MA20R30: Multifamily New Construction Baseline Study

FINAL

March 2, 2022

SUBMITTED TO:
The Massachusetts Electric and Gas Program Administrators

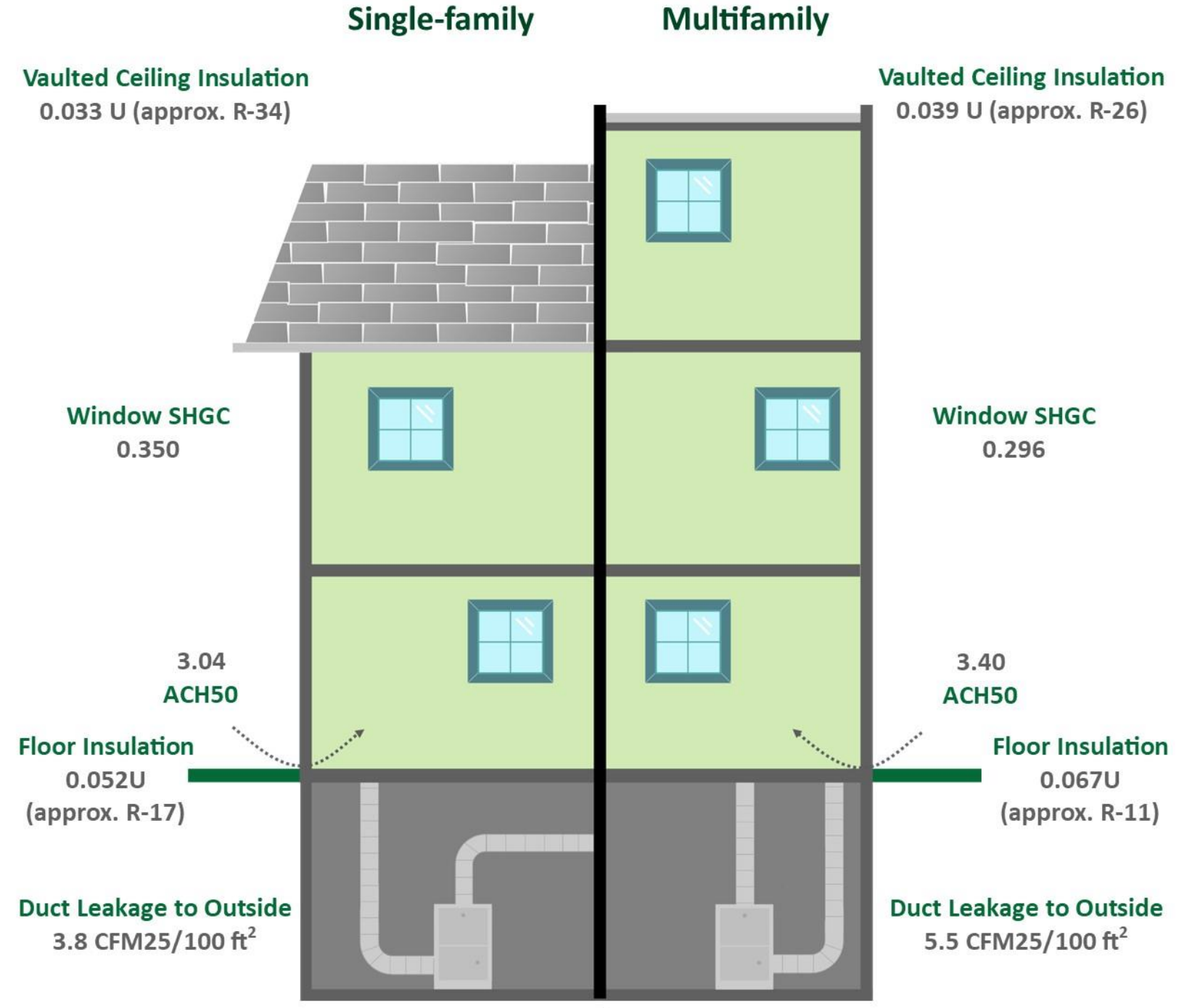
SUBMITTED BY:
NMR Group, Inc.

MA Low-Rise Multi-Family Baseline

This study explores differences between single-family (SF) and low-rise multifamily (MF) home construction. A new UDRH for low-rise MF homes was developed using the results of this research.

Primary Differences between Single-family and Multifamily

The diagram below highlights the portions of homes where practices differ the most between SF and MF home construction. While MF is more likely to include tankless or electric resistance water heaters, the average efficiencies are similar to SF. See below for more about mechanical equipment.



Methods and Analysis

This study is primarily based on HERS ratings purchased from RESNET, which NMR supplemented with construction records collected from building departments. Addresses for the building department data collection were sourced from utility account information, real estate listings and public records such as assessors' databases.

Extensive data cleaning was performed on the RESNET data before merging the building department records to produce a single dataset. In an interim memo comparisons were made between many different subsets of the data, and to data from other recent studies, to explore potential biases or important differences between groups. These results were presented to a panel of stakeholders who helped the develop the low-rise multifamily UDRH through a consensus-seeking process.

Key Findings & Results

While there are some measure-level differences, the base code and stretch code buildings in this study are broadly similar, with the same average HERS index score of 54.

Registered HERS ratings are a rich source of vetted information for hard to reach market segments such as multifamily residential construction.

The team estimates that the buildings sampled for this study represent 33% to 41% of the non-participant low-rise multifamily market. The sampled projects represent 27% to 38% of the non-program base code market and 36% to 42% of the non-program stretch code market.

Mechanical Equipment Efficiencies

The table below compares the existing SF UDRH to the new MF UDRH, where an asterisk (*) indicates reference efficiencies if there is no natural gas service.

Few data points for MF homes heated with propane or heat pumps were uncovered in this study, and overall heating equipment efficiencies were similar to those observed in the single–family baseline. As a result, the MF UDRH values for this category are the same as for SF.

	Hot Water			Heating			Cooling
	Natural Gas (EF)	Propane * (EF)	Electric* (EF)	Natural Gas (AFUE)	Propane * (AFUE)	Electric* (HSPF)	(SEER)
SF	0.87	As built	Resistance: As built Heat pump: 0.92	93.5	97.1	9.28	14.9
MF	0.93	0.93	1.00	93.5	97.1	9.28	13.8

Table of Contents

EXECUTIVE SUMMARY **1**
RESEARCH QUESTIONS 2
METHODOLOGY 2
KEY FINDINGS 3
KEY LIMITATIONS AND SOURCES OF UNCERTAINTY 4
RECOMMENDATION 4
CONSIDERATIONS 5
SECTION 1 INTRODUCTION **6**
1.1 BACKGROUND 6
1.1.1 Study Goals 6
1.2 RESEARCH QUESTIONS 7
SECTION 2 METHODOLOGY AND APPROACH **8**
2.1 DATA SOURCES 8
2.1.1 Primary Data Sources 8
2.1.2 Secondary Data Sources 9
2.2 SAMPLING PLAN 10
2.3 SAMPLE COMPOSITION 10
2.4 DATA CLEANING 12
SECTION 3 RESULTS AND COMPARISONS **14**
3.1 PAIRED RESNET AND BUILDING DEPARTMENT DATA 14
3.2 UDRH AND NON-PROGRAM 15
3.3 BASE VS. STRETCH CODE 17
3.3.1 Base Code Comparison by Source 19
3.3.2 Stretch Code Comparison by Source 20
3.4 LOW-RISE VS. MID-RISE 22
APPENDIX A LOW-RISE MULTIFAMILY USER DEFINED REFERENCE HOME **24**
A.1 MEASURE-LEVEL FINDINGS 24
A.1.1 Shell Measures 24
A.1.2 Air and Duct Leakage 25
A.1.3 Heating Equipment 25
A.1.4 Water Heating Equipment 26
A.1.5 Cooling Equipment 27

