



MA19R18: Residential New Construction Incremental Cost Update

Final Report

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SUBMITTED TO:

The Massachusetts Electric and Gas Program
Administrators

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Executive Summary

The goal of this study is to provide an updated estimate of the incremental costs associated with participating in the Massachusetts low-rise Residential New Construction (RNC) program for the Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) consultants. Specifically, this research updates the RLPNC 17-14 Massachusetts Residential New Construction Incremental Cost study results,¹ providing updated estimates of the incremental costs for recent program homes against the new non-program home baseline described in the MA19X02-B-RNCBL Residential New Construction Compliance/Baseline Study.

This report provides incremental costs for single-family homes and low-rise² multifamily housing units, describing the incremental costs per square foot of conditioned floor area (CFA) to move from baseline construction practices to construction practices commonly found in recent RNC program projects. High-rise³ multifamily buildings are not included in the scope of this update.

The updated incremental cost calculations included in this study are intended for use in the PAs' 2019 annual report filing.

METHODOLOGY

In the RLPNC 17-14 Study, the team estimated measure-level incremental costs associated with participating in the RNC program based on pricing quotes provided by Massachusetts contractors. Those contractors estimated how much more they would charge to build to program levels of efficiency over baseline levels. The NMR team then aggregated the measure-level incremental cost values to calculate the average incremental cost for participating in the RNC program.

In this study, the team developed new incremental cost estimates that assessed costs for recently-built program homes against the most recent non-program baseline, to provide a more up-to-date estimate of the incremental costs associated with program participation.

To increase the reliability of results, this study used two main approaches to develop updated incremental cost estimates for participants. The first approach relied on the contractor estimates of incremental costs that were provided as a part of the 17-14 study. The second was a new approach that incorporated the cost values included in the National Renewable Energy Laboratory's (NREL) National Residential Efficiency Measures Database (NREMD). This update compares the results using those two different data sources.

Approach 1: 17-14 Contractor Responses

The first approach (Approach 1) relied on the incremental cost estimates provided by contractors in the 17-14 study. In the 17-14 study, contractors provided incremental costs for achieving specific levels of performance relative to fixed baseline values. Using those estimates, we

¹ http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_17-14_RNCIncrementalCost_26JUL2018_Final.pdf

² Buildings with three stories or less.

³ Buildings with four or more stories.

calculated the incremental costs for a given unit of improvement in efficiency, e.g., the incremental cost for a 20% improvement in wall R-value. We plotted those improvement percentages and the associated costs to develop lines of best fit that could estimate the incremental cost for any particular efficiency level found in the program home data relative to the new baseline data for that measure. The resulting measure-level costs were then scaled up to reflect the mix of program homes, as with the 17-14 study.

Approach 2: NREL National Residential Efficiency Measures Database

The second approach (Approach 2) relied on cost data from the NREL NREMD.⁴ NREL's Building Energy Optimization Tool (BEopt) energy modeling software incorporates NREMD's national average measure-level costs for retrofit and RNC applications.⁵ NMR extracted NREMD RNC installation costs (labor and/or material costs, as appropriate), and applied them to the recent home data.

As with Approach 1, the team developed equations representing lines of best fit for the NREMD cost data, in order to estimate the costs for specific baseline and program home values, yielding the associated incremental costs. We then applied those values to each home at the measure level, to create a comparison point for the incremental costs derived from the 17-14 contractor estimates.

Differences between the 17-14 study and the MA19R18 Incremental Cost Update

This study leveraged primary data gathered during the 17-14 study, but given the changes in program structure since that study was published (e.g., the removal of performance tiers for program homes), the methods used to calculate the incremental cost for the low-rise program differ from the methods applied in the 17-14 study. Key differences include:

- The 17-14 approach estimated measure-level incremental costs for each of the three program performance tiers. This update does not estimate values within home performance tiers, as the program no longer uses tiers for incentives.
- The 17-14 approach estimated all measure-level incremental cost estimates within each home type (single-family attached/detached and multifamily). Costs by home type were only considered separately for this study when the estimates contractors provided in the 17-14 study differed by home type.
- The measure-level incremental costs estimated in this study are applied to each individual measure and vary depending on the efficiency improvement for the given measure relative to the new baseline.

