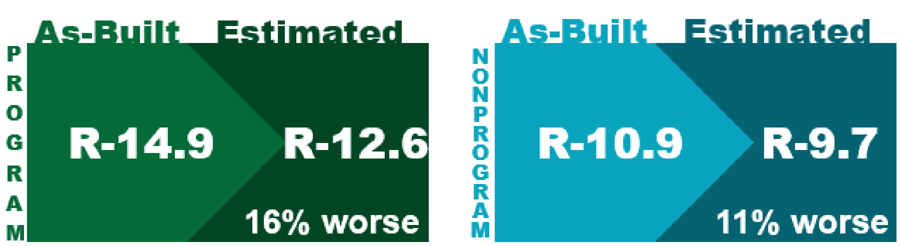
Panelists estimated that the R-values of vaulted ceilings would be 7% worse in both program and non-program homes.

Insulation grade would be 41% worse in program homes and 2% worse in non-program homes.

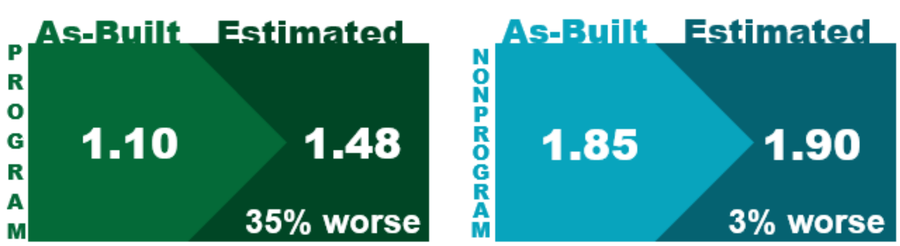


2.1.5.5 Foundation Walls

Panelists estimated that the R-values of conditioned foundation walls would be 16% worse in program homes and 11% worse in non-program homes if the program did not exist.



Insulation grade would be 35% worse in program homes and 3% worse in non-program homes.



2.1.6 Windows

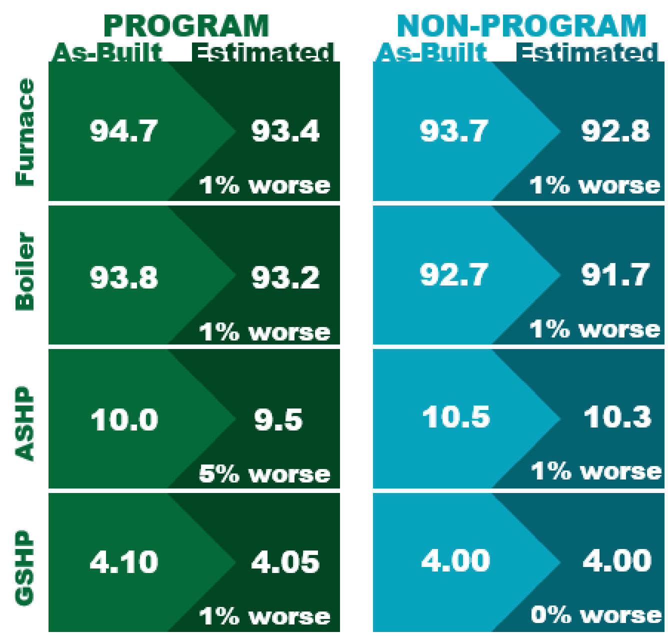
Panelists estimated that window U-values would be 3% worse in both program and non-program homes in the absence of the program, a relatively minor change.

"Residential windows and their improved u-factors have generally tracked energy codes and tax incentives more than they have efficiency programs. The tight groupings in the 2011 and 2016 results suggest to me that most builders are taking what the supply houses offer, which are code compliance-driven, primarily. Most of the larger manufacturers bumped their technology a few tenths of a u-factor to take advantage of the federal tax credits in the late 2000s, and that established a new standard. High-performance builders have dug deeper to install U-factors down in the 0.15 range, but absent a program, that becomes a narrower percentage than with the program."
– HERS Provider

2.1.7 Heating

Panelists estimated that there would be only minimal reductions in heating system efficiency in the absence of the program, indicating that the program had less impact on the efficiency of selected heating system than it appears to have on other home measures, such as insulation quality.

Panelists estimated that without the program, there would have been a 5% reduction in average rated efficiency for air source heat pumps (ASHPs) in program homes; otherwise, they predicted a change of no more than 1% for all other systems in both program and non-program homes.



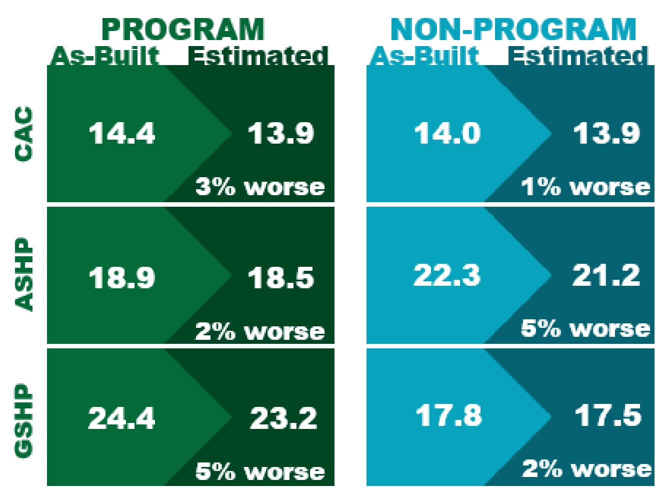
Efficiency units: AFUE for furnaces and boilers, HSPF for ASHPs, COP for GSHP.

Panelists indicated that the program may have slightly impacted the types of systems selected – that potentially more efficient system types might have been installed due to the program, rather than the program having a substantial impact on the efficiency of the systems themselves.[38] For example, the panelists estimated that share of heating systems in program homes that were ground source heat pumps would drop from 25% in the real world to 13% in the hypothetical scenario and that the share of furnaces would increase from 57% to 67% in the hypothetical scenario. Panelist estimates indicated that, for the most part, middle- and high-efficiency furnaces and boilers are the equipment types that would have been installed in the counterfactual scenario rather than the GSHPs that were actually installed. Modeling system changes was out of the scope of the study given the complicated assumptions associated with distribution system and fuel changes.[39]

> "I see the program as changing the distribution of heating system types more so than the efficiency of those systems. This is due to the relatively small efficiency gains between the minimum standard and highest available efficiency products on the market. Changing heating system types has been one strategy to meet more stringent HERS codes and/or optional efficiency certifications. I also see relatively little program impact on the average efficiency of the heating equipment in the NPH, so I matched the PH average efficiency in absence of the program to the lower of the NPH or PH values."
> – Non-CT RNC Program Manager

2.1.8 Cooling

Panelists estimated slightly larger reductions in average rated efficiency for cooling equipment than for heating equipment, although the differences were still minimal. For program homes, ground source heat pumps (GSHP) would have had the largest percentage decrease in rated efficiency (average EER values dropping by 3% without the program), followed by central air conditioner systems (CAC), at a 3% reduction in average SEER. ASHPs (including ductless mini-splits) would have had average SEER values drop by 2% without the program. Without the program, panelists predicted that half of the GSHPs in program homes would be replaced with CACs of varying efficiencies.



Efficiency units: SEER for CAC and ASHP, EER for GSHP.

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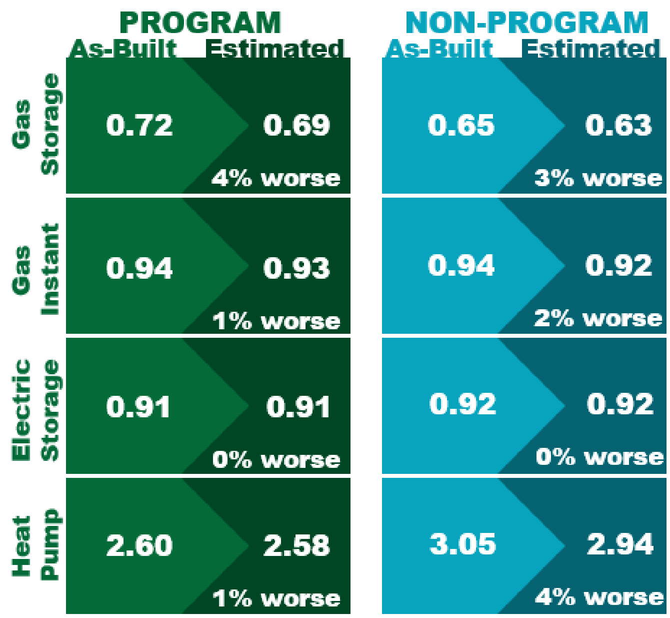
[38] The counterfactual REM/Rate models only had their mechanical system efficiencies adjusted; the system types were not adjusted, as this would result in more significant changes to the models, such as changing fuel types and distribution systems.

[39] One would expect that the increased GSHP penetration due to the program would have a slightly positive effect on the NTG ratio had it been able to be factored into this analysis.

In non-program homes, ASHPs would have had the steepest reduction in rated efficiency (a 5% drop in average SEER), followed by GSHPs (a 2% drop in average EER) and CACs (a 1% drop in average SEER). Panelists predicted little change in the types of systems in these homes.

> "Cooling systems in our region tend to track the federal minimums in the absence of a compelling argument to go beyond. Modern Heat Pumps provide that argument, and high-performance homes, in general, have builders/clientele that recognize a bit more value in better equipment. There's less difference in performance of AC between program and non-program homes, except with the shift to Heat Pumps."
> – HERS Provider

2.1.9 Domestic Hot Water



Panelists also estimated fairly minimal changes in efficiency (Energy Factor, or EF) for water heating systems in the absence of the program. For program homes, gas storage systems had the largest estimated EF decrease (4%) followed by gas instantaneous systems and heat pumps (each having average EFs drop by about 1%). The panelist estimated no other changes for the remaining program water heating systems.[40]

For non-program homes, panelists estimated that heat pumps would have 4% reduction in rated Energy Factor, followed by gas storage systems at 3%, and gas instantaneous systems at 2%. The panelists estimated that all the other water heater systems would have seen no reduction in average rated efficiency in non-program homes.

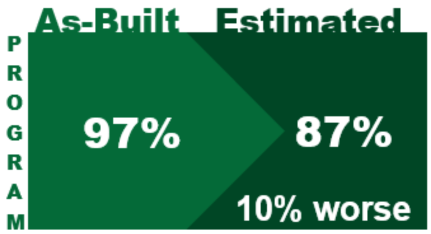
> "The program probably has a bigger impact on more "cutting edge" water heating - such as storage heat pumps and high efficiency tankless water heaters. Therefore, no program would have a big impact on heat pumps - with people choosing conventional electric storage instead. For tankless, many people are familiar with the technology - but would probably choose the less expensive, and less efficient tankless heaters without education and a subsidy."
> – HERS Provider

2.1.10 Lighting

Panelists provided estimates for the socket-level saturation of efficient lighting in the absence of the program. They estimated that the percentage of sockets with efficient lighting would have

[40] Panelists also provided estimates for indirect, ground source heat pump, oil-fueled storage, electric instantaneous, and tankless coil water heaters, which were found across the program and non-program home samples.

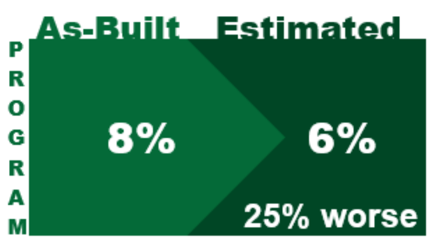
dropped by 10% in program homes and 9% in non-program homes in the absence of the program, suggesting substantial impact on the non-program lighting adoption (spillover).



"Since 2011, LED lighting has dropped in price, while reliability, versatility and form factors have increased making LEDs very well accepted, it should be a no-brainer for builders. Program builders will continue to use LEDs in the absence of the program, but it may drop a few percentage points. Without the outside influence of the Program via its participating builders and marketing efforts, the penetration of high efficacy lighting in non-program homes will drop."
– Non-CT RNC Program Manager

2.1.11 Solar PV, PV-Readiness, and Net Zero Homes

Panelists estimated how many homes would have solar photovoltaic (PV) panels installed in the absence of the program. They estimated that the amount of program homes with solar PV would drop by 25% and the amount of non-program homes with solar PV would have dropped by 14% without the program, recognizing that these large percentage decreases would have only represented a two percentage point decrease in program homes (8% of homes with solar down to 6% without the program) and a one percentage point decrease in non-program homes (a 7% penetration down to 6%).



"Without the program, there are few incentives for homes to be solar ready. We assume, without the program, that some builders would have offered solar ready homes, in addition to homes with PVs installed, as a marketing opportunity. The proportion would have been smaller for the non-program homes. With the program, we assume that some builders of program homes who also build non-program homes would continue to make some of their non-program homes solar ready and some non-program home builders would make some of their homes solar ready to compete with program builders."
– National Evaluator

Panelists were asked to estimate what percentage of homes would generate 100% or more of their electric consumption from on-site solar in the absence of the program – such homes could be considered *net zero homes* if they also used electric mechanical systems.[41] Panelists were shown the sampled homes' on-site solar production relative to their electric consumption. The panel predicted that while overall solar production would go down, the amount of homes that produced 100% or more of their electric consumption from on-site solar would remain the same with or without the program in both the program and non-program samples. In other words, the panel said that while the program influenced the decision to install solar power production on some homes, the decision makers in homes with a *lot* of solar production were likely motivated by factors outside of the program, such as by a personal interest in sustainability.

Panelists were also asked to estimate the percentage of homes that would meet the Energize Connecticut "Zero Energy Ready Home PV-Ready Checklist" requirements in the absence of the program.[42] For program homes, panelists were shown the percentage of homes that met the requirements based on program records. In non-program homes, since this data was not available, panelists were asked to estimate the percentage of homes meeting the requirements in both the real world and hypothetical scenario. Panelists predicted that the percent of program homes that did not meet the requirements would increase from 6% to 50% in the absence of the program. For the non-program sample, panelists estimated that currently 68% of homes do not meet the requirements, and that 78% would not meet the requirements in the absence of the program.

2.2 Multifamily Results

One goal of this study was to assess the RNC program's effectiveness in promoting efficiency in multifamily housing units. Since there was no multifamily baseline study of non-program homes to leverage, this study used adjustment factors to estimate multifamily impacts (for more information regarding the multifamily adjustment factor, see Appendix A.3.3).[43] Additionally, panelists were asked to provide qualitative responses about the program's effects on the multifamily market relative to the single-family market. For a variety of measures, panelists were asked if they thought the program was more, less, or equally effective at increasing the efficiency of the measure in multifamily housing units relative to single-family units.[44] Panelists were also asked about this effectiveness overall, not just at the measure level. The overall effectiveness ratings were compiled and scored and used to create small adjustment factors that were used in developing the multifamily counterfactual consumption estimates.

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[41] A *net zero home* is a home that consumes no more energy than it produces on-site. Typically, such homes are built to high efficiency standards and include onsite solar photovoltaic technology. The program requires homes earn a HERS index value of 50 or below before solar can be counted towards incentives.

[42] See the requirements at https://www.energizect.com/sites/default/files/FINAL-W0047-2017-Resi-PV-Readiness-Checklist-Rev117-WEB-FF.pdf

[43] Given the lack of non-program multifamily measure-level data, the study created a non-program multifamily dataset based on the consumption difference between program and non-program single-family homes. The study also created a counterfactual multifamily dataset based on the consumption difference between single-family counterfactual and single-family as-built homes.

[44] At the measure-level, panelists were asked to rate the program as much more effective, somewhat more effective, about as effective, somewhat less effective, and much less effective at achieving results in multifamily homes relative to its effectiveness at impacting the single-family market.