A.1.6 Measures Not Considered for LRMF UDRH Update..... 28

APPENDIX B 19R19 SINGLE-FAMILY NON-PARTICIPANT VS. RESNET DATA..... 29

Glossary

Term	Definition
ACH50	Air Changes per Hour with a 50-Pascal pressure gradient
AFUE	Annual Fuel Utilization Efficiency
ASHP	Air-Source Heat Pump; a ducted, fixed refrigerant flow heat pump
BD	Building department
CAC	Central Air Conditioner
CFM25	Cubic Feet per Minute with a 25-pascal pressure gradient
COP	Coefficient of Performance; a measure of equipment efficiency, usually heating
EEAC	Energy Efficiency Advisory Council
EF	Energy Factor; a measure of equipment efficiency used for water heating
ERI	Energy Rating Index; summarizes a home's overall efficiency; lower is better
Grade	Insulation installation quality; Grade I is best.
HERS	Home Energy Rating System; summarizes a home's efficiency; lower is better
HSPF	Heating Season Performance Factor; a measure of electric heating efficiency
IAF	Index adjustment factor
IECC	International Energy Conservation Code
LRMF	Low-rise multifamily
MSHP	Mini-split Heat Pump
PAs	Massachusetts Gas and Electric Program Administrators
R-value	Measure of a material's resistance to the flow of heat; higher is better
RESNET	Residential Energy Services Network
RLNC	Residential Lighting and New Construction
RNC	Residential New Construction
SEER	Seasonal Energy Efficiency Ratio; a measure of cooling system efficiency
SHGC	Solar Heat Gain Coefficient; a measure of how much infrared light passes through a window
U-factor	Measure of a material's resistance to the flow of heat; lower is better
UDRH	User-Defined Reference Home; the hypothetical baseline home for the RNC program

Executive Summary

The MA20R30 Multifamily New Construction Baseline study compares the findings for low-rise multifamily (LRMF) sites to those for single-family new construction homes in Massachusetts. NMR compared Residential Energy Services Network (RESNET) and building department data to results from the most recent single-family new construction baseline study (MA19X02)[1] as well as the non-program model review study (MA19R19).[2] Subsequently, NMR led working group sessions with representation from the Program Administrators (PAs), Energy Efficiency Advisory Council (EEAC), Residential New Construction (RNC) program implementation team, and Home Energy Rating System (HERS) community to develop a LRMF User Defined Reference Home (UDRH).

Table 1 presents the agreed upon UDRH specifications for key measures. The full UDRH, including a comparison to the current single-family version, can be found in Appendix A.

Table 1: LRMF UDRH Specifications for Key Measures

Measure	New LRMF UDRH Specifications
Shell Measures	
Above Grade Wall U-factor	0.064
Frame Floor U-factor	0.067
Flat Ceiling U-factor	0.034
Vaulted† Ceiling U-factor	0.039
Window U-factor	0.283
Window SHGC	0.296
Air and Duct Leakage	
Air Leakage (ACH50)	3.40
Duct Leakage to Outside (CFM25/100 ft^2)	5.51
Heating Equipment	
Natural Gas (AFUE)	93.5
No Natural Gas (AFUE/HSPF)	97.1 AFUE / 9.28 HSPF
Water Heating Equipment	
Natural Gas (EF)	0.93
Propane (EF)	0.93
Electric (EF)	1.0
Cooling Equipment	
Cooling Equipment (SEER)	13.8

[1] NMR Group. (Apr. 1, 2020). 2019 Residential New Construction Baseline/Compliance Study (MA19X02-B-RNCBL). http://ma-eeac.org/wordpress/wp-content/uploads/MA19X02-B-RNCBL_ResBaselineOverallReport_Final_2020.04.01_v2.pdf

[2] NMR Group. (June 26, 2020). MA19R19 Residential New Construction Non-Program Model Review. http://ma-eeac.org/wordpress/wp-content/uploads/MA19R19_NonProgramModelReview_Final_2020.06.26.pdf

RESEARCH QUESTIONS

The study seeks to address the following questions:

- How do the measure-level efficiencies for both non-HERS rated base code projects and RESNET registered HERS ratings of LRMF homes compare to the following?
  - Measure-level efficiencies established by the residential new construction baseline study of single-family homes (MA19X02).
  - Measure-level efficiencies observed in the registered ratings of single-family homes in the non-program model review study (MA19R19).
- Which measures in LRMF new construction, if any, differ significantly from single-family construction practices?
  - Where might PAs need to focus attention in LRMF buildings?

METHODOLOGY

This study used a combination of primary and secondary data sources to determine what the average measure-level efficiencies are for non-program LRMF buildings in Massachusetts. Specifically, this study used building department documentation and a database of certified HERS ratings from RESNET to calculate average efficiencies for the LRMF market. Each of these sources provide value in different ways:

- **Building department documentation**: This information is publicly available at building departments, though the amount of detail available can vary by municipality or building within a municipality. Building department documentation was included in this study primarily because it represents the most accessible source of non-HERS rated data in Massachusetts.
- **RESNET database**: The RESNET database was purchased on behalf of the PAs and represents all certified HERS ratings conducted in Massachusetts.[3] The RESNET data provide a robust sample size and relative affordability compared to on-site data collection or building department visits. Given the prevalence of stretch code adoption in Massachusetts, having a dataset that covers HERS rated homes provides substantial value.

Combined, these datasets were used to compare LRMF findings to the current single-family UDRH in place since 2020. The team compared a sample of sites in which we procured both RESNET data and building department documentation for the same set of buildings. This comparison showed some measure-level differences in terms of energy efficiency between the two sources, but the overall HERS scores were nearly identical (Table 7).

Ultimately, the team proposed using these data sources to characterize the LRMF market due to the challenges collecting data from multifamily properties via on-site inspections. The team

[3] The dataset purchased for this study was limited to reflect ratings from January 2017 through April of 2019. This is the time period the team could reasonably identify non-program projects within the RESNET data.

anticipated on-site data collection to be even more challenging than it has been historically given the COVID-19 pandemic.

KEY FINDINGS

Data suggests that LRMF buildings differ from SF buildings, although which of the two is more efficient varies by measure. Certain measures are more efficient in LRMF buildings than SF buildings. For example, the results of this study show that LRMF buildings have more efficient natural gas furnaces, natural gas water heaters, and slightly more efficient windows. However, SF buildings show higher efficiencies than LRMF buildings for many measures, such as wall insulation, air leakage, and duct leakage. Interestingly, the average HERS scores between LRMF and SF buildings are very similar (54.1 and 55.7, respectively).[4] Please see Section 3.2 for more detailed comparisons.

The team estimates that the buildings sampled for this study represent 33% to 41% of the non-participant low-rise multifamily market. The sampled projects represent 27% to 38% of the non-program base code market and 36% to 42% of the non-program stretch code market. Building department documentation represents 10% to 21% of the non-program base code market and 1% to 7% of the non-program stretch code market – the rest of the sample is from RESNET data. More details on these values can be found in Table 5.

RESNET data offers robust sample sizes and third-party verified data for LRMF buildings. NMR, on behalf of the PAs, obtained records for 54,873 registered HERS ratings in Massachusetts since 2005. The team restricted the sample included in our analyses to cover the time frame for which we could reasonably exclude program participants (January 2017 through April 2019). That said, this sample still represents over 175 buildings and 4,500 LRMF units (see Table 4).

In addition to providing robust sample sizes, the RESNET data represents third-party verified data from on-site inspections conducted by certified HERS raters. Therefore, the RESNET data represents high-quality information. While high quality, the RESNET data did require extensive cleaning to process and analyze.

The RESNET data largely comes from stretch code communities since HERS ratings are required to comply with the stretch energy code.

Identifying non-program projects in base code communities was challenging. By 2018, 67% of municipalities in Massachusetts had adopted the stretch code, covering 76% of the population. Although 116 municipalities still employed the base energy code, these only accounted for one-fourth of all multifamily new construction during the study timeframe, according to Census Bureau permit data. As part of this study, the team identified only 18 base code municipalities with LRMF new construction activity that were not captured by the RESNET data. The small number of municipalities with base code LRMF new construction, along with difficult outreach given the

[4] The average HERS score of 55.7 for SF buildings is based on using Ekotrope energy models. That value rises to 59.3 when using REM/Rate values. Note, the LRMF average HERS scores are based on a mix of Ekotrope and REM/Rate energy models.

COVID-19 pandemic, made it challenging to identify buildings and subsequently gather building department documentation for non-program base code projects.

Overall, base code and stretch code data achieve comparable whole-building efficiencies, though there are measure-level differences. The average HERS index score for base code LRMF buildings sampled in this study was 54.2, compared to 54.1 for stretch code buildings (Table 14). The similarity in HERS scores, which is an assessment of overall building efficiency, suggests that LRMF buildings within base and stretch code communities are very alike from an efficiency standpoint. While the overall efficiency is nearly identical, there are measure-level efficiency differences between the two code groups (see Section 3.3).

The average measure-level efficiencies from building department data are typically more efficient than those from RESNET data. This is true for both base code and stretch code projects. Building department data for both base and stretch code samples show more efficient shell measures and air and duct leakage results than the RESNET data. The results for mechanical equipment either trend more efficient using the RESNET data or the two sources are comparable. Note, the building department sample sizes are too small to identify statistically significant differences between the samples.

