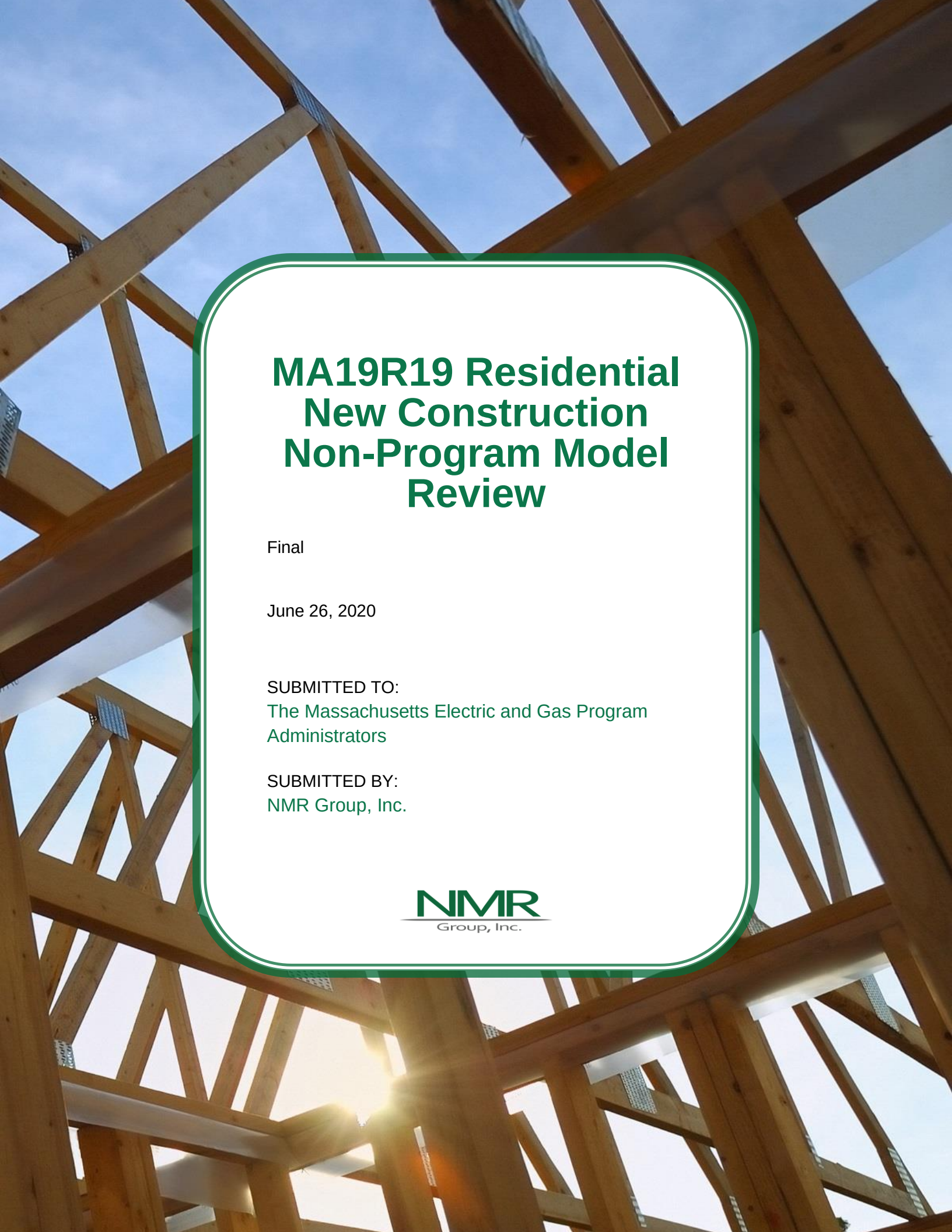

MA19R19 Residential New Construction Non-Program Model Review

Final

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SUBMITTED TO:
The Massachusetts Electric and Gas Program Administrators

SUBMITTED BY:
NMR Group, Inc.