The importance of these responses is twofold: they provide a qualitative assessment of current program performance in multifamily buildings, while also contributing to an adjustment factor for estimating a NTG value for the program influence on multifamily homes, in the absence of non-program multifamily efficiency data. The following are key findings from the responses provided by panelists.

2.2.1 Overall Multifamily Assessments

> "In other jurisdictions I am familiar with, RNC programs appear to be similarly effective for both single- and multifamily housing projects." – National Evaluator

Multifamily program homes. When asked about overall efficiency in program homes, half of the panelists (six) rated the program as similarly effective at driving efficiency in multifamily and single-family housing units; four said it was more effective in the multifamily market than in the single-family market. Only two rated the program's multifamily component as less effective overall than it was at impacting single-family program homes. [45]

Multifamily non-program homes. Overall, panelists indicated that the program is less effective (four panelists) or about as effective (four panelists) at achieving efficiency results in multifamily non-program homes than for single-family non-program homes. Panelists who thought the program would be less effective cited a greater sensitivity among multifamily decision makers to marginal increases in material costs paired with reduced (i.e., split) incentives. Additionally, some felt that the program is more geared towards single-family projects than multifamily projects at times, citing both differing decision-making processes and marketing. Only two said the program was more effective in the multifamily non-program market than it was in the single-family non-program market, stating that there are fewer builders in the multifamily market relative to the single-family market and that tightly-knit multifamily design teams would facilitate quick information transfer, including of advanced building requirements.

2.2.2 Measure-Level Multifamily Assessments

> "My guess is that there may be less spillover of impacts to developers of multifamily projects than to single-family builders. Many multifamily projects will be working with an architect and design team developing specifications and if they are not participating in the program there is no direct program impact."
> – National Evaluator

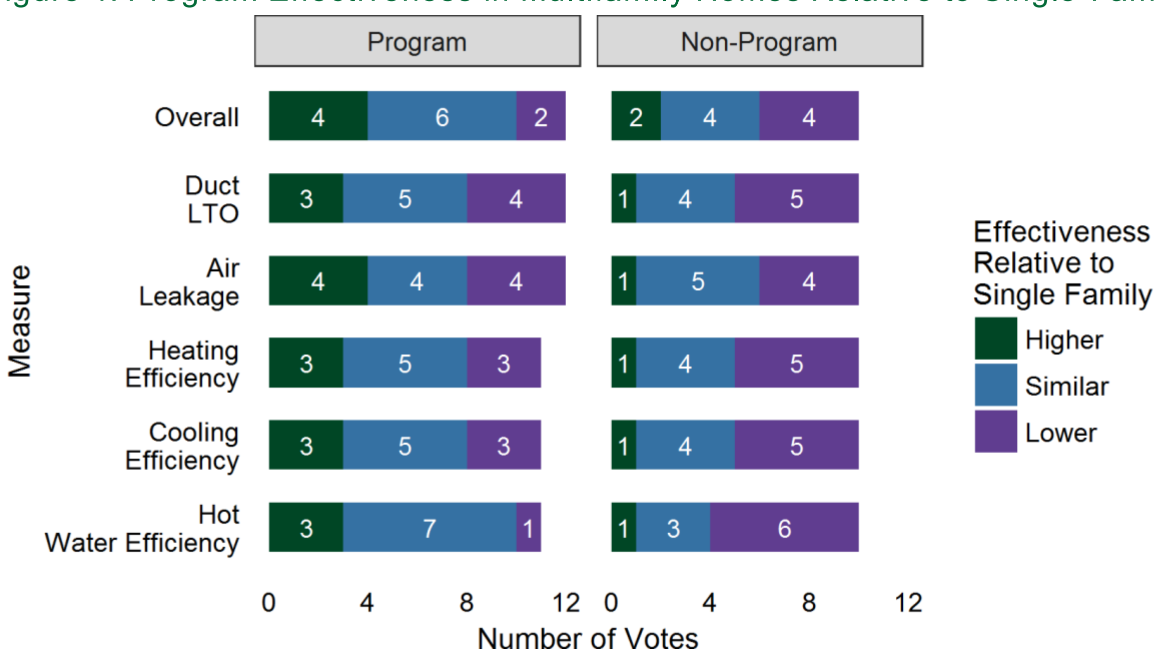
Figure 4 displays panelists' responses for selected measures. For each measure in program homes, the most frequent panelist response was that the program was *similarly effective* in the multifamily market as in the single-family market. In non-program homes, the most frequent response was that the program was *less effective* in the multifamily market relative to the single-family market, except for air leakage, where *similarly effective* was the most frequent response.

[45] Twelve respondents provided multifamily assessments for program homes and ten provided assessment for non-program homes.

On the program side, air leakage and duct leakage were the measures most often identified as areas where the program was *less effective* in multifamily units than in single-family units, with four votes (33% of the responses) each. Air leakage was the sole instance where was no majority opinion - an equal number of panelists ranked the program more effective, equally effective, or less effective at achieving results for this measure in multifamily homes. Across measures, there was generally a split among panelists between *more effective* and *less effective* votes – one exception was lighting (not shown below), where four panelists indicated they thought the program was more effective in multifamily homes relative to single-family homes, versus just one indicating lower effectiveness. For the non-program impacts, panelists generally indicated that the program was similarly or less effective at achieving efficiency in multifamily homes relative to single-family homes. For a comprehensive breakdown of responses for each measure, see Figure 11 in Appendix C.

The program was cited as being the least effective at driving domestic hot water system efficiency in the multifamily market relative to the single-family market. In program homes, most panelists said that the program would be similarly effective in the multifamily and single-family markets regarding water heaters. They said that builders in both markets could be easily persuaded to choose efficient water heaters with incentives and the promise of lower maintenance costs. Additionally, panelists said that similar systems in each market result in similar choices. In the non-program market, a majority felt the program would be less effective – citing higher sensitivity to costs without incentives and that there may be less spillover relative to the single-family market.

Figure 4: Program Effectiveness in Multifamily Homes Relative to Single-Family



3

Section 3 Program Savings

This section presents the results of the single-family modeling effort in the following order: gross savings, program net savings, and non-program net savings estimates followed by overall net savings and net-to-gross (NTG) ratios. Additional single-family NTG ratios taking into account PV savings estimated by the Delphi panelists are also presented. This section then provides multifamily NTG ratios. The multifamily values could be considered to be more speculative than the single-family values (which are themselves based on panelist speculation), given that there was no non-program multifamily baseline study from which to draw non-program efficiency values; thus, the multifamily estimates are based on adjustment factors.

REM/Rate energy models provide end-use consumption estimates for space heating, cooling, water heating, lighting, and appliances (grouped into one category). Because the RNC program calculates lighting savings using engineering calculations and does not claim savings for appliances, lighting and appliance values were left unmodified in the counterfactual energy models from the values in the as-built models. This study calculated lighting savings outside of REM/Rate.

The tables below also include 90% confidence intervals around key estimates, in order to make clear that these are estimated values.

3.1 Overall: Single-Family and Multifamily

Later subsections provide details on the savings results for single-family and multifamily homes, but Table 7 shows a key result – the percentage by which a given home's energy consumption would have increased, on average, if the program had been cancelled at the end of 2011. These percentages are based on the average difference between as-built energy consumption and the modeled energy consumption of counterfactual energy models, informed by the Delphi panelists' estimates.

Table 7: Average Increase in Consumption without Program (MMBtu per Home)

	Program	Non-Program
Single-Family	9.6%	10.9%
Multifamily	7.4%	7.8%

Table 8 summarizes the final retrospective NTG estimates for the single-family and multifamily program components and the program overall.

Table 8: Net Savings and Net-to-Gross Ratios by Home Type (MMBtu)

	Overall	Single-Family	Multifamily
Number of homes (Program/Non-Program)	*1,654/3,723*	*376/2,432*	*1,278/1,291*
Gross Program Savings	40,057	18,801	21,256
Net Program Savings	12,452	6,025	6,427
Net Non-Program Savings	49,986	43,760	6,226
Free-Ridership	0.69	0.68	0.70
Non-Participant Spillover	1.25	2.33	0.29
Net-to-Gross Ratio			
Low CI	1.22	2.02	0.56
Mid-Point[1]	1.56	2.65	0.60
High CI	1.90	3.27	0.63

[1] Overall NTG ratio reported may not calculate exactly to the NTG formula of $1 - Free\ Ridership + Non\ Participant\ Spillover$ due to errors in rounding.

3.2 Single-Family

The following section describes the savings associated with the program's single-family program activity, which served as the basis for the Delphi panelists' estimates. These values are the focus of the report – Delphi panelists reviewed detailed single-family data. The multifamily results used adjustment factors based on the single-family results, as there was no multifamily component to the R1602 residential baseline study.

3.2.1 Gross Program Savings

3.2.1.1 Gross Program Savings by Fuel Type

Gross savings were calculated for 2015 program single-family homes by comparing program home consumption from REM/Rate energy models with the consumption from a user-defined reference home (UDRH), which is a hypothetical comparison home built with the baseline efficiency features described in the UDRH section of the R1602 baseline report.[46] Lighting savings from efficient bulbs were calculated using the Connecticut Program Savings Document (PSD) savings estimates listed in Appendix A.4. Table 9 presents the estimated average gross savings per home for the 2015 program by fuel type.

[46] By running a UDRH comparison – which the RNC program does for every program home – the as-built home gets compared to a home built to *typical* new home practices, based on the results of the R1602 baseline study. The UDRH is distributed to program HERS raters, and all program homes are compared to UDRH consumption. The UDRH comparison process adjusts the thermostat setpoints in both the as-built home and the baseline home so that consumption is based on similar usage patterns.

Table 9: Average per Home 2015 Gross Savings Estimates by Fuel Type

	Overall (MMBtu)	Electricity		Natural Gas		Propane	
		kWh	MMBtu	Therms	MMBtu	Gallons	MMBtu
n	*70*	*70*		*32*		*26*	
Mid-Point	50.0	6,033.7	20.6	347.7	15.9	399.7	13.6

NMR used the estimated average gross savings per home from the program sample to project savings for the entire population of homes that participated in the program in 2015. In Table 10, this study estimates that 376 single-family projects were completed in 2015 program, based on an average unit count across 2014 and 2015 program tracking records.[47]

Table 10: Fuel Use Distribution for 2015 Single-Family Homes

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
N	*376*	*376*	*172*	*140*
% Using Fuel	100%	100%	46%	37%

The overall gross savings for the 2015 program year by fuel type, shown in Table 11, were estimated by multiplying the per-home gross savings estimates reported in Table 9 by the number of homes that use each fuel type in Table 10.

Table 11: Total Estimated Gross Savings for Single-Family Homes in 2015 Program Year by Fuel Type

	Overall (MMBtu)	Electricity		Natural Gas		Propane	
		kWh	MMBtu	Therms	MMBtu	Gallons	MMBtu
N	*376*	*376*		*172*		*140*	
Low CI	17,093	2,098,283	7,154	51,232	5,123	42,296	3,870
Mid-Point	18,801	2,268,652	7,735	59,807	5,981	55,964	5,121
High CI	20,510	2,439,022	8,316	68,382	6,838	69,631	6,371

3.2.1.2 Gross Program Savings by End Use

Table 12 presents the estimated average gross savings per home for the 2015 program by end use; note that not every home had cooling installed. Lighting and space heating dominate the gross savings.

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[47] Due to inconsistencies in program tracking records, this study used unit counts from 2014 and 2015 tracking data to estimate an average number of homes to use as the basis of these calculations.

Table 12: Average per Home 2015 Gross Savings Estimates by End Use (MMBtu)

	Overall	Space Heating	Cooling	Water Heating	Lighting
n	*70*	*70*	*66*	*70*	*70*
Mid-Point	50.0	29.3	0.7	4.9	15.2

The overall gross savings for the 2015 program year by end use, shown in Table 13, were estimated by applying the method used to calculate gross savings, split by energy end-use rather than fuel type. Average per-home gross savings estimates reported in Table 12 were multiplied by the total number of program homes. Approximately 6% of single-family program homes did not have cooling systems.

Table 13: Total Estimated Gross Savings for Single-Family Homes in 2015 Program Year by End Use (MMBtu)

	Overall	Space Heating	Cooling	Water Heating	Lighting
N	*376*	*376*	*344*	*376*	*376*
Low CI	17,093	9,523	181	1,617	5,366
Mid-Point	18,801	11,019	230	1,829	5,717
High CI	20,510	12,515	278	2,042	6,068

3.2.2 Net Savings Estimates: Program Homes

This section presents the single-family program homes net savings estimates by fuel type and end use. The net savings values represent the difference between as-built consumption from REM/Rate energy models of real homes and the consumption of the counterfactual energy models – the altered models are given new, often less efficient measures based on the estimates provided by the Delphi panelists.

3.2.2.1 Program Net Savings by Fuel Type

Table 14 displays the average per home as-built energy consumption (based on real-world home data), counterfactual energy consumption (based on the Delphi panelists estimates of the hypothetical world wherein the program was cancelled), and net savings per program participant by fuel type. Net savings attributable to program participation is the difference in the counterfactual energy consumption and the as-built energy consumption.

This modeling effort resulted in a counterfactual scenario in which the average program home would have consumed 9.6% more energy if the program had not existed.

Table 14: Summary of Average per-Home Program Participant Net Savings by Fuel Type

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
n	*70*	*70*	*32*	*26*
As-Built Energy Consumption	77.0	8,985.0	452.5	614.2
Counterfactual Energy Consumption	84.4	9,204.3	540.4	693.4
Net Savings: Program Homes	16.0*	2,744.6*	87.9	80.5

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD (gross) lighting savings were calculated from 36 program homes and were equal to 2,525.3 kWh per home with 90% CI = (1,981.3, 3,069.4) or 8.6 MMBtu with 90% CI = (6.8, 10.5).

The overall 2015 program net savings, shown in Table 15, were estimated by multiplying the program consumption and savings estimates (reported in Table 14) by the number of homes that use each fuel type (see Table 10).

Table 15: Total Program Participant Net Savings by Fuel Type

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
N	*376*	*376*	*172*	*140*
As-Built Energy Consumption				
Low CI	26,878	3,044,521	65,092	70,884
Mid-Point	28,944	3,378,351	77,830	85,986
High CI	31,011	3,712,182	90,567	101,089
Counterfactual Energy Consumption				
Low CI	29,378	3,060,578	78,939	82,424
Mid-Point	31,730	3,460,819	92,944	97,073
High CI	34,082	3,861,060	106,948	111,722
Net Savings: Program Homes				
Low CI	5,372	933,622	11,043	6,746
Mid-Point	6,025*	1,031,986*	15,114	11,272
High CI	6,679	1,130,350	19,186	15,798

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD (gross) lighting savings were calculated from 36 program homes and were equal to 2,525.3 kWh per home with 90% CI = (1,981.3, 3,069.4) or 8.6 MMBtu with 90% CI = (6.8, 10.5).

3.2.2.2 Program Net Savings by End Use

The net-savings by end use in this section were calculated using the same method applied to the program net savings by fuel type. Table 16 displays the average per home as-built energy consumption, counterfactual energy consumption, and net savings per program participant by end use.

Table 16: Summary of Average per-Home Program Participant Net Savings by End Use (MMBtu)[1]

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
n	*70*	*70*	*64*	*70*	*70*
As-Built Energy Consumption	77.0	41.4	3.2	11.3	23.3
Counterfactual Energy Consumption	84.4	48.4	3.2	11.6	23.3
Net Savings: Program Homes	16.0*	7.0	0.0	0.4	8.6*

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD (gross) lighting savings were calculated from 36 program homes and were equal to 2,525.3 kWh per home with 90% CI = (1,981.3, 3,069.4) or 8.6 MMBtu with 90% CI = (6.8, 10.5).