Key Limitations and Sources of Uncertainty

The RESNET data is necessarily biased toward stretch code cities and towns. As previously mentioned, the stretch code requires that homes have a HERS rating to show compliance with the energy code. In theory, a HERS rater is involved in every new construction project in stretch code communities. All certified HERS ratings must be submitted to RESNET, the governing body of the HERS rating system. The RESNET data represents certified HERS ratings and as a result is potentially biased towards more efficient projects. HERS rater involvement in these projects creates this potential bias and may push builders or developers to adopt more efficient practices than they would without HERS rater involvement.

Building department documentation represents unconfirmed efficiency values. Most energy-related documentation is filed at building departments before an inspector has verified the installation. In theory, code officials verify that what is listed on the documentation is installed in the project, but this study did not confirm that for these projects. As a result, the building department documentation gathered in this study may not always represent what was ultimately installed in a project.

Recommendation

Recommendation #1: Adopt the LRMF UDRH recommendations developed by the UDRH working group. The team recommends that the PAs adopt the LRMF UDRH that was put together as part of this study. As a reminder, the working group consisted of representatives from the PAs, EEAC, RNC program implementation team, and program HERS raters. The group discussed and agreed on all parameters included in Appendix A.

CONSIDERATIONS

Consideration #1: The PAs should consider using only RESNET data for future LRMF UDRH updates. As previously discussed, the results of this study for stretch code and base code projects are very similar, particularly in terms of whole building efficiency (i.e., HERS scores). The RESNET data primarily represents stretch code projects, which is why the team included building department visits as part of this study. Given the similarities across stretch and base code projects (and subsequently RESNET and building department documentation), the team suggests the PAs consider using only RESNET data for future LRMF updates. The RESNET data is a relatively low-cost dataset that provides substantial sample sizes and high-quality data. Building department documentation, while valuable, is not always available, can be expensive to collect, and may not be verified by code officials.

The adoption of upcoming code options could affect how the PAs handle future LRMF UDRH updates. For example, if many municipalities with significant levels of multifamily construction that are currently stretch code communities revert to the base code, it may not make sense to use only RESNET data for future UDRH updates.

Consideration #2: The PAs should consider updating the LRMF UDRH two to three years after a new code goes into effect. The team suspects that new LRMF construction may take anywhere from one to three years to complete after the permit is issued. To account for lag, the team suggests the PAs consider updating the LRMF UDRH two to three years after a new code goes into effect. This will allow enough projects to be completed under the new code and used to update the UDRH inputs.

Massachusetts is set to update the energy code in 2022, likely to go into effect in 2023. This means the next time to revisit the LRMF UDRH would likely be in 2025 or 2026.

Section 1 Introduction

1.1 Background

The Massachusetts Program Administrators (PAs) and the Energy Efficiency Advisory Council (EEAC) consultants contracted NMR (from here on referred to as "the team") to conduct a low-rise multifamily (LRMF) baseline study using recent Home Energy Rating System (HERS) data from the Residential Energy Services Network (RESNET) and building department documentation. For this assessment, the team compared RESNET and building department data to data collected in the most recent single-family new construction baseline study (MA19X02)[5] as well as the non-program model review study (MA19R19).[6] The team included building department data in this study to capture non-HERS rated homes, particularly in base code communities, because of the inherent bias toward stretch code communities in RESNET data.

Historically, Massachusetts has not conducted LRMF baseline studies and doing so via on-site inspections is particularly problematic amidst the COVID-19 pandemic. The RESNET and building department data offer mechanisms to develop an evidence based LRMF User Defined Reference Home (UDRH) rather than assume that this sector follows the same practices as single-family new construction.

This assessment is being carried out under the Residential Lighting and New Construction (RLNC) evaluation contract, for which NMR is the prime contractor. It serves as a follow-up study to the most recent single-family new construction baseline study (MA19X02) and the non-program model review study (MA19R19), both led by NMR.

1.1.1 Study Goals

This study has the following primary goals:

- Analyze the combined RESNET and building department data set and compare it to the results of the MA19X02 and MA19R19 single-family construction studies.
- Facilitate a working group process with key stakeholders and develop a LRMF UDRH, if appropriate.

[5] NMR Group. (Apr. 1, 2020). 2019 Residential New Construction Baseline/Compliance Study (MA19X02-B-RNCBL). http://ma-eeac.org/wordpress/wp-content/uploads/MA19X02-B-RNCBL_ResBaselineOverallReport_Final_2020.04.01_v2.pdf

[6] NMR Group. (June 26, 2020). MA19R19 Residential New Construction Non-Program Model Review. http://ma-eeac.org/wordpress/wp-content/uploads/MA19R19_NonProgramModelReview_Final_2020.06.26.pdf

1.2 RESEARCH QUESTIONS

The study seeks to address the following questions:

- How do the measure-level efficiencies for both non-HERS rated base code projects and RESNET-registered HERS ratings of LRMF homes compare to the following?
  - Measure-level efficiencies established by the residential new construction baseline study of single-family homes (MA19X02).
  - Measure-level efficiencies observed in the registered ratings of single-family homes in the non-program model review study (MA19R19).
- Which measures in LRMF new construction, if any, differ significantly from single-family construction practices?
  - Where might PAs need to focus attention in LRMF buildings?

Section 2 Methodology and Approach

This study used a combination of primary and secondary data sources to determine what the average measure-level efficiencies are for non-program LRMF buildings in Massachusetts. Specifically, this study used building department documentation and a database of certified HERS ratings from RESNET to calculate average efficiencies for the LRMF market. This section details these data sources, the original sampling plan, final sample composition, and a discussion of the data cleaning required prior to analysis.

2.1 Data Sources

2.1.1 Primary Data Sources

Building Department Data. Buildings within the RESNET data set have some level of HERS rater involvement, which may have influenced builder practices. Consequently, there was concern about the representativeness of this data in base code jurisdictions, which do not require ratings to establish code compliance. Furthermore, the RESNET data is limited to official ratings for homes in Massachusetts, yet the building code does not require a registered rating to establish code compliance in stretch code communities.[7] Instead, the building code sets a maximum permissible Energy Rating Index (ERI), which is comparable to a HERS Index score for the 2015 reference code.

Table 2 shows the coverage of multifamily new construction from 2017 and 2018. Counts are shown for the number of municipalities with multifamily new construction activity and the number of buildings those municipalities represent. The data is broken down to show the coverage of RESNET data and municipalities/buildings not covered by the RESNET data. Lastly, the table shows the sample targets for the building department data collection task. To minimize the potential bias in the RESNET data toward stretch code buildings, the team attempted to supplement the RESNET data with efficiency-related filings from building departments, particularly in base code communities.

[7] Rating certification requires a fee to a private entity and the HERS Index is a proprietary protocol. These properties preclude registered ratings from being a legal requirement. Instead, the American National Standards Institute (ANSI) 301 standard used for ERIs is an open HERS analog. The two were largely equivalent until IECC 2018, although RESNET provides continuous revisions to its rating procedures. HERS Index scores now include an index adjustment factor (IAF) to compensate for the size of very large and very small homes, among other subtle differences.

Table 2: Jurisdictions with Multifamily New Construction circa 2017–2018

	Municipalities		Buildings	
	Base	Stretch	Base	Stretch
RESNET Data	23	43	45	164
No RESNET Data	18	13	111	272
Total	41	56	156	436
Building Department Sample Targets				
RESNET Verification	8	6	16	12
No RESNET Data	18	13	30	30

The team completed outreach to 62 building departments representing both base code and stretch code communities. Under the current conditions related to the ongoing COVID-19 pandemic, we prioritized electronic records requests, but our in-person visits to building departments were the most effective method to collect suitable data for the study. Even so, the data available from the building departments varied greatly. Our team collected information related to HERS Index ratings, shell insulation, windows, air and duct leakage test results, and various mechanical equipment details.

Data from Residential New Construction Baseline and Code Compliance Study. One of the study objectives was to compare the results to the most recent single-family new construction baseline study (MA19X02).[8] The MA19X02 study included energy audits of 100 non-program homes permitted on or after January 1st, 2017, including 52 homes built under 2015 IECC base code and 48 homes built under an updated version of the stretch code.

2.1.2 Secondary Data Sources

Data from Residential New Construction Non-Program Model Review. Our team procured a sample of non-participant energy models submitted to Ekotrope, who also warehouses the RNC program energy models, between May 1, 2018, and April 30, 2019. These registered HERS ratings represent a sample of homes that completed construction in a comparable time frame to those included in the most recent RNC baseline study, approximately January 2017 to July 2018.