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Executive Summary

The goal of this study is to assess the relative merits of using Home Energy Rating System (HERS) data, obtained from Ekotrope Inc., as an additional data source to inform research on the performance of new homes built outside of the Program Administrators' (PAs') low-rise residential new construction (RNC) program.[1] For the purposes of this report, homes built outside of the RNC program that have had a registered HERS rating and were provided by Ekotrope are referred to as "Ekotrope non-participant" homes. Given the cost and difficulty of collecting data for baseline studies via conventional site visits, alternative methods of data collection, such as registered HERS ratings, could be a valuable source for learning more about how non-program homes are built. These methods might allow for the development of more statistically robust, lower-cost, and/or more frequent updates to the User Defined Reference Home (UDRH), which serves as the RNC program's baseline.

This study answers the following research questions:

- How well do the homes within the Ekotrope non-participant sample compare to homes from the recent MA19X02-B-RNCBL baseline study (referred to as "baseline" homes)?
- What are the strengths and weakness of data from onsite visits vs. Ekotrope HERS ratings?
- What opportunities exist to use Ekotrope HERS rating data to inform baseline studies? How much would these approaches cost?

METHODOLOGY

Our team procured a sample of non-participant energy models submitted to Ekotrope as official HERS ratings – who also warehouses the RNC program energy models – between May 1, 2018 and April 30, 2019. These models exist for stretch code homes due to regulatory requirements, but the reason that ratings in base code communities exist is less clear. Some possible reasons for the creation of base code HERS ratings are listed below:

- Code compliance via the Energy Rating Index (ERI) path
- Use of HERS ratings in marketing materials
- Builder/owner curiosity about home performance
- Upselling efforts by HERS raters since diagnostic testing is already required to meet the base code requirements under any compliance pathway
- As a byproduct of home certification such as ENERGY STAR, a prerequisite for a green mortgage, or as part of an incomplete program application.

[1] Ekotrope is a RESNET certified HERS rating software platform. https://ekotrope.com/home-page/

Our team made statistical comparisons for numerous measures between 292 Ekotrope non-participant energy models of single-family detached homes and the sample of 100 baseline homes that participated in the MA19X02-B-RNCBL study. Based on our research, it is clear that homes in the Ekotrope non-participant sample and those included in the baseline study were constructed in a comparable time frame. This study compared Ekotrope non-participant and baseline study data for all key shell measures, mechanical equipment, lighting, appliances, HERS ratings, and MA-REC compliance. More details on the study methods can be found in Section 1.3.

FINDINGS

- The Ekotrope non-participant sample is heavily weighted towards stretch code communities, with 75% of all Ekotrope non-participant models coming from these municipalities. This is significantly different than the baseline study composition, which sought to achieve an even distribution between stretch code and base code towns (Section 2.1.1).
- MA-REC compliance scores (Section 2.2.1) are significantly different between the Ekotrope non-participant and baseline samples.
- HERS ratings (Section 2.3.1) are not statistically different between the Ekotrope non-participant and baseline samples.
- Propane heating is much more common in the Ekotrope non-participant sample than in the baseline sample (Section 2.1.5).
- Air infiltration is significantly lower in the Ekotrope non-participant sample than in the baseline sample (Section 2.3.2).
- Duct leakage to outside (LTO) is not significantly different between the samples (Section 2.3.8).
- Flat ceilings are more likely to be insulated with cellulose among the Ekotrope non-participant sample (Section 2.3.4).
- Frame floor insulation in the Ekotrope non-participant sample is more than four times as likely to be recorded as Grade I compared to the baseline sample (Section 2.3.6).
- Baseline audits captured freezers, coolers, and secondary refrigerators absent from the Ekotrope non-participant sample, representing an additional 361 kWh/yr per home of electric consumption (Section 2.3.10).
- The cost per site associated with the Ekotrope data is substantially lower than the cost associated with collecting information through typical baseline study onsite inspections (Section 3).