[1] End use energy consumption excludes PV and does not sum up to overall energy consumption.

The overall 2015 program net savings shown in Table 17 were estimated by multiplying the program consumption and savings estimates reported in Table 16 by the total number of homes. Approximately 8.5% of homes did not have cooling consumption.

Table 17: Total Program Participant Net Savings by End Use (MMBtu)[1]

	Overall	Heating	Cooling	Water	Lighting & Appliances
N	*376*	*376*	*344*	*376*	*376*
As-Built Energy Consumption					
Low CI	26,878	14,058	1,018	3,974	8,361
Mid-Point	28,944	15,569	1,100	4,235	8,772
High CI	31,011	17,080	1,181	4,495	9,184
Counterfactual Energy Consumption					
Low CI	29,378	16,357	1,012	4,103	8,361
Mid-Point	31,730	18,206	1,112	4,370	8,772
High CI	34,082	20,055	1,213	4,637	9,184
Net Savings: Program Homes					
Low CI	5,372	2,027	(24)	45	2,947
Mid-Point	6,025*	2,637	13	135	3,240*
High CI	6,679	3,248	49	225	3,532

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD (gross) lighting savings were calculated from 36 program homes and were equal to 2,525.3 kWh per home with 90% CI = (1,981.3, 3,069.4) or 8.6 MMBtu with 90% CI = (6.8, 10.5).
[1] End use energy consumption excludes PV and does not sum up to overall energy consumption.

3.2.3 Net Savings Estimates: Non-Program Homes

This section presents the net savings estimate for non-program homes by fuel type and end use. These values compare the consumption from as-built non-program homes to the consumption of energy models from hypothetical non-program homes, altered based on the Delphi panelists' estimates.

3.2.3.1 Non-Program Net Savings by Fuel Type

Net savings from non-program participation was calculated by subtracting as-built energy consumption from counterfactual energy consumption. Table 18 displays the summary of results for the average per home as-built energy consumption, counterfactual energy consumption, and net savings per non-program participant home by fuel type.[48]

The Delphi panelist estimates informed a modeling effort that estimated that non-program homes would have consumed 10.9% more energy on average than they actually do.

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[48] Two homes used wood as a secondary heating fuel. Wood comprised 0.3% of the overall sample consumption. This small consumption amount is included in "Overall" values but is not broken out as an individual fuel in the tables below.

Table 18: Summary of Average per-Home Non-Program Net Savings by Fuel Type

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
n	*70*	*70*	*38*	*34*
As-Built Energy Consumption	114.2	10,354.4	823.4	761.2
Counterfactual Energy Consumption	126.6	10,516.3	970.7	830.8
Net Savings: Non-Program Homes	18.0*	1,793.1*	147.3	69.6

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD lighting savings were equal to 1,631 kWh per home with 90% CI = (1,408.7, 1,853.9) or 5.6 MMBtu with 90% CI = (4.8, 6.4).

NMR used the estimated average non-program savings per home from the non-program sample to project savings for the entire population of non-program homes in 2015. As shown in Table 19, an estimated 2,432 single-family non-program projects were completed in 2015, based on Census permit records.

Table 19: Fuel Use Distribution for 2015 Single-Family Non-Program Homes

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
N	*2,432*	*2,432*	*1,320*	*1,181*
% Using Fuel	100%	100%	54%	49%

The overall 2015 non-program net savings shown in Table 20 were calculated by multiplying the non-program consumption and savings estimates in Table 18 by the number of homes that use each fuel type in Table 19.

Table 20: Total Non-Program Participant Net Savings by Fuel Type

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
N	*2,432*	*2,432*	*1,320*	*1,181*
As-Built Energy Consumption				
Low CI	252,610	23,071,494	910,052	760,468
Mid-Point	277,613	25,181,949	1,086,911	898,974
High CI	302,616	27,292,390	1,263,770	1,037,481
Counterfactual Energy Consumption				
Low CI	276,784	23,372,216	1,050,872	823,590
Mid-Point	307,837	25,575,642	1,281,372	981,219
High CI	338,889	27,779,077	1,511,872	1,138,848
Net Savings: Non-Program Homes				
Low CI	33,705	3,493,529	123,058	36,612
Mid-Point	43,760*	4,360,929*	194,461	82,245
High CI	53,815	5,228,331	265,865	127,878

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD lighting savings were equal to 1,631 kWh per home with 90% CI = (1,408.7, 1,853.9) or 5.6 MMBtu with 90% CI = (4.8, 6.4).

3.2.3.2 Non-Program Net Savings by End Use

Table 21 displays the summary of results for the average per home as-built energy consumption, counterfactual energy consumption, and net savings per non-program participant home by fuel type.

Table 21: Summary of Average per-Home Non-Program Net Savings by End Use (MMBtu)[1]

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
n	*70*	*70*	*67*	*70*	*70*
As-Built Energy Consumption	114.2	67.8	6.2	13.1	29.0
Counterfactual Energy Consumption	126.6	80.7	6.3	13.3	28.2
Net Savings: Non-Program Homes	18.0*	12.9	0.1	0.2	4.8*

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD lighting savings were equal to 1,631 kWh per home with 90% CI = (1,408.7, 1,853.9) or 5.6 MMBtu with 90% CI = (4.8, 6.4).

[1] End use energy consumption excludes PV and does not sum up to overall energy consumption.

The overall 2015 non-program net savings by end use shown in Table 22 were estimated by multiplying the non-program consumption and savings estimates in Table 21 by the total number of homes. Approximately 4% of single-family non-program homes did not have cooling consumption.

Table 22: Total Non-Program Participant Net Savings by End Use (MMBtu)[1]

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
N	*2,432*	*2,432*	*2,328*	*2,432*	*2,432*
As-Built Energy Consumption					
Low CI	252,610	148,236	12,945	29,401	63,503
Mid-Point	277,613	164,897	14,385	31,793	70,548
High CI	302,616	181,557	15,826	34,185	77,594
Counterfactual Energy Consumption					
Low CI	276,784	172,655	13,022	30,001	63,209
Mid-Point	307,837	196,311	14,576	32,384	68,576
High CI	338,889	219,967	16,130	34,767	73,943
Net Savings: Non-Program Homes					
Low CI	33,705	21,868	(246)	(287)	7,821
Mid-Point	43,760*	31,415	190	591	11,564*
High CI	53,815	40,961	627	1,470	15,306

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD lighting savings were equal to 1,631 kWh per home with 90% CI = (1,408.7, 1,853.9) or 5.6 MMBtu with 90% CI = (4.8, 6.4).

[1] End use energy consumption excludes PV and does not sum up to overall energy consumption.

3.2.4 Overall Net Savings and Net-to-Gross Ratios

Overall net savings by fuel type were calculated by combining the program and non-program net savings from Table 15 and Table 20. The net savings for single-family homes are shown in Table 23 and are estimated to be approximately 49,800 MMBtu, 5.4 million kWh, 210,000 Therms, and 93,500 gallons of propane.

Table 23: Overall Net Savings for 2015 Single-Family Homes by Fuel Type[1]

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
N	*2,808*	*2,808*	*1,492*	*1,320*
Low CI	38,758	4,531,599	139,842	48,947
Mid-Point	49,785	5,392,915	209,576	93,517
High CI	60,813	6,254,231	279,309	138,087

[1] The participant and non-participant savings from Table 15 and Table 20 do not sum exactly to the net savings reported in this table due to errors in rounding.

This study also combined the program and non-program net savings from Table 17 and Table 22 to calculate the overall net savings by end use (shown in Table 24). The net savings for single-family homes are estimated to be approximately 34,000 MMBtu for space heating, 203 MMBtu for cooling, 725 MMBtu for water heating, and 14,800 MMBtu for lighting (appliances are only included to the extent there may be unavoidable interactive effects included in the energy models – appliance efficiency values remained constant in the as-built and counterfactual energy models).

Table 24: Overall Net Savings for 2015 Single-Family Homes by End Use (MMBtu)[1]

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
N	*2,808*	*2,808*	*2,672*	*2,808*	*2,808*
Low CI	38,758	24,614	-229	-145	11,099
Mid-Point	49,785	34,052	203	727	14,803
High CI	60,813	43,490	635	1,598	18,507

[1] The participant and non-participant savings from Table 16 and Table 22 do not sum exactly to the net savings reported in this table due to errors in rounding.

NTG ratios were calculated by comparing the net savings of program and non-program homes to the estimated 2015 gross savngs. Table 25 and Table 26 present the overall gross and net savings estimates, estimated free-ridership, non-participant spillover, and NTG ratios by fuel type and end use, respectively.

$$Free\ Ridership = \frac{(Gross\ Program\ Savings - Counterfactual\ Program\ Savings)}{Gross\ Program\ Savings}$$

$$Non\ Participant\ Spillover = \frac{Counterfactual\ Non - Program\ Savings}{Gross\ Program\ Savings}$$

$$Net\ to\ Gross\ Ratio = 1 - Free\ Ridership + Non\ Participant\ Spillover$$

The overall, estimated single-family NTG ratio is 2.65 and the fuel specific NTG ratios are 2.38 for electricity, 3.50 for natural gas, and 1.67 for propane. NTG ratios by end use are 3.09 for heating, 0.88 for cooling, 0.40 for water heating, and 2.59 for lighting. Note that these overall values are quite high, but reflect the altered consumption based on the informed, expert opinions of the Delphi panelists. The low program penetration rate, estimated to be around 13% for single-family homes, ends up driving the non-participant spillover values quite high as the program's impact on the non-program market is based on relatively low penetration.

Table 25: Net Savings and Net-to-Gross Ratios by Fuel Type

	Overall (MMBtu)	Electricity		Natural Gas		Propane	
Number of homes (Program/ Non-Program)	376/2,432	*376/2,432*		*172/1,320*		*140/1,181*	
Gross Program Savings		**kWh**	**MMBtu**	**Therms**	**MMBtu**	**Gallons**	**MMBtu**
Low CI	17,093	2,098,283	7,154	51,232	5,123	42,296	3,870
Mid-Point	18,801	2,268,652	7,735	59,807	5,981	55,964	5,121
High CI	20,510	2,439,022	8,316	68,382	6,838	69,631	6,371
Net Program Savings							
Low CI	5,372	933,622	3,183	11,043	1,104	6,746	617
Mid-Point	6,025	1,031,986	3,519	15,114	1,511	11,272	1,031
High CI	6,679	1,130,350	3,854	19,186	1,919	15,798	1,446
Net Non-Program Savings							
Low CI	33,705	3,493,529	11,911	123,058	12,306	36,612	3,350
Mid-Point	43,760	4,360,929	14,869	194,461	19,446	82,245	7,526
High CI	53,815	5,228,331	17,826	265,865	26,587	127,878	11,701
Free-Ridership							
Low CI	0.63	0.49		0.67		0.71	
Mid-Point	0.68	0.55		0.75		0.80	
High CI	0.73	0.60		0.82		0.89	
Non-Participant Spillover							
Low CI	1.71	1.54		1.85		0.51	
Mid-Point	2.33	1.92		3.25		1.47	
High CI	2.95	2.30		4.25		2.09	
Net-to-Gross							
Low CI	2.02	2.00		2.25		0.80	
Mid-Point	2.65*	2.38		3.50		1.67	
High CI	3.27	2.76		4.76		2.54	

*Overall net-to-gross ratio reported may not calculate exactly to the net-to-gross formula of $1 - Free\ Ridership + Non\ Participant\ Spillover$ due to errors in rounding.

Table 26: Net Savings and Net-to-Gross Ratios by End Use (MMBtu)

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
Number of homes (Program/Non-Program)	*376/2,432*	*376/2,432*	*344/2,328*	*376/2,432*	*376/2,432*
Gross Program Savings					
Low CI	17,093	9,523	181	1,617	5,366
Mid-Point	18,801	11,019	230	1,829	5,717
High CI	20,510	12,515	278	2,042	6,068
Net Program Savings					
Low CI	5,372	2,027	(24)	45	2,947
Mid-Point	6,025	2,637	13	135	3,240
High CI	6,679	3,248	49	225	3,532
Net Non-Program Savings					
Low CI	33,705	21,868	-246	-287	7,821
Mid-Point	43,760	31,415	190	591	11,564
High CI	53,815	40,961	627	1,470	15,306
Free-Ridership					
Low CI	0.63	0.70	0.79	0.88	0.37
Mid-Point	0.68	0.76	0.94	0.93	0.43
High CI	0.73	0.82	1.10	0.98	0.49
Non-Participant Spillover					
Low CI	1.71	1.91	-1.05	-0.15	1.37
Mid-Point	2.33	2.85	0.83	0.32	2.02
High CI	2.95	3.79	2.71	0.80	2.68
Net-to-Gross					
Low CI	2.02	2.15	-1.00	-0.08	1.93
Mid-Point	2.65*	3.09	0.88	0.40	2.59
High CI	3.27	4.03	2.77	0.88	3.25

*Overall net-to-gross ratio reported may not calculate exactly to the net-to-gross formula of $1 - Free\ Ridership + Non\ Participant\ Spillover$ due to errors in rounding.

3.2.5 Overall Net Savings and Net-to-Gross Ratios with PV Savings

The NTG ratios in this section reflect the fact that Delphi panelists were given the opportunity to estimate the program's impact on solar PV adoption, and these NTG values include savings due to solar PV impacts. The overall net savings and NTG ratios with PV savings were calculated separately because the program does not claim PV savings.

In the as-built program and non-program single-family home samples that served as the basis of the panelists estimates, 7% of homes had solar PV installed. The Delphi panel indicated that without program intervention, only 6% of program and non-program homes would have solar PV installed – a slight drop in penetration. To create a counterfactual scenario that took this into account, 1% of solar PV homes were randomly selected to have their PV installations removed for energy modeling.

Table 27 presents the overall gross and net savings estimates and NTG ratios by fuel type while accounting for PV savings. In the counterfactual scenario, fewer homes have PV installed and the electricity demand that would have been met by PV generation must be met using electricity from the grid. The increase in counterfactual electricity consumption results in higher net savings and drives up the overall NTG ratio from 2.65 to 2.68 (a 1.0% increase). This change is reflected in the electricity consumption of the home where overall net savings increased by 172,162 kWh and electric NTG increased from 2.38 to 2.45 (2.9% increase).

Table 27: Net Savings and Net-to-Gross Ratios by Fuel Type, Including PV Savings

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
Number of homes (Program/Non-Program)	*376/2,432*	*376/2,432*	*172/1,320*	*140/1,181*
Gross Program Savings				
Low CI	17,093	2,098,283	51,232	42,296
Mid-Point	18,801	2,268,652	59,807	55,964
High CI	20,510	2,439,022	68,382	69,631
Net Program Savings				
Low CI	5,489	958,386	11,043	6,746
Mid-Point	6,141	1,065,810	15,114	11,272
High CI	6,793	1,173,234	19,186	15,798
Net Non-Program Savings				
Low CI	34,219	3,619,760	123,058	36,612
Mid-Point	44,232	4,499,268	194,461	82,245
High CI	54,245	5,378,774	265,865	127,878
Free-Ridership				
Low CI	0.63	0.47	0.67	0.71
Mid-Point	0.67	0.53	0.75	0.80
High CI	0.72	0.59	0.82	0.89
Non-Participant Spillover				
Low CI	1.72	1.60	3.23	0.58
Mid-Point	2.35	1.98	3.25	1.47
High CI	2.98	2.37	3.27	2.36
Net-to-Gross				
Low CI	2.05	2.07	3.43	0.77
Mid-Point	2.68*	2.45	3.50	1.67
High CI	3.31	2.84	3.58	2.57

*Overall net-to-gross ratio reported may not calculate exactly to the net-to-gross formula of $1 - Free\ Ridership + Non\ Participant\ Spillover$ due to errors in rounding.