RESNET Data. RESNET maintains a registry of official HERS ratings produced with approved modeling tools such as Ekotrope, which the PAs use to calculate energy savings for all low-rise RNC participants. The team received data from official HERS ratings in Massachusetts purchased on behalf of the PAs. The study works from the full spectrum of Massachusetts HERS ratings, because RESNET is the official repository for registered ratings and includes those produced with both Ekotrope and REM/Rate. This is unlike the non-program model review study (MA19R19), which only leveraged non-program HERS rating data from the Ekotrope software. The MA20R30 study provides a significantly expanded window into the construction practices of non-program LRMF housing units.

[8] NMR Group. (Apr. 1, 2020). 2019 Residential New Construction Baseline/Compliance Study (MA19X02-B-RNCBL). http://ma-eeac.org/wordpress/wp-content/uploads/MA19X02-B-RNCBL_ResBaselineOverallReport_Final_2020.04.01_v2.pdf

Given the relative cost and challenges of collecting multifamily data via on-site inspections, a compiled database of home data afforded an opportunity to learn how LRMF homes are built, allowing the PAs to develop a multifamily-specific UDRH for the RNC program's baseline. In collaboration with the PAs, NMR obtained records for 54,873 registered HERS ratings in Massachusetts since 2005.

2.2 Sampling Plan

The original sampling plan was to acquire building department records for 28 addresses with RESNET data and for another 60 in communities not represented by the RESNET data. These were to be split almost evenly between base and stretch code, with specifics shown in Table 3. However, the work plan did not outline a methodology of selecting communities or addresses for information collection. The team chose communities randomly from those with known construction, weighted by the number of constructed units. Addresses from the RESNET data were chosen similarly.

Data acquisition proved to be more difficult than anticipated. For example, building departments had no records but had the building permit for a certain address, or we discovered that the multifamily site recorded in the Census permit data was a collection of townhomes or a mid-rise building. Consequently, we expanded our outreach efforts to include more municipalities than planned. This included pursuing additional addresses uncovered during assessors' database/building department queries, real estate listings, search engines, and the single-family residential new construction baseline study (19X02) data request.[9]

Table 3: Sample Size by Code

Sample		Municipalities		Sites*	
Source	Stage	Base	Stretch	Base	Stretch
RESNET — BD (Paired)	Planned	8	6	16	12
	Research & Outreach	14	12	–	–
	Achieved	6	7	5	4
No Data — BD	Planned	18	13	30	30
	Research & Outreach	32	17	–	–
	Achieved	10	2	9	2

*Site estimates are not provided for 'Research & Outreach' as the number of sites available for research was highly variable and difficult to track as part of this research effort.

2.3 Sample Composition

Table 4 presents the sampled data included in the analyses presented in this report. The counts shown in the "Approximate Sample" columns represent conservative estimates of non-program multifamily buildings and housing units based on the RESNET data and assessor's database information, whereas the "Data Records" columns show the number of specific buildings and units

[9] Interestingly, several of these sites were in communities not represented in the Census permit data. This, as well as the inclusion of (unknown quantities) of townhomes and mid-rise buildings (include those with five or more stories), preclude the use of Census data to weight the data in this study as originally planned.

for which we have information-specific documentation. A site is the highest level of categorization, representing a property managed by a single entity, and it is the favored unit of analysis in this report. Multiple buildings can exist at a given site, each containing five or more housing units. The unit counts presented in Table 4 are particularly conservative, as the RESNET data may not comprehensively cover all units in a building, and information on unit counts for building department documentation was not always available from either the documentation itself or associated assessor's database records.

The team restricted the sample included in our analyses to cover the time frame (January 2017 to April 2019) for which we could reasonably exclude program participants. The RESNET data covers an extended time period that the team does not have program participant information for comparison.

To produce more robust sample sizes, the team included four-story mid-rise buildings in the sample. During the building department data collection effort, it became clear that the sample sizes associated with LRMF new construction would be too small to draw any meaningful conclusions. The team and RNC working group agreed to include four-story projects in the sample. A comparison of low-rise and mid-rise efficiencies can be found in Section 3.3.2. Table 30 shows that the HERS ratings for low-rise and mid-rise housing units are comparable, which supports the inclusion of mid-rise buildings in the analyses, as does the lack of statistically significant difference for most other measures. Additional support for the inclusion of mid-rise buildings is the increasing prevalence of "five-over-one" style construction, which exploits quirks of the building code to construct timber-framed upper floors over an inflammable concrete/steel ground floor.[10] These taller buildings fall under commercial code, and indeed the ground floor is frequently commercial space or parking. However, the upper residential floors follow conventional stick-framing techniques.

Table 4: Analyzed Data

Code	Source	Sites	Approx. Sample		Data Records	
			Buildings	Units	Buildings	Units
Base	BD (Paired)*	1	3	53	1	4
	BD	15	32	1,293	15	–
	RESNET	19	28	725	26	721
	Base Total	34	60	2,018	42	725
Stretch	BD (Paired)*	3	4	151	3	26
	BD	6	32	373	6	6
	RESNET	126	153	3,090	149	3,069
	Stretch Total	132	185	3,463	155	3,101
Unknown	RESNET	4	4	103	4	103
Grand Total		169	248	5,584	201	3,929

*These are sites for which the team compared RESNET and building department documentation, discussed in Section 3.1.

[10] Justin Fox, "Why America's New Apartment Buildings All Look the Same", *Bloomberg Businessweek,* Feb. 13, 2019. https://www.bloomberg.com/news/features/2019-02-13/why-america-s-new-apartment-buildings-all-look-the-same

By combing data from Table 2 and Table 4, it is possible to calculate the approximate fraction of non-program multifamily new construction sampled by this study (Table 5). However, per previous discussion, these values are only estimates since Census permit data includes permits for non-low-rise multifamily projects. This inflates the denominator, resulting in an underestimate of coverage. On the other hand, our data collection efforts also uncovered a few projects in communities that were not represented in the Census permit data, which would contribute to an overestimate.

Table 5: Estimated Coverage of New Multifamily Buildings circa 2017–2018

	Base Code	Stretch Code
Total Number of Non-Program Buildings in Census Survey	156	436
Number of Data Records Inspected	42	155
Minimum Estimate; Data Records ÷ Total Buildings	27%	36%
Building Departments	*10%*	*1%*
RESNET	*17%*	*34%*
Approximate Number of Buildings Represented	60	185
Conservative Estimate; Approximate Sample ÷ Total Buildings	38%	42%
Building Departments	*21%*	*7%*
RESNET	*18%*	*35%*

As previously mentioned, the team restricted the sample time frame used in our analysis to ensure only non-program housing units were included. Table 6 presents the counts associated with the data excluded from our analysis.

Table 6: Extra Data

Code	Source	Sites	Approx. Sample		Data Records	
			Buildings	Units	Buildings	Units
Base	*BD (Paired)*	*3*	*18*	*522*	3	9
	BD	2	2	38	2	11
	RESNET	14	30	1,094	15	962
	Base Total	16	32	1,132	3	9
Stretch	*BD (Paired)*	1	2	12	–	–
	BD	–	–	–	–	–
	RESNET	72	102	2,145	95	1,945
	Stretch Total	73	104	2,157	95	1,945
Grand Total		87	134	3,251	116	2,928

2.4 Data Cleaning

The team identified program sites included in the RESNET data while developing the stage three plan to exclude them from our analyses. Subsequent cleaning also removed a handful of duplicate

ratings and further refined the initial classification of home type.[11] Many records that were marked as multifamily in the RESNET data were excluded when found to represent townhouses, duplexes, or buildings of five or more stories. The manner of verification varied from site to site, but the primary methods were assessors' database results and satellite or street-view mapping imagery.

The RESNET data includes both U-factors and R-values for many measures, although they frequently conflict with one another. RESNET informed the team that the U-factor should be considered the authoritative data point. Therefore, R-values were ignored where U-factors were available and fell within reasonable parameters,[12] and questionable data for individual measures were removed from the analysis. Unfortunately, this cleaning reduced the sample size and still yielded some questionable values. To address this, both flat attic ceilings and above-grade walls were analyzed twice, once with the cleaned RESNET data and again with NMR calculated U-factors. The NMR U-factors were used to fill in the gaps for building department data where R-value information was available but U-factor data was not.

For the RESNET data, the NMR U-factor represents a U-factor calculation based on the R-values and applicable framing and grade information. The analysis is only possible for these measures because they report both cavity and continuous R-values.[13] Above-grade wall details also include framing factor and insulation grade.[14] Flat attic ceiling details do not contain information about framing or insulation grade but do record whether the insulation is blown-in or batt. The calculated ceiling U-factors therefore assume 2×10 joists with a 14% framing factor, and Grade II for batt insulation or Grade I for blown-in insulation.