CONCLUSIONS

As noted above, our team identified multiple significant differences between the Ekotrope non-participant and baseline samples in our analyses. There are a few metrics (e.g., MA-REC compliance, air leakage, insulation installation grades) that suggest the Ekotrope non-participant sample is more efficient than the baseline sample. Interestingly, HERS ratings, which assess the overall efficiency of homes, were not significantly different between the samples due to a high degree of variance within the baseline.[2] There were no significant differences between base code and stretch code samples in the MA19X02-B-RNCBL baseline study. However, given that 75% of the Ekotrope non-participant sample is comprised of stretch code homes, it will be important to monitor the difference between base and stretch code requirements and actual construction practices if the Ekotrope data is leveraged to inform baseline studies moving forward.

Based on our analyses and review of the Ekotrope non-participant data, it seems there are pros and cons to both forms of data collection. The non-program models contain data that complement some of the gaps in conventional baseline audits, such as windows and slab insulation. That said, the Ekotrope non-participant sample also lacks common data points collected in baseline studies, such as builder type (custom vs. spec), equipment age, and ENERGY STAR status.

In terms of study costs, the Ekotrope non-participant data offers a larger sample size at a substantially lower cost than typical baseline studies. In addition, the Ekotrope non-participant data includes a sample of multifamily units that the PAs could use to help inform a multifamily-specific baseline in the future.[3]

CONSIDERATION

For future baseline research, the PAs should consider adopting a hybrid approach: incorporating data from non-program HERS-rated homes, evaluator-led energy audits, and other methods as appropriate. The blend of sources in such an evaluation (i.e., HERS rating data vs. evaluator site visits) may differ between building code samples and the design of future evaluations would need to balance considerations about the availability of data and its representativeness. More specifically, it will be important for any future study to acknowledge the potential bias towards high-efficiency homes that could be associated with non-program HERS rating data. The involvement of a HERS rater in the construction process should increase the efficiency of a home due to the HERS rater's expertise and consulting services. Moreover, in base code towns where HERS ratings are not required, the involvement of a HERS rater likely indicates a heightened appreciation of energy efficiency by the builder or the homeowner. That said, a blended approach that is designed to account for bias would likely result in timelier and more robust baseline research at a lower cost than an approach that only consists of evaluator-led energy audits.

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[2] Ekotrope non-participant ratings ranged from 16 to 71, whereas baseline ratings are from -13 to 129. The values differ when excluding the HERS benefits of installed photovoltaics from two baseline and five Ekotrope non-participant homes; however, there is no change in significance.

[3] Analyzing the multifamily data was not within the scope of this study as the primary purpose was to compare the Ekotrope non-participant sample to the baseline sample, which only include single-family homes. A future study could quickly analyze the multifamily sample.

Section 1 Introduction

1.1 Background

The Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) consultants contracted NMR Group, Inc. (NMR) to produce a quick hit assessment of the relative merits of using pre-existing Home Energy Rating System (HERS) rating data to assess the performance of new homes built outside of the PAs' low-rise residential new construction (RNC) program. For the purposes of this report, homes built outside of the RNC program that have had a registered HERS rating and were provided by Ekotrope are referred to as "Ekotrope non-participant" homes. Please note that these homes differ from the sample of non-program homes that participated in the MA19X02-B-RNCBL baseline study. That sample of homes was drawn from all non-program homes independent of whether or not they had a HERS rating. Homes from the baseline study will be referred to as "baseline" homes.

The PAs operate a low-rise RNC program that incentivizes energy-efficient design and construction. The PAs periodically conduct baseline studies to determine how new homes outside of the program are built so that program homes are compared to a contemporary baseline. These studies typically involve detailed onsite data collection at the measure level (as was the case with the recent MA19X02-B-RNCBL Residential New Construction Compliance/Baseline Study). Currently, 278 Massachusetts municipalities (79% of the state and 86% of the population) have adopted the stretch code.[4] The stretch code is an enhanced version of the base energy code that is currently based on the 2018 International Energy Conservation Code (IECC). All homes built under the stretch code must obtain HERS ratings as part of the code compliance process, and homes built under the base code may comply with code via the Energy Rating Index (ERI), a HERS rating-analogous performance path. Consequently, many new homes in Massachusetts have HERS ratings conducted as a matter of course, even if they did not participate in the PA's RNC program.