The overall PV net savings is 589 kWh with 90% CI = (-212, 1,390) with other end-use net savings unchanged. A PV NTG ratio was not calculated since the program does not claim savings for PV.

3.3 Multifamily

The following section describes the savings associated with the program's multifamily program activity. Note that there was no multifamily component to the R1602 residential baseline study, and artificial non-program multifamily consumption values were estimated based on adjustment factors. Additionally, Delphi panelists did not provide detailed, measure-level counterfactual efficiency estimates for multifamily homes as they did for single-family homes, meaning that the counterfactual values used to generate net savings are based on adjustment factors, which included slight adjustments to the estimated counterfactual consumption values based on panelists' qualitative assessments of the program's effectiveness in the multifamily market.[49] Table 28 provides a breakdown of multifamily actual and artificial data. Refer to Appendix A.3.3 for additional details regarding the multifamily methodology.

Table 28: Multifamily Actual and Artificial Consumption Values

	As-built	UDRH	Counterfactual
Program	Actual	Actual	Artificial
Non-Program	Artificial	N/A	Artificial

3.3.1 Multifamily Gross Program Savings

This section presents the multifamily program homes gross savings estimates by fuel type and end use.

3.3.1.1 Multifamily Gross Program Savings by Fuel Type

Multifamily gross savings were calculated for 2015 program homes by comparing as-built program homes with a user-defined reference home (UDRH).[50] Lighting savings from efficient bulbs were calculated using the engineering savings calculations described in Appendix A.4. Table 29 and

	Overall (MMBtu)	Electricity		Natural Gas		Propane	
		kWh	MMBtu	Therms	MMBtu	Gallons	MMBtu
n	*165*	*165*		*141*		*22*	
Mid-Point	16.6	1,931.8	6.59	109.4	9.35	69.3	0.84

[49] For the qualitative adjustment, the multifamily counterfactual consumption values were slightly adjusted using a point system derived from the panelists' estimates of the program's effectiveness on multifamily homes relative to single-family homes. On average, panelists said that the program was slightly more effective at driving savings in multifamily program homes than single-family program homes, and slightly less effective for multifamily non-program homes relative to single-family non-program homes.

[50] To estimate gross savings, thermostat set points for program homes were adjusted during the REM/Rate modeling stage to match the thermostat set points of UDRH homes.

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Table 30 present the estimated average gross savings per home for the 2015 program by fuel type and end use, respectively.

Table 29: Multifamily Average per Home 2015 Gross Savings Estimates by Fuel Type

	Overall (MMBtu)	Electricity		Natural Gas		Propane	
		kWh	MMBtu	Therms	MMBtu	Gallons	MMBtu
n	*165*	*165*		*141*		*22*	
Mid-Point	16.6	1,931.8	6.59	109.4	9.35	69.3	0.84

Table 30: Multifamily Average per Home 2015 Gross Savings Estimates by End Use (MMBtu)

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
n	*165*	*165*	*150*	*165*	*165*
Mid-Point	16.6	6.4	0.4	4.2	5.7

3.3.2 Multifamily Net Savings Estimates: Program Homes

This section presents the multifamily program homes net savings estimates by fuel type and end use. Since there was no multifamily non-program baseline study to leverage, NTG ratios were estimated by adjusting the multifamily as-built program consumption using two factors: (1) a "Delphi panelist multifamily effectiveness factor" based on qualitative responses about the program's effectiveness in the multifamily market relative to the single-family market, and (2) a "multifamily counterfactual adjustment factor" equal to the average percent change in single-family as-built consumption to single-family counterfactual consumption.[51] Readers should note that this study was unable to fully account for fuel-specific interactive effects in multifamily net savings estimates. Unlike with single-family REM/Rate energy models, multifamily net savings values were calculated by adjusting the multifamily program home energy model *results* – the actual multifamily REM/Rate energy models were not manipulated. Therefore, tables showing multifamily fuel-level counterfactual consumption and savings values may not sum up to the overall values.

Table 31 displays the average per home as-built energy consumption, counterfactual energy consumption, and net savings per program participant by fuel type. Net savings attributable to program participation were calculated by differencing the counterfactual energy consumption and the as-built energy consumption.

[51] See Appendix A.3.3 for a full discussion on the methods used to estimate multifamily NTG ratios.

Table 31: Summary of Multifamily Average per-Home Program Participant Net Savings by Fuel Type

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
n	*165*	*165*	*141*	*22*
As-Built Energy Consumption	35.4	4,528.6	214.7	114.2
Counterfactual Energy Consumption[1]	38.0	4,645.7	259.0	129.4
Net Savings: Program Homes[1]	5.0*	825.6*	44.2	15.2

*Net savings of the overall energy consumption and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD (gross) lighting savings were calculated from 146 program homes and were equal to 708.6 kWh per home with 90% CI = (681.9, 735.3) or 2.4 MMBtu with 90% CI = (2.3, 2.5).
[1] Fuel-specific interactive effects not accounted for; fuel consumption and savings may not sum up to overall values.

The net-savings by end use in this section were calculated using the same method applied to the program net savings by fuel type. Table 32 displays the average per home as-built energy consumption, counterfactual energy consumption, and net savings per program participant by end use.

Table 32: Summary of Multifamily Average per-Home Program Participant Net Savings by End Use (MMBtu)[1]

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
n	*165*	*165*	*150*	*165*	*165*
As-Built Energy Consumption	35.4	13.3	1.6	8.2	12.4
Counterfactual Energy Consumption	38.0	15.6	1.6	8.5	12.4
Net Savings: Program Homes	5.0*	2.3	0.02	0.3	2.4*

*Net savings of the overall energy consumption and lighting and appliances consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD (gross) lighting savings were calculated from 146 program homes and were equal to 708.6 kWh per home with 90% CI = (681.9, 735.3) or 2.4 MMBtu with 90% CI = (2.3, 2.5).
[1] End use energy consumption excludes PV and does not sum up to overall energy consumption.

3.3.3 Multifamily Net Savings Estimates: Non-Program Homes

This section presents the net savings estimates for multifamily non-program homes by fuel type and end use. Because the R1602 residential baseline study did not include a multifamily component, non-program multifamily consumption values were estimated based on adjustment factors. As previously mentioned, this study was not able to fully account for fuel-specific interactive effects in multifamily homes' net savings values. Therefore, non-program multifamily fuel consumption and net savings may not sum up to overall values.

3.3.3.1 Non-Program Net Savings by Fuel Type

Table 33 and Table 34 summarize the results for the average per home, as-built energy consumption, counterfactual energy consumption, and net savings estimated from artificial non-program data. Results are presented by fuel type and end use, respectively.

Table 33: Summary of Multifamily Average per-Home Non-Program Net Savings by Fuel Type

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Propane (Gallons)
n	*165*	*165*	*141*	*22*
As-Built Energy Consumption[1]	49.6	5,375.4	404.7	138.6
Counterfactual Energy Consumption[1]	53.4	5,457.7	476.6	153.1
Net Savings: Non-Program Homes[1]	4.8*	364.9*	71.9	14.5

*Net savings from the overall energy and electric consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD (gross) lighting savings were calculated from 146 non-program homes and is equal to 282.5 kWh per home with 90% CI = (271.9, 293.2) or 1.0 MMBtu with 90% CI = (0.9, 1.0).

[1] Fuel-specific interactive effects not accounted for; fuel consumption and savings may not sum up to overall values.

Table 34: Summary of Multifamily Average per-Home Non-Program Net Savings by End Use (MMBtu)[1]

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
n	*165*	*165*	*150*	*165*	*165*
As-Built Energy Consumption	49.6	21.8	3.1	9.5	15.5
Counterfactual Energy Consumption	53.4	25.9	3.1	9.7	15.0
Net Savings: Non-Program Homes	4.8*	4.1	0.04	0.2	0.5*

*Net savings of the overall energy consumption and lighting and appliances consumption accounted for PSD lighting savings and are not equal to the difference between the counterfactual consumption and the as-built consumption. PSD (gross) lighting savings were calculated from 146 non-program homes and is equal to 282.5 kWh per home with 90% CI = (271.9, 293.2) or 1.0 MMBtu with 90% CI = (0.9, 1.0).

[1] End use energy consumption excludes PV and does not sum up to overall energy consumption.

3.3.4 Multifamily Overall Net Savings and Net-to-Gross Ratios

NTG ratios were calculated by comparing the program net savings and artifical non-program net savings to the 2015 gross savings. Table 35 and Table 36 present the speculated overall gross and net savings estimates, estimated free-ridership, non-participant spillover, and NTG ratios by fuel type and end use, respectively.

The overall multifamily NTG ratio is 0.60 and the fuel specific NTG ratios are 0.62 for electricity, 1.07 for natural gas, and 0.43 for propane. NTG ratios by end use are 1.00 for heating, 0.15 for cooling, 0.11 for water heating, and 0.52 for lighting and appliances.

Table 35: Multifamily Net Savings and Net-to-Gross Ratios by Fuel Type[1]

	Overall (MMBtu)	Electricity		Natural Gas		Propane	
Number of homes (Program/Non-Program)	*1,278/1,291*	*1,278/1,291*		*1,092/1,103*		*170/172*	
Gross Program Savings		**kWh**	**MMBtu**	**Therms**	**MMBtu**	**Gallons**	**MMBtu**
Low CI	20,158	2,344,932	7,995	111,071	11,107	10,514	962
Mid-Point	21,256	2,468,853	8,418	119,416	11,942	11,783	1,078
High CI	22,353	2,592,774	8,840	127,761	12,776	13,053	1,194
Net Program Savings							
Low CI	6,157	1,021,412	3,483	45,227	4,523	2,293	210
Mid-Point	6,427	1,055,176	3,598	48,284	4,828	2,578	236
High CI	6,698	1,088,941	3,713	51,341	5,134	2,863	262
Net Non-Program Savings							
Low CI	5,846	456,488	1,556	74,257	7.426	2,225	204
Mid-Point	6,226	471,055	1,606	79,275	7,928	2,502	229
High CI	6,606	485,622	1,656	84,294	8,429	2,778	254
Free-Ridership							
Low CI	0.68	0.55		0.56		0.75	
Mid-Point	0.70	0.57		0.60		0.78	
High CI	0.72	0.60		0.63		0.81	
Non-Participant Spillover							
Low CI	0.27	0.18		0.60		0.18	
Mid-Point	0.29	0.19		0.66		0.21	
High CI	0.32	0.20		0.73		0.24	
Net-to-Gross							
Low CI	0.56	0.59		1.00		0.39	
Mid-Point	0.60*	0.62		1.07		0.43	
High CI	0.63	0.64		1.14		0.48	

*Overall net-to-gross ratio reported may not calculate exactly to the net-to-gross formula of $1 - Free\ Ridership + Non\ Participant\ Spillover$ due to errors in rounding.

[1] Fuel-specific interactive effects not accounted for; fuel consumption and savings may not sum up to overall values.

Table 36: Multifamily Net Savings and Net-to-Gross Ratios by End Use (MMBtu)

	Overall	Space Heating	Cooling	Water Heating	Lighting & Appliances
Number of homes (Program/Non-Program)	*1,278/ 1,291*	*1,278/ 1,291*	*1,162/ 1,174*	*1,278/ 1,291*	*1,278/ 1,291*
Gross Program Savings					
Low CI	20,158	7,294	396	4,960	7,040
Mid-Point	21,256	8,211	447	5,325	7,273
High CI	22,353	9,128	497	5,690	7,505
Net Program Savings					
Low CI	6,157	2,763	21	333	2,987
Mid-Point	6,427	2,970	22	346	3,089
High CI	6,698	3,178	23	359	3,192
Net Non-Program Savings					
Low CI	5,846	4,890	44	216	658
Mid-Point	6,226	5,258	47	224	698
High CI	6,606	5,625	49	233	737
Free-Ridership					
Low CI	0.67	0.59	0.94	0.93	0.56
Mid-Point	0.70	0.64	0.95	0.94	0.58
High CI	0.72	0.69	0.96	0.94	0.59
Non-Participant Spillover					
Low CI	0.27	0.56	0.09	0.04	0.09
Mid-Point	0.29	0.64	0.10	0.04	0.10
High CI	0.32	0.72	0.12	0.05	0.10
Net-to-Gross					
Low CI	0.56	0.91	0.14	0.10	0.50
Mid-Point	0.60*	1.00	0.15	0.11	0.52
High CI	0.63	1.10	0.17	0.11	0.54

*Overall net-to-gross ratio reported may not calculate exactly to the net-to-gross formula of $1 - Free\ Ridership + Non\ Participant\ Spillover$ due to errors in rounding.

Section 4 Panelist Comments on the Program's Future

This study gathered qualitative feedback from the Delphi panelists about the future of the program. Panelists described which efficiency measures and which program activities would be important to achieving energy savings in the next few years. This section presents those qualitative results.

4.1 Delphi Panelists' Comments on the Program's Future

4.1.1 Program Effectiveness

Panelists were given a list of efficiency measures and were asked whether the program would have more, less, or about the same impact on the efficiency of that measure moving forward. For most measures, panelists typically described that the program's current level of influence would continue or increase for the next few years. For six measures, a majority of panelists assessed the program as continuing on its current level of effectiveness among the program population; for another five measures, a majority of panelists indicated they believed the program would be increasingly effective over the next few years. Figure 5 displays responses for select measures where voting *strayed* from the most common response, or in other words, measures for which panelists thought there would be no change in the level of the program's impact on that measure moving forward.

The following are some key findings from panelist responses:

- Very few panelists reported that the influence of the program on the listed measures would decrease moving forward.
- Views on lighting were split, but this was the only measure where a substantial portion of the panelists reported that program influence would decrease over the next few years.
  - Five out of thirteen said that program influence on lighting would decrease over the next few years, in both program and non-program homes. (No other measure received more than two votes that the program's influence on would decrease.)
- Panelists reported that the program would become more effective at promoting overall home efficiency moving forward in both program and non-program homes.

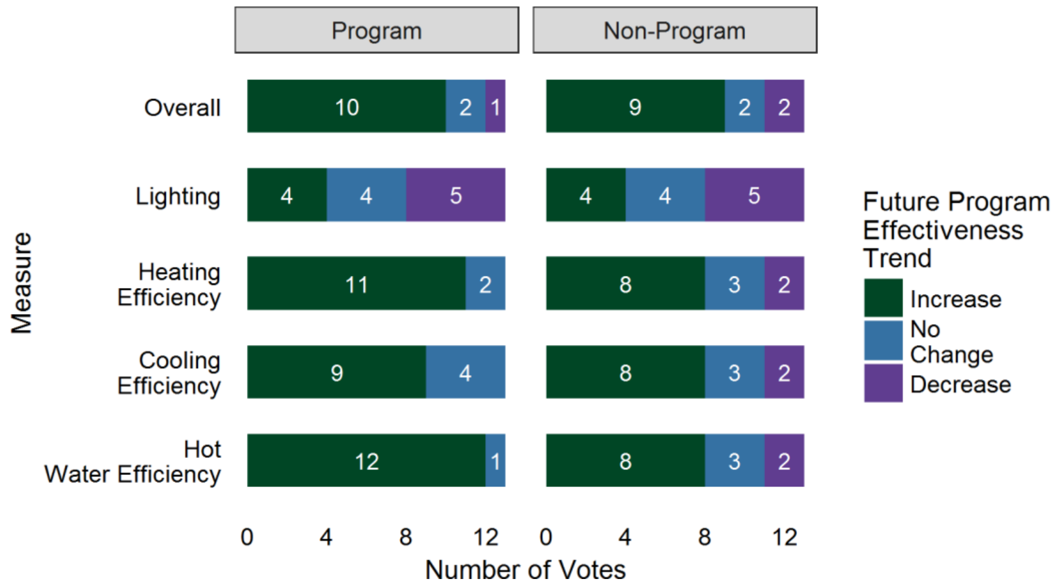
"[The] program is continually driving innovation and more efficient homes, in particular with the design of $50/extra HERS point below 50." – Non-CT RNC Program Manager

- Panelists concluded consistently across both program and non-program homes that the program will become increasingly effective at promoting efficiency among all types of mechanical systems included in the survey – heating, cooling, and water heating.