The 17-14 report provides details on the specific methodological approach used to calculate the previous incremental costs for the low-rise RNC program.

⁴ <https://remdb.nrel.gov/about.php>

⁵ <https://beopt.nrel.gov/downloadBEopt2>

RESULTS

Overall results. The updated incremental cost estimates for the low-rise RNC program are presented in [Table 1](#), and are presented in units of dollars per square foot of CFA across program homes. It shows the costs from the 17-14 study and also the updated costs based on the two methodological approaches used in this update, Approach 1 relying on 17-14 contractor estimates and Approach 2 relying on NREL’s NREMD data, along with an average of those two approaches.

The incremental costs for all home types have decreased from the original 17-14 incremental cost study. Non-program home performance has increased for nearly all measures since the 17-14 study at a faster rate than program homes. This yields lower incremental costs to participate, given that it takes limited labor and materials to achieve program performance relative to a rising baseline. Note that the 17-14 study results and the results from this study, which relied on the 17-14 values, are not perfectly comparable. This is due to the fact that we needed to adjust the methodology in this update to accommodate programmatic changes and the new baseline efficiencies.

Approach 1 vs. Approach 2. Overall, Approach 2 yields incremental costs that are about 33% lower than those from Approach 1. *Two measures drive the majority (75%) of the difference: air sealing (ACH50) and window U-factor.* The higher air-sealing costs resulting from Approach 1 appear to be driven by differences in labor costs; the 17-14 contractor estimates were based on Massachusetts-specific labor costs, while NREMD provides national averages, which may underestimate costs for the Massachusetts market. The difference in window costs from Approach 1 and Approach 2 is likely driven by the small sample size of contractor responses from the 17-14 study, where some contractors offered substantially differently-priced windows from their peers.

Table 1: Incremental Costs per Square Foot of Conditioned Floor Area

Home Type	Incremental Cost (\$/ft ²)			
	Previous Results 17-14 Study	MA19R18 Update		
		Approach 1: 17-14	Approach 2: NREMD	Average
Single-Family Detached	\$2.06	\$1.25	\$0.83	\$1.04
Single-Family Attached	\$1.66	\$1.17	\$0.77	\$0.97
Low-rise Multifamily	\$2.25	\$1.29	\$0.97	\$1.13
Overall	\$2.00	\$1.23	\$0.83	\$1.03

CONCLUSIONS AND RECOMMENDATIONS

Based on the results from this study, we offer the following conclusion and recommendation.

Conclusion: The incremental cost associated with participating in the low-rise RNC program is estimated to be between \$1.23 and \$0.83 per square foot of CFA across all housing types. The average from both methodologies and data sources results in an incremental cost of \$1.03 per square foot of CFA.

Recommendation. We recommend that the PAs apply the overall average incremental cost of \$1.03 per CFA for the low-rise RNC program. If the PAs' cost-effectiveness testing requires the incremental costs to be broken out by home type, the team recommends using the average incremental cost per CFA by home type as presented in [Table 1](#).

Section 1 Introduction

The following subsections describe the program home population, the measures that are included in this study, and details on the methodology used to calculate the incremental cost of the low-rise RNC program.

1.1 LOW-RISE RNC PROGRAM HOMES

This study includes the population of program homes built between May of 2018 and April of 2019. The measure level data for the program was obtained from Ekotrope⁶ energy models. The number of program participants by home type are displayed in [Table 2](#). The estimated incremental cost results are provided by home type in [Appendix B](#).

