Low-Rise Residential New Construction NTG Study (MA20X05-B-RNCNTG)

FINAL

July 27, 2021

SUBMITTED TO:
The Massachusetts Electric and Gas Program Administrators

SUBMITTED BY:
NMR Group, Inc.

Executive Summary

This study updated net savings and net-to-gross (NTG) ratios for Program Administrators' (PAs') efforts in the Residential New Construction (RNC) market for the 2022-2024 program period. It is the third iteration of RNC NTG evaluations and incorporates new information from the 2019 Residential New Construction Baseline/Compliance Study. It improves on the previous studies by estimating separate ratios for single-family and multifamily markets. It assumes program designs remain the same.

Study Objectives

1. **Objective 1.** Estimate retrospective NTG ratios for single-family and low-rise multifamily homes permitted in 2017-2019.
2. **Objective 2.** Estimate annual prospective NTG ratios for single-family and low-rise multifamily homes permitted in 2022-2024.
3. **Objective 3.** Estimate retrospective and prospective net savings for single-family and low-rise multifamily homes split by program participation and building code.

Methodology

NMR recruited 14 experts in the RNC industry to serve on a multi-round Delphi panel. The Delphi panel estimated measure-level efficiencies for homes built between 2017 and 2019 as if the PAs' RNC initiatives had ceased operation on January 1, 2017. NMR used the panelists' estimates to adjust 200 energy models of homes built between 2017 and 2019 and compared the resulting "counterfactual" consumption estimates with actual consumption to determine net savings. NMR then developed prospective net savings and NTG ratios for the years 2022-2024 by leveraging the retrospective net savings and panelist-estimated forecasts of RNC activity.

Key Findings

- **The PAs' RNC efforts had the greatest impact on duct leakage, air leakage, foundation walls, and electric water heaters.**
- **The overall impact of the RNC efforts, as estimated by the Delphi panel, decreased across most measures since the previous study. Lighting, duct leakage, and air leakage impacts decreased the most. Duct and air leakage are still the top two measures most impacted by the RNC efforts.**
- **"Electric storage water heaters" was the only measure for which the RNC efforts' impacts increased, as estimated by the Delphi panel. Panelists said the RNC program increased heat pump water heater adoption by 15%.**
- **Panelists indicated that the RNC efforts had substantial impact on insulation Grade (i.e., installation quality).**
- **Single-family NTG has decreased due to high program penetration, reducing the population for spillover. Multifamily NTG is higher than single-family NTG because there is much lower program penetration in the multifamily market.**

Prospective NTG Ratio Estimates (Without Program Changes)

	Single-family	Multifamily	Overall
2022	0.30	1.02	0.49
2023	0.29	0.84	0.43
2024	0.27	0.71	0.38

Recommendations

- **The PAs should explore new ways to generate savings in the RNC market.**
- **The PAs should claim net savings from the code promulgation efforts separately from other RNC efforts examined in this study using the framework and 90% attribution factor from the Code Promulgation Attribution Study (MA19X07-B-CDPROMATT).**

Table of Contents

EXECUTIVE SUMMARY **1**
STUDY OBJECTIVES 1
METHODOLOGY OVERVIEW 2
KEY FINDINGS 3
Key Delphi Panel Findings 3
Key NTG Ratio Findings 5
RECOMMENDATIONS 6
KEY LIMITATIONS AND SOURCES OF UNCERTAINTY 7
SECTION 1 INTRODUCTION **8**
1.1 BACKGROUND 8
1.1.1 Earlier Relevant Studies 9
1.2 OBJECTIVES 9
SECTION 2 METHODOLOGY **10**
2.1 RECRUITING THE DELPHI PANEL 10
2.2 FIELDING DELPHI PANEL ROUNDS 11
2.3 COUNTERFACTUAL MODELING 13
2.3.1 Modeling Counterfactual Mechanical Equipment 15
2.4 RETROSPECTIVE METHODOLOGY 16
2.4.1 Single-Family Retrospective Methodology 16
2.4.2 Multifamily Retrospective Methodology 17
2.5 PROSPECTIVE ANALYSIS 19
2.5.1 Single-Family Prospective Analysis 19
2.5.2 Multifamily Prospective Analysis 21
SECTION 3 DETAILED FINDINGS **22**
3.1 DELPHI PANEL FINDINGS 22
3.1.1 Duct leakage 24
3.1.2 Air Leakage 24
3.1.3 Lighting 25
3.1.4 Windows 25
3.1.5 Shell Insulation Measures 25
3.1.6 Mechanical Equipment 27
3.1.7 Multifamily Findings 28

3.1.8 Construction Activity Findings 30
3.1.9 Stretch Code Adoption Findings 31
3.1.10 Program Penetration Findings 32
3.2 NTG Ratios 32
3.2.1 Retrospective NTG Estimates 33
3.2.2 Prospective NTG Estimates 34
3.3 Recommendations 35
Appendix A Alternative NTG Estimates 36
A.1 NTG Estimates with Lighting Included 36
A.1.1 Modeling Counterfactual Lighting Efficiency 37
A.2 NTG Estimates with Promulgation Included 37
Appendix B Net Savings 39
B.1 Single-Family Net Savings 39
B.2 Multifamily Net Savings 43
Appendix C Detailed Methodological Example 46
Appendix D Screenshots from Delphi Instruments 49

Tables

Table 1: Key Impacted Measures 4
Table 2: Delphi Panelists' Average Estimated Reduction in Insulation Grade 4
Table 3: Retrospective NTG Ratios (2017-2019) 6
Table 4: Prospective NTG Ratios 6
Table 5: Delphi Panel Disposition 11
Table 6: Measure-Level Building Component List 14
Table 7: Average Electric Water Heater Energy Factor from Baseline Data 15
Table 8: Reduction in HPWHs by Sample 16
Table 9: Retrospective Multifamily Population Estimate (2017-2019) 18
Table 10: Multifamily Claimed Savings (2018-2019) 18
Table 11: Forecasted Single-Family Gross Savings Per Home (MMBtu) 20
Table 12: Delphi Panelists' Average Estimated Reduction in Measure-level Efficiency by Stratum and Study 23
Table 13: Delphi Panelists' Average Estimated Reduction in Insulation Grade by Stratum and Study 24
Table 14: Delphi Panelists' Estimates of Average Relative Effectiveness of Measures in the Multifamily Market 29
Table 15: Forecasted Single-Family New Construction Activity 30
Table 16: Forecasted Multifamily New Construction Activity 30
Table 17: Forecasted and Counterfactual Stretch Code Adoption 31

TABLE 18: FORECASTED SINGLE-FAMILY PROGRAM PENETRATION RATES 32
TABLE 19: FORECASTED MULTIFAMILY PROGRAM PENETRATION RATES 32
TABLE 20: NTG RATIO SETS 33
TABLE 21: SINGLE-FAMILY RETROSPECTIVE NTG RATIOS (2017-2019) 33
TABLE 22: MULTIFAMILY RETROSPECTIVE NTG RATIOS (2017-2019)....34
TABLE 23: OVERALL RETROSPECTIVE NTG RATIOS (2017-2019) 34
TABLE 24: PROSPECTIVE NTG RATIOS – OVERALL....35
TABLE 25: PROSPECTIVE NTG RATIOS – SINGLE-FAMILY 35
TABLE 26: PROSPECTIVE NTG RATIOS – MULTIFAMILY....35
TABLE 27: SINGLE-FAMILY RETROSPECTIVE NTG RATIOS – LIGHTING INCLUDED....36
TABLE 28: MULTIFAMILY RETROSPECTIVE NTG RATIOS – LIGHTING INCLUDED 36
TABLE 29: OVERALL RETROSPECTIVE NTG RATIOS – LIGHTING INCLUDED....36
TABLE 30: PROSPECTIVE NTG RATIOS – LIGHTING INCLUDED....36
TABLE 31: ESTIMATED RESIDENTIAL GTP SAVINGS FROM PAS' PROMULGATION EFFORTS (MMBTU) 38
TABLE 32: PROSPECTIVE NTG RATIOS PROMULGATION NET SAVINGS REMOVED – LIGHTING EXCLUDED....38
TABLE 33: PROSPECTIVE NTG RATIOS PROMULGATION NET SAVINGS REMOVED – LIGHTING INCLUDED....38
TABLE 34: SUMMARY OF AVERAGE PER-HOME SINGLE-FAMILY PROGRAM NET SAVINGS (2017-2019)....39
TABLE 35: TOTAL SINGLE-FAMILY PROGRAM NET SAVINGS (2017-2019)....40
TABLE 36: SUMMARY OF AVERAGE PER-HOME SINGLE-FAMILY NON-PROGRAM NET SAVINGS (2017-2019)....41
TABLE 37: TOTAL SINGLE-FAMILY NON-PROGRAM NET SAVINGS (2017-2019)....42
TABLE 38: SINGLE-FAMILY NTG RATIOS BY FUEL (2017-2019) 43
TABLE 39: SUMMARY OF AVERAGE PER-UNIT MULTIFAMILY PROGRAM NET SAVINGS 2017-2019 (MMBTU)* 44
TABLE 40: TOTAL MULTIFAMILY PROGRAM NET SAVINGS 2017-2019 (MMBTU) 44
TABLE 41: SUMMARY OF AVERAGE PER-UNIT MULTIFAMILY NON-PROGRAM NET SAVINGS 2017-2019 (MMBTU)* 45
TABLE 42: TOTAL MULTIFAMILY NON-PROGRAM NET SAVINGS 2017-2019 (MMBTU) 45
TABLE 43: SINGLE-FAMILY NTG ANALYSIS SUMMARY 48

Figures

FIGURE 1: DELPHI PANEL INPUTS AND OUTPUTS BY ROUND 13
FIGURE 2: ROUND ONE DELPHI INSTRUMENT EXAMPLE....49
FIGURE 3: ROUND TWO DELPHI INSTRUMENT EXAMPLE....49

Acronyms

Acronym	Definition
2019 Baseline Study	2019 Residential New Construction Baseline/Compliance Study (MA19X02-BRNCBL)
Code Promulgation Attribution Study	Code Promulgation Attribution Study (MA19X07-B-CDPROMATT)
CSCS	Codes and Standards Compliance and Support initiative, formerly known as the Code Compliance Support initiative
EEAC	Energy Efficiency Advisory Council
GTP	Gross Technical Potential
kWh	kilowatt hours
PA	Program Administrators
MMBtu	Million British thermal units
NMR	NMR Group Inc.
NTG	Net-to-gross
R-value	A measure of a material's ability to resist heat transfer.
RNC	Residential New Construction
RNC & CCSI Attribution Assessment Study TXC48	Residential New Construction and CCSI Attribution Assessment (TXC48)
UDRH	User-Defined Reference Home

Executive Summary

This study estimates the net-to-gross (NTG) ratios for the Massachusetts Program Administrators' (PAs') efforts in the residential new construction (RNC) market for the 2022-2024 program period. The PAs administer four RNC efforts:

- The **RNC Program** provides incentives to builders for building homes that consume at least 5% less energy than a reference home.
- The **Codes and Standards Compliance and Support (CSCS) Initiative**, formerly known as the "CCSI" Initiative, provides trainings and technical support for builders, contractors, and code officials to increase building energy code compliance.
- The **Passive House Program** provides incentives and technical support to builders who build homes that obtain passive house certification.
- The **Codes and Standards Promulgation Initiative** involves PA efforts to develop proposals to amend building codes and standards to increase energy-efficiency requirements.

This study follows methods similar to those used in the 2018 *Residential New Construction and CCSI Attribution Assessment* (RNC & CCSI Attribution Assessment Study, number TXC48),[1] which estimated NTG ratios for the 2019-2021 program period. This study leverages new information from the 2019 RNC Baseline/Compliance Study (i.e., 2019 Baseline Study)[2] and improves on the RNC & CCSI Attribution Assessment Study by estimating separate ratios for the single-family and low-rise multifamily markets.[3]

Study Objectives

The study has the following objectives:

- Estimate retrospective NTG ratios for single-family and low-rise multifamily homes permitted from 2017 through 2019.
- Estimate annual prospective NTG ratios for single-family and low-rise multifamily homes permitted from 2022 through 2024.
- Estimate retrospective and prospective net savings for single-family and low-rise multifamily homes split by program participation (e.g., program and non-program) and building code (e.g., base code and stretch code).

[1] https://ma-eeac.org/wp-content/uploads/TXC_48_RNCAttribution_24AUG2018_Final.pdf
[2] http://ma-eeac.org/wordpress/wp-content/uploads/MA19X02-B-RNCBL_ResBaselineOverallReport_Final_2020.04.01_v2.pdf
[3] Previously, due to a lack of multifamily data, the evaluation team assumed measure-level efficiencies in the single-family market were representative of the multifamily market. The low-rise multifamily market includes buildings that are three stories or less and in which each unit has separate utilities.

- Recommend 2022-2024 research activities to ensure that applying the estimated NTG ratios yields accurate and reliable estimates of total net savings.

METHODOLOGY OVERVIEW

The study relied on a Delphi Panel of 14 building energy experts to estimate how efficiently homes would have been built in the absence of the PAs' RNC efforts (i.e., counterfactual efficiency). The panel included building efficiency consultants working in and outside of Massachusetts, Massachusetts building code officials, Massachusetts municipal representatives, RNC program managers working outside Massachusetts, national energy-efficiency program evaluators, and national building energy code experts.

The Delphi approach is a multi-round survey process. In the first round, panelists provided their own estimates for measure-level counterfactual efficiencies for homes permitted between 2017 and 2019. NMR selected this period because a new base energy code and stretch energy code went into effect on January 1, 2017, based on the 2015 International Energy Conservation Code.