> "The mix of water heater types in program homes is changing with more types of water heaters available. I think the program will be a driver of increasing the penetration of the most efficient systems." – National Evaluator

To view a comprehensive breakdown of responses for all measures, see Figure 12 in Appendix D.

Figure 5: Future Effectiveness Trends for Select Measures



4.1.2 Future Opportunities for Energy Savings

Panelists were provided with a list of efficiency measures targeted by the program, such as insulation R-value, heating system efficiency, duct leakage, window U-value, and so forth. Each panelist selected the five that they thought would be the most important to the program in terms of creating energy savings over the next few years and ranked them from most important to the fifth most important.

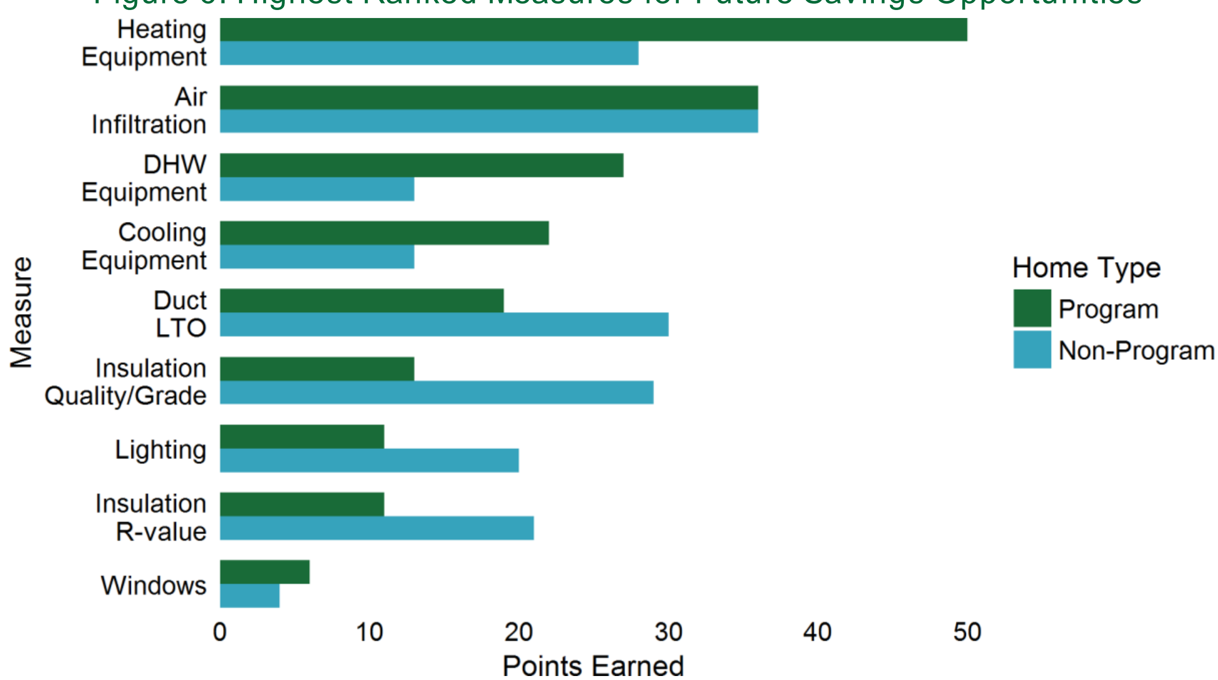
This study used a point system to analyze the ranked responses; a measure rated by a panelist as the most important measure received a score of five points, down to the measure rated as fifth most important, which received one point. Point totals are displayed in Figure 6.

- High efficiency heating, water heating, and cooling systems were identified as some of the most important measures with which the program would generate energy savings in program homes in the future.
  - Heating was the most important measure, water heating was the third most important measure, and cooling was the fourth most important measure. This aligns with program home responses from the previous forward-looking question, where

mechanical system efficiencies were most commonly cited as measures where the program's influence would increase moving forward.

- Panelists identified air sealing and duct sealing as the measures that would be most important to the program in terms of generating savings in non-program homes over the next few years (i.e., with spillover potential).
- Air infiltration was identified as an important measure for future savings opportunities in program and non-program homes. It was the highest ranked measure in non-program homes and the second highest (after heating system efficiencies) in program homes. Air infiltration was identified as an important measure for future savings opportunities in program and non-program homes. It was the highest ranked measure in non-program homes and the second highest (after heating system efficiencies) in program homes.
- Duct leakage to outside (LTO) was ranked as the second most important measure for future savings non-program homes, and fifth for program homes.

Figure 6: Highest Ranked Measures for Future Savings Opportunities



4.1.3 Importance of Program Activities

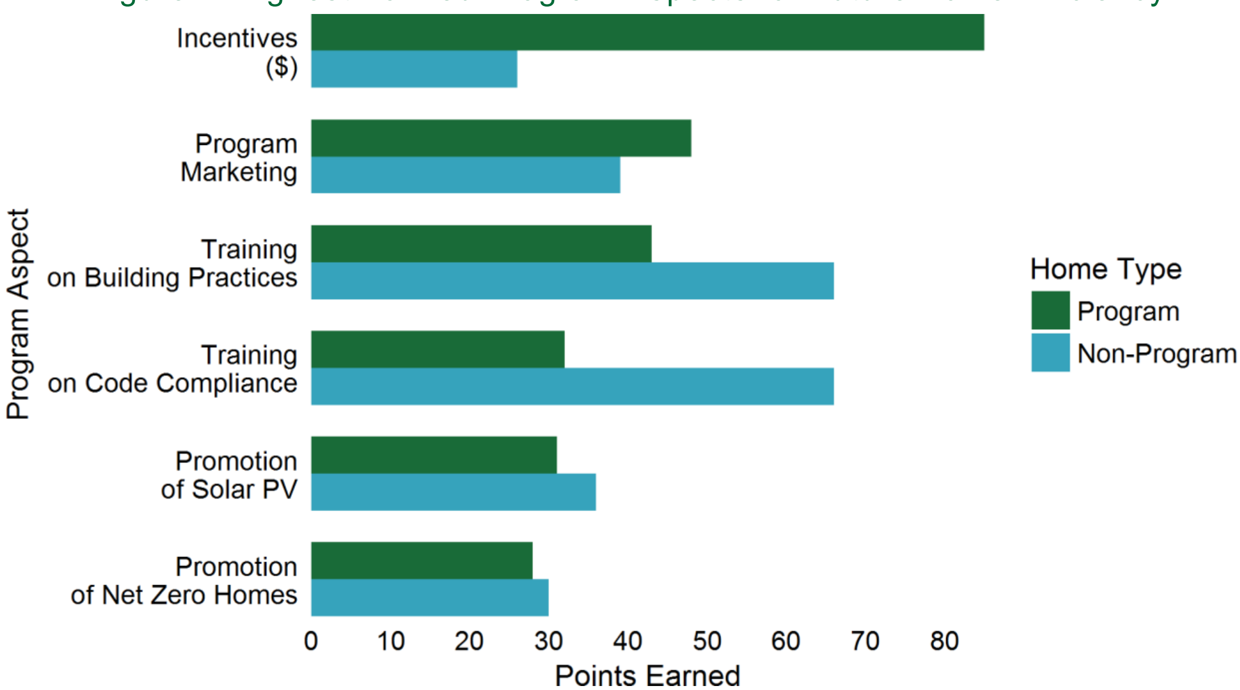
Panelists were asked to rank six program elements in terms which ones would most drive home efficiency in the next few years, using a scale of 1 to 6, where one is the *most important* and six is the *least important*. Program elements included the following:

- Incentives
- Program marketing
- Training on code compliance
- Training on building practices
- Promotion of solar PV
- Promotion of Net Zero homes

A point system was used to generate an overall score, where a ranking of 1 was allotted six points and a ranking of 6 was allotted one point. Figure 7 shows the point totals for each of the six program aspects,

- Not surprisingly, incentives were ranked as the most important program aspect for increasing efficiency in program homes in the next few years. Program marketing and training on building practices rounded out the top three.
- In non-program homes, program trainings on code compliance and building practices had the highest potential to impact builders working outside of the program.
- Incentives were the least important aspect on the non-program side since non-program homes do not receive incentives. Promotion of Solar PV and Net Zero Homes also ranked low in terms of importance.

Figure 7: Highest Ranked Program Aspects for Future Home Efficiency



4.1.4 Upcoming Trends in Lighting

A final forward-looking question asked panelists to describe changes they see coming in the lighting market in the next few years that may affect the adoption of high efficiency lighting in new construction.

Panelists noted that LEDs are becoming the norm in the lighting market, and that this is expected to continue outside of the program, which will lessen the programs' impact on efficient lighting saturation. This aligns with the panelists' responses to the first forward-looking question, where panelists described the program as achieving less impactful results with lighting in the future.

> "LEDs will continue to gain acceptance in non-program homes as LEDs continue to gain popularity. Home buyers will expect LEDs in homes they are considering."
> – Non-CT RNC Program Manager

Additional observations on the future of the lighting in new construction included the following:

- One respondent suggested that as LEDs become more ubiquitous, the program could focus more on efficient home lighting design, to better take advantage of the flexibility of LEDs.
- Two respondents mentioned improvements in advanced lighting controls as a trend that will impact efficient lighting moving forward.
- Continued evolution of code requirements was another factor mentioned multiple times – both in pushing efficient lighting requirements and in requiring advanced controls.

“Controls are likely to become more common. As code starts requiring them, costs come down, and builders and buyers become aware of the benefits. The program will need to change to account for those benefits.”
– National Evaluator

Appendix A Methodology

A.1 Delphi Panel Process

The following describes the Delphi panel process and survey instruments used for this study. Panelists were offered $500 for their participation and were recruited by phone and email. The EA team pre-approved a list of experts to recruit for the panel. Panelists provided initial estimates in the Round 1 survey instrument. The Round 2 survey instrument displayed all the Round 1 responses and gave respondents the opportunity to adjust their answers based on the other panelists' responses.

A.1.1 Round 1 Survey Instrument

A.1.1.1 Background Information

The Round 1 survey instrument was a Microsoft Excel workbook that provided a great deal of background information to panelists, in the form of additional sheets, or tabs, in the Excel workbook. Panelists were asked to review the background materials before making any estimates. The following describes the background information provided to the panelists:

- **The Program Design** sheet described the design and history of the program including the incentive structure dating back to 2011.
  - Summary: The CT RNC program started in the 1990's with two tracks: a prescriptive incentive track and a tiered, whole-home approach based on HERS Index thresholds. In 2013, the program started shifting its focus away from the prescriptive track and, by 2015, stopped offering prescriptive incentives. Additionally, starting in 2015, homes applying for Tier 2 or higher had to meet the Connecticut version of the DOE Zero Energy Ready home PV-ready checklist. In 2017, the program added Tier 4 for homes with HERS indices of zero. Eligible buildings include single-family detached and attached homes, multifamily buildings with three stories or fewer, and four or five story buildings where all the units have their own heating, cooling, and hot water equipment.
- **The Building Practices and Codes** sheet showed measure-level changes in the Connecticut residential new construction market from 2011 to 2016 by displaying results for single-family program and non-program samples and multifamily program samples from 2011 and 2016 baseline studies. Additionally, this sheet summarized the 2006 IECC code requirements which were applicable to the 2011 samples of homes and the 2009 IECC code requirements which were applicable to the 2016 samples of homes, including how those code versions differed.
  - Summary: For single-family non-program homes, there was improvement between 2011 the 2016 samples. Notably, the efficient lighting saturation became 480% better, duct leakage became 65% tighter, and floors over unconditioned basements became 25% better. The HERS index got 13% better, dropping from 82 to 71. Program homes

also saw improvement over time. Floor insulation became 36% better, duct leakage got 18% better, and air infiltration got 16% better. The HERS index dropped 9%, from 53 to 49.

Between the 2006 IECC and 2009 IECC, only a few measures increased in stringency, while the rest stayed the same. The 2009 IECC required duct leakage and air leakage tests to meet certain thresholds, while the 2006 IECC had no such requirements.[52] Additionally, the 2009 IECC required 50% saturation of efficient lighting in hard-wired fixtures, while the 2006 IECC had no requirement. Exterior walls were required to have R-19 insulation in the 2006 IECC and R-20 in 2009 IECC.[53]

- **The Market Penetration** sheet displayed the annual market penetration of the program for single-family and multifamily units from 2007 to 2016 by comparing counts of program participating units based on publicly available program records to building permits the U.S. census with a one-year lag.[54]
  - Summary: Depending on the year, the penetration rate ranged from 9% to 34%.[55]
- **The Program Code Support** sheet displayed a calendar of code compliance training events sponsored by the program between 2011 and 2016.
  - Summary: Trainings targeted code officials, builders, design professionals, and mechanical contractors. Extensive training on the 2009 IECC took place in 2011 and 2012. The first 2012 IECC training took place in 2013, although Connecticut did not adopt the 2012 IECC until 2016.
- **The Program Marketing** sheet described the program's marketing efforts and campaigns.
  - Summary: Efforts included annual program rollouts for industry members, email blasts to builders and HERS raters, and the program website. Additionally, the program advertises in *Connecticut Builder* magazine, reaches out to local trade organizations, and sponsors building industry events in the state. The program also does some marketing to the general public, specifically about its Zero Net Energy Challenge.
- **The Net Zero Homes** sheet described the program's efforts to encourage the construction of zero net energy homes.
  - Summary: The Zero Net Energy Challenge was launched in 2012 and it rewards architects and builders with publicity and cash prizes for achieving cost-effective zero net energy homes. 2016 saw the most participants of any previous year with 17 homes.

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[52] For a duct leakage in 2009 IECC, a home must have no more than 8 CFM25/ 100 sq. ft. leakage to outside or 12 CFM25/100 sq. ft. total duct leakage, both from post-construction tests. Homes must have an ACH50 no more than 7.
[53] Both codes allow walls to meet this requirement by having R-13 in the cavity and R-5 continuous insulation.
[54] Annual program counts were taken from the Connecticut Statewide Energy Efficiency Dashboard at https://ctenergydashboard.com/Login.aspx.
[55] Note that the penetration rate used to scale up savings to the entire population in the NTG analysis was based on program tracking databases and not the Connecticut Statewide Energy Efficiency Dashboard.