[11] Units reported as 'low-rise multifamily' in RESNET's data includes single-family (duplex, 3-5 units, townhouses) and mid-rise (4-6 story) properties.
[12] For example, the U-factors of some records indicated an uninsulated assembly, whereas the R-value indicated a typical level of insulation for new construction. In other cases, U-factors greater than 1 were recorded. Entries such as 23.66 could potentially be construed as mis-entered R-values, but a vaulted ceiling R-value of 97 is as suspect as a U-factor of 97 (R-0.01 equivalent).
[13] This recalculation assumes the walls and ceilings are uniformly insulated, whereas the RESNET-reported U-factor may represent multiple assembly types. However, the RESNET data included many ceilings with blown-in R-30 cavity insulation ranging from 0.036 U (R-27) to 0.072 U (R-13.9), and the latter would require that half of the ceiling be uninsulated to achieve such a low effective R-value.
[14] For standard wood-stud framed walls, the framing depth was inferred from the R-value, predominantly 2×6.

Section 3 Results and Comparisons

This section presents the results from our analyses. The counts in the tables below represent sites analyzed for any given measure. Some sites may be counted multiple times if they have units with a mix of equipment or building types. For example, a site with both furnace- and baseboard-heated units, or low-rise and mid-rise buildings, would be counted twice in the associated tables.

3.1 Paired RESNET and Building Department Data

One goal of the building department visits was to measure building department data against RESNET data for the same set of buildings. In other words, the team compared the RESNET data for a given site to the same site's building department documentation. The team made these comparisons for 11 sites. Table 7 presents the results of comparisons for measures in which we had at least four observations.

Table 7: RESNET and Building Department Comparison for Paired Sites (N=11)

Measure	*n*	RESNET	BD
HERS Index Rating	5	55.7	55.6
Air Leakage (ACH50)	6	2.258	1.895
Above-Grade Wall U-factor	4	0.074*	0.045
NMR U-factor	11	0.067*	0.035
Flat Ceiling U-factor	4	0.066*	0.030
NMR U-factor	9	0.035*	0.020
Window U-factor	8	0.277	0.290
Window SHGC	8	0.277	0.264
Cooling COP‡	7	3.928	4.137
Heating COP‡	5	0.959	0.953
Water Heating EF	7	1.151	0.924

* Significantly different at the 90% confidence level.
‡ Equipment efficiencies were converted to COP to simplify analysis and reporting, by treating 100 AFUE as 1.0 COP and 3.412 SEER or 3.412 HSPF as 1.0 COP.

The observation count of most measures in Table 7 is lower than the total number of sites because building departments frequently did not have data available for every measure. As shown, the RESNET and building department data are not a perfect match. However, only the above-grade wall and flat ceiling U-factors are significantly different.[15] In general, the building department records indicate greater efficiency than the RESNET data.

[15] Note that the wall and ceiling U-factors, as well as air leakage data, frequently required additional processing and assumptions to convert building department data into a comparable unit as that provided by RESNET. For instance, the U-factor of a wall depends upon the framing factor as well as the insulation R-value that might be available from a REScheck report. The team used defaults from REM/Rate for such assumptions where possible, like that of a 23% framing factor for 16-inch centered stud walls.

3.2 UDRH AND NON-PROGRAM

This section presents the results of the current single-family UDRH specifications compared to the following data sources:

- Non-program RESNET data (RESNET).
- Non-program and non-RESNET building department data (BD).
- A combination of the RESNET and building department data (RESNET + BD). In some cases for paired sites, one source may contain data for a given measure that the other does not. Therefore, this blended data set maximizes the data points considered. Where both sources provide data for a measure, we favor RESNET data over building department data.

The team was unable to calculate efficiency values for each of the current UDRH inputs. This is because the data available in RESNET documentation and at building departments were often not specific enough to perfectly match some of the current UDRH specifications. For example, information on foundation wall and slab insulation locations was either unavailable or did not specify whether the adjoining space was conditioned for most sites reviewed as part of this study. Below we present comparisons for the building shell and mechanical equipment measures with sufficient detail for analysis.

Both RESNET HERS Index Ratings and building department data were generated with a mixture of REM/Rate and Ekotrope software, 76% REM/Rate in RESNET data and 63% REM/Rate in building department data. Table 8 shows multifamily HERS scores are slightly lower than the baseline sample used to develop the single-family UDRH.

Table 8: Average HERS Index – UDRH

Measure	*n*	Baseline	*n*	RESNET	*n*	BD	*n*	RESNET + BD
HERS Index Rating	100	59.3 REM 55.7 Ekotrope	193	54.0	5	62.00	194	54.1

Table 9 presents the efficiency findings for building shell measures. The most noticeable differences between the multifamily data and the current single-family UDRH are for frame floor and vaulted ceiling U-factors. Above-grade wall and flat ceiling U-factors show substantial differences when using the smaller sample that is the cleaned RESNET and building department data. However, when using NMR-calculated U-factors, which have larger sample sizes and in the opinion of the team are more reliable, the differences are much smaller.

Table 9: Average Building Shell – UDRH

Measure	*n*	Current UDRH	*n*	RESNET	*n*	BD	*n*	RESNET + BD
Above-Grade Wall U	100	0.062	80	0.079	*21*	*0.052*‡	95	0.075
NMR U-factor			169	0.065	21	0.052	183	0.064
Frame Floor U-factor	91	0.052	70	0.069	9	0.042	77	0.067
Flat Ceiling U-factor	73	0.033	82	0.037	*13*	*0.035*‡	92	0.037
NMR U-factor			136	0.033	13	0.035	147	0.034
Vaulted† Ceiling U-factor	61	0.033	105	0.039	6	0.045	108	0.039
Window U-factor	27	0.290	193	0.282	16	0.290	203	0.283
Window SHGC	25	0.350	193	0.295	12	0.294	199	0.296

† Vaulted ceilings represent any ceiling with less than one foot of air space between the ceiling insulation and roof deck. Consequently, the rubber membrane roofs prevalent in multifamily construction are frequently entered as vaulted roofs.
‡ Building department data is generally furnished as an R-value, therefore italic entries are NMR calculated U-factors.

Both air leakage and duct leakage are less efficient for multifamily projects than the current UDRH when using a combination of the RESNET and building department documentation (Table 10).

Table 10: Average Air and Duct Leakage – UDRH

Measure	*n*	Current UDRH	*n*	RESNET	*n*	BD	*n*	RESNET + BD
Air Leakage (ACH50)	99	3.04	193	3.42	9	2.05	197	3.40
Duct Leakage to Outside (CFM25/100 ft^2)	87	3.80	182	5.54	3	3.83	185	5.51

As shown in Table 11, the prevalence of propane and electric heating is much lower in multifamily properties than single-family population. The natural gas heating efficiencies are similar for multifamily properties and the current UDRH.

Table 11: Average Heating Efficiency by Fuel – UDRH

Measure	n	Current UDRH	*n*	RESNET	*n*	BD	*n*	RESNET + BD
Natural Gas (AFUE)	70	93.50	116	95.06	12	92.23	124	94.80
Propane (AFUE)	62	97.10	6	90.33	–	–	6	90.33
Electric (HSPF)	31	9.28	7	8.26	2	11.05	7	8.26

Table 12 presents the findings for water heating. Not surprisingly, propane is seldom used in multifamily new construction for water heating. The RESNET and building department data suggest that natural gas water heating equipment in multifamily new construction is slightly more

efficient than the current UDRH, while electric water heating is slightly less efficient. The latter is due to a slightly higher prevalence of resistance water heaters in multifamily (38% versus 32%).

Table 12: Average Water Heating Efficiency by Fuel – UDRH/Baseline*

Measure	*n*	Current UDRH/ Baseline	*n*	RESNET	*n*	BD	*n*	RESNET + BD
Natural Gas (EF)	48	0.87	132	0.93	7	0.90	136	0.93
Propane (EF)	31	0.87	6	0.89	–	–	6	0.89
Electric (EF)	28	2.54	39	2.27	3	0.94	40	2.23
Resistance (EF)	9	0.89	18	0.92	3	0.94	19	0.93
Heat Pump (EF)	19	3.34	21	3.42	–	–	21	3.42

*The values presented in the 'Current UDRH/Baseline' column are not necessarily the values used in the current single-family UDRH, as some fuel types were merged for the final UDRH. As such, this column is labeled to point out that some of these are UDRH values and some are simply values from the previous baseline study.

Using the combined RESNET and building department documentation, the analysis shows that multifamily properties have a lower cooling equipment efficiency than the current UDRH (Table 13).