In subsequent rounds, panelists received all the estimates and written rationales from the other panelists and were given the opportunity to revise their original responses or keep them the same. This approach 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.[4] In addition to measure-level efficiency estimates, panelists provided forecasts of new construction activity, split by program participation and building code.

NMR used the results from the Delphi panel to alter actual (i.e., "as-built") energy models from homes permitted between 2017 and 2019. The energy models came from the 2019 Baseline Study and program data. Specifically, NMR made a total of 400 counterfactual models, consisting of two models for each of the 200 homes from the baseline study. The 200 homes represented four subgroups, or strata, of the population of new single-family and multifamily homes in Massachusetts:

- 50 program stretch code homes
- 49 non-program stretch code homes
- 50 program base code homes
- 51 non-program base code homes

NMR then subtracted the energy consumption of the as-built model for each home from the average energy consumption of the two counterfactual models for each home to get per-home net savings. NMR averaged the per-home net savings in each stratum to get an estimated

[4] See: (A) Hsu, C. and B.A. Sandford. (2007). The Delphi technique: making sense of consensus. ǁ 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 https://joe.org/joe/1997october/tt2.php

average per-home net savings for the stratum. Lastly, NMR multiplied each average per-home net savings value by the stratum population size to get total net savings for the stratum.

NMR then calculated free-ridership, spillover, and NTG ratios for each stratum using the population-level net savings estimates and program-claimed savings, as described in Section 2.4.1.2. For a full description of the methodology used in this study, see Section 2.

KEY FINDINGS

This section highlights key findings from this study, including Delphi panelist results and NTG ratios. For detailed findings, see Section 3.

Key Delphi Panel Findings

The PAs' RNC efforts had the greatest impact on duct leakage, air leakage, foundation walls, and electric water heaters. Table 1 shows how much less efficient each measure type would be on average in homes permitted from 2017 through 2019 had these efforts not occurred, as estimated by the Delphi panelists. Darker red signifies a greater impact of the program. The previous study (RNC & CCSI Attribution Assessment Study, number TXC48) also found the RNC efforts had a high impact on duct leakage, air leakage, and foundation walls. Other measures, not listed in the Table 1 because of the efforts' minimal impact, are building shell insulation measures, windows, and mechanical equipment efficiency.

The overall impact of the RNC efforts, as estimated by the Delphi panel, has decreased across most measures since the previous study, especially for lighting, air leakage, and duct leakage.[5] The previous study's panel estimated that without the RNC efforts, the efficiency of the lighting would be reduced by between 13% and 20% in homes permitted between 2014 and 2016. The current panel estimated lighting efficiency would be reduced by between 2% and 4%, signifying that the RNC efforts are no longer having an impact on lighting. The RNC efforts' impact on air leakage has decreased from between 28% and 37% to between 10% and 17%. The RNC efforts' impact on duct leakage has decreased from between 46% and 73% to between 10% and 40%.[6] While these three measures have seen steep reductions in program impacts since the previous study, duct leakage and air leakage are the top two measures most impacted by the RNC efforts.

Electric storage water heaters was the only measure for which the RNC efforts' impacts increased, as estimated by the Delphi panel. The previous study panel estimated the RNC efforts' impact on electric water heaters to be between 1% and 4%, while the current study panel estimated the RNC efforts' impact on electric storage water heaters to be between 4% and 12%. Panelists credited this increase to the RNC efforts supporting greater adoption of heat pump water heaters (HPWHs) rather than standard electric resistance water heaters.

[5] Only four of the 14 panelists were on the previous panel.
[6] *Impact* refers to the impact on measure-level efficiency values (e.g., insulation R-values, measured duct leakage, and measured air leakage).

Table 1: Key Impacted Measures

(Average Percent Reduced Efficiency without RNC Efforts)

	This Study (2017-2019)				RNC & CCSI Attribution Assessment Study, TXC48 (2014-2016)			
	Program Stretch	Non-Program Stretch	Program Base	Non-Program Base	Program Stretch	Non-Program Stretch	Program Base	Non-Program Base
Duct Leakage	38%	19%	40%	10%	68%	46%	73%	58%
Air Leakage	10%	12%	17%	13%	28%	36%	37%	35%
Fdn. Walls	9%	15%	12%	18%	11%	29%	11%	17%
Electric Water Heaters	10%	4%	11%	12%	2%	4%	2%	1%
Lighting	3%	2%	4%	4%	20%	18%	14%	13%

Panelists indicated that the RNC efforts had substantial impact on insulation Grade (i.e., installation quality). The lower the insulation Grade, the more effectively the insulation will perform. Table 2 shows the average reduction in insulation Grade, as estimated by the panelists in the current and previous studies. The RNC efforts' impacts are slightly lower than estimated in the previous study, yet they are still substantial. Panelists estimated a particularly large impact on frame floor insulation Grade in program homes. They explained that since frame floor insulation code requirements are hard for code officials to enforce, the requirements for program participation have a greater impact on that measure.

Table 2: Delphi Panelists' Average Estimated Reduction in Insulation Grade

(Average Percent Reduced Efficiency without RNC Efforts)

	This Study (2017-2019)				RNC & CCSI Attribution Assessment, TXC48 (2014-2016)			
	Program Stretch	Non-Program Stretch	Program Base	Non-Program Base	Program Stretch	Non-Program Stretch	Program Base	Non-Program Base
Wall	27%	11%	33%	13%	37%	12%	40%	8%
Flat Ceil	23%	10%	21%	15%	30%	17%	37%	22%
Cath Ceil	17%	11%	25%	19%	34%	10%	54%	6%
Frame Floor	48%	3%	37%	2%	9%	9%	22%	8%
Foundation Wall	14%	5%	12%	11%	45%	9%	59%	6%

Key NTG Ratio Findings

NMR estimated retrospective NTG ratios for the 2017-2019 program period and prospective annual NTG ratios for each year from 2022 through 2024. The methodology, which used a Delphi panel, was similar to that used in the RNC & CCSI Attribution Assessment Study, with the following added considerations:

- **Inclusion of multifamily-specific NTG ratios:** To estimate multifamily NTG ratios, NMR leveraged program multifamily data and qualitative estimates from the Delphi panel regarding RNC effort impacts on the multifamily market relative to the single-family market.
- **Consideration of the RNC efforts' impacts on stretch code adoption:** The Delphi panelists estimated that fewer municipalities would have adopted (retrospectively) or would adopt (prospectively) the stretch code without the RNC program, since the program provides incentives that can reduce the burden of meeting stretch code requirements. Therefore, the NTG estimates incorporate the RNC efforts' impact on stretch code adoption.
- **Exclusion of lighting impacts:** Since the PAs do not expect to claim savings from residential lighting programs in the future, NMR excluded lighting savings from the NTG analysis. For reference, NTG estimates including lighting are shown in Appendix A.1.

The retrospective NTG ratios include impacts from the RNC Program and the CSCS Initiative but exclude Passive House Program impacts, since that program began in 2019. The prospective NTG ratios *do* include impacts from the Passive House Program.

Both the retrospective and prospective NTG estimates exclude Code Promulgation impacts, since the PAs will claim code promulgation savings separately by applying an attribution factor determined in the 2020 Code Promulgation Attribution Study (MA19X07-B-CDPROMATT). [7]

The retrospective NTG value is 0.95 overall. This value is driven down by the low single-family NTG ratio (0.31) and up by the relatively high multifamily NTG ratio (2.91). Table 3 shows the retrospective NTG ratios for single-family homes and multifamily homes.[8] The single-family NTG ratio is lower than the multifamily NTG ratio largely because program penetration is significantly higher in the single-family market (70%[9]) than in the multifamily market (27%[10]). With higher program penetration, there is a smaller non-participant population and thus more free-ridership and less spillover. Since program penetration is lower in the multifamily market than the single-family market, spillover is higher in the multifamily market, driving the multifamily NTG ratio above 1.0.[11]

[7] https://ma-eeac.org/wp-content/uploads/MA19X07-B-CDPROMATT_OverallReport_Final_2020.09.15.pdf
[8] The "overall" column is the average of the single-family and multifamily values weighted by the share of the population that is single-family or multifamily.
[9] See section 5.1.2 at https://ma-eeac.org/wp-content/uploads/MA19X02-B-RNCBL_ResBaselineOverallReport_Final_2020.04.01_v2.pdf
[10] See Section 2.4.2.
[11] Future studies could consider additional weighting schemes such as weighting by gross savings.

Table 3: Retrospective NTG Ratios (2017-2019)

	Single-Family	Multifamily	Overall
N	7,224	2,367	9,591
Free-Ridership	0.85	0.63	0.80
Non-Participant Spillover	0.16	2.54	0.75
NTG	0.31	2.91	0.95

Prospective NTG ratios are low due to increasing program penetration and diminishing per-home program savings. Table 4 shows the prospective NTG ratios for the single-family and multifamily markets. Note that the prospective NTG ratios in this report and in Table 4 assume the program designs will stay the same.

The prospective NTG values are lower than the retrospective values because they assume growing program penetration (i.e., less opportunity for non-participant spillover) compounded by greater stretch code adoption (which increases program penetration even further).[12] The Delphi panelists assumed that per-home net savings would continue to decrease over time, likely in part because the last four RNC baseline studies have shown that the gap in efficiency between program and non-program homes is consistently shrinking.

Table 4: Prospective NTG Ratios

	Single-Family	Multifamily	Overall
2022	0.30	1.02	0.49
2023	0.29	0.84	0.43
2024	0.27	0.71	0.38

RECOMMENDATIONS

The PAs should explore new ways to generate savings in the RNC market. For the 2022-2024 program period, free-ridership is high and spillover is decreasing, resulting in low NTGRs (from 0.49 to 0.38). To increase the impact of the program on savings, the PAs should explore other ways to influence the RNC market. Some possible approaches include increasing the threshold of the percentage over UDRH that program homes need to achieve in order to qualify, and putting more resources into the Passive House program since, by definition, a passive home entails construction practices that result in greater energy savings than those used in the RNC program. The PAs are currently considering changes to the RNC program design.

[12] As found in the 2019 Baseline Study, Stretch code towns have higher program penetration than base code towns. Stretch code towns require homes to receive a HERS rating to comply with code; thus program participation entails less additional effort than in base code towns, where HERS ratings are not required. In addition, HERS raters advocate for the program, so including them in a project increases the likelihood of program participation.

The PAs should claim net savings from the code promulgation efforts documented in the Code Promulgation Attribution Study separately from other RNC efforts examined in this study. The Code Promulgation Attribution Study developed a framework for calculating gross savings associated with the PAs' two residential amendments to the 2018 International Energy Conservation Code adopted into the Massachusetts state building code. The PAs should estimate gross savings from those amendments when more information (e.g., construction activity) is available. Once gross savings are known, the PAs should apply the 90% attribution factor determined by the Code Promulgation Attribution Study to calculate net savings.

KEY LIMITATIONS AND SOURCES OF UNCERTAINTY

- **Multifamily NTG ratios.** While NMR based single-family NTG ratios on measure-level efficiency estimates provided by the Delphi panel, we based multifamily NTG ratios only on panelists' qualitative responses about the impact of the RNC efforts relative to the single-family market. Additionally, since non-program multifamily energy models were unavailable, NMR had to develop energy consumption estimates for multifamily homes.
- **Future expectations of program performance and populations may not be realized.** While Delphi panelists used historical data to provide estimates of the efforts' future performance and to forecast new construction permit activity, stretch code adoption, and program penetration, the past is not always representative of the future.
- **Assumed constant program design.** As mentioned above, the prospective findings in this study assume that the basic structure of the RNC program will remain the same, with the UDRH changing as the baseline becomes more efficient. At the time of writing this report, the PAs were considering structural changes to the RNC program. Such changes were not considered in this study and may alter future NTG ratios.
- **Future building code requirements are uncertain.** Massachusetts regularly adopts new building energy codes on approximately three-year cycles. Recent legislation mandates the creation of a net-zero opt-in energy code. NMR did not specifically factor future codes into the prospective analysis; however, panelists were shown the evolution of code requirements over time so they could make their own assumptions about future codes. To further account for evolving codes, the analysis assumes decreased prospective per-home average savings relative to current levels as the codes increase and the baseline becomes more efficient. Panelists supported this assumption.

Section 1 Introduction

The Massachusetts Program Administrators (PAs)[13] contracted NMR Group, Inc., (NMR) to estimate retrospective net-to-gross (NTG) ratios and forecast prospective NTG ratios for the low-rise Residential New Construction (RNC) market in Massachusetts. The NTG ratios assess the net impacts of four PA efforts to increase the efficiency of new single-family and low-rise multifamily homes in Massachusetts. The retrospective estimates cover homes permitted from 2017 through 2019 and the prospective NTG ratios are for the years 2022 through 2024.

1.1 Background

This study assesses the net savings of four PA offerings in the low-rise RNC market:

- **RNC Program**: Started in 2004 as a statewide offer, this program offers incentives to builders to build single-family or low-rise multifamily homes that are at least 5% more energy-efficient than a reference home.
- **Codes and Standards Compliance and Support Initiative (CSCS):** Started in 2014 and formerly known as the Code Compliance Support Initiative, this initiative offers trainings, resources, and technical support to assist builders in complying with energy codes and to increase understanding and enforcement of energy codes by code officials.
- **Passive House Program:** Started in 2019, this program offers incentives to builders constructing Passive House-certified multifamily buildings. As no low-rise buildings participated from 2017 through 2019, this study considers impacts from the Passive House program in the forecasted (i.e., prospective) NTG ratios but not the retrospective NTG ratios.
- **Codes and Standards Promulgation Initiative:** Started in 2018, this initiative includes PA efforts to develop proposals to amend building codes and standards to increase energy-efficiency requirements. In 2020, Massachusetts adopted two residential amendments developed by the PAs into the state building energy code. The code went into effect in November 2020, so it is considered in the prospective, but not the retrospective, estimates.