- **The Process Evaluation** sheet summarized the key findings of a process evaluation of the program conducted by NMR in 2016, based on interviews with program administrators, program HERS raters, program builders, and participating homeowners.
  - Summary: Some key findings included that program satisfaction is high across builders and HER raters but that the paperwork can be burdensome, homebuyers care about efficiency, but it does not tip the scales when deciding to purchase a home, the program has been crucial to establishing the CT HERS market, the program has improved builders' practices (particularly for air and duct sealing), and that HERS rater play vital role in program execution.
- **The Solar PV** sheet showed the percentages of program and non-program homes that had onsite solar photovoltaic systems in the 2016 and 2011 baseline and program data samples. The sheet also listed all the solar incentives available in Connecticut since 2011.
  - Summary: In the 2011 sample, only 3% of program homes had solar PV and non-program homes had no solar PV. In the 2016 sample, 8% of program homes and 7% of non-program homes had solar PV. Identified solar incentives included those from the Connecticut Green Bank that started in 2012 and local property tax waivers for renewables that started in 2011. Additionally, solar PV in Connecticut was eligible for a federal residential renewable energy tax credit starting in 2006.
- **The Multifamily Activities** sheet describes the program's efforts to encourage efficiency in new multifamily construction.
  - Summary: The program offers three types of incentives: subsidies for energy simulations, financial incentives per square foot for achieving efficiencies various percentages above code, and bonus incentives for LEED or ENERGY STAR certifications.
- **The Other Programs** sheet describes other programs or incentives available in Connecticut between 2011 and 2016 that could have influenced the efficiency of residential new construction projects.
  - Summary: Such programs included equipment rebates, the Home Energy Solutions Rebate Program which subsidizes energy audits and provides rebates and financing for efficiency upgrades in existing homes, and the federal residential renewable energy tax credit.
- **The Program Trainings** sheet provides a calendar of trainings on efficient building practices sponsored by the program since 2011.
  - Summary: Training topics included ENERGY STAR Version 3.1, energy modeling, heat pumps, HVAC systems, Energy Efficiency Board presentations, and program opportunities.

A.1.1.2 Measure-Level Efficiency Questions

The Round 1 survey showed panelists measure-level efficiencies for a sample of 198 program homes and a sample 70 non-program homes. The data for the 70 non-program homes came from the 2016 R1602 Residential New Construction Baseline study.[56] The data for the 198 program homes came from REM/files of program participating homes that were identified as being built at the same time as the homes in the non-program baseline study. Panelists were asked to estimate what the efficiencies of the following measures would have been in both the program and non-program samples if the program had ended on December 31st, 2011:

- Duct leakage to outside (CFM25/100 sq. ft. of CFA)
- Air infiltration (ACH50)
- Window U-value
- Lighting (percent of sockets with efficient bulbs)
- Wall insulation R-value
- Wall insulation Grade (installation quality)
- Frame floor insulation R-value and Grade
- Flat ceiling insulation R-value and Grade
- Cathedral ceiling insulation R-value and Grade
- Conditioned foundation wall insulation R-value and Grade
- Heating system efficiency (by system type)
- Cooling system efficiency (by system type)
- Water heating system efficiency (by system type)
- Solar PV presence

Figure 8 shows an example from the Round 1 survey instrument of a measure-level efficiency question, in its blank form as a template, and then with answers filled in. The example only shows the display for the program sample; however, the survey had an identically formatted display for the non-program sample data and estimations. For each measure, the program and non-program displays were next to each other so that panelists could easily examine a single measure at a time.

As shown in Figure 8, the measure of interest, “duct leakage to outside,” is identified in the upper left corner of the question display. The mean efficiency value from the actual data, 1.8 in this example, is displayed. Beneath the mean efficiency value, efficiency values of the actual data are presented in tiers. The tiers are comprised of the 25% least efficient homes, the 50% middle efficiency homes, and the 25% most efficient homes for each measure. The range of each tier is displayed with the tier name.

In the light blue shaded cells, panelists were asked to provide the mean energy-efficiency value for each tier in the absence of the program. Additionally, panelists were given the opportunity to redistribute the percentage of homes that would fall into each tier. A cell in the upper right corner automatically showed panelists the weighted mean of their responses and compared it to the real-world value. A cell next to each tier compared the response for that tier to the real-world value. A cell in the bottom row of each question switched from red to green when the panelists’ estimated percentages in each tier summed to 100%.

[56] For the average measure level values used in the survey, see the R1602 Residential New Construction Baseline study at https://www.energizect.com/sites/default/files/R1602_Residential%20New%20Construction%20Baseline%20Study_Final%20Report_12.5.17.pdf

Figure 8: Round 1 Survey Question Example

Duct Leakage to Outside	Program Homes (single-family only)				
	2016		Percent of Homes in Each Tier In Absence of Program	Average Duct Leakage in Each Tier In Absence of Program	You have not completed this section yet. Please fill in the blank blue cells.
	% of Homes	Duct Leakage			
Average Leakage to Outside (CFM25/100 ft^2 conditioned space)	100%	1.8			
High (poor) Duct Leakage Tier 2.4 to 9.2 CFM25/100 ft^2	25%	3.4			
Mid Duct Leakage Tier 1.0 to 2.4 CFM25/100 ft^2	50%	1.6			
Low Duct Leakage Tier 0.0 to 1.0 CFM25/100 ft^2	25%	0.6			
			0%		

Duct Leakage to Outside	Program Homes (single-family only)				
	2016		Percent of Homes in Each Tier In Absence of Program	Average Duct Leakage in Each Tier In Absence of Program	**Your estimates result in an overall average of 2.9, which is 61% higher (worse) than the baseline average.**
	% of Homes	Duct Leakage			
Average Leakage to Outside (CFM25/100 ft^2 conditioned space)	100%	1.8			
High (poor) Duct Leakage Tier 2.4 to 9.2 CFM25/100 ft^2	25%	3.4	35.0%	4.6	35% Higher (worse)
Mid Duct Leakage Tier 1.0 to 2.4 CFM25/100 ft^2	50%	1.6	50.0%	2.4	50% Higher (worse)
Low Duct Leakage Tier 0.0 to 1.0 CFM25/100 ft^2	25%	0.6	15.0%	0.9	50% Higher (worse)
			100%		

Each panelist also provided their reasoning behind their decisions, in an open-ended response for each measure and rated their level of familiarity with the measure on a scale of 1 to 5, where 1 is *not at all familiar* and 5 is *extremely familiar*. In Round 2, this self-assessment of each panelist's own expertise was shown to other panelists, so that panelists could attribute more or less weight to a given response. See Appendix F for details about the panelists' familiarity assessments.

Additionally, the Round 1 survey included more qualitative questions on the program's effect on the multifamily market, which measures will be most important for the program to focus to achieve energy savings in the future, which features of the program will be the most important to encourage participation in the future, and what changes will be seen in the residential lighting market.

A.1.2 Round 2 Survey Instrument

In the Round 2 survey, panelists were shown the average responses from the Round 1 survey and given the opportunity to adjust their own responses. Figure 9 shows an example for the duct leakage measure question in the Round 2 survey blank and then completed. Again, only the program sample display is shown. The light green columns present the actual data for the sample and tiers – this is identical to the data provided in the Round 1 survey. Next, the orange cells show the average responses for each tier – both the average percentage of homes and the average efficiency – of all panelists from the Round 1 survey. They yellow cells show the Round 1 responses for the individual panelist. Each panelist received their own customized version of the survey comparing their own responses to the average response. Additionally, the survey provided the individual responses from every panelist along with every panelists' open-ended reasoning and self-rated familiarity with the measure. Panelists' identities were kept anonymous.

Again, the survey asked panelists to fill in the blue cells. They could enter the same responses as they did in Round 1 or they could enter new responses – therefore indicating that viewing the other panelists' responses swayed their original thinking. Panelists were also asked to provide an open-ended response on why they did or did not change their responses.

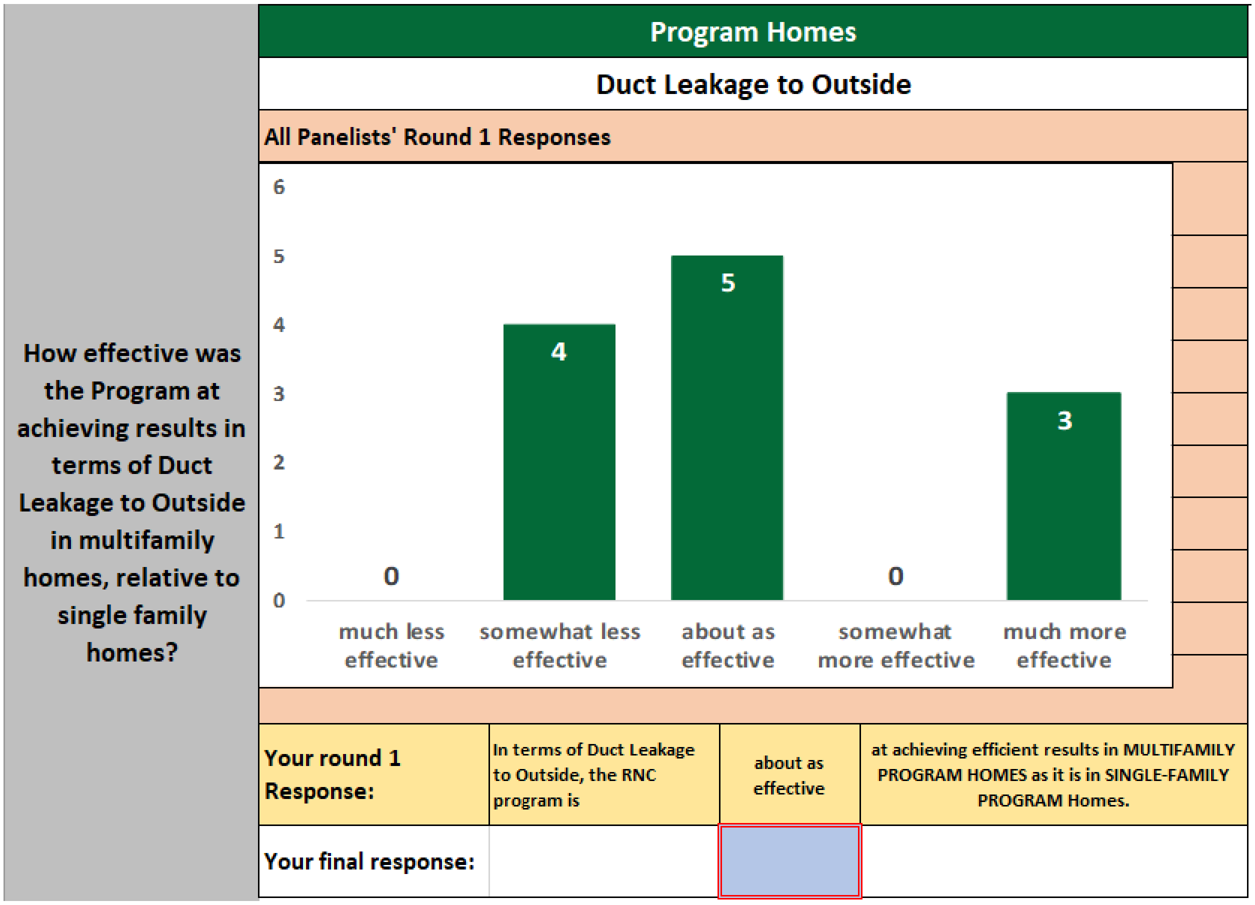
Figure 9: Round 2 Survey Question Example

Program Homes (single-family only)									
Duct Leakage Tiers (CFM25/100 sq. ft. of conditioned floor area)	Actual 2016 Values		All Panelists' Round 1 Responses in Absence of Program		Your Original Response in Absence of Program		Your New Response in Absence of Program		
	% of Homes	Duct Leakage	% of Homes	Duct Leakage	% of Homes	Duct Leakage	% of Homes	Duct Leakage	Comparison to Actual 2016 Values
High (poor) Duct Leakage Tier 2.4 to 9.2 CFM25/100 ft2	25%	3.4	52.0%	5.5	70.0%	7.0			
Mid Duct Leakage Tier 1.0 to 2.4 CFM25/100 ft2	50%	1.6	32.6%	2.0	20.0%	2.0			
Low Duct Leakage Tier 0.0 to 1.0 CFM25/100 ft2	25%	0.6	15.3%	0.8	10.0%	1.0			
Average Duct Leakage	1.8						0%	Please Fill in All Blue Cells Above	

Program Homes (single-family only)									
Duct Leakage Tiers (CFM25/100 sq. ft. of conditioned floor area)	Actual 2016 Values		All Panelists' Round 1 Responses in Absence of Program		Your Original Response in Absence of Program		Your New Response in Absence of Program		
	% of Homes	Duct Leakage	% of Homes	Duct Leakage	% of Homes	Duct Leakage	% of Homes	Duct Leakage	Comparison to Actual 2016 Values
High (poor) Duct Leakage Tier 2.4 to 9.2 CFM25/100 ft2	25%	3.4	52.0%	5.5	70.0%	7.0	60%	6.0	76% Higher (worse)
Mid Duct Leakage Tier 1.0 to 2.4 CFM25/100 ft2	50%	1.6	32.6%	2.0	20.0%	2.0	30%	2.0	25% Higher (worse)
Low Duct Leakage Tier 0.0 to 1.0 CFM25/100 ft2	25%	0.6	15.3%	0.8	10.0%	1.0	10%	1.0	67% Higher (worse)
Average Duct Leakage	1.8						100%	Your Round 2 overall average is: 4.3, which is 139% higher (worse) than the real world average.	

For the qualitative questions, the Round 2 survey provided histograms of the responses from the Round 1 survey, showed each panelist their Round 1 response, and then provided the opportunity to change or confirm their Round 1 response. Figure 10 shows an example from a question that asked, "how effective was the Program at achieving results in terms of duct leakage to outside in multifamily homes relative to single-family homes?"

Figure 10: Round 2 Survey Qualitative Question Example



A.2 Modeling Homes with Estimated/Counterfactual Energy-Efficiency Values

Four data sets, two each for program and non-program homes, were generated to reflect the Delphi panel estimates, which were all based on single-family home data. Within these data sets, for each sampled home, a new efficiency value was generated for each of the building components considered by the Delphi panel. The estimates created by the Delphi panelists for a given measure were used to create a distribution of possible counterfactual measure values that would be used in the counterfactual energy models, and each home was assigned a counterfactual measure value such that the average measure value across the sample was similar to the average value estimated by the panelists for that measure.

The efficiency values assigned to each home were unique in each of the four data sets, allowing two counterfactual REM/Rate models to be developed for both program and non-program samples. Modeling two different estimates of energy consumption in the absence of the program rather than one allowed for a greater combination of interactive effects among the models and ultimately resulted in a more robust net savings estimate for the program. The process of generating values and modeling under counterfactual assumptions is presented in more detail in Appendix A.3.

The program's effect on the percentage of homes with on-site solar production was also incorporated into the four data sets. Panelists were shown the percentage of homes in both the program and non-program samples that had onsite solar production and estimated what percentage of homes would still have onsite solar production in the absence of the program.[57] Solar capacity was then removed from the counterfactual models of randomly selected homes to make the percentage of homes with onsite solar in the estimated samples match the solar PV penetration estimated by the panelists.

Models were made using REM/Rate version 15.4. While the energy models used by raters and submitted to the program were done in version 14, version 15 provided a more accurate result that took into account various bug fixes. To keep comparisons consistent, consumption values for the program homes were recalculated using version 15.4.

A.3 Calculations

This section describes the process used to generate the measure-level counterfactual values based on the Delphi panelists' estimates of the RNC program's impacts. This study had samples of non-program REM/Rate files from the 70 non-program homes included in the R1602 baseline study, along with actual REM/Rate files from the 2015 program year that were also provided as a part of that study. Seventy, single-family program REM/Rate files were sampled to mirror the sample size of the R1602 non-program sample. The original REM/Rate energy models for the homes in the program and non-program samples will be referred to as the *as-built* homes. Counterfactual models were generated by replacing the as-built building efficiency values with Delphi panelists' estimates of the counterfactual efficiency values. Each as-built model was compared to two counterfactual models to estimate program savings for the two samples (program and non-program homes). The savings estimated from the counterfactual models and the as-built models were used to calculate the net-to-gross (NTG) ratio for the program.