Table 2: Program Home Types

	All Low-Rise Program Homes	Detached Single-Family Homes	Attached Single-Family Homes	Apartments and Condominiums
<i>n-value</i>	6,282	3,552	1,513	1,217
Percent of program population	100%	57%	24%	19%

1.2 MEASURES AND SPECIFICATIONS

There are several building components, systems, and practices that impact the efficiency of newly constructed residential units. The team maintained a similar approach to the 17-14 study, which was to focus and prioritize the measures that have the most impact on energy efficiency and are common practice in program homes. The team analyzed the program home data to determine how program building practices have changed since the previous incremental cost study.

The measure list remains largely the same between this update and the original 17-14 measure list, as the same type of systems and components are still the majority of the program. The team determined a few notable differences which include the increased application of Energy Recovery Ventilators (ERVs) and mini- or multi- split heat pump systems (MSHPs).⁷ Note that the baseline efficiencies for traditional ducted air-source heat pumps (ASHPs) and MSHPs are separated.

⁶ <https://ekotrope.com/home-page/>

⁷ Mini- or multi-split system heat pumps are heat pump systems with an inverter-driven compressor, which traditionally condition space through one or more distribution points (single-zone or multi-zone) – such as a wall-mounted cassette or a ceiling cassette. Ductless mini-split system configurations have evolved over time and now can be either ductless, ducted, or a mixed configuration. For the purposes of this report, the mini- and multi-split heat pump systems (MSHP) include inverter-driven heat pump systems, regardless of configurations; while ASHPs denote traditional heat pump systems, which condition space through a central distribution system.

Table 3 below describes the following:

- The measures addressed in this study and the percentage of program homes with these measures.
- The baseline efficiency values observed on-site, during the recent MA19X02-B-RNCBL Residential New Construction Compliance/Baseline Study.

Baseline efficiency values are derived from both the User-Defined Reference Home (UDRH) inputs, when applicable, and directly from the baseline report.⁸ The baseline efficiency values indicate the cutoff point to which incremental costs are applied to program homes. Efficiency values below the baseline are attributed no incremental cost, and homes that outperform the baseline are assigned a calculated incremental cost.

Table 3: Measure list and Baseline Efficiency Values Summary

Measure Description	Baseline Efficiency	Percent of Program Homes with Measure (n=6,282)
Building Shell		
Conditioned Walls (R-value)	21.8	100%
Flat Ceiling (R-value)	43.8	56%
Cathedral Ceiling (R-value)	41.6	66%
Framed Floor (R-value)	30.1	44%
Higher Efficiency Windows (U-value)	0.29	100%
HVAC Equipment		
Gas Furnace (AFUE)	94.4	83%
Gas Boiler (AFUE)	94.9	9%
Central AC (SEER)	14.1	82%
ASHP – Cooling (SEER)	16.7	10%
MSHP – Cooling SEER	19.7	
Instantaneous Gas WH (EF)	0.95	61%
Conventional Gas WH (EF)	0.69	17%
Heat Pump Water Heater (EF)	3.39	17%
Additional Measures		
Duct Leakage (CFM25/100 ft ²)	3.80	91%
Air Infiltration (ACH50)	3.10	100%
Ventilation – Bath Fans (watts)	60	88%
Ventilation – HRVs (SRE)	0.70	5%
Ventilation – ERVs (SRE)	0.72	16%
Lighting (% of hard-wired efficient fixtures)	92.1%	100%

⁸ In some instances, the UDRH provides values that are combined between systems or fuels, such as HVAC, or provides U-values for entire building shell components rather than the average nominal R-value.

Section 2 Measure-Level Incremental Cost Estimates

This section provides the measure-level incremental costs associated with building to program performance levels.

Table 4 below describes the following:

- The percentage of program homes with a given measure.
- The percentage of program homes with an associated incremental cost for that measure. Homes that are above the baseline efficiency value have an incremental cost associated with that given measure, homes that do not outperform the baseline are attributed no incremental cost.
- The average measure-level incremental cost for program performance, calculated in dollars per square foot of CFA. Incremental cost values are shown as calculated using Approach 1 (17-14 values), Approach 2 (NREMD values), and the average from both approaches.
 - Incremental cost is equal to the total upgrade cost for each measure divided by the total CFA of the program.