[13] The PAs comprise Berkshire Gas, Cape Light Compact, Eversource, Eversource Gas of Massachusetts, Liberty Utilities, National Grid, and Until.

1.1.1 Earlier Relevant Studies

This study is the third in a series of studies that have used similar methods to estimate NTG ratios for the low-rise RNC market in Massachusetts. The PAs and the EEAC contracted NMR to conduct the studies in three-year increments, with the first occurring in 2014,[14] the second in 2017,[15] and the third (current) in 2020. (Throughout this document, we refer to the second, 2017 study as the "previous" study.) As the PAs have increased their portfolio of efforts to impact the RNC market, the studies have increased in complexity to account for more PA initiatives. This study improves on earlier efforts by including separate estimates for the single-family and low-rise multifamily markets. Earlier studies only based estimates on the single-family market.

Additionally, this study follows the approach taken in the Code Promulgation Attribution Study, which determined an attribution factor for the PAs' 2018 code promulgation efforts. Based on the findings of the Code Promulgation Attribution Study, NMR decided to account for code promulgation findings separately from the other three RNC efforts.

In 2019, NMR undertook an RNC baseline evaluation (2019 Baseline Study). For this study, NMR conducted onsite inspections of 100 single-family homes permitted from 2017 through 2019 that had not participated in the RNC program, and analyzed energy models of program homes built over the same time. NMR used the measure-level efficiencies and energy models from the 2019 Baseline Study to inform the estimates in the current study.

1.2 OBJECTIVES

The study objectives were as follows:

- Estimate retrospective NTG ratios for single-family and low-rise multifamily homes permitted from 2017 through 2019.
- Estimate annual prospective NTG ratios for single-family and low-rise multifamily homes permitted from 2022 through 2024.
- Estimate retrospective and prospective net savings for single-family and low-rise multifamily homes split by program participation (e.g., program and non-program) and building code (e.g., base code and stretch code)
- Recommend 2022-2024 research activities to ensure that applying the estimated NTG ratios yields accurate and reliable estimates of total net savings.

[14] https://ma-eeac.org/wp-content/uploads/Residential-New-Construction-Net-Impacts-Report-1-27-14.pdf
[15] https://ma-eeac.org/wp-content/uploads/TXC_48_RNCAttribution_24AUG2018_Final.pdf

Section 2 Methodology

As with the two earlier NTG evaluations of the RNC market in Massachusetts, NMR used a Delphi Panel to provide data to estimate retrospective and prospective NTG ratios. The Delphi approach is an interactive and iterative process that relies on a panel of experts to develop a group judgment, often by providing and reviewing responses via multiple rounds of questions. The Delphi approach 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 iterative feedback.[16]

The Delphi Panel estimated what retrospective measure-level efficiencies for new construction would have been had the PAs' RNC efforts ceased operation on January 1, 2017. NMR then used these measure-level efficiencies to alter energy models of homes built between 2017 and 2019 to calculate retrospective net savings. NMR compared the net savings to program savings to calculate a retrospective NTG ratio.

NMR estimated a prospective NTG ratio for the years 2022 through 2024 based on the Delphi findings and other considerations, discussed below. NMR solicited feedback from the Delphi panel on the prospective NTG estimates before finalizing the results. The rest of this section fully details the study methodology.

2.1 Recruiting the Delphi Panel

NMR identified a list of 48 potential Delphi panel candidates who are experts in the MA RNC market, codes and standards, residential energy efficiency, or energy-efficiency evaluation. The sample frame included potential candidates from the following categories:

- Building efficiency consultants working in Massachusetts
- Building efficiency consultants working outside Massachusetts
- Code officials working in Massachusetts
- RNC program managers working outside Massachusetts
- Evaluators working nationally
- Municipal representatives
- National building energy code experts

NMR targeted recruiting 15 panelists, with at least two in each of the categories above. Potential panelists were invited via email and phone to participate in the panel. NMR offered participants

[16] See: (A) Hsu, C. and B.A. Sandford. (2007). The Delphi technique: making sense of consensus. ǁ 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 https://joe.org/joe/1997october/tt2.php

honoraria of $1,000 for completing all three rounds of the Delphi panel.[17] To maintain consistency with previous research while avoiding biasing the panel with a preponderance of participants who were more connected to the PAs' RNC efforts, NMR sought to have a balance of participants who had served on the Delphi panel of the previous study and those who had not. NMR limited panelists to one participant per company.

NMR recruited 18 panelists, but only 14 completed all three rounds of the survey. Table 5 characterizes the Delphi Panel by category and past participation.

Table 5: Delphi Panel Disposition

Category	Participated in TXC48?		Total Count
	Yes	No	
Building efficiency consultants working in Massachusetts	2	1	3
Building efficiency consultants working outside Massachusetts	--	2	2
Code officials working in Massachusetts	--	2	2
Evaluators working nationally	1	2	3
Municipal representatives	--	1	1
RNC program managers working outside of MA	--	1	1
National building energy code experts	1	1	2
Total	**4**	**10**	**14**

2.2 Fielding Delphi Panel Rounds

NMR asked Delphi panelists to participate in three rounds of data collection. NMR fielded the first round in November 2020, the second round in December 2020, and the third round in March 2021. Figure 1 summarizes the inputs and outputs for each round of the Delphi panel. Each round consisted of an *instrument* in the form of a Microsoft Excel workbook. For examples of the Round One and Round Two Delphi instruments, see Appendix D.

In the first round, NMR sent panelists a data collection instrument (the "Round One" instrument) with background information and actual average measure-level efficiency values split by building code (e.g., *stretch* and *base*) and program participation (i.e., *program* and *non-program*) for homes permitted between 2017 and 2019. For each measure, the instrument broke homes into three tiers: the least efficient 25%, the middle 50%, and the most efficient 25%. The instrument provided panelists with the average efficiency value for each tier for each measure. Then the instrument asked panelists to estimate what the efficiency value for each tier in each measure would have been had the PAs' RNC efforts ceased operation on January 1, 2017. NMR selected

[17] NMR gave $650 to panelists after their completion of Round Two of the Delphi panel and gave them the remaining $350 after completion of the third round.

this date because it is the date that the 2015 International Energy Conservation Code base code and 2017 Stretch Code went into effect.[18]

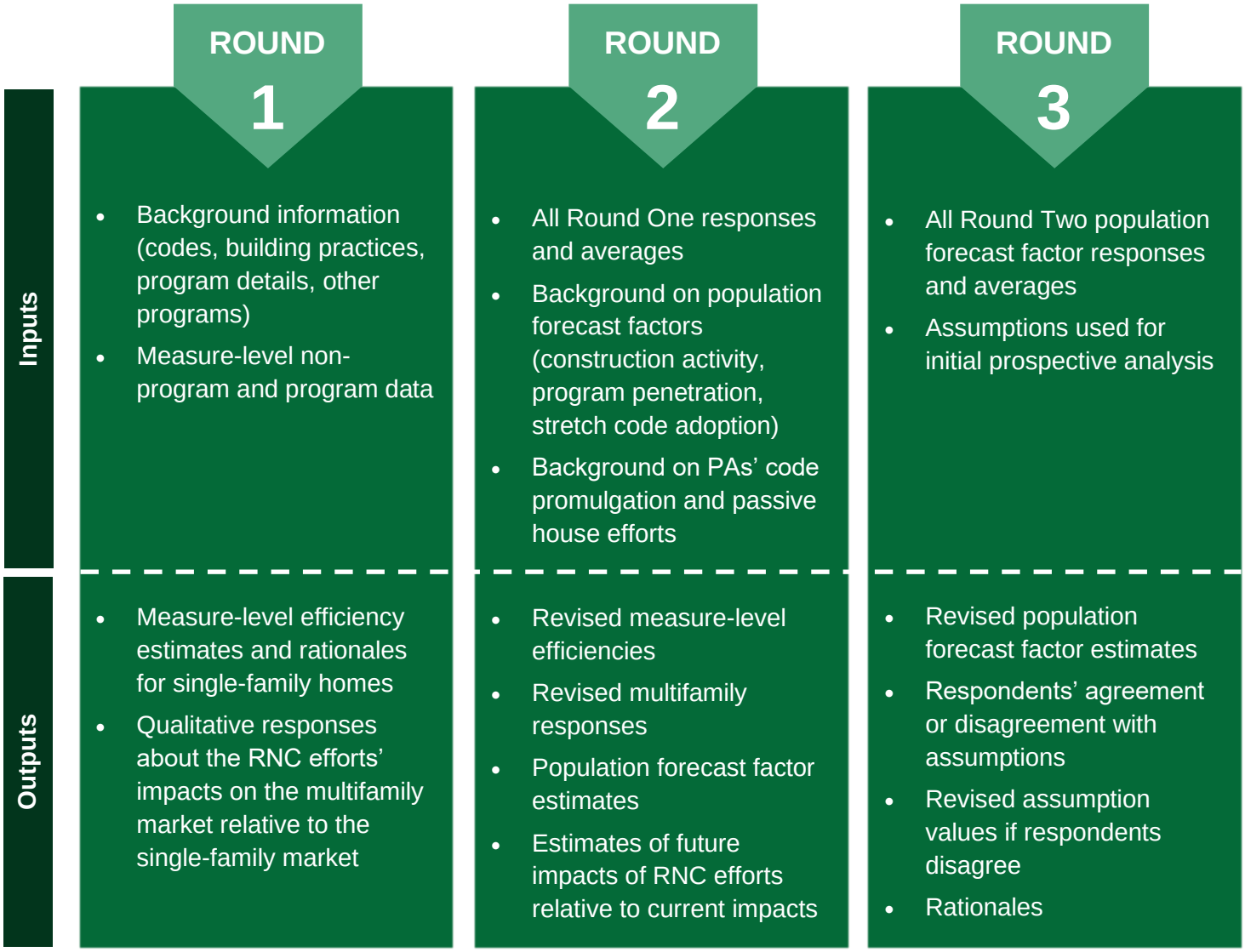
In the instrument, NMR also asked panelists to qualitatively estimate the RNC efforts' impacts on the multifamily market relative to the single-family market for each measure and overall.

The Round Two instrument showed panelists the average responses from all panelists for each question, as well as all the individual responses and rationales. It also showed each panelist their own Round One response to each question. NMR then gave panelists the opportunity to revise their Round One responses or keep them the same. The Round Two instrument also showed respondents background information on three factors that would be used to forecast population sizes in the prospective analysis: new construction permit activity, stretch code adoption, and program penetration. The instrument asked panelists to provide forecasts for each of the three factors for the years 2022 through 2024. Finally, the instrument asked panelists to estimate the impact of each of the four RNC efforts (i.e., the RNC program, CSCS initiative, Passive House Program, and the Code Promulgation effort) in the future relative to their impact in the 2017 through 2019 period. NMR used the Round Two measure-level efficiency outputs to conduct the counterfactual modeling, detailed in Section 2.3, and the Round Two population forecast factor estimates to conduct the initial prospective analysis, detailed in Section 2.5.

The Round Three instrument showed the panelists the average Round Two population forecast factor estimates and the panelists' individual responses and rationales. NMR gave panelists the opportunity to revise their individual estimates or keep them the same. The Round Three instrument also showed panelists assumptions used in the prospective analysis about (1) the difference between future program home and non-program home energy performance and (2) low-rise multifamily construction activity. Panelists stated whether they agreed with the assumptions and provided new estimates if they disagreed. NMR used the results of the Round Three instrument to alter the initial prospective estimates by adjusting the population forecasts.

[18] The 2015 IECC-based base code stayed in effect until November 2020, when a 2018 IECC-based base code went into effect. The 2017 stretch code remains in effect for stretch code towns at the time of writing.

Figure 1: Delphi Panel Inputs and Outputs by Round



2.3 COUNTERFACTUAL MODELING

As mentioned above, NMR conducted counterfactual modeling of single-family homes between Round Two and Round Three of the Delphi panel. NMR made energy models of single-family homes due to a lack of available data for multifamily homes. The multifamily analysis leveraged the single-family model results, as described in Section 2.4.2. To estimate counterfactual energy consumption, NMR altered existing (i.e., *as-built*) models of the following number of single-family homes for each of the four strata:

- 50 program stretch code homes
- 49 non-program stretch code homes
- 50 program base code homes
- 51 non-program base code homes

The non-program single-family home models came from the 2019 Baseline Study on-site visits. The program single-family home models came from a sample of program Ekotrope files for homes that were built during the same period as the non-program homes. The sample of program homes had characteristics that, on average, matched the population of program homes over that period.

For each of the three tiers for each measure in Table 6, NMR generated a distribution of efficiency values based on the Delphi panelists' results. NMR then randomly assigned homes a tier for each measure, using a probability of 25% for the lowest tier, 50% for the middle tier, and 25% for the highest tier. We used the distribution from the assigned tier to select counterfactual measure-level efficiency values that would replace as-built values in the energy models of each home to create counterfactual models. We undertook this process twice to create two separate counterfactual models for each home. During this process, we made special considerations for mechanical equipment, as detailed in Section 2.3.1.