Given the relative cost and difficulty of collecting data for baseline studies via conventional site visits, existing Ekotrope non-participant data could be a valuable source for learning more about how non-program homes are built. This new data source might allow for the development of more statistically robust, lower-cost, and/or more frequent updates to the User Defined Reference Home (UDRH), which serves as the RNC program's baseline.

[4] https://www.mass.gov/files/documents/2019/11/14/stretch-code-towns-adoption-by-community-map-and-list.pdf

1.2 RESEARCH QUESTIONS

The study seeks to address the following questions:

- How well do the homes within the Ekotrope non-participant sample represent the general population of non-program homes in Massachusetts?
- How do the data within the Ekotrope non-participant energy models compare to the data collected in the MA19X02-B-RNCBL baseline study onsite visits?
- What are the strengths and weakness of data from onsite visits vs. third-party ratings?
  - What are the potential sources of bias in the data?
  - What data collection points are more-or-less reliable in one method vs. the other?
  - What information is gathered in one method but not the other?
- What opportunities exist to use the Ekotrope non-participant rating data to inform baseline studies, and how much would these approaches cost?

1.3 METHODS

NMR purchased a sample of 870 anonymized registered HERS rating energy models for the same time frame as the baseline sample, May 1, 2018 to April 30, 2019,[5] from Ekotrope, the software company that is currently used to run all low-rise RNC program HERS ratings.[6] After receiving the data, our team worked to ensure program participant and baseline sample sites were excluded before the analysis of Ekotrope non-participant homes commenced. Specifically, we worked to ensure that any homes that participated in the RNC program or our baseline study were excluded from this analysis in order to avoid double-counting or comparing a house to itself. However, the overlap between the samples of HERS ratings from both sources is included as Figure 4 in the next section. Ultimately, we identified and excluded three program homes, two baseline study homes, and hundreds of multifamily units, yielding a sample of 373 homes. This study focused on single-family homes to ensure a reasonable comparison between the Ekotrope non-participant sample and the baseline sample.

Before beginning our analysis, we segmented the sample by building code (i.e., base code vs. stretch code). Our team made preliminary efforts using ZIP Codes, the sole geographic identifier in the anonymized data. We found that many ZIP Codes span multiple municipalities, which resulted in inaccurate results. An example of the disparities that can arise from ZIP Code and municipality-based building code determination can be seen in Table 3. To improve the analysis, the team provided Ekotrope a look-up table of city, town, village and neighborhood names, along with the building code in effect in these locales during the pertinent time frame, so that they could correctly classify homes. This resulted in a change in building code classification for approximately 30% of the Ekotrope non-participant sample versus assignment by ZIP Code.

[5] Registered HERS ratings submitted and approved between May of 2018 and April of 2019 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.
[6] As of May 2018, low-rise RNC program home energy models are processed with Ekotrope (https://ekotrope.com).

Finally, our team compared individual measures of the Ekotrope non-participant homes to the results for the matching code in the 2019 Residential New Construction Compliance/Baseline Study (MA19X02-B-RNCBL). The baseline study consisted of 100 on-site inspections of non-program single-family homes permitted between 2017 and 2019, including 51 homes built under the base code and 49 homes built under the stretch code. Inspections of these homes included full HERS ratings, conducted between June and October of 2019.

Section 2 Analysis

This section includes comparisons of standard baseline reporting metrics for multiple measures across the baseline and Ekotrope non-participant samples, as well as a comparison of sample composition. Although our team discovered multiple significant differences, there are several similarities between the samples (such as square footage).