Table 13: Average Cooling Efficiency – UDRH

Measure	*n*	Current UDRH	*n*	RESNET	*n*	BD	*n*	RESNET + BD
Cooling Equipment (SEER)	157	14.9	129	13.8	13	15.5	136	13.8

3.3 Base vs. Stretch Code

This section compares the efficiency values for key building components in the RESNET + BD sample between base code and stretch code municipalities. The data also cover multiple data sources and building sizes, as discussed in Section 2.

There is virtually no difference in HERS Index ratings between codes (Table 14).[16]

Table 14: HERS Index – Code Comparison

Measure	*n*	Base	*n*	Stretch	*n*	RESNET + BD
HERS Index Rating	28	54.2	162	54.1	194	54.1

While there is a significant difference between based and stretch codes for the RESNET-reported U-factors of above-grade walls and vaulted ceilings, there is no difference for the NMR-calculated wall U-factors (Table 15).

[16] These ratings come from both RESNET data and building department documentation.

Table 15: Building Shell – Code Comparison

Measure	*n*	Base	*n*	Stretch	*n*	RESNET + BD
Above-Grade Wall U-factor	24	0.063*	70	0.079	95	0.075
NMR U-factor	31	0.065	153	0.064	184	0.064
Frame Floor U-factor	18	0.053	58	0.071	77	0.067
Flat Ceiling U-factor	23	0.039	69	0.037	92	0.037
NMR U-factor	26	0.037	121	0.033	147	0.034
Vaulted Ceiling U-factor	19	0.033*	87	0.040	108	0.039
Window U-factor	36	0.295*	163	0.280	203	0.283
Window SHGC	32	0.310	163	0.294	199	0.296

* Significantly different at the 90% confidence level.

Counterintuitively, air leakage and total duct leakage are both lower in base code projects than stretch code projects (Table 16).

Table 16: Air and Duct Leakage – Code Comparison

Measure	*n*	Base	*n*	Stretch	*n*	RESNET + BD
Air Leakage (ACH50)	30	2.86*	163	3.52	197	3.40
Duct Leakage to Outside (CFM25/100 ft^2)	29	3.59*	153	5.97	185	5.51

* Significantly different at the 90% confidence level.

Condensing units represent most heating equipment in both codes, and there is no significant difference in efficiency (Table 17).

Table 17: Heating Efficiency by Fuel – Code Comparison

Measure	*n*	Base	*n*	Stretch	*n*	RESNET + BD
Natural Gas (AFUE)	26	93.73	96	95.07	124	94.79
Propane (AFUE)	1	96.00	5	89.20	6	90.33
Electric (HSPF)	2	6.86	5	8.82	7	8.26

Tankless units represent most combustion water heaters in both codes, and there is no significant difference in efficiency for these or electric units, which are predominantly heat pumps (Table 18).

Table 18: Water Heating Efficiency by Fuel – Code Comparison

Measure	*n*	Base	*n*	Stretch	*n*	RESNET + BD
Natural Gas (EF)	23	0.93	111	0.93	136	0.93
Propane (EF)	–	–	6	0.89	6	0.89
Electric (EF)	5	2.48	35	2.20	40	2.23
Resistance (EF)	2	0.93	17	0.93	19	0.93
Heat Pump (EF)	3	3.51	18	3.40	21	3.42

There is no appreciable difference between cooling efficiencies by code (Table 19).

Table 19: Cooling Efficiency – Code Comparison

Measure	*n*	Base	*n*	Stretch	*n*	RESNET + BD
Cooling Equipment (SEER)	25	14.09	108	13.78	136	13.83

3.3.1 Base Code Comparison by Source

This section presents a comparison of base code data by source. The third column in these tables, "All Base," is similar to the RESNET + BD data presented in previous tables, although in this case the paired RESNET and building department data are counted twice.

Table 20 shows that the building department documentation produced more efficient results than the RESNET data for most shell measures.

Table 20: Building Shell – Base Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Base
Above-Grade Wall U-factor	14	0.072	11	0.050	25	0.062
NMR U-factor	21	0.072	11	0.051	32	0.062
Frame Floor U-factor	13	0.059	5	0.038	18	0.053
Flat Ceiling U-factor	15	0.039	8	0.034	22	0.037
NMR U-factor	18	0.038	18	0.034	28	0.037
Vaulted Ceiling U-factor	17	0.033	2	0.028	19	0.033
Window U-factor	28	0.294	9	0.297	37	0.295
Window SHGC	28	0.307	5	0.326	33	0.310

Table 21 again shows that the building department documentation produced more efficient results than the RESNET data for air leakage and duct leakage.

Table 21: Air and Duct Leakage – Base Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Base
Air Leakage (ACH50)	28	2.93	2	1.93	30	2.86
Duct Leakage to Outside (CFM25/100 ft^2)	28	3.66	1	1.70	29	3.59

For gas heating equipment, the RESNET data produced more efficient results than the building department documentation (Table 22). The team did not find any documentation of propane or electric heating equipment for base code projects in the building department documentation.

Table 22: Heating Efficiency by Fuel – Base Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Base
Natural Gas (AFUE)	20	95.00	7	90.29	27	93.78
Propane (AFUE)	1	96.00	–	–	1	96.00
Electric (HSPF)	2	6.86	–	–	2	6.86

Table 23 presents the efficiencies for water heating equipment in base code municipalities. As shown, the RESNET data produced more efficient results than the building department documentation regardless of the fuel being used.

Table 23: Water Heating Efficiency by Fuel – Base Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Base
Natural Gas (EF)	21	0.93	3	0.91	24	0.93
Propane (EF)	25	1.24	5	0.92	30	1.19
Electric (EF)	4	2.87	1	0.93	5	2.48

Table 24 shows that the cooling efficiency is slightly higher in the RESNET data than in the building department documentation.

Table 24: Cooling Efficiency – Base Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Base
Cooling Equipment (SEER)	20	13.91	6	14.50	26	14.05

3.3.2 Stretch Code Comparison by Source

This section presents a comparison of base code data by source. The third column in these tables, "All Base," is similar to the RESNET + BD data presented in previous tables although in this case the paired RESNET and building department data are counted twice.

Similar to the base code comparison in the previous section (3.3.1), the building department data for most measures in Table 25 are more efficient than those form the RESNET data; window U-factors are comparable, and the NMR calculated ceiling U-factor for collected data is less efficient.

Table 25: Building Shell – Stretch Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Stretch
Above-Grade Wall U-factor	65	0.081	10	0.052	75	0.077
NMR U-factor	148	0.064	10	0.053	158	0.064
Frame Floor U-factor	56	0.072	4	0.046	60	0.070
Flat Ceiling U-factor	65	0.037	5	0.037	70	0.037
NMR U-factor	118	0.033	5	0.037	123	0.033
Vaulted Ceiling U-factor	86	0.040	4	0.029	90	0.040
Window U-factor	161	0.280	7	0.281	168	0.280
Window SHGC	161	0.293	7	0.271	168	0.292

Air and duct leakage results tend be more efficient in the building department documentation than they are in the RESNET data, though the building department sample sizes are very small (Table 26).

Table 26: Air and Duct Leakage – Stretch Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Stretch
Air Leakage (ACH50)	161	3.53	7	2.08	168	3.47
Duct Leakage to Outside (CFM25/100 ft^2)	151	5.99	2	4.90	153	5.97

Mechanical equipment information was rarely included in building department records; however, furnace efficiency for stretch code homes in Table 27 appears to be similar to that from RESNET. The RESNET data includes one home with an electric furnace and another with electric baseboards, which reduces the average HSPF for that slice of data.

Table 27: Heating Efficiency by Fuel – Stretch Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Stretch
Natural Gas (AFUE)	95	95.07	5	95.10	100	95.07
Propane (AFUE)	5	89.20	–	–	5	89.20
Electric (HSPF)	5	8.82	2	11.05	7	9.46

As with heating equipment, there was limited building department data on water heaters; however, the average efficiency of combustion water heaters are similar between both sources in Table 28, whereas the RESNET data represents more heat pump water heaters.

Table 28: Water Heating Efficiency by Fuel – Stretch Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Stretch
Natural Gas (EF)	109	0.93	1	0.94	113	0.93
Propane (EF)	6	0.89	4	0.90	6	0.89
Electric (EF)	35	2.20	2	0.94	37	2.13

Once again, the small sample size for cooling equipment efficiencies (Table 29) precludes in depth comparisons; however, the sample compositions differ. Two of seven building department data points are heat pumps, whereas only three of 106 RESNET sites possessed heat pumps, and another eight used room air conditioners.