Table 6: Measure-Level Building Component List

Air Sealing and Insulation
Duct leakage to outside (CFM 25/100 sq. ft.)
Air infiltration (ACH50)
Window U-value
Wall insulation R-value
Wall insulation average Grade
Frame floor insulation R-value
Frame floor insulation Grade
Flat ceiling insulation R-value
Flat ceiling insulation Grade
Cathedral ceiling insulation R-value
Cathedral ceiling insulation Grade
Cond. foundation wall insulation R-value
Cond. Foundation wall insulation Grade
Heating Equipment
Gas/propane furnace AFUE
Gas/propane boiler AFUE
Air source heat pump and ductless mini-split HSPF
Ground source heat pump COP
Cooling Equipment
Central air-split SEER
Air source heat pump and ductless mini-split SEER
Ground source heat pump COP
Domestic Hot Water Equipment
Gas/propane conventional storage EF
Gas/propane instantaneous EF
Electric conventional storage EF
Heat pump water heater EF
All fuels indirect fired EF

2.3.1 Modeling Counterfactual Mechanical Equipment

During the first two rounds of the Delphi panel, NMR provided panelists the average efficiency of heating, cooling, and water heating equipment types and the share of systems across each stratum for each type. Delphi panelists provided counterfactual efficiency estimates *and* counterfactual estimates of the share of each system type. We asked for estimates of system shares to examine the possibility that builders would have selected different system types without the program. For example, without the program, builders might have installed fewer heat pumps in favor of more conventional non-electric systems. Overall, panelists indicated that there would be few changes in shares of system or fuel types between the as-built and counterfactual scenarios for heating, cooling, and water heating. One common rationale had to do with panelists' perception that, retrospectively, it was unlikely that homes would have relied on different fuel types in the counterfactual scenario from those in the as-built scenario. The one exception was for electric water heaters.

"Electric water heaters" is a single measure in the RNC program's user-defined reference home (UDRH) that is based on an overall weighted average efficiency of electric resistance water heaters and heat pump water heaters (HPWHs). Panelists estimated a substantial reduction in average electric water heater efficiency (as shown in Table 12 in Section 3), reasoning that without the program, there would be fewer HPWHs installed and more electric resistance water heaters installed. Such switches would not require a change in fuel.

To model this change, NMR took the average electric resistance water heater efficiency and HPWH efficiency for each stratum, as shown in Table 7, and calculated the number of HPWHs that would need to be converted to electric resistance water heaters to result in the overall average counterfactual efficiency for electric water heaters as estimated by the Delphi panel. We then changed all electric resistance water heaters to have the average electric resistance water heater efficiency of homes in their stratum, and did the same for HPWHs with the average HPWH efficiency. Lastly, NMR converted the calculated number of HPWHs in each stratum to electric resistance water heaters and gave them the electric resistance water heater efficiency, so that the overall average efficiency for each sample matched the Delphi panelists' estimate.

Table 7: Average Electric Water Heater Energy Factor from Baseline Data

Stratum	Electric Resistance EF	HPWH EF
Stretch Code Program Homes	0.93	3.39
Stretch Code Non-Program Homes	0.85	3.41
Base Code Program Homes	0.93	3.37
Base Code Non-Program Homes	0.92	3.29

Table 8 shows the percent reduction in HPWHs by stratum and overall.

Table 8: Reduction in HPWHs by Sample

Stratum	Reduction in HPWHs
Stretch Code Program Homes	14%
Stretch Code Non-Program Homes	9%
Base Code Program Homes	15%
Base Code Non-Program Homes	25%
Overall	15%

2.4 RETROSPECTIVE METHODOLOGY

The sections below describe the methodologies used to estimate retrospective NTG ratios for single-family and low-rise multifamily homes permitted from 2017 through 2019. After calculating NTG ratios for the single-family and multifamily markets individually, NMR calculated an overall average NTG ratio by weighting the single-family and multifamily values by the share of the total units (i.e., homes or apartments) in each market.[19]

2.4.1 Single-Family Retrospective Methodology

To calculate single-family NTG ratios, we first calculated the net savings for each stratum and then calculated an NTG ratio.

2.4.1.1 Calculating Single-Family Net Savings

To calculate total net savings, we first calculated average per-home net savings following the same method used in the RNC & CCSI Attribution Assessment Study. As mentioned in Section 2.3, NMR created two counterfactual models (i.e., *runs*) for each home. We averaged the counterfactual, *CF*, energy consumption from the two runs for each home *h*:

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

Next, we subtracted the as-built energy consumption from the counterfactual energy consumption for each home *h*. NMR then averaged the net savings for the total homes *n* to obtain the average per-home net savings using the following equation for each stratum *s*:

$$Average\ per\text{-}home\ net\ savings_s = \frac{1}{n_s}\sum(CF\ energy\ consumption_{h,s} - As-built\ energy\ consumption_{h,s})$$

We then multiplied the average per-home net savings for each stratum by the size of each population *N* to get the total net savings for each population. NMR calculated population sizes using U.S. Census building permit data and program penetration estimates by code from the 2019 Baseline Study. Note that the total *N* values for each population reflected a reduction in stretch code adoption as estimated by the Delphi panel (shown in Section 3.1.9).

[19] Future studies can consider weighting by different schemes such as weighting by gross savings.

2.4.1.2 Calculating Single-Family NTG Ratios

To get an overall NTG ratio, we first calculated free-ridership (*FR*) and spillover (*SO*) for each code *c* using the following equations:

$$FR_c = \frac{Claimed\ Savings_c - Program\ Net\text{-}savings_c}{Claimed\ Savings_c}$$

$$SO_c = \frac{Non\text{-}Program\ Net\text{-}savings_c}{Claimed\ Savings_c}$$

We then calculated NTG ratios for each code *c:*

$$NTG_c = 1 - FR_c + SO_c$$

The overall NTG ratio is the average of NTG ratios by code weighted by the number of homes constructed under each code.

2.4.2 Multifamily Retrospective Methodology

To calculate NTG ratios for the low-rise multifamily market, NMR needed to identify or develop the following four types of values for each of the four strata:

- Population by code and program participation
- Claimed savings
- As-built energy consumption
- Counterfactual energy consumption

The sections below describe the methods we used to calculate each set of values.

2.4.2.1 Multifamily Population

To estimate the population sizes of low-rise multifamily units permitted annually in Massachusetts, NMR leveraged U.S. Census Building Permit Survey data and analysis from the 20R30 Residential New Construction Multifamily Baseline Study Stage 3 Plan. The U.S. Census building permit survey shows 17,000 low-rise units were completed in New England in 2019. We calculated Massachusetts' share of the New England low-rise units by taking the three-year average of permitted multifamily units in Massachusetts from 2017 to 2019 relative to all of New England (14%). This resulted in 2,367 low-rise multifamily units in Massachusetts.[20]

Next, NMR calculated the share of low-rise multifamily permits that were in base code and stretch code towns using municipal-level U.S. Census building permit data.[21] We then took the counts of program units by code as determined as part of the 20R30 Residential New Construction

[20] 17,000 * 0.13926 = 2,367

[21] When summing counts of multifamily permits by town, NMR reduced the counts of units in building with five units or more to remove high-rise buildings. NMR did this by subtracting our estimate of low-rise units (2,367) by the total multifamily units permitted in 2018 (9,785), resulting in 7,508 high-rise units. We assumed all of these units were in buildings with five units or more. We divided by the count of units in buildings with five units or more (8,841) to get a ratio of 85%. Therefore, we removed 85% of the units in buildings with five units or more when determining the share of low-rise units permitted in each town.

Multifamily Baseline Study Stage 3 workplan and subtracted program units from total units to get non-program counts by code (Table 9).

Table 9: Retrospective Multifamily Population Estimate (2017-2019)

	Stretch Code	Base Code
Total low-rise units in MA	2,367	
Share of low-rise units	82%	18%
Counts by code	1,936	431
Program counts (20R30)	556	84
Non-program counts	1,380	347
Program penetration	29%	19%

2.4.2.2 Multifamily Claimed Savings Per-unit

Multifamily gross savings are based on the average per-home savings from multifamily program files given to NMR by ICF as part of the 2019 Baseline study. ICF provided NMR with savings data for all multifamily units that went through the program in a similar period to that of the non-program homes inspected as part of the 2019 Baseline study. To screen out failed projects, NMR removed units that did not perform at least 5% better than the *reference* (i.e., UDRH) home.[22] NMR multiplied the per-unit savings by the program population sizes to get total claimed savings. Table 10 shows the claimed savings per-unit scaled to the program populations.

Table 10: Multifamily Claimed Savings (2018-2019)

	Stretch Code	Base Code
Average Per-unit Savings (MMBtu)	19.1	18.1
Program Population (Units)	556	84
Claimed Savings (MMBtu)	10,616.2	1,522.3

2.4.2.3 Multifamily As-Built Energy Consumption

For program as-built energy consumption, NMR used the average as-built energy consumption from the program files of the 2019 Baseline Study data request. However, NMR did not have reliable data on non-program as-built consumption and thus had to estimate non-program as-built data.

We followed the same methodology as used in a similar study conducted in Connecticut[23] to estimate as-built consumption data. NMR created adjustment factors for each end use that equaled the difference between single-family program and non-program as-built consumption. We multiplied these factors by the multifamily program as-built data to estimate multifamily non-program as-built consumption.

[22] The program requires homes to be 5% better than the reference home.

[23] https://www.energizect.com/sites/default/files/R1707%20NTG%20Study%20for%20CT%20RNC_Final%20Report_10.5.18.pdf

2.4.2.4 Multifamily Counterfactual Consumption

To estimate multifamily counterfactual consumption, NMR used the same method as in the Connecticut study. This involved altering as-built consumption by the following two factors:

- **Single-family counterfactual adjustment factor,** which is the ratio of single-family counterfactual consumption over single-family as-built consumption
- **Delphi panelists' multifamily relative effectiveness factor,** which is the effectiveness of the PAs' RNC efforts on the multifamily market relative to the RNC efforts' impact on the single-family market

In Rounds One and Two of the Delphi panel, NMR asked panelists to rate the effectiveness of the program in the multifamily market relative to the single-family market on a scale of 1 to 5, where 1 represents "much less effective" and 5 represents "much more effective." NMR used the average ratings for *overall efficiency* to create the Delphi panelists' *relative multifamily effectiveness factor*. The Delphi panelists' average responses are shown in Table 14 in Section 3.1.7.

2.5 PROSPECTIVE ANALYSIS

This section explains our methodology for estimating prospective net savings and NTG ratios for the years 2022 through 2024.

2.5.1 Single-Family Prospective Analysis

The single-family prospective analysis followed the same method as the RNC & CCSI Attribution Assessment Study, with the following two changes:

1. **Increased Delphi panelist input for scaling variables**. In the RNC & CCSI Attribution Assessment Study, NMR forecasted the three scaling variables (new construction activity, stretch code adoption, and program penetration) internally and then asked panelists if they agreed with our assumptions in Round Three. In this study, NMR asked panelists for their own forecasts during Round Two and used that to inform our internal analysis. In Round Three, NMR showed panelists all the other panelists' responses and gave them the chance to revise their responses or keep them the same.
2. ***Delta-HERS* assumption reflects minimum requirement.** Delta-HERS refers to the difference in the average HERS ratings between program and non-program homes. The Delta-HERS is used to forecast gross savings. The last three baseline studies have shown the Delta-HERS consistently decreasing as the baseline continues to become more efficient. In the RNC & CCSI Attribution Assessment Study, NMR used the rate of reduction in Delta-HERS between baseline studies to forecast the continued reduction in Delta-HERS. For this study, the most recent baseline found a Delta-HERs of 7%. However, the program requires homes to perform at least 5% better than the reference

home.[24] If NMR were to use the reduction rate over the earlier studies to forecast Delta-HERS, NMR would immediately get a value less than 5%. Considering this, we set the Delta-HERS for each forecasted year at the floor of 5%. To date, we have not seen any plans for program changes that would indicate that the Delta-HERS will increase on average.[25] Panelists indicated that they agreed with this assumption.

The sub-sections below describe the prospective analysis for the single-family market.

2.5.1.1 Estimating Future Gross Savings Per Home

To estimate future gross savings per home, NMR divided the current gross savings in MMBtu by the current Delta-HERS to create a gross savings per Delta-HERS. We then multiplied that value by our projections of future Delta-HERS to get future gross savings for each year. Since NMR assumed the same Delta-HERS for each year (5%), gross savings are the same for each year (Table 11).

Table 11: Forecasted Single-Family Gross Savings Per Home (MMBtu)

Year	Stretch Code	Base Code
2022	36.5	31.1
2023	36.5	31.1
2024	36.5	31.1

2.5.1.2 Estimating Future Net Savings Per Home

To estimate future net savings per home, NMR asked the panelists to estimate whether the impact of each program, and for all efforts combined, would stay the same, increase, or decrease, and by what percentage. Overall, the panelists thought the efforts would become only 6% more effective on average, with 64% of respondents saying the impact would stay the same. To be conservative and to match the previous study, NMR assumed the overall impact would stay the same.

Since the impact of the RNC efforts was projected to the stay the same, NMR reduced the current net savings per home proportionally to the forecasted reduction in per-home gross savings. Specifically, NMR reduced the net savings for the years 2022 through 2024 relative to the retrospective net savings (2017 through 2019).

2.5.1.3 Scaling to Populations

We forecasted population sizes for the four strata using the average forecast from the Delphi panel (with outliers removed) of construction activity, stretch code adoption, and program penetration by code for each year. Panelists based their forecasts on annual single-family permit data from the U.S. Census Building Permit survey.