It should be noted that the Ekotrope non-participant sample is comprised entirely of homes that received a HERS rating, while the baseline study sample included only a handful of homes that we know received a HERS rating. HERS raters theoretically enhance the efficiency of new homes by providing energy-efficiency consulting services to builders. As such, there may be a bias towards higher-efficiency construction in the Ekotrope non-participant sample. The HERS-rated Ekotrope non-participant data exists for stretch code homes due to regulatory requirements, but the reason that ratings in base code communities exist is less clear. Some possible reasons for the creation of base code HERS ratings are listed below:

- Code compliance via the Energy Rating Index (ERI) path
- Use of HERS ratings in home marketing materials
- Builder/owner curiosity about home performance
- Upselling efforts by HERS raters since diagnostic testing is already required to meet the base code requirements under any compliance pathway
- As a byproduct of home certification such as ENERGY STAR, a prerequisite for a green mortgage, or as part of an incomplete program application.

Key Findings

- The Ekotrope non-participant sample is heavily weighted towards stretch code communities, with 75% of all Ekotrope non-participant models coming from these municipalities. This is significantly different than the baseline study composition, which sought to achieve an even distribution between stretch code and base code towns (Table 1).
- MA-REC compliance scores (Section 2.2.1) are significantly different between the Ekotrope non-participant and baseline samples.
- HERS ratings (Section 2.3.1) are not statistically different between the samples.
- The ratio of attached to detached homes is higher among Ekotrope non-participant homes than the baseline (Section 2.1.4).
- Except for a dearth of homes in Barnstable county, Ekotrope non-participant sample homes are well-distributed across the state (Section 2.1.3).
- Propane is the predominant heating fuel in base code Ekotrope non-participant homes (94%), but is used in less than one-half of baseline homes (Section 2.1.5).

- Air infiltration is significantly lower in the Ekotrope non-participant sample than in the baseline sample (Section 2.3.2).
- Duct leakage to outside (LTO) is not significantly different between the samples (Section 2.3.8).
- Flat ceilings are more likely to be insulated with cellulose among Ekotrope non-participant homes than baseline homes (Section 2.3.4).
- Frame floor insulation in Ekotrope non-participant homes is more than four times as likely to be recorded as Grade I than in baseline homes (Section 2.3.6).
- Baseline audits captured freezers, coolers, and secondary refrigerators that are absent from the Ekotrope non-participant sample and represent an additional 361 kWh/yr per home of electric consumption (Section 2.3.10).
- Central air-conditioner SEER was significantly lower (0.6 points) in Ekotrope non-participant stretch code homes compared to baseline stretch code homes (Table 7).

2.1 SAMPLE COMPARISON

Our team drew the baseline sample from single-family homes with permit dates between January 2017 and July 2018, while the Ekotrope non-participant sample consists of all HERS ratings for single-family homes from Ekotrope that would have been constructed during a similar time frame – those that were registered between May 2018 and April 2019.

2.1.1 Composition

Stretch code represents a disproportionate and significantly different number of homes within the Ekotrope non-participant sample in Table 1 because every stretch code home must receive a HERS rating. The Ekotrope non-participant data represents 54% of non-program homes in stretch code communities and 6% of non-program homes in base code communities.[7] Overall, the Ekotrope non-participant data captured 17% of non-program new construction for the sampled period, while the baseline captured 5%.