A.3.1 Development of Counterfactual Efficiency Values

The Delphi panelists completed the two rounds of the Delphi panel where they provided measure-level efficiency estimates for the building components as well as the percentage of homes that would-have fallen into either a high, medium, or low efficiency tier in the absence of the program. This study constructed probability distributions using the panelist responses (excluding outliers) to assign counterfactual efficiency values for each energy model. The following describes the procedure for generating the counterfactual values based on the panelists' estimates.

First, each sampled home was randomly assigned to one of three efficiency tiers based on the average percentage of homes that the panelists predicted would fall into each tier in the counterfactual scenario. For example, on average, 31% of homes were estimated to have had low-efficiency wall insulation in the absence of the program. This meant that a home had a 31% chance of being assigned to a low efficiency wall insulation tier.

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[57] The program does not directly incentivize onsite solar production but does promote solar, including by offering homes an additional cash incentive for every point below a HERS index value of 50 as long as home achieves a HERS index value of 50 before renewables are added to the project.

Next, an efficiency value was generated based on the Delphi panelist responses for that assigned tier using the following method:

1. Each panelist had been asked to estimate an *average* counterfactual efficiency value for each efficiency tier.
2. A probability distribution was generated for that tier with a mean equal to the average of the panelists' estimated, counterfactual efficiency values.
3. A final efficiency value was randomly drawn from this distribution for each building component.

Continuing with the wall insulation example, assume the efficiency value for poor efficiency wall insulation was 18.61, with values ranging from 18.61 to 20.00. Therefore, the probability distribution for poor efficiency wall insulation had a mean of 18.61 and was bounded by the minimum (18.61) and maximum (20.00) of the panelist responses. A counterfactual efficiency value was randomly drawn from the distribution for each home and assigned to the low efficiency wall insulation tier. In the case of mechanical systems, panelist estimates were used to create new efficiency values for each mechanical system in a given home's energy model, but the fuel distribution or system type was not changed in the model. Doing so would have resulted in introducing numerous additional changes to the model for which we did not have supporting data. For example, switching a home from a boiler to a furnace would have required adding a duct system to the energy model, requiring modelers to make numerous additional assumptions about efficiency that were not informed by panelists' estimates (e.g., duct location, duct area, duct insulation, duct leakage).

Finally, this process was repeated for all tiers across all efficiency measures for program and non-program homes.

NMR repeated the entire procedure twice for program and non-program homes to obtain a total of four sets of inputs used to run two counterfactual models per home. This approach allowed NMR to model the average panelist efficiency values as a well as account for variation in the responses within each tier.

Two counterfactual REM/Rate models were created for each sampled home, and these became the basis of the savings calculations.

A.3.2 Net Savings Calculations

The net savings were calculated in two steps. First, the counterfactual (CF) energy consumption from the two counterfactual runs were averaged for each home *j:*

$$CF\ energy\ consumption_j = \frac{Run\ 1\ energy\ consumption_j +\ Run\ 2\ energy\ consumption_j}{2}$$

Second, the energy consumption from the counterfactual model was subtracted by the energy consumption from the as-built model for each home *j.* The net savings for the total homes *n* were then averaged to obtain the average net savings using the following equation:

$$Average\ net\ savings = \frac{1}{n}\sum_j(CF\ energy\ consumption_j + as - built\ energy\ consumption_j).$$

The average net savings were calculated for the single-family program (*n=70*) and non-program (*n=70*) homes. Lastly, 90% confidence intervals were constructed around the estimates.

A.3.3 Development of Multifamily Program Counterfactual and Non-Program Values

The evaluation team calculated multifamily NTG ratios. However, since a multifamily non-program baseline study was not conducted, NMR generated an artificial program counterfactual consumption dataset by adjusting the as-built program consumption using two factors:

- **Delphi Panelists' Multifamily Effectiveness Factor.** Average Panelist Score for Program's Overall MF Effectiveness Relative to SF Homes (slightly increases consumption for program homes relative to single-family homes, slightly decreases consumption for non-program homes)
- **Multifamily Counterfactual Adjustment Factor.** Average percent change in consumption single-family as-built to single-family counterfactual (increases consumption)

The team also did not have access to non-program multifamily unit data and generated artificial non-program as-built consumption by adjusting the as-built consumption for multifamily program homes using the percentage increase of single-family non-program consumption to program consumption and then applying the multifamily counterfactual adjustment factor to produce non-program counterfactual consumption values.

A.4 Lighting

The RNC program does not use REM/Rate to quantify lighting savings for program homes, instead it uses this PSD formula from the Connecticut Program Savings Document (PSD) that uses wattage and hours of use (by room type) variables to determine a kilowatt per hour savings value.[58]

$$Watt_{\Delta} = (Watt_{ratio} - 1)\ x\ Watt_{post}$$

$$AKWH = 1.04\ x\ \frac{Watt_{\Delta}\ x\ h_d\ x\ 365}{1000}$$

For new construction, the Program Savings Document provides default $Watt_{ratio}$ values for CFLs (3.6) and LEDs (3.7) but requires data on room type for daily hours of use (h_d) and bulb wattage ($Watt_{post}$) to complete the savings calculations. Because the team lacked room-level data for Program homes, a value for *unknown* room types (2.9) provided by the PSD was used for all program home calculations. While there were room-level data for non-program homes, the team

[58] https://www.energizect.com/sites/default/files/2017%20CT%20Program%20Savings%20Document_Final.pdf (Lighting can be found beginning on page 114)

decided to utilize a similar approach and use the unknown room HOU value for an apples-to-apples comparison.

For the required wattage variable, the team leaned on a wealth of data provided by years of fieldwork collecting information on CFL and LED bulbs in Massachusetts to determine average wattage values for the types of bulbs recorded in the program lighting data – general LEDs, LED downlights, and CFLs. These values were 15.8 watts for CFLs, 9.9 watts for LED downlights, and 9.3 watts for general LEDs. Bulb counts for non-program homes were provided by the R1602 baseline study, while program home bulb counts were provided by the program lighting tracking data.

A.5 Data Quality Issues

This study found the Companies to be prompt and responsive in answering questions about the data provided for this study, including going back to old program records to provide more information about PY2011 homes and program activities.

Data quality issues, however, resulted in some complications in the evaluation process. Given that much of the data from this evaluation was leveraged from the R1602 baseline study, there were similar issues in this study. These data issues included:

- Poor and inconsistent labeling of REM files
- Not having PY2011 REM files
- Lack of unique identifiers to match program REM/Rate files with program tracking data
- Gaps between United Illuminating (UI) and Eversource data
    - Lack of data on UI-specific trainings for panelists
    - Incomplete 2016 UI program tracking data
    - Lack of bulb-level lighting data in UI program tracking data
- Lack of room-level lighting data
- Inconsistencies in participation rates from program tracking data and CT Statewide Dashboard[59]

Bugs within the newly updated REM/Rate program resulted in wrongly modeled home energy consumption which required manual identification of problem homes and adjustment of the homes' parameters. The REM/Rate files for program homes, for example, would indicate a home was in Alaska instead of Connecticut, resulting in an incorrect cooling consumption of zero.

NTG ratios were impacted by inconsistent tracking of program records and missing data. Accurate penetration and count data greatly impact program and non-program savings estimates which are necessary for calculating NTG ratios. Due to inconsistencies between program tracking data and the CT Statewide Dashboard that describes program activity, penetration rates varied sporadically year by year, with unclear reliability. To mitigate the impact of this issue, permit and program counts for PY2014 and PY2015 were averaged to create a more reliable estimate of penetration rates for PY2015 – the basis of the scaling up of home-level results to the broader population.

[59] https://ctenergydashboard.com/Public/PublicHome.aspx

Including PY2016 data would have improved the accuracy of the estimate but could not be included due to UI data not having been provided as part of the R1602 study.

B

Appendix B Comparable RNC Markets and Programs in the Region

This section compares the Connecticut RNC program and market to similar programs and markets in Massachusetts, Rhode Island, and Vermont. When considering the program's influence on the Connecticut market, one must consider the potential cross-over influences from neighboring markets. For instance, some participants in the Connecticut residential new construction market work in surrounding states, and vice versa. Additionally, regional trade organizations facilitate information sharing across state lines.

All three comparison states have reasonably similar programs to encourage energy efficiency in their residential new construction markets, suggesting that it is not other states in particular driving outcomes in Connecticut (though synergistic effects across state lines are certainly possible). Results from the recent process evaluation of the Connecticut RNC program indicate that it is the *Connecticut* program that played a vital role in the efficiency of Connecticut's RNC market – namely by teaching Connecticut builders new skills and fueling the growth of the HERS rater market. Despite some cross-over between regional markets, efficiency gains in the Connecticut RNC market appear to have been dependent specifically on Energize Connecticut's Residential New Construction program.

Table 37 compares the energy codes and residential new construction programs of Connecticut, Massachusetts, Rhode Island, and Vermont – four New England states that recently had baseline evaluations for their RNC programs. The RNC programs in each state are similar. Homes receive incentives for demonstrating efficiencies above a user defined reference home (UDRH), which is based on average efficiency values found in recent baseline studies. A home's efficiency performance is calculated using an energy model, such as REM/Rate™, and homes can earn greater incentives by reaching higher efficiency tiers.

As shown in Table 37, the comparison states adopted newer versions of energy codes than did Connecticut during the study period. However, as demonstrated by the HERS index values in Table 38 and Table 39, the newer codes did not lead to significant differences in efficiency between markets during the study period. This could be due to similarities between codes and a natural lag in the adoption of new code practices by builders.

Table 37: Comparison to Similar Programs in the Region

	Connecticut	Massachusetts	Rhode Island	Vermont
Applicable Code by Year				
2011	2009 IECC	2009 IECC	2009 IECC	2009 IECC[a]
2012				>2009 IECC[b]
2013		2012 IECC/Stretch[d]	2012 IECC	
2014				
2015				2015 IECC[c]
2016				
Program Characteristics				
PY2015 Participation (Units)	1,654	1,660	273 (projects)	1,367
Compliance Paths	Performance	Performance	Performance	Prescriptive & performance incentives
Savings Baseline	Baseline studies	Baseline studies	Baseline studies	Baseline studies
Program Tiers				
Low	HERS 70-61	15% savings over UDRH	15% savings over UDRH	Base prescriptive standards
Medium	HERS 60-51	30% savings over UDRH	25% savings over UDRH	High performance prescriptive standards
High	HERS <50	40% savings over UDRH	45% savings over UDRH	NA

[a] Department of Energy determined that the Vermont energy code (RBES) was equivalent to the 2009 IECC.
[b] VT energy code remained based on the 2009 IECC but included some amendments from 2012 IECC.
[c] Department of Energy determined that Vermont energy code (RBES) was equivalent to the 2015 IECC.
[d] Massachusetts had a Stretch code based on the 2009 IECC that could be adopted at the city/town level.

Table 38 and Table 39 show the measure-level efficiencies of non-program and program homes from Connecticut, Massachusetts, and Rhode Island using data from recent baseline studies conducted in each state.[60] For non-program homes, the Connecticut sample has efficiency values in line with the comparison states. For program homes, the Connecticut sample has similar or slightly more efficient values than the comparison states. This suggests that there is little evidence that the comparison states' markets have undue influence on the efficiency of the Connecticut market.

[60] Vermont is excluded because, at the time of writing, the Vermont data was not publicly available.

Table 38: Non-Program Home Efficiency by State

	Connecticut	Massachusetts	Rhode Island
Sample Vintage	**2015-2016**	**2013-2016**	**2015-2017**
HERS Index (REM/Rate v.14)	70	68	73
External Wall R-value	20.8	20.8	19.9
Flat Ceiling R-value	36.9	40.7	33.4
Vaulted Ceiling R-value	36.7	32.4	29.4
Frame Floor R-value	25.7	30.7	20.6
Conditioned Foundation Wall R-value	10.9	15.6	7.9
Air Leakage ACH50	4.9	3.6	5.2
Duct Leakage	6.2 LTO, 18.7 TDL	3.9 LTO, 9.1 TDL	8.7 LTO, 20.6 TDL

Table 39: Program Home Efficiency by State

	Connecticut	Massachusetts	Rhode Island
Sample Vintage	**2015**	**2015**	**2015**
HERS Index (REM/Rate v.14)	48	55	62
External Wall R-value	22.3	21.1	20.4
Flat Ceiling R-value	46.0	41.0	38.6
Vaulted Ceiling R-value	40.0	37.6	37.7
Frame Floor R-value	28.0	30.3	29.6
Conditioned Foundation Wall R-value	16.3	14.8	18.4
Air Leakage ACH50	3.0	2.9	4.1
Duct Leakage (per 100 sq. ft.)	1.9 LTO, 4.2 TDL	2.6 LTO	4.7 LTO, 18.3 TDL

Conclusions from the recent process evaluation of the program specifically credit the program for efficiency gains in the Connecticut RNC market. Builders and trade allies consistently stated during interviews that builders had changed their practices since participating in the program and that the builders would have been unlikely to change their practices without the program.[61] Program incentives allow builders to overcome a learning curve for efficient building. Additionally, builders indicated that they apply lessons learned in the program to projects outside of the program:

"I learned about how small changes could effectuate a big return, so I was all about it. And when you do well on one home, you want to do better on the next, so you do more and more. It becomes a game."

HERS raters in the process evaluation indicated that the program is crucial for the HERS rating industry in Connecticut. One rater, speculating that the HERS market would not currently exist

[61] See Section 7 of R1602 Residential New Construction Program – Process Evaluation, Released August 14, 2017.

in Connecticut without the program, said that the program has been *vitally important* for the growth of HERS rater business. Given that builders reported depending on HERS raters to teach them about efficient building practices, the program's major role in propping up the HERS rating industry was clearly essential for efficiency gains in the market.

Appendix C Multifamily Delphi Responses

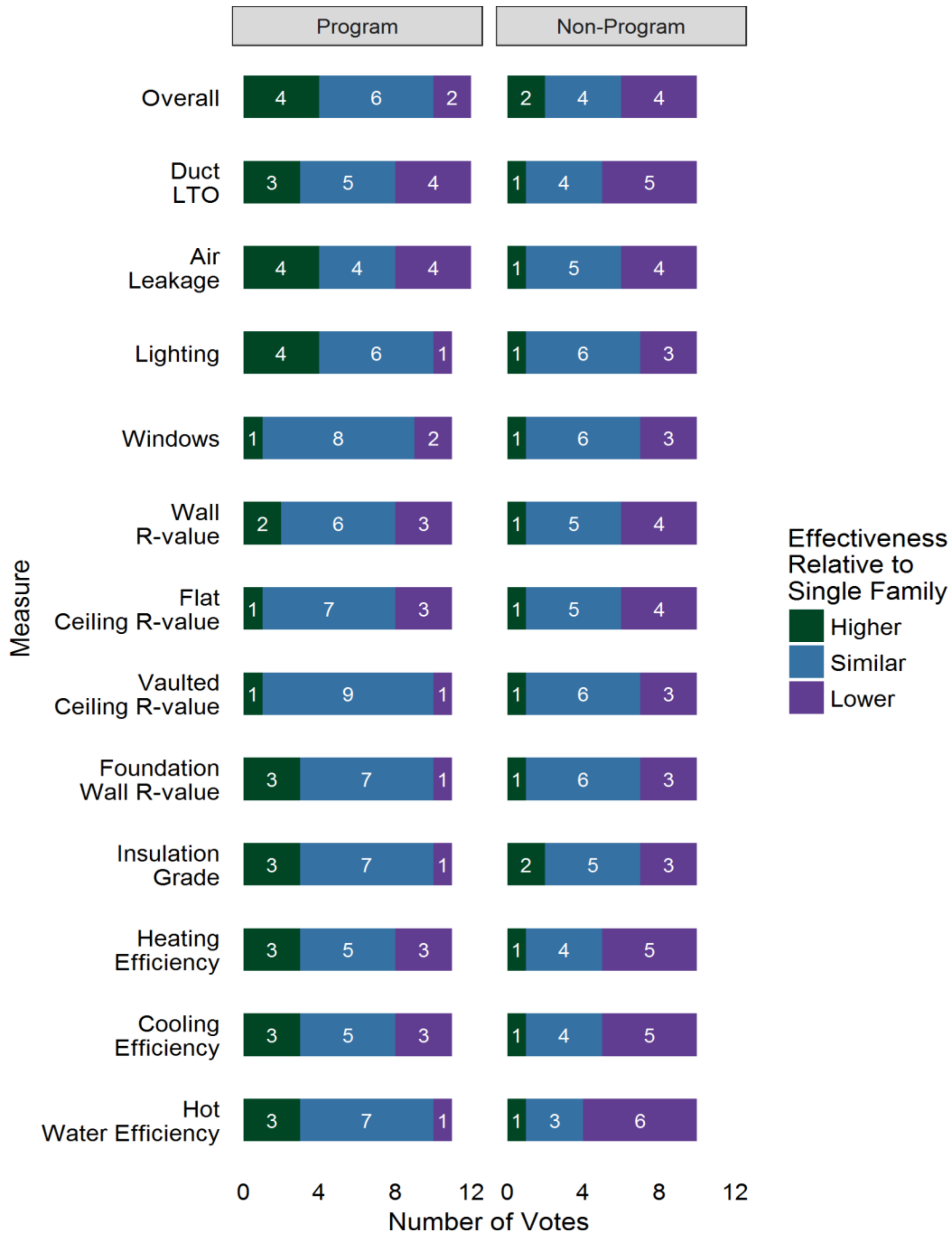
Figure 11 displays panelists' responses for all measures included in the multifamily qualitative question that asked for panelists to rate the effectiveness of the program's impacts in multifamily homes relative to single-family homes.