We then multiplied the per-home gross savings and per-home net savings by the population forecasts to get total gross savings and net savings per population.

---

[24] https://www.masssave.com/-/media/Files/PDFs/Save/Residential/Pay-for-Savings.pdf?la=en&hash=67420BCA38A8BC3BBDB8B9DE41949DE58D22C964

[25] After NMR finished fielding the Delphi panel and conducting analysis for this study, the PAs drafted plans with potential efforts to increase per-home savings. At time of writing, such efforts remained uncertain.

2.5.1.4 Calculating Prospective NTG Ratios

NMR calculated prospective NTG ratios the same way as the retrospective ratios: by comparing program and non-program net savings by code to the program savings per code.

2.5.2 Multifamily Prospective Analysis

NMR calculated prospective multifamily NTG ratios the same way as for prospective single-family NTG ratios, except for making some assumptions for the three scaling variables since we did not ask Delphi Panelists to provide permit growth rate values specifically for the multifamily market. Below are the methods we used to forecast each of the three scaling variables for multifamily.

- **Construction activity:** Originally, we assumed that multifamily construction activity would grow at the same rate as forecasted by the Delphi panel for single-family activity, and increased our estimates of multifamily permits by the same rates. We then showed these estimates to the Delphi panel in Round Three, asked them if they agreed or disagreed, and asked them to provide an estimate if they disagreed. The final values were the average response from the Delphi panel Round Three instrument.
- **Stretch code adoption:** This does not vary by market type, so it was the same for single-family and multifamily.
- **Program penetration**: In Round Three, Delphi panelists provided revised estimates of the annual increase in multifamily program penetration. We increased our estimations of program penetration by code by these percentages.

After determining the scaling variables as described above, NMR followed the same methods as with the single-family market to estimate multifamily NTG ratios.

Section 3 Detailed Findings

This section details the findings from the Delphi panel, net savings analysis, and NTG estimates.

3.1 Delphi Panel Findings

Table 12 shows the Delphi panelists' estimated average reduction in measure-level efficiency from the real-world, as-built scenario and the counterfactual scenario in which the PAs' RNC efforts ceased operation on January 1, 2017. Values are shown for this study and the previous RNC NTG study (RNC & CCSI Attribution Assessment Study, TXC48), which looked at homes permitted from 2014 through 2016. Values are further split by each of the four strata. Darker red cells represent a greater reduction in efficiency. Table 13 shows the results specifically for insulation Grade (i.e., installation quality). Below are some key findings:

- The RNC efforts had the greatest impact on duct leakage, air leakage, foundation walls, and electric water heaters.
- The RNC efforts had less impact on lighting from 2017 through 2019 than from 2014 through 2016, and more impact on electric water heating.
- Overall, the RNC efforts had less impact from 2017 through 2019 than from 2014 through 2016.
- Panelists indicated that the RNC efforts had substantial impact on insulation Grade.

The rest of this section details measure-level findings from the Delphi panel and findings related to the population forecast variables.

Table 12: Delphi Panelists' Average Estimated Reduction in Measure-level Efficiency by Stratum and Study

(Average Percent Reduced Efficiency)

	This Study (2017-2019)				RNC & CCSI Attribution Assessment Study TXC48 (2014-2016)			
	Program Stretch	Non-program Stretch	Program Base	Non-program Base	Program Stretch	Non-program Stretch	Program Base	Non-program Base
Duct Leakage	38%	19%	40%	10%	68%	46%	73%	58%
Air Leakage	10%	12%	17%	13%	28%	36%	37%	35%
Lighting	3%	2%	4%	4%	20%	18%	14%	13%
Windows	4%	3%	6%	4%	4%	1%	3%	4%
Wall R-value	3%	4%	3%	5%	3%	4%	2%	5%
Flat Ceiling R-value	4%	10%	6%	5%	7%	7%	8%	8%
Cathedral Ceiling R-value	5%	9%	7%	9%	9%	6%	9%	3%
Frame Floor R-value	5%	8%	4%	6%	3%	5%	3%	7%
Foundation Wall R-value	9%	15%	12%	18%	11%	29%	11%	17%
Furnace (Heat)	1%	0%	1%	1%	1%	1%	1%	1%
Boiler (Heat)	1%	1%	1%	1%	3%	3%	2%	1%
ASHP (Heat)	1%	2%	6%	1%	3%	2%	0%	2%
MSHP (Heat)	4%	-1%	1%	3%	3%	2%	0%	7%
GSHP (Heat)	2%	NA	1%	NA	3%	7%	10%	NA
Central AC (Cool)	2%	2%	2%	7%	2%	1%	1%	1%
ASHP (Cool)	6%	4%	8%	8%	5%	3%	4%	2%
MSHP (Cool)	8%	2%	5%	5%	5%	3%	4%	2%
GSHP (Cool)	2%	NA	5%	NA	NA	NA	NA	NA
Fossil fuel storage (DHW)	4%	1%	3%	3%	5%	4%	3%	3%
Instantaneous (DHW)	1%	2%	2%	3%	3%	0%	2%	2%
Electric Storage (DHW)	10%	4%	11%	12%	2%	4%	2%	1%

Table 13: Delphi Panelists' Average Estimated Reduction in Insulation Grade by Stratum and Study

(Average Percent Reduced Efficiency)

	This Study (2017-2019)				RNC & CCSI Attribution Assessment Study, TXC48 (2014-2016)			
	Program Stretch	Non-Program Stretch	Program Base	Non-Program Base	Program Stretch	Non-Program Stretch	Program Base	Non-Program Base
Wall	27%	11%	33%	13%	37%	12%	40%	8%
Flat Ceil	23%	10%	21%	15%	30%	17%	37%	22%
Cath Ceil	17%	11%	25%	19%	34%	10%	54%	6%
Frame Floor	48%	3%	37%	2%	9%	9%	22%	8%
Foundation Wall	14%	5%	12%	11%	45%	9%	59%	6%

3.1.1 Duct leakage

Panelists indicated that the RNC efforts had a larger impact on duct leakage than on any other measure. However, panelists estimated a much larger impact in program homes (38% stretch and 40% base) than in non-program homes (19% stretch and 10% base).

Panelists believed that a larger share of homes undergo duct leakage testing in stretch code towns than in base code towns since duct leakage testing is required to get a HERS index value, which must be submitted in stretch code towns. While base code requires duct leakage testing, panelists indicated that some base code homes likely did not receive duct leakage testing due to weak enforcement. This difference in duct leakage testing between codes resulted in a smaller difference between program and non-program homes in stretch code towns than in base code towns. One RNC program manager said,

> *"Many builders and contractors participating in the program were educated about reducing duct leakage. The top tier would continue these efforts, but not as thoroughly if the results were not incentivized. Building inspectors would have some knowledge of duct leakage, but without the program there would be fewer incentives in place to encourage quality installations. Homes would still need Stretch Code requirements, however."*

3.1.2 Air Leakage

Panelists indicated that the RNC efforts had a larger impact on air leakage (between 10% and 17%) than on most other measures. This impact was less than in the previous study (between 28% and 37%). One Massachusetts code official said, "air infiltration should be a priority of all builders with or without the program. All homes are required to be tested and Massachusetts has adopted amendments statewide, which should mean [similar air leakage values] with or without the program."

Panelists said the RNC efforts' impact on air leakage resulted from (1) educating builders about best practices, (2) educating code officials and thus increasing enforcement, and (3) incentivizing builders to build tighter homes. A building efficiency consultant working in Massachusetts said,

"Code enforcement is strengthened by the program. Without the program, raters would not have the incentive tool to help show the added value of these measures."

3.1.3 Lighting

Panelists indicated minimal average impact from the RNC efforts on lighting efficiency (between 2% and 4%). This is a substantial decrease from the RNC efforts' impact as estimated by panelists in the previous study (between 13% and 20%). Panelists explained that the lower cost and increased availability of LED lighting over the last few years has reduced the importance of the program to builders' decision-making regarding lighting. Industry standard practice includes a high saturation of LEDs. One code official in Massachusetts said, "As LEDs have become more available at lower pricing and with more design options (including color ranges), incentives for purchase are less important."

3.1.4 Windows

On average, panelists indicated that the RNC efforts had a small impact on window efficiency (between 3% and 6%). The small impact is similar to that estimated in the previous study (between 1% and 4%). Panelists explained that the main factor determining window efficiency is availability. Manufacturers do not supply windows that are much less efficient than actual as-built values shown to panelists. Therefore, without the program, builders still would not be able to buy less-efficient windows. Due to the high price of efficient windows relative to other efficiency upgrades, the program does not appear to move the needle on window efficiency. One building efficiency consultant working in Massachusetts said, "Poor window performance is getting harder to find. Window manufacturers are building fewer and fewer high u-value (low efficiency) products, so in many cases, a worse window would be a special-order item." A building efficiency consultant working outside of Massachusetts said, "[The program is] less likely to have an influence than are outside factors like what is being stocked at local supply stores/retailers and things like ENERGY STAR rating."

3.1.5 Shell Insulation Measures

NMR asked panelists to provide estimates for two characteristics of building shell insulation: (1) insulation R-value and (2) insulation Grade. R-value is a measurement of the insulation's ability to resist the conductive flow of heat. As noted earlier, insulation Grade is a measurement of the quality of insulation installation. The lower the insulation Grade, the more effectively the insulation will perform. For example, reducing insulation Grade from Grade I to II can reduce insulation effectiveness by about 5%; reducing insulation Grade from Grade I to III can reduce insulation effectiveness by between 6% and 15%.

Table 12 shows the reduction in R-value efficiency as estimated by the panelists in the counterfactual scenario. Table 13 shows the estimated reduction in insulation Grade in the counterfactual scenario.

Overall, panelists estimated that with one exception – foundation walls – the RNC efforts' impacts on insulation R-values are minimal, while on insulation Grade they are substantial across the board, especially frame floor insulation in program homes.

Panelists estimated that R-values would be between 9% and 18% less efficient without the program. This matches the pattern from the previous study, which also found minimal impact on R-values in all building shell measures besides foundation walls. Panelists explained that insulation R-value is mostly impacted by code, and most builders install insulation at the code level regardless of program participation. As one building energy consultant said, “The projects outside the program are still mandated to meet the 2015 IECC for code compliance. I do not feel any of our clients who ‘flip-flop’ back and forth from program and non-program to stretch code to base code would do anything differently, as the overwhelming concern is IECC compliancy [sic] not an incentive value.”

Panelists also explained that frame floor insulation code requirements are harder for code officials to enforce, so the program participation requirements have more of an impact on that measure. As one building energy consultant said, “The framed floor is the most difficult to police. Depending upon the floor joist type, the installation quality changes drastically.” Reducing insulation Grade from Grade I to II can reduce insulation effectiveness by about 5%. Reducing it from Grade I to III reduces effectiveness by 6% to 15%.

The following subsections detail findings for each of the building shell insulation measures.

3.1.5.1 Walls

R-value. Delphi panelists indicated that the RNC efforts had minimal impact on conditioned wall insulation R-value. The panelists from this study estimated an average reduction in R-value in the absence of the program (between 3% and 5%) similar to that estimated by the panel in the previous study (between 2% and 5%, Table 12).

Grade. Panelists estimated the impact on wall insulation installation Grade is comparatively substantial, at between 11% and 33% (Table 13). The RNC efforts’ impact on insulation Grade is particularly high in program homes. The impact on insulation Grade is slightly smaller than in the previous study.

3.1.5.2 Flat Ceilings

R-value. Delphi panelists indicated that the RNC efforts’ impact on flat ceiling insulation R-value was also small, though larger than the impact on wall insulation, and larger in non-program stretch code homes than in other homes. Overall, the impact on flat ceiling insulation R-values (between 4% and 10%) is similar to the impact estimated in the previous study (between 7% and 8%, Table 12).

Grade. Panelists estimated a moderate program impact on flat ceiling insulation Grade (between 10% and 23%). This is slightly smaller than the impact estimated in the previous study (between 17% and 30%, Table 13).

3.1.5.3 Cathedral Ceilings

R-value. Delphi panelists indicated that the RNC efforts’ impact on cathedral ceiling insulation R-values is similar to that of flat ceilings – small, yet also larger than the impact on wall insulation. The current panelists’ average estimate of the program impact, between 5% and 9%, is similar to that estimated in the previous study (between 3% and 9%, Table 12).

Grade. The panelists estimated that RNC efforts' impact on cathedral ceiling insultation Grade was similar to its impact in flat ceilings (between 11% and 25%, Table 13). This estimation is slightly less than that of the previous study, which was between 6% and 54%.

3.1.5.4 Frame Floor

R-value. Delphi panelists indicated that the RNC efforts' impact on frame floor insulation R-value was small, at between 4% and 8%. This is similar to the impact estimated in the previous study of between 3% and 7% (Table 12).

Grade. Panelists indicated that the program had a large impact on frame floor insulation Grade in program homes (48% in stretch code and 37% in base code, Table 13). This is a substantial increase in impact from the previous study.

3.1.5.5 Conditioned Foundation Walls

Panelists indicated that the RNC efforts' impact on foundation wall R-values (between 9% and 18%) was larger than the impact on R-values of any other shell measure (Table 12). However, panelists also indicated that the programs' impact on insulation Grade (between 5% and 14%) is lower than the impact on Grade for the other shell measures (Table 13).