Table 1: Single-family New Construction Permits and Sample Composition

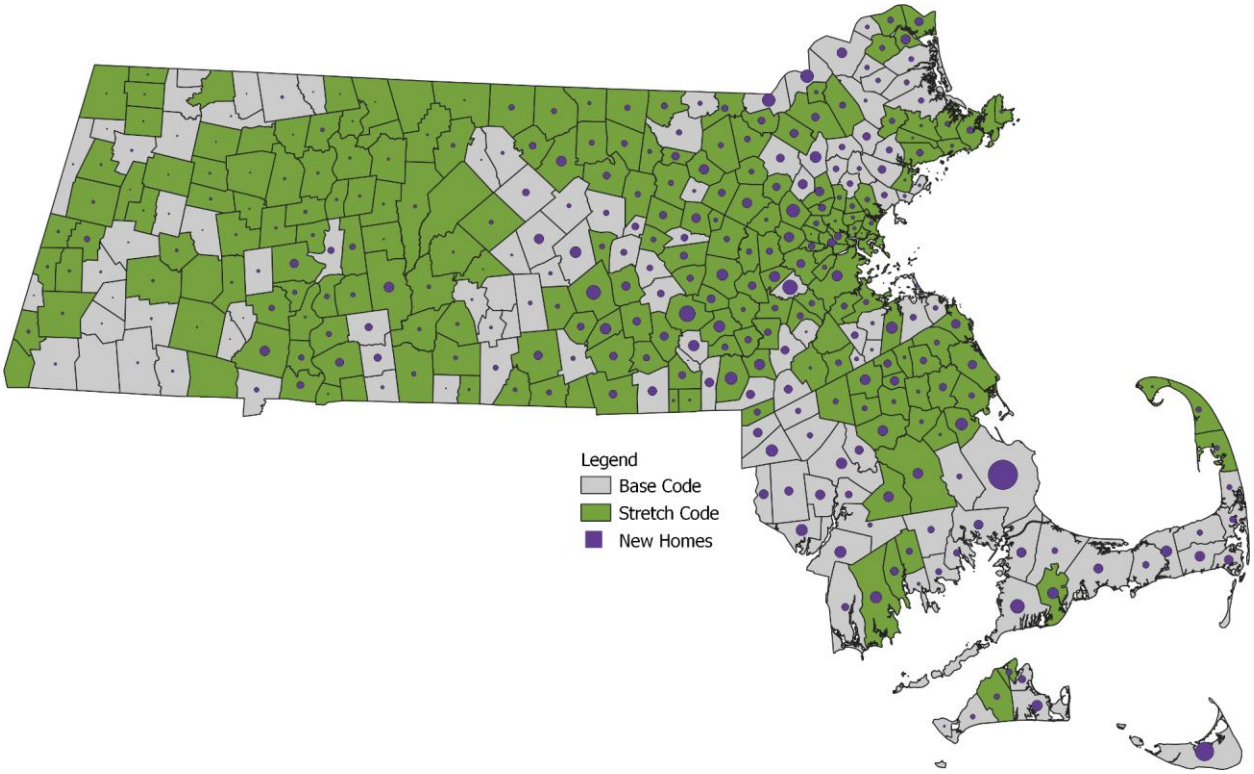
	Base	Stretch	Statewide	Base	Stretch	Statewide
Permits[a]	3,282	3,942	7,224	45%	55%	100%
Program	1,650	3,423	5,073	33%	67%	70%
Non-program	1,632	519	2,151	76%	24%	30%
Baseline	51	49	100	51%†	49%†	1%
Ekotrope Non-part.	93	280	373	25%	75%	5%

a. Permit counts are from the baseline study (MA19X02-B-RNCBL) and are the average of Census Bureau annual data for 2017 and 2018. These homes were constructed in 95% of communities.
† Significantly different from matching Ekotrope non-participant code at the 90% confidence interval.

[7] While all stretch code homes must receive a HERS rating, other software packages beyond Ekotrope, such as REM/Rate, can be used to display compliance. Presumably other software packages make up the remaining 46% of non-program homes in stretch code communities.

Figure 1 shows the relative rate of single-family new construction permits from 2017 and 2018 by municipality. The municipalities are color coded based on whether projects are required to follow stretch code or base code requirements, and the circles are scaled based on the number of permits issued. Please note that this map represents the status of each community at the time these permits were filed. The stretch code designations in many communities has changed in the interim.

Figure 1: Average New Construction by Community in 2017 and 2018



When baseline studies include building department visits to collect construction documentation, our team makes efforts to limit the site visit sample to one home per builder. In the absence of this step, only one home per development is permitted within the sample to avoid over-representation of a single builder's practices. Similar constraints are possible for the anonymized data in the Ekotrope non-participant sample by selecting a single random site per builder; although we did not apply any such limitations for this analysis. While the baseline study limits site visits to one home per development, the weighting scheme that is used to scale the results reflects the mix of custom vs. spec homes that exist throughout the state. This weighting scheme accounts for the fact that there are more spec homes than custom homes statewide and adjusts the results to reflect the existence of developments where numerous homes with comparable designs and efficiencies are built by one builder. As a result, leaving multiple homes per builder in the Ekotrope non-participant sample creates a reasonable comparison to the baseline study results.