Table 4: Incremental Cost Summary Table (All Program Homes)

Measure	Percent of Homes with Measure (n=6,282)	Percent of Homes with Upgrade (n=6,282)	Incremental Cost (\$/ft ²)		
			Approach 1: 17-14	Approach 2: NREMD	Average
Building Shell					
Conditioned Walls	100%	20%	\$0.04	\$0.02	\$0.03
Flat Ceiling	56%	23%	\$0.13	\$0.08	\$0.10
Cathedral Ceiling	66%	8%	\$0.04	\$0.04	\$0.04
Framed Floor	44%	4%	\$0.02	\$0.01	\$0.01
Higher Efficiency Windows	100%	69%	\$0.32	\$0.17	\$0.24
HVAC Equipment					
Gas Furnace	83%	75%	\$0.07	\$0.05	\$0.06
Gas Boiler	9%	2%	\$0.00	\$0.00	\$0.00
Central AC	82%	14%	\$0.01	\$0.02	\$0.02
ASHP - Cooling	10%	4%	\$0.02	\$0.00	\$0.01
Instantaneous Gas WH	61%	27%	\$0.00	\$0.01	\$0.00
Conventional Gas WH	17%	12%	\$0.03	\$0.03	\$0.03
Heat Pump Water Heater ^a	17%	12%	\$0.00	\$0.00	\$0.00
Additional Measures					
Duct Leakage CFM25/100 ft ²	91%	83%	\$0.29	\$0.28	\$0.29
Air Infiltration ACH50	100%	93%	\$0.22	\$0.09	\$0.15
Ventilation – Bath Fans ^a	88%	87%	\$0.01	\$0.01	\$0.01
Ventilation – HRVs ^a	5%	2%	\$0.00	\$0.00	\$0.00
Ventilation – ERVs ^a	16%	2%	\$0.00	\$0.00	\$0.00
Lighting ^{a,b}	100%	97%	\$0.00	\$0.00	\$0.00
Total Incremental Cost			\$1.23	\$0.83	\$1.03

^a Heat pump water heater, ventilation, and light bulb cost data was limited in BeOpt. The values presented for both Approach 1 and Approach 2 rely on primary data collected during the original 1714 study, and the values are equal.

^b LED light bulbs are provided by the Massachusetts RNC Program at no cost to builders. The incremental cost for lighting was developed with secondary data sources. See [Appendix A](#) for additional details.

Appendix A Lighting Incremental Cost

The estimated incremental cost associated with efficient lighting follows the same approach as outlined in the 17-14 incremental cost study (detailed in Appendix A of that report). The baseline lighting specifications are based on the 2019 baseline results, and cost data was obtained from the recent MA19R06 Massachusetts Lighting Sales Data Analysis report.⁹

The low-rise RNC program provides participant builders with LED light bulbs at no cost. Therefore, there is no builder cost for efficient lighting in the low-rise program due to the program incentive. Below we summarize the methodological process to estimate the theoretical incremental cost for builders to upgrade to efficient light bulbs without direct program support.

Ekotrope energy models, used in the RNC program, only require raters to input the saturation of efficient lighting at the hard-wired fixture level, and do not include bulb-level details. The program participant bulb counts were estimated by applying a bulb per square foot ratio for hard-wired fixtures, obtained from the 2019 baseline data. The bulb count per square foot ratio was then applied to each program participant. The estimated bulb count was multiplied by the saturation of efficient fixtures present in each home to determine the number of bulbs to be upgraded.

The 2019 baseline data was also used to determine the technology mix for efficient (LED and CFL) and inefficient (incandescent and halogen). The lightbulb cost assigned to inefficient and efficient lightbulbs were weighted by the proportion of lighting technology. Incremental costs were applied to program participants that were above the baseline and then rolled up to get the estimated incremental cost per square foot for lighting upgrades.