3.1.6 Mechanical Equipment

NMR asked panelists to provide two estimates for each mechanical equipment system type: (1) a counterfactual average efficiency value and (2) the share of relevant systems (e.g., heating) that would replace each type (e.g., furnace, boiler, air-source heat pump) in the counterfactual scenario. These two estimates sought to determine what the reduction in efficiency level for each system type would be without the program, and whether builders would have selected different types of systems without the program.

Overall, panelists indicated only minor program impacts on average system efficiency values, except for electric storage water heaters and, to a lesser extent, heat pumps used for cooling. As one code official said, "Builders now are installing the most efficient systems that are available regardless of the presence of a program or stretch code. Efficient systems are a strong selling point and are becoming more available at reasonable prices."

The reduction in electric water heater efficiency in Table 13 is the result of panelists thinking that builders would choose more electric resistance water heaters and fewer HPWHs in the absence of the PAs' efforts. Both system types are electric storage water heaters. NMR grouped them in the instrument since the program groups them into one category when calculating savings, as previously presented in Table 7, Section 2.3.1. As Table 8 in Section 2.3.1 shows, panelists estimated that, on average, the share of HPWHs would decrease by 15% without the program. One building efficiency consultant working in Massachusetts said, "The program has incentivized builders to move towards HPWHs. This would backtrack in the absence of the program, even in non-program homes."[26]

[26] While panelists indicated that the program had increased electric water heater efficiency by 4% to 12%, a future program could theoretically increase electric water heater efficiency by more than 100% by replacing a larger share of electric resistance water heaters with HPWHs given the high efficiency of HPWHs.

Panelists indicated that builders typically would have selected the same heating, cooling, and water heating system types without the program. The only noteworthy change in heating and cooling system types that panelists estimated was a shift of about 3% to 6% of heat pumps to conventional systems in counterfactual non-program stretch homes. Panelists did not estimate similar shifts from heat pumps to conventional systems for heating or cooling for any of the other three strata. Panelists provided no explanation justifying the larger program impact on heating and cooling systems in non-program stretch code homes than other homes, so the 3% to 6% values could be mathematical noise.

3.1.7 Multifamily Findings

In Rounds One and Two of the Delphi panel, NMR asked panelists to rate the effectiveness of the RNC efforts in the multifamily market relative to the single-family market, using a scale of 1 to 5 where 1 represents "much less effective" and 5 represents "much more effective." Table 14 shows the average panelist response for each measure. A rating of 3 indicates that the programs are equally effective in the multifamily and single-family markets. Darker red means the programs are less effective in the multifamily market than the single-family market, while darker green means the program are more effective in the multifamily market than the single-family market.

Overall, panelists indicated that the RNC efforts are somewhat less effective in the multifamily market than in the single-family market in stretch-code towns, and about as effective in both markets in base-code towns.[27] Respondents who thought the programs were less effective in the multifamily market expressed that multifamily projects are more complicated, and thus compliance with a program is of less importance. They also thought that multifamily builders "lock in more of their decisions before the program or HERS raters can influence them."

Under both codes, panelists indicated that the program is less impactful on duct leakage in the multifamily market than the single-family market. Explaining that duct leakage is not as big a concern for multifamily builders as it is for single-family builders, one panelist said, "Most of the multifamily ducts are already in conditioned space so there is less opportunity for improvement."

[27] While the panelists indicated that the RNC efforts are less effective in the multifamily market than in the single-family market, the larger non-participant population in the multifamily market leads to increased spillover and thus a larger NTG ratio relative to the single-family market.

Table 14: Delphi Panelists' Estimates of Average Relative Effectiveness of Measures in the Multifamily Market

	Stretch Program	Stretch Non-Program	Base Program	Base Non-Program
Overall Efficiency	2.5	2.5	3.1	3.1
Duct Leakage	2.3	2.4	2.5	2.7
Air Infiltration	3.2	2.8	3.5	3.4
Lighting	2.5	2.4	2.8	2.7
Windows	2.7	3.3	3.2	3.2
Walls	3.2	3.1	3.5	3.2
Flat Ceilings	3.4	2.7	3.4	2.8
Cathedral Ceilings	3.4	2.8	3.5	2.8
Foundation Walls	3.3	2.9	3.7	3.0
Insulation Grade	3.0	2.9	3.0	3.0
Heating Equipment	3.2	2.8	2.9	2.8
Cooling Equipment	3.3	2.4	2.7	2.7
DHW Equipment	2.9	3.2	3.2	3.2

Much less effective 1.0 2.0 3.0 4.0 5.0 Much more effective

3.1.8 Construction Activity Findings

As mentioned in Section 2.5.1.3, in the Round Two instrument NMR provided panelists with annual single-family permit counts from the years 2014 through 2020 and asked them to estimate the number of permits that will be issued annually for the years 2021 through 2024. NMR used these estimates to forecast future populations per stratum to scale per-home savings up to the entire market. In Round Three, we provided panelists all the estimates from their fellow panelists along with the average responses. NMR gave panelists the opportunity to revise their original estimates or to keep them the same. Table 15 shows the actual permit count values through 2020 and the average forecasted values from Round Three of the survey. Black values are actual historical data and red values are forecasted.

Table 15: Forecasted Single-Family New Construction Activity

Year	Permit Count	Growth Rate
2014	7,330	--
2015	6,922	-6%
2016	7,641	10%
2017	7,278	-5%
2018	7,169	-1%
2019	6,292	-12%
2020	6,754	7%
2021	6,641	-2%
2022	6,904	4%
2023	7,083	3%
2024	7,207	2%

[a] Black values are actual historical and red values are panelist estimates.

To forecast Multifamily New Construction activity, the Round Three instrument showed the panelists NMR's estimates and forecasts of low-rise multifamily activity, as explained in Section 2.4.2.1 and Section 2.5.2. NMR asked panelists if they wanted to keep our estimate or provide a revised estimate. Table 16 shows the average response from all panelists.

Table 16: Forecasted Multifamily New Construction Activity

Year	Permit Count (# of Units)
2021	2,296
2022	2,441
2023	2,527
2024	2,619

3.1.9 Stretch Code Adoption Findings

As described in Section 2.4.1.1, NMR asked panelists to estimate the impact of the PAs' efforts on stretch code adoption. In Round Two, NMR showed panelists the cumulative total of towns that had adopted stretch code by January 1 of each year from 2017 through 2021 and the results from a 2017 Stretch Code Market Effects study that qualitatively assessed the RNC program's impact on stretch code adoption.[28] NMR then asked panelists to estimate the number of towns that would have adopted stretch code each year from 2017 through 2021 had the program not existed. NMR asked them to provide two forecasts of stretch code adoption for the years 2022 through 2024: one assuming the PAs' efforts would continue and one assuming the PAs' efforts had stopped on January 1, 2017. In Round Three, NMR showed panelists the responses from other panelists and gave them the opportunity to revise their original response or keep it the same. Table 17 shows the results from Round Three of the survey. Black values are actual historical values and red values are panelists' average estimates. The NTG ratios in Section 3.2 use the stretch code adoption rates in the third column of the table, labeled "Without Programs."

Table 17: Forecasted and Counterfactual Stretch Code Adoption

Year	Percent of Towns with Adopted Stretch Code	
	With Programs[a]	Without Programs[a]
2017	54%	44%
2018	62%	50%
2019	71%	57%
2020	79%	62%
2021	81%	65%
2022	83%	69%
2023	86%	73%
2024	89%	76%

[a] Black values are actual historical and red values are panelist estimates.

[28] https://ma-eeac.org/wp-content/uploads/Stretch-Code-Market-Effects-Study.pdf

3.1.10 Program Penetration Findings

In Round Two, NMR provided panelists with program penetration rates over time by building code for single-family homes and asked them to forecast program penetration for the years 2022 through 2024 for each code. In Round Three, panelists were shown the other panelists' estimates and given the opportunity to change their original responses or keep them the same. Table 18 shows the results from the Round Three instrument for single-family homes. Black values are actual historical values and red values are panelist estimates.

Table 18: Forecasted Single-Family Program Penetration Rates

Year	Stretch Code[a]	Base Code[a]
2015-2016	70%	24%
2017-2019	87%	50%
2022	89%	57%
2023	91%	61%
2024	93%	67%

[a] Black values are actual historical and red values are panelist estimates.

Similarly, panelists provided estimates for multifamily program penetration by code. Table 19 shows the Round Three estimates for multifamily program penetration.

Table 19: Forecasted Multifamily Program Penetration Rates

Year	Stretch Code	Base Code
2017-2019	29%	19%
2022	36%	26%
2023	41%	32%
2024	47%	38%

[a] Black values are actual historical and red values are panelist estimates.

3.2 NTG Ratios

This section shows the retrospective and prospective NTG estimates. NMR calculated four sets of retrospective and prospective NTG ratios, as shown in Table 20. During a conference call with the PAs, NMR, and EEAC, the stakeholders agreed to use the set of NTG ratios that accounts for the PAs' impacts on stretch code adoption but does not account for the PAs' code promulgation efforts (i.e., Set 2). On the advice of NMR, the consensus group decided to exclude code promulgation from this study to avoid double-counting savings from code promulgation efforts. (The program plans to claim code promulgation savings separately for the PAs' 2018 code promulgation efforts once more information is available, using the 90% attribution factor from the Code Promulgation Attribution Study.[29,30]) For reference, Appendix A.2 shows NTG estimates accounting for the PAs' code promulgation efforts.

[29] https://ma-eeac.org/wp-content/uploads/MA19X07-B-CDPROMATT_OverallReport_Final_2020.09.15.pdf

[30] Including code promulgation in this study would have reduced gross savings and thus increased the NTG ratios. In addition, the assumption of a constant 5% Delta-HERS implies that future program homes would perform 5% better

Table 20: NTG Ratio Sets

NTG Set	Accounting for PAs' Impacts on Stretch Code Adoption	Accounting for PAs' Code Promulgation
1	No	No
2	Yes	No
3	No	Yes
4	Yes	Yes

Additionally, none of the NTG estimates in this section include impacts from efficient lighting. This is because the PAs are not expected to claim savings from lighting in the 2022 through 2024 period. NTG estimates including lighting are provided in Appendix A.1.

3.2.1 Retrospective NTG Estimates

Table 21 shows free-ridership, spillover, and NTG ratios for single-family homes by code and overall for 2017 to 2019. As a reminder, the values account for the PAs' impact on stretch code adoption and exclude lighting savings from net and gross calculations. The overall NTG value of 0.31 is the result of a high free-ridership value (0.85).

Table 21: Single-Family Retrospective NTG Ratios (2017-2019)

	Stretch Code	Base Code	Overall
N	3,628	3,596	7,224
Free-Ridership	0.88	0.82	0.85
Non-Participant Spillover	0.03	0.30	0.16
NTG	0.15	0.48	0.31

Table 22 shows the NTG ratios for low-rise multifamily units. The higher NTG value of 2.91 is the result of lower program penetration in the multifamily market than in the single-family market, which results in a larger population for spillover. The NTG is lower in stretch code towns than in base code towns because stretch code towns have higher program penetration and thus less spillover.

The high spillover values are the result of having a much larger non-participant population in the multifamily market relative to the single-family market. The spillover is larger in base-code towns compared to stretch-code towns because base-code towns have larger shares of non-participants, and panelists indicated the RNC efforts are slightly more effective in base-code towns than in stretch-code towns. As Table 14 shows, panelists did not indicate that the RNC efforts are any more effective in the multifamily market than in the single-family market at the measure-level, so the high non-participant spillover is not driven by RNC effectiveness on multifamily measures.

than code with or without the promulgation efforts – but the promulgation efforts are built into the code. This study assumes program homes will perform 5% better than the code with the promulgation efforts included.

Table 22: Multifamily Retrospective NTG Ratios (2017-2019)

	Stretch Code	Base Code	Overall
N	1,188	1,179	2,367
Free-Ridership	0.95	0.31	0.63
Non-Participant Spillover	0.28	4.82	2.54
NTG	0.33	5.50	2.91

Table 23 shows the overall retrospective NTG ratios with single-family and multifamily combined. The values are the average of the single-family and multifamily ratios weighted by the count of units that are single-family and multifamily in each code and overall.

Table 23: Overall Retrospective NTG Ratios (2017-2019)

	Stretch Code	Base Code	Overall
N	4,816	4,775	9,591
Free-Ridership	0.90	0.69	0.80
Non-Participant Spillover	0.09	1.42	0.75
NTG	0.19	1.72	0.95

3.2.2 Prospective NTG Estimates

Table 24 through Table 28 show the prospective NTG ratios across both codes for single-family, multifamily, and overall. The NTG ratios include accounting for the programs' impact on stretch code adoption and exclude lighting. The prospective values relied on forecasts of the following three variables provided by the Delphi panelists during Round Three of the survey:

- New construction activity
- Program penetration
- Stretch code adoption with and without the program

As mentioned above, panelists said the overall effectiveness of the PAs' RNC efforts would largely remain the same. Therefore, our analysis assumes that the impact of the offerings will collectively stay the same.

The overall free-ridership ranges from 0.83 in 2022 to 0.82 in 2024, the overall spillover ranges from 0.31 in 2022 to 0.20 in 2024, and the NTG values range from 0.49 to 0.38 over the same period. This implies that the program needs reshaping to generate more substantial savings. Free-ridership remains at a consistently high level over time. This reflects the assumption that the Delta-HERS will remain 5% even as the baseline improves, since performing 5% better than the baseline is a program requirement. Spillover decreases over time due to increasing program penetration and the decreasing population of non-participants.