Statistics on the number of homes per builder/development project and rater are included in Table 2. Raters are included since rater practices vary and if a majority of the ratings were conducted by a small number of raters it could skew the data in a manner similar to the over-representation of a builder.

Table 2: Homes per Builder and Rater – Ekotrope Non-participant vs. Baseline

	Ekotrope Non-participant		Baseline	
	Builders	Raters	Projects	Raters
n	*199*	*41*	*100*	*8*
Homes	373		100	
Mode	1	1	1	–
Mean	1.9	9.1	1	12.5
Max	29	55	1	25

2.1.2 Household Income

Table 3 shows the average median household income for different segments in Massachusetts; that is, the average of the median income per ZIP Code tabulation area (ZCTA) or municipality within the segment weighted by the number of households per ZCTA/municipality. It also includes the average home valuation and an average median income weighted by the number of 2018 single-family housing starts per municipality. This analysis suggests that new construction, the baseline report, and the Ekotrope non-participant sample tend to be located in communities with higher average median income than the state as a whole. However, the average median income of Ekotrope non-participant stretch code households and base code households calculated per municipality are slightly lower than the corresponding average median income in municipalities with new home construction.

Table 3: Average Median Household Income[8,9]

	ZCTA		Municipal	
	Base	Stretch	Base	Stretch
Massachusetts	$84,149	$82,169	$84,836	$81,301
Ekotrope Non-participant	$96,311[a]	$96,234[a]	$96,282	$94,741
Baseline	$90,567	$102,397	$89,829	$103,422
New Homes[b]	–	–	$90,201	$100,395
Average New Home Valuation	–	–	$336,551	$340,494

[a] An approximation since code is set at the municipal level and some ZIP Codes span multiple cities and towns. In fact, assigning building code via ZIP Code results in misclassification of 30% of Ekotrope non-participant homes.

[b] This only represents municipalities that had new building permits in 2018.

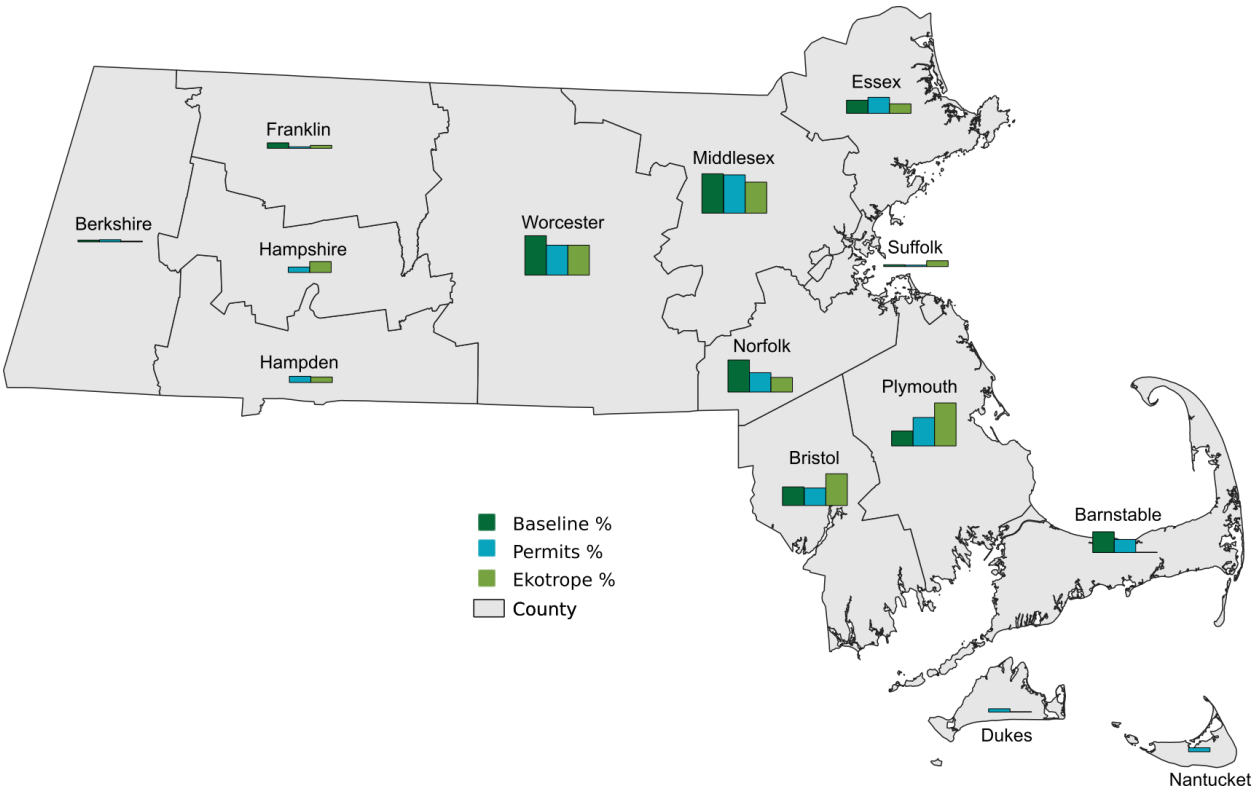
[8] U.S. Census Bureau, Income in the Past 12 Months (in 2018 Inflation-Adjusted Dollars) – 2018 American Community Survey 5-Year Average Estimates (S1901). (Accessed January 8, 2020).