⁹http://ma-eeac.org/wordpress/wp-content/uploads/MA19R06-E-LtgSalesDataAnalysisReport_FINAL_2019.10.29.pdf

Appendix B Measure-level Incremental Cost Estimates by Home Type

The following tables display the incremental cost per square foot for program participants, separated by home type. The incremental costs presented in the main body of this report are for the full low-rise program population, regardless of home type. [Table 5](#) displays the estimated incremental cost for detached single-family homes. [Table 6](#) displays the estimated incremental cost associated with attached single-family homes. [Table 7](#) displays the estimated incremental cost for low-rise multifamily apartments and condominiums.

Table 5: Detached Single-family Incremental Cost Summary Table

Measure	Percent of Homes with Measure (n=3,552)	Percent of Homes with Upgrade (n=3,552)	Incremental Cost (\$/ft ²)		
			Approach 1: 17-14	Approach 2: NREMD	Average
Building Shell					
Conditioned Walls	100%	17%	\$0.04	\$0.02	\$0.03
Flat Ceiling	68%	30%	\$0.13	\$0.08	\$0.10
Cathedral Ceiling	73%	8%	\$0.05	\$0.04	\$0.04
Framed Floor	62%	6%	\$0.02	\$0.01	\$0.02
Higher Efficiency Windows	100%	76%	\$0.34	\$0.18	\$0.26
HVAC Equipment					
Gas Furnace	86%	78%	\$0.07	\$0.05	\$0.06
Gas Boiler	9%	1%	\$0.00	\$0.00	\$0.00
Central AC	84%	14%	\$0.01	\$0.02	\$0.02
ASHP - Cooling	8%	4%	\$0.02	\$0.00	\$0.01
Instantaneous Gas WH	56%	25%	\$0.00	\$0.00	\$0.00
Conventional Gas WH	19%	12%	\$0.02	\$0.03	\$0.02
Heat Pump Water Heater ^a	20%	14%	\$0.00	\$0.00	\$0.00
Additional Measures					
Duct Leakage CFM25/100 ft ²	94%	79%	\$0.29	\$0.27	\$0.28
Air Infiltration ACH50	100%	98%	\$0.23	\$0.10	\$0.16
Ventilation – Bath Fans ^a	85%	83%	\$0.01	\$0.01	\$0.01
Ventilation – HRVs ^a	6%	1%	\$0.00	\$0.00	\$0.00
Ventilation – ERVs ^a	21%	3%	\$0.01	\$0.01	\$0.01
Lighting ^{a,b}	100%	96%	\$0.00	\$0.00	\$0.00
Total Incremental Cost			\$1.25	\$0.83	\$1.04

^a Heat pump water heater, ventilation, and light bulb cost data was limited in BeOpt. The values presented for both Approach 1 and Approach 2 rely on primary data collected during the original 1714 study, and the values are equal.

^b LED light bulbs are provided by the Massachusetts RNC Program at no cost to builders. The incremental cost for lighting was developed with secondary data sources. See [Appendix A](#) for additional details.