Table 24: Prospective NTG Ratios – Overall

	Free-Ridership			Spillover			NTG		
	Stretch	Base	Overall	Stretch	Base	Overall	Stretch	Base	Overall
2022	0.90	0.65	**0.83**	0.09	0.83	**0.31**	0.18	1.18	**0.49**
2023	0.90	0.60	**0.82**	0.07	0.74	**0.25**	0.16	1.14	**0.43**
2024	0.90	0.55	**0.82**	0.05	0.65	**0.20**	0.15	1.10	**0.38**

Table 25: Prospective NTG Ratios – Single-Family

	Free-Ridership			Spillover			NTG		
	Stretch	Base	Overall	Stretch	Base	Overall	Stretch	Base	Overall
2022	0.90	0.68	**0.83**	0.02	0.39	**0.13**	0.12	0.71	**0.30**
2023	0.90	0.64	**0.83**	0.02	0.38	**0.11**	0.12	0.74	**0.29**
2024	0.90	0.59	**0.82**	0.01	0.33	**0.09**	0.12	0.74	**0.27**

Table 26: Prospective NTG Ratios – Multifamily

	Free-Ridership			Spillover			NTG		
	Stretch	Base	Overall	Stretch	Base	Overall	Stretch	Base	Overall
2022	0.93	0.56	**0.81**	0.28	2.09	**0.83**	0.35	2.53	**1.02**
2023	0.93	0.49	**0.81**	0.22	1.81	**0.65**	0.29	2.32	**0.84**
2024	0.93	0.43	**0.81**	0.17	1.57	**0.51**	0.25	2.14	**0.71**

3.3 RECOMMENDATIONS

The PAs should explore new ways to generate savings in the RNC market. For the 2022-2024 program period, free-ridership is high and spillover is decreasing, resulting in low NTGRs (from 0.49 to 0.38). To increase the impact of the program on savings, the PAs should explore other ways to influence the RNC market. Some possible approaches could include increasing the threshold of the percentage over UDRH that program homes need to achieve in order to qualify and putting more resources into the Passive House program, since, by definition, a passive home entails construction practices that result in greater energy savings than those used in the RNC program.

The PAs should claim net savings from the code promulgation efforts documented by the Code Promulgation Attribution Study separately from other RNC efforts examined in this study. The Code Promulgation Attribution Study developed a framework for calculating gross savings associated with the PAs' two residential amendments to the 2018 International Energy Conservation Code adopted into the Massachusetts state building code. The PAs should estimate gross savings from those amendments when more information (e.g., construction activity) is available. Once gross savings are known, the PAs should apply the 90% attribution factor determined by the Code Promulgation Attribution Study to calculate net savings.

Appendix A Alternative NTG Estimates

This appendix shows alternative NTG estimates that include lighting savings or promulgation effects.

A.1 NTG Estimates with Lighting Included

Table 27 through Table 30 show NTG results retrospectively and prospectively if lighting savings are included. The NTG ratios presented in the body of this report exclude lighting savings from NTG since the PAs will not be claiming lighting savings in the future.

Table 27: Single-Family Retrospective NTG Ratios – Lighting Included

	Stretch Code	Base Code	Overall
N	3,628	3,596	7,224
Free-Ridership	0.89	0.84	0.87
Non-Participant Spillover	0.02	0.25	0.13
NTG	0.13	0.41	0.27

Table 28: Multifamily Retrospective NTG Ratios – Lighting Included

	Stretch Code	Base Code	Overall
N	1,188	1,179	2,367
Free-Ridership	0.95	0.42	0.69
Non-Participant Spillover	0.24	4.02	2.12
NTG	0.28	4.60	2.43

Table 29: Overall Retrospective NTG Ratios – Lighting Included

	Stretch Code	Base Code	Overall
N	4,816	4,775	9,591
Free-Ridership	0.91	0.74	0.82
Non-Participant Spillover	0.07	1.18	0.62
NTG	0.17	1.44	0.80

Table 30: Prospective NTG Ratios – Lighting Included

	Single-Family	Multifamily	Overall
2022	0.26	0.86	0.41
2023	0.25	0.71	0.37
2024	0.23	0.60	0.33

A.1.1 Modeling Counterfactual Lighting Efficiency

For most measures, the RNC program calculates savings by inputting them into a home energy model and then comparing the overall performance of that energy model to that of a reference home. For lighting, the program calculates savings separately by multiplying the number of efficient bulbs by a deemed savings value for each bulb type. To match this approach, both this and the previous study calculated savings from lighting separately.

NMR provided Delphi panelists with the average percent of sockets in homes that contained efficient bulbs (i.e., CFL, LED, or fluorescent) for each of the four strata for three tiers of homes. NMR based the three tiers on the saturation of efficient lighting per home, with the first tier being the 25% least-efficient homes, followed by the middle 50% of homes, and the 25% most-efficient homes. The panelists estimated the average counterfactual saturation of efficient bulbs for each tier in each stratum.

To determine the counterfactual efficient lighting saturation per home, NMR looked at each tier in each stratum separately. We took the sum of all sockets across all homes in each tier and determined how many efficient bulbs would have to be replaced with inefficient bulbs to result in the average counterfactual saturation values estimated by the Delphi panelists. Since the program only provided LEDs during this study period, NMR only *replaced* LEDs with inefficient bulbs, keeping CFLs and fluorescent bulbs as-is. Once NMR knew how many LEDs would be removed from each tier in each stratum, NMR randomly selected homes from which to remove each LED. On a per-home basis NMR limited the reduction of LEDs to the total number of LEDs present in the as-built home for non-program homes and to the total number of LEDs provided by the program for program homes.[31] In other words, for a non-program home, NMR could only remove as many LEDs as were present in the as-built home, and for program homes, NMR could only remove as many LEDs as were provided by the program. We conducted the randomized reduction in LEDs twice to create two counterfactual saturations for each home and averaged them. NMR multiplied the average counterfactual counts of LEDs in each home by the per-bulb deemed savings value to calculate counterfactual savings.

A.2 NTG ESTIMATES WITH PROMULGATION INCLUDED

In 2020, Massachusetts enacted two residential energy code amendments that the PAs developed and proposed. In the Code Promulgation Attribution Study , NMR estimated the Gross Technical Potential (GTP) savings for the two amendments for each year between 2022 and 2024, as shown in Table 31.[32]

[31] ICF provided NMR with the counts of LEDs given to each program home.
[32] https://ma-eeac.org/wp-content/uploads/MA19X07-B-CDPROMATT_OverallReport_Final_2020.09.15.pdf

Table 31: Estimated Residential GTP Savings from PAs' Promulgation Efforts (MMBtu)

Year	Savings
2022	19,505
2023	18,604
2024	10,803

Theoretically, these savings represent an increase in the baseline because they reflect changes to the energy code. Table 32 and Table 33 show the overall prospective NTG ratios, with lighting excluded and included, respectively, when the gross savings from Table 31 are removed from the forecasted gross savings for the RNC program for the same period. NMR removed the gross savings from Table 31 from the gross savings of the single-family and multifamily markets proportionally to each market's share of gross savings. This method increases the NTG ratio.

Table 32: Prospective NTG Ratios Promulgation Net Savings Removed – Lighting Excluded

	Single-Family	Multifamily	Overall
2022	0.41	1.31	0.64
2023	0.39	1.07	0.57
2024	0.31	0.81	0.44

Table 33: Prospective NTG Ratios Promulgation Net Savings Removed – Lighting Included

	Single-Family	Multifamily	Overall
2022	0.33	1.05	0.52
2023	0.31	0.86	0.46
2024	0.26	0.66	0.37

In a conference call on March 22, 2021, NMR, the PAs, and EEAC agreed to remove promulgation considerations from this study (i.e., use the NTG values in Table 25 instead of those in Table 32). This decision was based on the assumption that the PAs' will follow the framework established in the Code Promulgation Attribution Study to claim promulgation savings separately. To claim Code Promulgation Attribution Study savings, the PAs should estimate gross savings from the promulgation efforts once more data become available and then apply a 90% attribution factor to these savings. If the PAs end up not claiming the promulgation savings separately, they could possibly use the NTG ratios from Table 32. Note that such an approach would go against the guidance from the Code Promulgation Attribution Study and would be dependent on further review by the EEAC.

Appendix B Net Savings

The section summarizes the net saving findings for single-family and multifamily homes.

B.1 Single-Family Net Savings

Table 34 through Table 37 summarize the average single-family per-home net savings and total net savings for program and non-program populations by code. The total net savings for program homes is 27,705 MMBtu (Table 35). The total net savings for non-program homes is 22,681 MMBtu (Table 37).

Base code homes appear to have more average per-home net savings (6.44 MMBtu) than stretch code homes (5.11 MMBtu). Panelists did not provide rationales that specifically justified this phenomenon. Since homes are slightly more efficient in stretch code towns, there could be less savings for program homes in stretch code towns. Still, the difference in net savings between codes in Table 34 is not significant, and the 2019 baseline did not find a significant difference between stretch and base code homes.

Table 34: Summary of Average Per-Home Single-Family Program Net Savings (2017-2019)

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
Base Code					
n	50	50	30	1	20
As-Built Energy Consumption	89.34	7,053	633.43	307.21	723.34
Counterfactual Energy Consumption	95.79	7,185	686.36	336.48	798.22
Net Savings	6.44	132.17	52.93	29.27	74.88
Stretch Code					
n	50	50	34	0	19
As-Built Energy Consumption	94.90	7,342	620.53	-	796.89
Counterfactual Energy Consumption	100.01	7,393	678.30	-	825.89
Net Savings	5.11	51.01	57.76	-	28.99

Table 35: Total Single-Family Program Net Savings (2017-2019)

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
Base Code					
n	1,798	1,798	1,079	36	719
As-Built Energy Consumption	160,639	12,680,417	683,470	11,060	520,080
Counterfactual Energy Consumption	172,223	12,918,062	740,581	12,113	573,919
Net Savings	11,584	237,645	57,112	1,054	53,839
Stretch Code					
n	3,156	3,156	2,146	0	1,119
As-Built Energy Consumption	299,507	23,170,576	1,331,661	-	955,476
Counterfactual Energy Consumption	315,628	23,331,576	1,455,624	-	990,240
Net Savings	16,121	161,000	123,964	-	34,764
Total Net Savings	**27,705**	**398,645**	**181,076**	**1,054**	**69,960**

Table 36 shows the net savings for non-program homes in base code and stretch code towns. Note that the average net savings for non-program homes as modeled appear larger than net savings for program homes in Table 34. NMR calculated net savings for each of the four samples independently based on distributions estimated by the Delphi panel following the same methodology as in the previous two RNC NTG studies. The generation of counterfactual measure-level efficiency values happened to result in the net savings values shown in Table 34 and Table 36, but both reflect counterfactual values selected using probabilities determined by the Delphi panel for each sample. The following additional considerations apply:

- As-built program homes consume less energy than as-built non-program homes. A similar percentage decrease in efficiency in program homes results in less net savings than the same percentage decrease in efficiency in non-program homes in MMBtu, since non-program homes have a larger denominator.
- Interactive effects can make program homes less sensitive to certain measure-level changes. For example, homes with better shells are less sensitive to reductions in HVAC and duct system efficiency. Program homes have better shells than non-program homes. This is compounded by panelists estimating larger R-value reductions in non-program homes than in program homes.
- The highly speculative nature of the Delphi panel providing measure-level responses can result in false precision. As Table 12 shows, the impacts of the program have decreased drastically since the previous study. For most measures, there is little difference between program and non-program samples. For insulation measures, the impacts appear larger in non-program homes. For duct leakage, the impacts are larger in program homes. The

difference in net savings as a percentage of consumption is only about 3% between program non-program samples.

Table 36: Summary of Average Per-Home Single-Family Non-Program Net Savings (2017-2019)

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
Base Code					
n	51	51	31	0	23
As-Built Energy Consumption	95.89	7,412	716.73	-	656.47
Counterfactual Energy Consumption	106.39	7,793	799.51	-	757.57
Net Savings	10.50	381.36	82.78	-	101.09
Stretch Code					
n	49	49	23	0	32
As-Built Energy Consumption	96.11	8,242	506.32	-	735.15
Counterfactual Energy Consumption	104.18	8,647	528.54	-	828.42
Net Savings	8.07	404.75	22.22	-	93.27

Table 37: Total Single-Family Non-Program Net Savings (2017-2019)

	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
Base Code					
n	1,798	1,798	1,093	0	811
As-Built Energy Consumption	172,415	13,326,551	783,391	-	532,401
Counterfactual Energy Consumption	191,286	14,012,233	873,865	-	614,386
Net Savings	18,871	685,682	90,474	-	81,985
Stretch Code					
n	472	472	222	0	308
As-Built Energy Consumption	45,363	3,890,455	112,403	-	226,425
Counterfactual Energy Consumption	49,173	4,081,496	117,335	-	255,152
Net Savings	3,810	191,041	4,933	-	28,726
Total Net Savings	**22,681**	**876,723**	**95,407**	**-**	**110,711**

Error! Not a valid bookmark self-reference. shows NTG ratios by fuel for single-family homes. As a reminder, NTG ratios are unitless. The NTG ratio for electricity is the lowest of all fuels for both base code (0.17) and stretch code (0.04) -- since the program has little impact on lighting and cooling is not a large load. The NTG ratios for fuels in base code homes are higher than for those in stretch code homes due to the higher program penetration in stretch code towns. Fuel-level NTG analysis was not possible for multifamily units, due to the artificial nature and increased uncertainties of the multifamily analysis.