Table 29: Cooling Efficiency – Stretch Code Source Comparison

Measure	*n*	RESNET	*n*	BD	*n*	All Stretch
Cooling Equipment (SEER)	106	13.79	7	16.34	113	13.94

3.4 Low-Rise vs. Mid-Rise

This section compares the efficiency data of low-rise (one to three stories) vs. mid-rise (four-story) buildings. As shown in Table 30, the HERS scores are similar for low-rise and mid-rise projects.

Table 30: Average HERS Index – Building Type

Measure	*n*	1–3 Story	*n*	4 Story	*n*	RESNET + BD
HERS Index Rating	168	54.3	26	52.3	194	54.1

The NMR calculated U-factor for above-grade walls is significantly different between low-rise and mid-rise buildings, while the remaining shell measures are largely indistinguishable (Table 31).

Table 31: Average Building Shell – Building Type

Measure	*n*	1–3 Story	*n*	4 Story	*n*	RESNET + BD
Above-Grade Wall U	77	0.076	18	0.071	95	0.075
NMR U-factor	159	0.067*	25	0.047	183	0.064
Frame Floor U-factor	62	0.064	15	0.077	77	0.067
Flat Ceiling U-factor	78	0.036	13	0.043	92	0.037
NMR U-factor	126	0.033	21	0.035	150	0.034
Vaulted Ceiling U-factor	91	0.039	17	0.040	109	0.039
Window U-factor	173	0.284	30	0.279	203	0.283
Window SHGC	170	0.296	29	0.298	199	0.296

* Significantly different at the 90% confidence level.

Air leakage for mid-rise buildings is significantly lower on average than in low-rise buildings (Table 32). One contributing factor could be that mid-rise buildings have fewer surfaces exposed to ambient conditions (i.e., there could be more leakage between units or to conditioned common space as opposed to exterior conditions).

Table 32: Average Air and Duct Leakage – Building Type

Measure	*n*	1–3 Story	*n*	4 Story	*n*	RESNET + BD
Air Leakage (ACH50)	171	3.52*	25	2.66	197	3.40
Duct Leakage to Outside (CFM25/100 ft^2)	158	5.71	27	4.29	185	5.51

* Significantly different at the 90% confidence level.

Low-rise buildings have significantly more efficient natural gas heating equipment than mid-rise buildings, though the difference itself is relatively small (Table 33).

Table 33: Average Heating Efficiency by Fuel – Building Type

Measure	*n*	1–3 Story	*n*	4 Story	*n*	RESNET + BD
Natural Gas (AFUE)	106	95.04*	18	93.14	124	94.77
Propane (AFUE)	4	95.50	2	80.00	6	90.33
Electric (HSPF)	7	8.26	17	3.18	7	8.26

* Significantly different at the 90% confidence level.

Natural gas water heaters appear to be similar in both groups, whereas the sample size of water heaters using other fuels is too small to determine (Table 34).

Table 34: Average Water Heating Efficiency by Fuel – Building Type

Measure	*n*	1–3 Story	*n*	4 Story	*n*	RESNET + BD
Natural Gas (EF)	115	0.93	21	0.94	136	0.93
Propane (EF)	5	0.87	1	0.95	6	0.89
Electric (EF)	37	2.30	3	1.47	40	2.23

There is no detectable difference between the in-unit cooling system efficiencies in low- and mid-rise construction (Table 35).

Table 35: Average Cooling Efficiency – Building Type

Measure	*n*	1–3 Story	*n*	4 Story	*n*	RESNET + BD
Cooling Equipment (SEER)	112	13.94	24	13.30	136	13.83

Appendix A Low-Rise Multifamily User Defined Reference Home

One of the primary goals of the MA20R30 Multifamily Baseline Study was to facilitate a working group to develop a low-rise multifamily (LRMF) User Defined Reference Home (UDRH), if appropriate. The NMR team, representatives from the Program Administrators (PAs), the Energy Efficiency Advisory Council (EEAC), the Residential New Construction (RNC) program implementation team, and from the Home Energy Rating System (HERS) community, met twice to discuss the findings from this study to develop a LRMF UDRH for the RNC program. Specifically, the working group met on October 14, October 19, and December 17, 2021, to work through the 20R30 study results and agree to the parameters of a LRMF UDRH.

This appendix reflects the discussion and decisions that were made as part of the working group calls. The NMR team submitted an interim memo ahead of the working group meetings that detailed the results of this study's data collection and analyses. Specifically, the memo compared non-program RESNET data, building department data, and a combination of the two to the current UDRH specifications based on the 2019 single-family baseline study.[17] As detailed below, the working group agreed to adopt a combination of RESNET and building department documentation as the new UDRH specifications for LRMF projects for most measures. The combination of RESNET and building department data collection provide substantial sample sizes and the best representation of non-program LRMF characteristics for both stretch code and base code municipalities.

A.1 Measure-Level Findings

This section provides detailed measure-level findings for the current UDRH specifications and the proposed new LRMF UDRH specifications. **Please note that the current UDRH specifications are based on single-family baseline study results.[18]**

A.1.1 Shell Measures

The working group agreed to adopt the combination of RESNET and building department data for all shell measures. The new LRMF UDRH specifications for all shell measures are presented in Table 36.

The U-factors for above grade walls and flat ceilings represent the NMR U-factors that were presented in the interim memo. The NMR U-factors were used to increase the sample sizes available for above grade walls and flat ceilings. The values were used to fill in the gaps for building department data where R-value information was available, but U-factor data was not. For

[17] https://ma-eeac.org/wp-content/uploads/MA19X02-B-RNCBL_ResBaselineOverallReport_Final_2020.04.01_v2.pdf
[18] The single-family results have been used as a placeholder for LRMF results to date.

the RESNET data, the NMR U-factor simply represents a U-factor calculation based on the R-values and applicable framing and grade information.

Table 36: Shell Measures

Measure	*n*	Current SF UDRH Specification	*n*	New LRMF UDRH Specification
Above Grade Wall U-factor	100	0.062	183	0.064
Frame Floor U-factor	91	0.052	77	0.067
Flat Ceiling U-factor	73	0.033	147	0.034
Vaulted[+] Ceiling U-factor	61	0.033	108	0.039
Window U-factor	27	0.290	203	0.283
Window SHGC	25	0.350	199	0.296

A.1.2 Air and Duct Leakage

The working group agreed to use the combination of RESNET and building department data for air and duct leakage measures. The new LRMF UDRH specifications for air and duct leakage are presented in Table 37.

Table 37: Air and Duct Leakage

Measure	*n*	Current SF UDRH Specification	*n*	New LRMF UDRH Specification
Air Leakage (ACH50)	99	3.04	197	3.40
Duct Leakage to Outside (CFM25/100 ft^2)	87	3.80	185	5.51

A.1.3 Heating Equipment

The working group had an extensive discussion about which values to adopt for heating equipment. Ultimately, the group agreed to keep the current UDRH specifications for heating equipment. The primary reason for this is that the current UDRH includes a blended electric and propane baseline value for homes that do not have natural gas. The current study sample sizes for electric and propane heating were too small to create a comparable LRMF number using this same approach. As a result, the group agreed to leave all heating equipment set at the current UDRH specifications given the limited sample sizes in this study. While natural gas heating equipment had reasonable sample sizes in this study, the group determined that it was best to maintain consistency across all heating fuel types and therefore natural gas equipment will also continue to use the current UDRH specification. The final agreed upon UDRH specifications for heating equipment are presented in Table 38.

Table 38: Heating System Efficiencies

Measure	Current SF UDRH Specification	New LRMF UDRH Specification
Natural Gas (AFUE)	93.5	93.5
No Natural Gas (AFUE/HSPF)	97.1 AFUE / 9.28 HSPF	97.1 AFUE / 9.28 HSPF

A.1.4 Water Heating Equipment

As was the case with heating equipment, the working group had extensive discussion about water heating equipment. Specifically, the group talked at length about the small sample sizes for propane water heating equipment from the current study and the fact that the study results for electric water heating would essentially eliminate any LRMF projects that use electric resistance water heating from the program.

The working group did not come to a final decision during the two scheduled calls other than to update the natural gas values based on the current study results. The issue of electric and propane water heating was discussed again amongst a smaller group from the PAs, the EEAC, and the evaluation team on a RNC biweekly check-in call on October 28, 2021. During this call, the group continued the conversation around electric water heating – specifically the fact that LRMF projects using electric resistance water heating would be eliminated from the program if the current study results were adopted.[19] The PAs, EEAC, and evaluation team ultimately agreed that LRMF projects using electric water heating (either electric resistance or a heat pump water heater) should be subject to a baseline Energy Factor of 1.0 for the 2022 program year. After the 2022 program year, this baseline assumption should be revisited. A 1.0 Energy Factor for electric water heating will result in a small penalty for LRMF projects that choose to use electric resistance water heating, but the penalty should not be so large as to force them away from participating in the program.