For each measure in program homes, the most frequent panelist response was that the program was *similarly effective* in the multifamily market as in the single-family market. In non-program homes, the most frequent response was that the program was *less effective* in the multifamily market relative to the single-family market, except for air leakage, where *similarly effective* was the most frequent response.

On the program side, air leakage and duct leakage were the measures most often identified as areas where the program was *less effective* in multifamily units than in single-family units, with four votes (33% of the responses) each. Air leakage was the sole instance where opinion was evenly split, with an equal number of panelists ranking it more effective, equally effective, or less effective. Across measures, there was generally a split among panelists between *more effective* and *less effective* votes – one exception was lighting, where four panelists indicated they thought the program was more effective in multifamily homes relative to single-family homes, versus just one indicating lower effectiveness.

For the program's impact on non-program homes, panelists generally indicated that the program was similarly or less effective at achieving efficiency in multifamily homes relative to single-family homes. The program was cited as being the least effective at driving domestic hot water system efficiency in the multifamily market relative to the single-family market. Heating and cooling system efficiencies and duct leakage were the other non-program measures where the most common response from panelists was that the program was less effective in multifamily homes (five *less effective* votes each).

Figure 11: Program Effectiveness in Multifamily versus Single-Family



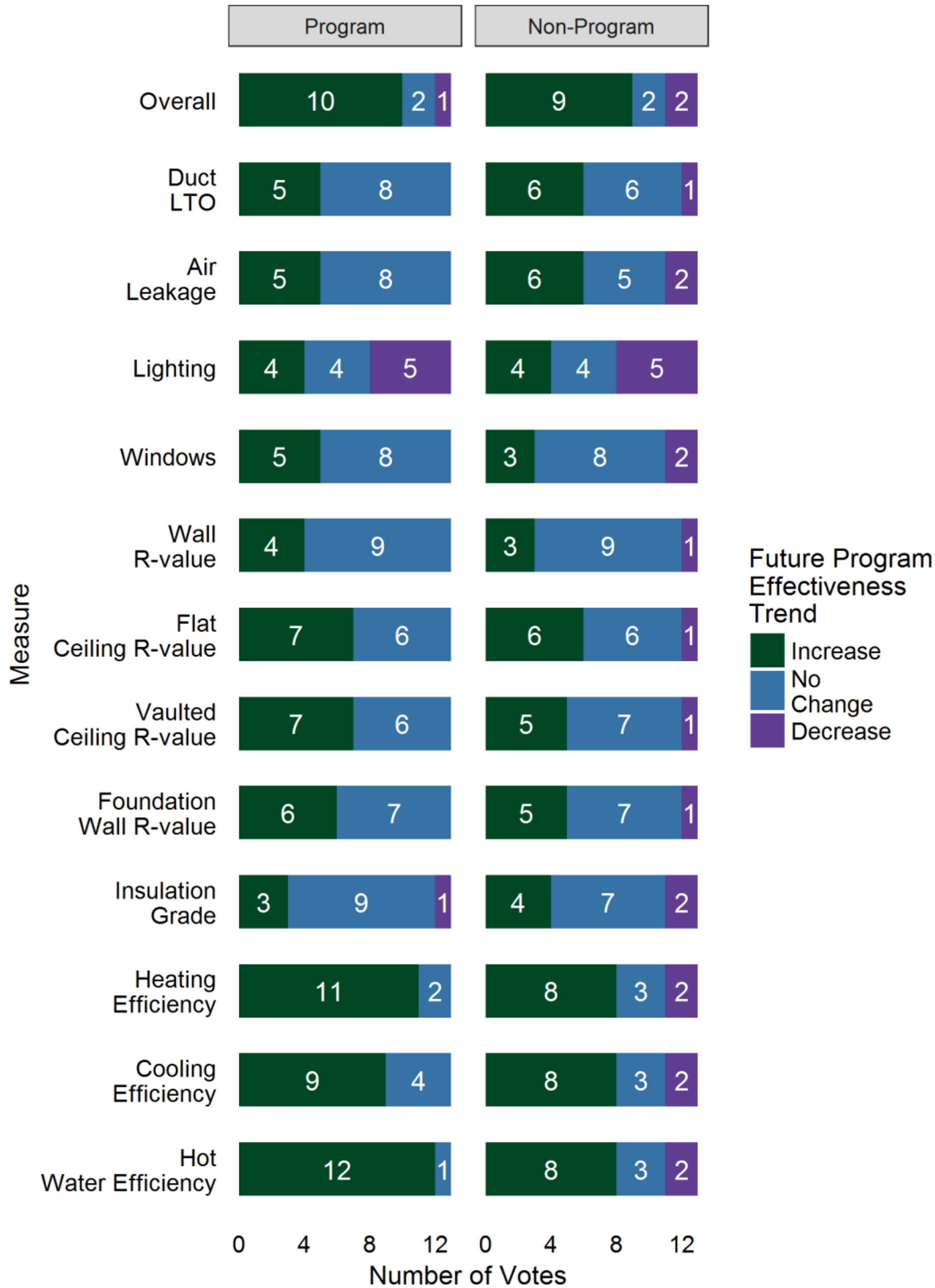
Appendix D Forward Looking Questions

Panelists were given a list of efficiency measures and asked whether the program would have more, less, or about the same impact on the efficiency of that measure moving forward. Figure 12 displays responses for all measures included in the question.

For most measures, panelists typically described that the program's current level of influence would continue or increase for the next few years. For six measures on the program side, a majority of panelists assessed the program as continuing on its current level of effectiveness. For another five measures, a majority of panelists indicated they believed the program would be increasingly effective over the next few years.

Very few panelists reported that the influence of the program on the listed measures would decrease moving forward. Views on lighting were split, but this was the only measure where a substantial portion of the panelists reported that program influence would decrease over the next few years. Five out of thirteen said that program influence on lighting would decrease over the next few years, in both program and non-program homes. (No other measure received more than two votes that the program's influence would decrease for either program or non-program homes). Panelists reported that the program would become more effective at promoting overall home efficiency moving forward in both program and non-program homes. Panelists concluded consistently across both program and non-program homes that the program will become increasingly effective at promoting efficiency among all types of mechanical systems included in the survey – heating, cooling, and water heating.

Figure 12: Comprehensive Breakdown of Program Effectiveness Trend Responses



Appendix E Comparing Round 1 and Round 2 Delphi Panel Responses

In Round 1 of the Delphi Panel, the experts provided initial estimates about what would have happened in the new construction market without the program. In Round 2, they reviewed their fellow panelists' estimates and were then given the opportunity to revise their own initial responses. Outlier values[62] at the end of Round 2 were excluded from further analyses. Outlier responses came from a range of respondents – no single respondent was consistently incongruent with the rest of the panel.

Table 40 and Table 41 show that this revision process led to the distribution of panel responses tightening for each measure in program and non-program homes. For each measure, Table 40 and Table 41 show the standard deviation of the distribution of means from the panelists' responses. In every case, the standard deviation is smaller in Round 2 than in Round 1, indicating that the panelists did take into account the responses of their fellow experts. The last column shows the final standard deviation of the panelists' estimates after removing outliers. Note that, while not displayed here, the mean response hardly changed between Round 1 and Round 2. While the mean responses stayed about the same, the standard deviation of each distribution of responses decreased. This supports the conclusion that the panel reached a stronger consensus in Round 2 after reviewing the other panelists' responses.

In program homes, duct leakage, cathedral ceiling insulation installation grade, and flat ceiling grade are the measures with the biggest overall change in standard deviation between the first and second rounds of the panel (i.e., those with the most substantial panelist revisions).

In non-program homes, cathedral ceiling insulation installation grade, wall insulation grade, and wall R-value were the measures with biggest drop in standard deviation between the first and second round of the panel.[63]

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[62] This study defines outliers as responses that are more than 1.5 times the interquartile range below the first quartile or above the third quartile.

[63] Specifically, for flat ceiling insulation grade, note that six respondents gave outlier responses that were removed from the Round 2 distribution. This is partly due to the fact that the range of possible grade assessments is small – there are only Grades I, II, and III.

Table 40: Panelist Responses for Program Homes - Round 1 vs. Round 2

Measure	Round 1 Std. Dev.	Round 2 Std. Dev.	Percent Change	Outliers Removed	Final Std. Dev.
Duct Leakage to Outside (CFM 25/ 100 sqft CFA)	1.11	0.76	-32%	0	0.76
Cathedral Ceiling Insulation Average Grade	0.43	0.30	-30%	0	0.30
Flat Ceiling Insulation Average Grade	0.38	0.27	-29%	0	0.27
Air Infiltration (ACH50)	1.05	0.79	-25%	1	0.53
Frame Floor Insulation Average Grade	0.46	0.35	-23%	0	0.35
Wall Insulation R-Value	0.74	0.57	-23%	0	0.57
Window U-Value	0.01	0.01	-19%	2	0.00
Cond. Foundation Wall Insulation Average Grade	0.38	0.31	-19%	0	0.31
Percent of Sockets with Efficient Lighting (%)	0.15	0.12	-19%	0	0.12
Wall Insulation Average Grade	0.32	0.27	-17%	0	0.27
Frame Floor Insulation R-Value	1.98	1.78	-10%	1	1.35
Flat Ceiling Insulation R-Value	3.11	2.87	-8%	3	1.70
Cond. Foundation Wall Insulation R-Value	1.88	1.74	-7%	0	1.74
Cathedral Ceiling Insulation R-Value	2.24	2.22	-1%	1	1.77

Table 41: Panelist Responses for Non-Program Homes - Round 1 vs. Round 2

Measure	Round 1 Std. Dev.	Round 2 Std. Dev.	Percent Change	Outliers Removed	Final Std. Dev.
Cathedral Ceiling Insulation Average Grade	0.79	0.08	-90%	0	0.08
Wall Insulation Average Grade	0.16	0.09	-42%	1	0.07
Wall Insulation R-Value	0.91	0.53	-42%	2	0.26
Cond. Foundation Wall Insulation R-Value	2.12	1.28	-40%	0	1.28
Window U-Value	0.02	0.01	-33%	0	0.01
Air Infiltration (ACH50)	0.75	0.51	-32%	0	0.51
Flat Ceiling Insulation Average Grade	0.11	0.08	-25%	6	0.01
Cond. Foundation Wall Insulation Average Grade	0.16	0.12	-25%	0	0.12
Duct Leakage to Outside (CFM 25/ 100 sqft CFA)	1.94	1.49	-23%	4	0.37
Frame Floor Insulation R-Value	2.65	2.19	-17%	1	1.81
Percent of Sockets with Efficient Lighting (%)	0.10	0.09	-9%	2	0.03
Cathedral Ceiling Insulation R-Value	2.05	1.91	-7%	0	1.91
Frame Floor Insulation Average Grade	0.12	0.12	-3%	1	0.05
Flat Ceiling Insulation R-Value	2.60	2.57	-1%	1	1.31

Appendix F Panelist Self-Reported Familiarity

In the first round of the Delphi panel, panelists were asked to rate their level of familiarity with each measure covered by the survey. In the second round of the panel, panelists were shown the individual (anonymized) responses of all their fellow panelists, including how familiar the panelists said they were with a given topic. This meant that in the second round of the panel – when panelists were being asked to consider revising their initial responses – they would have some additional information with which they could weigh the validity of their panelists responses.

If, for example, a panelist had said that they were not at all familiar with a topic, other panelists could choose to down-weight that person's feedback, and instead focus on the responses provided by more informed panelists. However, in this Delphi panel, the respondents indicated high levels of familiarity throughout the survey and never said that they were *not at all familiar* with a topic, an indication of the high overall confidence and expertise of panelists

Panelists were asked to provide subject matter familiarity assessments using a scale from 1 to 5, where 1 is *not at all familiar*, 2 is *slightly familiar*, 3 is *somewhat familiar*, 4 is *moderately familiar*, and 5 is *extremely familiar*. Note that a panelist's self-reported familiarity is affected by the individual panelist's personality and is thus only a proxy for a respondent's accuracy.

Table 42 shows the average familiarity rating of all 13 panelists for each topic. Panelists provided a high average response of 4 or higher for key topics such as insulation, air infiltration, windows, duct leakage, and lighting. Mechanical equipment familiarity ratings were only slightly less than 4 on average. Panelists considered themselves least familiar with solar measures, but they were still at least somewhat familiar with that topic (3.4 on average).

Table 42: Average Self-Reported Familiarity by Topic

(Base: Delphi panelists, n=13)

Measure	Average Familiarity
Shell Insulation	4.3
Air Infiltration	4.2
Windows	4.1
Duct Leakage	4.0
Lighting	4.0
Heating	3.9
Cooling	3.7
Water Heating	3.7
Solar	3.4

Table 43 lists the average self-reported familiarity rating for each respondent. Using the 1 to 5 scale, almost all the panelists gave themselves scores of at least 4 on average; only three came in just a bit below an average familiarity score of 4.

Table 43: Average Self-Reported Familiarity by Respondent

Panelist Type	Average Familiarity Rating
HERS Provider	4.8
Program Rater	4.8
Non-CT RNC Program Manager	4.7
National Evaluator	4.7
HERS Provider	4.3
National Evaluator	4.2
Program Builder	4.2
Non-CT RNC Program Manager	4.0
Non-CT RNC Program Manager	3.8
National Evaluator	3.7
Program Builder	3.7

Appendix G Measure-Level Comparison Between As-Built and Estimated Scenarios

Figure 13 shows the measure-level percent decrease in efficiency for each measure from the as-built to the estimated scenarios. A value of 100% means that the efficiency value estimated by panelists for the measure in the absence of the program is 100% worse than the as-built (i.e., real-world) efficiency.

Figure 13: Percent Efficiency Decrease from As-Built to Estimated Scenarios