Table 38: Single-Family NTG Ratios by Fuel (2017-2019)

	Overall	Electricity	Natural Gas	Fuel Oil	Propane
Base Code					
n (program/ non-program)	1798/1798	1798/1798	1079/1093	0	719/811
Free-ridership	0.82	0.96	0.84	-	0.79
Spillover	0.30	0.13	0.26	-	0.32
NTG	0.48	0.17	0.42	-	0.54
Stretch Code					
n (program/ non-program)	3156/472	3156/472	2146/222	0	1199/308
Free-ridership	0.88	0.98	0.85	-	0.94
Spillover	0.03	0.02	0.01	-	0.05
NTG	0.15	0.04	0.16	-	0.12

B.2 MULTIFAMILY NET SAVINGS

Table 39 through Table 42 summarize the average multifamily per-home net savings and total net savings for program and non-program populations by code. The total net savings for program homes is 1,613 MMBtu (Table 40). The total net savings for non-program homes is 10,317 MMBtu (Table 42).

Again, the program appears to create more average net savings in base code buildings than in stretch code buildings. This is an artifact of the multifamily analysis being based on single-family results. For program units, net savings represent 8% of average as-built energy consumption in base code towns units and 3% in stretch code towns.

Table 39: Summary of Average Per-unit Multifamily Program Net Savings 2017-2019 (MMBtu)*

	Overall	Heating	Cooling	Water Heating	Lights and Appliances
Base Code					
As-Built Energy Consumption	57.26	32.89	0.58	7.25	16.54
Counterfactual Energy Consumption	61.88	36.50	0.58	8.26	16.54
Net Savings	4.62	3.61	0.00	1.01	0.00
Stretch Code					
As-Built Energy Consumption	48.04	24.13	0.65	7.58	15.68
Counterfactual Energy Consumption	49.7	25.44	0.65	7.93	15.68
Net Savings	1.65	1.31	0.00	0.34	0.00

*There are no n values because NMR artificially created this data.

Table 40: Total Multifamily Program Net Savings 2017-2019 (MMBtu)

	Overall	Heating	Cooling	Water Heating	Lights and Appliances
Base Code					
n	227	227	227	227	227
As-Built Energy Consumption	12,998.02	7,466.03	131.66	1,645.75	3,754.58
Counterfactual Energy Consumption	14,046.76	8,285.50	131.66	1,875.02	3,754.58
Net Savings	1,048.74	819.47	0.00	229.27	0.00
Stretch Code					
n	342	342	342	342	342
As-Built Energy Consumption	16,429.68	8,252.46	222.30	2,592.36	5,362.56
Counterfactual Energy Consumption	16,997.40	8,700.48	222.30	2,712.06	5,362.56
Net Savings	564.30	448.02	0.00	116.28	0.00
Total Net Savings	**1,613.04**	**1,267.49**	**0.00**	**345.55**	**0.00**

For non-program units, net savings represent 12% of average as-built energy consumption in base code towns and 7% of average as-built energy consumption in stretch code towns.

Table 41: Summary of Average Per-Unit Multifamily Non-program Net Savings 2017-2019 (MMBtu)*

	Overall	Heating	Cooling	Water Heating	Lights and Appliances
Base Code					
As-Built Energy Consumption	62.87	36.43	1.51	8.64	16.29
Counterfactual Energy Consumption	70.57	43.10	1.58	9.60	16.29
Net Savings	7.70	6.66	0.07	0.97	0.00
Stretch Code					
As-Built Energy Consumption	50.9	25.51	1.30	8.37	15.72
Counterfactual Energy Consumption	54.43	28.46	1.32	8.93	15.72
Net Savings	3.53	2.95	0.01	0.56	0.00

*There are no n values because NMR artificially created this data.

Table 42: Total Multifamily Non-Program Net Savings 2017-2019 (MMBtu)

	Overall	Heating	Cooling	Water Heating	Lights and Appliances
Base Code					
n	952	952	952	952	952
As-Built Energy Consumption	59,852.24	34,681.36	1,437.52	8,225.28	15,508.08
Counterfactual Energy Consumption	67,182.64	41,031.20	1,504.16	9,139.20	15,508.08
Net Savings	7,330.40	6,340.32	66.64	923.44	0.00
Stretch Code					
n	846	846	846	846	846
As-Built Energy Consumption	43,061.40	21,581.46	1,099.80	7,081.02	13,299.12
Counterfactual Energy Consumption	46,047.78	24,077.16	1,116.72	7,554.78	13,299.12
Net Savings	2,986.38	2,495.70	8.46	473.76	0.00
Total Net Savings	**10,316.78**	**8,836.02**	**75.10**	**1,397.20**	**0.00**

Appendix C Detailed Methodological Example

This section provides an example of how NMR calculated the NTG values for single-family homes. The text below refers to the rows in Table 43 to describe the methodology and assumptions used at each step.

A. **Average per-home net savings** resulting from the counterfactual energy modeling based on Delphi panelist responses

B. **2017-2019 population** based on U.S. Census Building Permit Survey permit counts and program penetrations estimated in the 2019 Baseline Study

C. **Total net savings** equals A * B. Rounding makes the quotients appear incorrect in the table.

D. **Average gross savings** calculated by running the sample program files against the RNC program's UDRH file

E. **Total gross savings** equals D * B

F. **Free-ridership** equals (E-C) / E for program samples

G. **Spillover** equals C / E for non-program samples

H. **NTG by code** equals 1 – F +G

I. **Overall NTG** equals the NTG values in H weighted by the populations in B

J. **2019 Delta HERS** is the percent difference in HERS index values between program and non-program homes as identified in the 2019 Baseline Study

K. **2019 Average Gross Savings / Delta HERS** equals E / J

L. **Forecasted Delta HERS (2022-2024)** is 5%. As discussed above, NMR selected 5% because, if historical trends persist, the Delta HERS values would be less than 5%. However, since the program has a 5% savings threshold for participation, the Delta HERS has a floor of 5%.

M. **Forecasted Average Gross Savings** equals L * D.

N. **Forecasted Reduction in Gross Savings** equals (D – M) / D

O. **Forecasted Average Net Savings** is based on Delphi panelists' responses to a qualitative question about the effectiveness of the RNC efforts in 2022 through 2024. Panelists indicated that the RNC efforts would be about as effective in 2022 through 2024 as they were in 2017 through 2019. Therefore, NMR assumed the same share of net savings per gross savings. NMR reduced net savings from, A, by the percentage reduction in gross savings, N. This results in a proportional decrease in net savings relative to gross savings and follows the same method used in TXC 48.

P. **2022 Population** is based on estimates of new construction activity, program penetration, and stretch code adoption from the Delphi panel. The populations reflect a reduction in stretch code adoption in the absence of the program as estimated by panelists.

Q. **2023 Population** is based on estimates of new construction activity, program penetration, and stretch code adoption from the Delphi panel. The populations reflect a reduction in stretch code adoption in the absence of the program as estimated by panelists.

R. **2024 Population** is based on estimates of new construction activity, program penetration, and stretch code adoption from the Delphi panel. The populations reflect a reduction in stretch code adoption in the absence of the program as estimated by panelists.

S. **2022 Total Net Savings** equals O * P

T. **2023 Total Net Savings** equals O * Q

U. **2024 Total Net Savings** equals O * R

V. **2022 Total Gross Savings** equals M * P

W. **2023 Total Gross Savings** equals M * Q

X. **2024 Total Gross Savings** equals M * R

Y. **2022 Free-ridership** equals (V-S) / V for program homes

Z. **2023 Free-ridership** equals (W-T) / W for program homes

AA. **2024 Free-ridership** equals (X-U) / X for program homes

AB. **2022 Spillover** equals S / V for non-program homes

AC. **2023 Spillover** equals T / W for non-program homes

AD. **2024 Spillover** equals U / X for non-program homes

AE. **2022 NTG by Code** equals 1 – Y + AB

AF. **2023 NTG by Code** equals 1 – Z + AC

AG. **2024 NTG by Code** equals 1 – AA + AD

AH. **2022 NTG** equals the NTG values in AE weighted by the populations in P

AI. **2023 NTG** equals the NTG values in AF weighted by the populations in Q

AJ. **2024 NTG** equals the NTG values in AG weighted by the populations in R

Table 43: Single-Family NTG Analysis Summary

	Stretch Program	Stretch Non-Program	Base Program	Base Non-Program
Retrospective				
A. Average Per-Home Net Savings (MMBtu)	5.11	8.07	6.44	10.50
B. 2017-2019 Population	3,156	472	1,798	1,798
C. Total Net Savings (MMBtu)	16,121	3,810	11,584	18,871
D. Average Gross Savings (MMBtu)	41.9		35.37	
E. Total Gross Savings (MMBtu)	132,239		63,594	
F. Free-Ridership	0.88	NA	0.82	NA
G. Spillover	NA	0.03	NA	0.30
H. NTG by Code	0.15		0.48	
I. Overall NTG	0.31			
Prospective				
J. 2019 Delta HERS	6.8%		6.8%	
K. 2019 Average Gross Savings / Delta HERS	6.16		5.74	
L. Forecasted Delta HERS (2022-2024)	5%		5%	
M. Forecasted Average Gross Savings	30.8		26.0	
N. Forecasted Reduction in Gross Savings	26%		26%	
O. Forecasted Average Net Savings	3.76	5.93	4.74	7.72
P. 2022 Population	4,122	486	1,154	879
Q. 2023 Population	4,576	448	1,148	731
R. 2024 Population	4,960	400	1,148	575
S. 2022 Total Net Savings	15,488	2,881	5,465	6,786
T. 2023 Total Net Savings	17,194	2,660	5,435	5,647
U. 2024 Total Net Savings	18,636	2,373	5,435	4,441
V. 2022 Total Gross Savings	150,741		17,297	
W. 2023 Total Gross Savings	167,179		15,020	
X. 2024 Total Gross Savings	180,026		13,312	
Y. 2022 Free-Ridership	0.90	NA	0.68	NA
Z. 2023 Free-Ridership	0.90	NA	0.64	NA
AA. 2024 Free-Ridership	0.90	NA	0.59	NA
AB.2022 Spillover	NA	0.02	NA	0.39
AC. 2023 Spillover	NA	0.02	NA	0.38
AD.2024 Spillover	NA	0.01	NA	0.33
AE.2022 NTG by Code	0.12		0.71	
AF. 2023 NTG by Code	0.12		0.74	
AG.2024 NTG by Code	0.12		0.74	
AH.2022 NTG	0.30			
AI.2023 NTG	0.29			
AJ. 2024 NTG	0.27			

Appendix D Screenshots from Delphi Instruments

Figure 2 shows an example question from the Round One Delphi Instrument. Panelists were asked to provide values in the blue cells. They provided values for program participants and non-participants for various measures for stretch code and base code towns. Panelists were then asked to provide rationales. The example below is for duct leakage for homes built in stretch code towns.

Figure 2: Round One Delphi Instrument Example

	Program Homes in Stretch Code Communities (single-family only)				Non-program Homes in Stretch Code Communities (single-family only)		
	2019 Actual		Average Duct Leakage in Each Tier in Absence of Program		2019 Actual		Average Duct Leakage in Each Tier in Absence of Program
Duct Leakage to the Outside (LTO)	% of Homes	Duct Leakage		**Duct Leakage to the Outside (LTO)**	% of Homes	Duct Leakage	
High (poor) Duct Leakage Tier 3.01-9.05 CFM25/100 ft^2	25%	3.8	4.50	High (poor) Duct Leakage Tier 4.02 - 31.20 CFM25/100 ft2	25%	10.1	
Mid Duct Leakage Tier 0.29 - 3.01 CFM25/100 ft^2	50%	1.6	2.00	Mid Duct Leakage Tier 1.10 - 4.00 CFM25/100 ft2	50%	2.4	
Low Duct Leakage 0.00 - 0.29 CFM25/100 ft^2	25%	0.0	1.00	Low Duct Leakage Tier 0.00 - 0.70 CFM25/100 ft2	25%	0.3	
Average Duct Leakage (CFM25/100 ft^2)	100%	1.7	2.38	Average Duct Leakage (CFM25/100 ft^2)	100%	3.7	Enter values for each tier.
		Your overall estimate is 37% less efficient than the 2019 actual value.				Enter values for each tier.	

Please type an explanation of the reasoning behind your duct leakage estimates in the space below:

Figure 3 shows an example from the Round Two instrument for duct leakage in program homes in stretch code towns. Panelists were shown their original responses next to the average responses of all panelists from Round One and then given a chance to revise their Round One response in the blue box.

Figure 3: Round Two Delphi Instrument Example

Program Homes in Stretch Code Towns (single-family only)						
Duct Leakage Tiers (CFM25/100 sq. ft. of conditioned floor area)	**% of Homes**	**Actual 2019 Values (with program)**	**All Panelists' Round 1 Responses in Absence of Programs**	**Your Original Response in Absence of Programs**	**Your New Response in the Absence of the Programs**	**Comparison to Actual 2016 Values**
High (poor) Duct Leakage Tier 3.01-9.05 CFM25/100 ft²	25%	3.8	4.5	8.0	8.0	111% Higher (worse)
Mid Duct Leakage Tier 0.29 - 3.01 CFM25/100 ft²	50%	1.6	2.4	4.0	4.0	150% Higher (worse)
Low Duct Leakage 0.00 - 0.29 CFM25/100 ft²	25%	0.0	0.6	2.5	2.5	NA
Average Duct Leakage		**1.7**	2.5	4.6	**Your Round 2 overall average is: 4.6, which is 172% higher (worse) than the real world average.**	