The working group met one last time on December 17, 2021, to discuss propane water heating. The sample sizes for propane were too small in this study to draw any conclusions about what the baseline should be. Given the similarities between propane and natural gas, the group agreed to use the LRMF natural gas Energy Factor for propane water heating moving forward.

The decisions for water heating equipment are presented in Table 39.

[19] During the previous UDRH process for single-family homes the working group had agreed to allow LRMF projects using electric resistance water heating to be compared to an electric resistance water heating baseline in order to remove the penalty associated with electric resistance water heating in LRMF projects. As a result, LRMF projects using electric resistance water heating have not been penalized nor do they generate savings from their water heating decisions.

Table 39: Proposed Water Heating UDRH Specifications[20]

Measure	Current SF UDRH Specification	New LRMF UDRH Specification
Natural Gas (EF)	0.87	0.93
Propane (EF)	If natural gas is available 0.87; if gas is unavailable assume no savings or penalty	0.93
Electric (EF)	Assume no savings or penalty for electric resistance; 0.92 for HPWH	1.0

A.1.4.1 Recirculating Pumps

One item that was discussed during the initial working group meetings was accounting for recirculating pumps as part of the LRMF UDRH. The Regional Technical Forum (RTF) was recommended as a resource for recirculating pumps.[21] After review, the team was unsure how the baseline information within the RTF calculator would be applied to program energy models. The working group met for a third time on December 17, 2021, to discuss recirculating pumps and how to incorporate them into the UDRH. The working group agreed that it is important to account for recirculating pumps in the LRMF UDRH. The group discussed the fact that this evaluation was not able to produce baseline measurements for recirculating pumps due to limitations in the RESNET and building department documentation data. After some discussion, the group agreed to assume an interim baseline of a temperature controlled recirculating pump, with a loop length the same as the rated home, and to use the current RESNET default assumption for pump power of 50 watts for a rated home.[22] Table 40 presents the agreed upon UDRH inputs for recirculating pumps.

Table 40: Recirculating Pumps

UDRH Input	New LRMF UDRH Specification
Pipe insulation	Pipes insulated to R-3 or greater
Control type	Temperature controlled
Loop length	Same as rated home
Branch length	Same as rated home
Pump power	50 W

A.1.5 Cooling Equipment

The working group agreed to use the combination of RESNET and building department data for cooling equipment. The new LRMF UDRH specification is presented in Table 41.

[20] LRMF projects with either propane or electric resistance water heating equipment have had the baseline set to be the same as the rated home for the past year. As previously mentioned, this was primarily done to remove a penalty against projects using electric resistance water heating without giving them any savings credit for that technology decision.
[21] https://rtf.nwcouncil.org/measure/circulator-pumps
[22] Ratings should be modeled with the pump's rated wattage ÷ units served.

Table 41: Cooling Equipment

Measure	*n*	Current SF UDRH Specification	*n*	New LRMF UDRH Specification
Cooling Equipment (SEER)	157	14.9	136	13.8

A.1.6 Measures Not Considered for LRMF UDRH Update

The combination of RESNET and building department data did not allow for the team to update all the current UDRH inputs. Small sample sizes or questionable data limited the team to discussing and updating only the measures listed above. As a result, the team recommends that the program continue using the current UDRH inputs for each of the measures listed in Table 42.

Table 42: Measures to Maintain Current UDRH Specification

Measure	Current SF UDRH Specification
Foundation Walls – Conditioned Basement	R-14.3
Foundation Walls – Unconditioned Basement	R-0.6
Unheated Slab Below Grade – Under Insulation	R-4.7
Unheated Slab Below Grade – Perimeter Insulation	R-2.6
Unheated Slab On-or-Above-Grade – Under Insulation	R-4.9
Unheated Slab On-or-Above-Grade – Perimeter Insulation	R-2.7
Heated Slab – Under Insulation	R-15
Heated Slab – Perimeter Insulation	R-15
Skylights – U-factor	0.48
Skylights - SHGC	0.30
Doors U-factor	Same as rated home
Unconditioned Attic Ducts (Supply Only)	R-6.4
All Unconditioned Ducts Besides Unconditioned Attic Supply	R-5.6

A.1.6.1 Other UDRH Inputs

Table 43 shows other inputs that are currently included in the UDRH. These inputs were not identified as needing an update in this process. and were not discussed by the group.

Table 43: Other Inputs

UDRH Input	Current SF UDRH Specification
Climate Location	Same as Rated home
Thermostats	Set point in rated and design homes set to 72 degrees for heating and 75 degrees for cooling
Mechanical Ventilation	Balanced with RESNET 303.4.1(1) rate, hours, and watt defaults – same as Rated home
Appliances	Same as Rated home
Lighting	Same as Rated home

Appendix B 19R19 Single-Family Non-Participant vs. RESNET Data

This section compares the results of 19R19 single-family non-participant Ekotrope data to the multifamily RESNET data, with the latter shown for both Ekotrope only sites, and for all sites regardless of software used. While measure data should be the same across RESNET accredited software tools, there may be some subtle differences, such as assumptions in the calculation of U-factors from R-values and framing dimensions. Nevertheless, it is well known that the ratings from different packages can differ for the same home. Table 44 presents the HERS ratings from the various studies and software packages.

Table 44: Average HERS Index – 19R19/Ekotrope

Measure	*n*	19R19 SF Ekotrope	*n*	RESNET MF Ekotrope	*n*	RESNET MF Mixed
HERS Index Rating	292	53.5	66	50.9	193	54.0

The 19R19 study reported total insulation R-values for comparison to findings in the body of the 19X02 report, rather than its UDRH appendix. The U-factors for the 19R19 study below have been converted from cavity R-values using typical framing factors for each measure, and the most common (detached home) insulation grade reported in 19R19.

Table 45 suggests above-grade walls in multifamily buildings may have less insulation than observed in the non-participant Ekotrope study, while windows are nearly identical.

Table 45: Average Building Shell – 19R19/Ekotrope

Measure	*n*	19R19 SF Ekotrope	*n*	RESNET MF Ekotrope	*n*	RESNET MF Mixed
Above-Grade Wall U	371	0.058	4	0.029	80	0.079
NMR U-factor			58	0.079	169	0.065
Frame Floor U-factor	203	0.034	10	0.035	70	0.069
Flat Ceiling U-factor	292	0.026	15	0.026	81	0.037
NMR U-factor			34	0.036	136	0.033
Vaulted Ceiling U-factor	171	0.030	2	0.022	105	0.039
Window U-factor	372	0.283	66	0.283	193	0.282
Window SHGC	221	0.278	66	0.295	193	0.295

Table 46 presents the comparison of air and duct leakage results. The Ekotrope comparison shows multifamily housing units have higher duct leakage rates than single-family homes.

Table 46: Average Air and Duct Leakage – 19R19/Ekotrope

Measure	*n*	19R19 SF Ekotrope	*n*	RESNET MF Ekotrope	*n*	RESNET MF Mixed
Air Leakage (ACH50)	374	2.70	66	2.77	193	3.42
Duct Leakage to Outside (CFM25/100 ft^2)	263	3.59	66	4.47	182	5.54

Equipment counts for 19R19 in Table 47 though Table 49 are for individual devices rather than sites. Combustion heating equipment efficiency in the Ekotrope and RESNET are indistinguishable.

Table 47: Average Heating Efficiency by Fuel – 19R19/Ekotrope

Measure	*n*	19R19 SF Ekotrope	*n*	RESNET MF Ekotrope	*n*	RESNET MF Mixed
Combustion (AFUE)	484	94.8	34	94.93	122	94.80
Electric (HSPF)	20	10.7	–	–	7	8.26

Heat pump water heaters appear to be less common in the multifamily RESNET data.

Table 48: Average Water Heating Efficiency by Fuel – 19R19/Ekotrope

Measure	*n*	19R19 SF Ekotrope	*n*	RESNET MF Ekotrope	*n*	RESNET MF Mixed
All fuels (EF)	381	1.52	57	1.37	177	1.23

Central air conditioner efficiencies between the two purchased data sets (Ekotrope and RESNET) are very similar.

Table 49: Average Cooling Efficiency – 19R19/Ekotrope

Measure	*n*	19R19 SF Ekotrope	*n*	RESNET MF Ekotrope	*n*	RESNET MF Mixed
ASHP/MSHP (SEER)	23	19.5	–	–	4	25.53
CAC (SEER)	427	13.8	46	13.62	115	13.73