Table 6: Attached Single-Family Incremental Cost Summary Table

Measure	Percent of Homes with Measure (n=1,513)	Percent of Homes with Upgrade (n=1,513)	Incremental Cost (\$/ft ²)		
			Approach 1: 17-14	Approach 2: NREMD	Average
Building Shell					
Conditioned Walls	100%	19%	\$0.03	\$0.02	\$0.02
Flat Ceiling	51%	19%	\$0.15	\$0.08	\$0.12
Cathedral Ceiling	74%	9%	\$0.04	\$0.03	\$0.04
Framed Floor	35%	2%	\$0.00	\$0.00	\$0.00
Higher Efficiency Windows	100%	66%	\$0.27	\$0.14	\$0.21
HVAC Equipment					
Gas Furnace	87%	77%	\$0.08	\$0.06	\$0.07
Gas Boiler	6%	0%	\$0.00	\$0.00	\$0.00
Central AC	83%	10%	\$0.01	\$0.01	\$0.01
ASHP - Cooling	8%	3%	\$0.02	\$0.00	\$0.01
Instantaneous Gas WH	68%	27%	\$0.01	\$0.01	\$0.01
Conventional Gas WH	9%	6%	\$0.01	\$0.01	\$0.01
Heat Pump Water Heater ^a	19%	13%	\$0.00	\$0.00	\$0.00
Additional Measures					
Duct Leakage CFM25/100 ft ²	91%	75%	\$0.29	\$0.32	\$0.31
Air Infiltration ACH50	100%	93%	\$0.24	\$0.06	\$0.15
Ventilation – Bath Fans ^a	87%	87%	\$0.01	\$0.01	\$0.01
Ventilation – HRVs ^a	7%	3%	\$0.00	\$0.00	\$0.00
Ventilation – ERVs ^a	16%	2%	\$0.00	\$0.00	\$0.00
Lighting ^{a,b}	100%	98%	\$0.00	\$0.00	\$0.00
Total Incremental Cost			\$1.17	\$0.77	\$0.97

^a Heat pump water heater, ventilation, and light bulb cost data was limited in BeOpt. The values presented for both Approach 1 and Approach 2 rely on primary data collected during the original 1714 study, and the values are equal.

^b LED light bulbs are provided by the Massachusetts RNC Program at no cost to builders. The incremental cost for lighting was developed with secondary data sources. See [Appendix A](#) for additional details.

Table 7: Low-Rise Multifamily Incremental Cost Summary Table

Measure	Percent of Homes with Measure (n=1,217)	Percent of Homes with Upgrade (n=1,217)	Incremental Cost (\$/ft ²)		
			Approach 1: 17-14	Approach 2: NREMD	Average
Building Shell					
Conditioned Walls	100%	29%	\$0.07	\$0.04	\$0.05
Flat Ceiling	26%	8%	\$0.11	\$0.09	\$0.10
Cathedral Ceiling	37%	7%	\$0.04	\$0.03	\$0.04
Framed Floor	6%	1%	\$0.01	\$0.00	\$0.01
Higher Efficiency Windows	100%	55%	\$0.25	\$0.13	\$0.19
HVAC Equipment					
Gas Furnace	69%	61%	\$0.09	\$0.06	\$0.08
Gas Boiler	13%	7%	\$0.00	\$0.00	\$0.00
Central AC	73%	20%	\$0.04	\$0.06	\$0.05
ASHP - Cooling	18%	4%	\$0.04	\$0.00	\$0.02
Instantaneous Gas WH	70%	34%	\$0.01	\$0.01	\$0.01
Conventional Gas WH	18%	17%	\$0.14	\$0.15	\$0.15
Heat Pump Water Heater ^a	7%	6%	\$0.00	\$0.00	\$0.00
Additional Measures					
Duct Leakage CFM25/100 ft ²	81%	67%	\$0.29	\$0.29	\$0.29
Air Infiltration ACH50	100%	81%	\$0.17	\$0.06	\$0.11
Ventilation – Bath Fans ^a	97%	97%	\$0.02	\$0.02	\$0.02
Ventilation – HRVs ^a	2%	1%	\$0.00	\$0.00	\$0.00
Ventilation – ERVs ^a	3%	0%	\$0.00	\$0.00	\$0.00
Lighting ^{a,b}	100%	98%	\$0.00	\$0.00	\$0.00
Total Incremental Cost			\$1.29	\$0.97	\$1.13

^a Heat pump water heater, ventilation, and light bulb cost data was limited in BeOpt. The values presented for both Approach 1 and Approach 2 rely on primary data collected during the original 1714 study, and the values are equal.

^b LED light bulbs are provided by the Massachusetts RNC Program at no cost to builders. The incremental cost for lighting was developed with secondary data sources. See [Appendix A](#) for additional details.