[9] U.S. Census Bureau, Building Permits Survey, https://www2.census.gov/econ/bps/Place/Northeast%20Region/ne2018a.txt (Accessed January 16, 2020).

2.1.3 Geographic Distribution

The Ekotrope non-participant sample includes homes within every mainland county and a single site in Dukes county. In several instances, the proportion of homes per county within the 2019 baseline and Ekotrope non-participant samples differ from the population of new homes, as shown in Figure 2, but the differences are generally within the bounds of what can be reasonably rectified by weighting.[10]

Figure 2: 2019 New Construction Proportions by County and Climate



[10] Exceptions included Nantucket, which is absent from both samples; other unsampled counties within the baseline study (Hampshire, Hampden, and Dukes); and Barnstable county for the Ekotrope non-participant data. The lone Ekotrope non-participant site in Barnstable would need to be weighted 25.7 to 1 to be representative of the county.

2.1.4 Home Style

Census permit data do not clearly delineate attached and detached homes. In the absence of population statistics, Table 4 instead draws upon the RNC program data for comparison. The proportion of attached homes in the Ekotrope non-participant data is closer to that of program homes than the 2019 baseline report, but Table 6 shows that attached and detached homes are of similar construction, except for size, air leakage, and vaulted ceiling insulation. The similarity between attached and detached homes was observed previously, as noted in the 2011 and 2015 baselines.[11,12] The 2015 study also noted that a high percentage of attached homes participated in the RNC program.

Table 4: Percentage of Attached Homes

	Ekotrope Non-participant	Baseline	Program
Attached Homes	22%	5%†	30%

† Significantly different from Ekotrope non-participant at the 90% confidence interval.

2.1.5 Heating Fuel

There are a number of significant differences in the proportions of primary heating fuel both within the Ekotrope non-participant sample by code, and in comparison to the baseline (Table 5). Notably, almost all of the Ekotrope non-participant base code homes are recorded as propane-heated homes, which is corroborated by the hot water heater fuel of these homes: propane or electricity.

Table 5: Primary Heating Fuel

Fuel	Ekotrope Non-participant (Detached Homes)		Baseline	
	Base	Stretch	Base	Stretch
n	*78*	*213*	*51*	*49*
Propane	94%*	52%	35%†	51%
Natural Gas	6%*	41%	53%†	27%†
Electric	0%*	5%	12%†	22%†
Oil	0%	1%	0%	0%

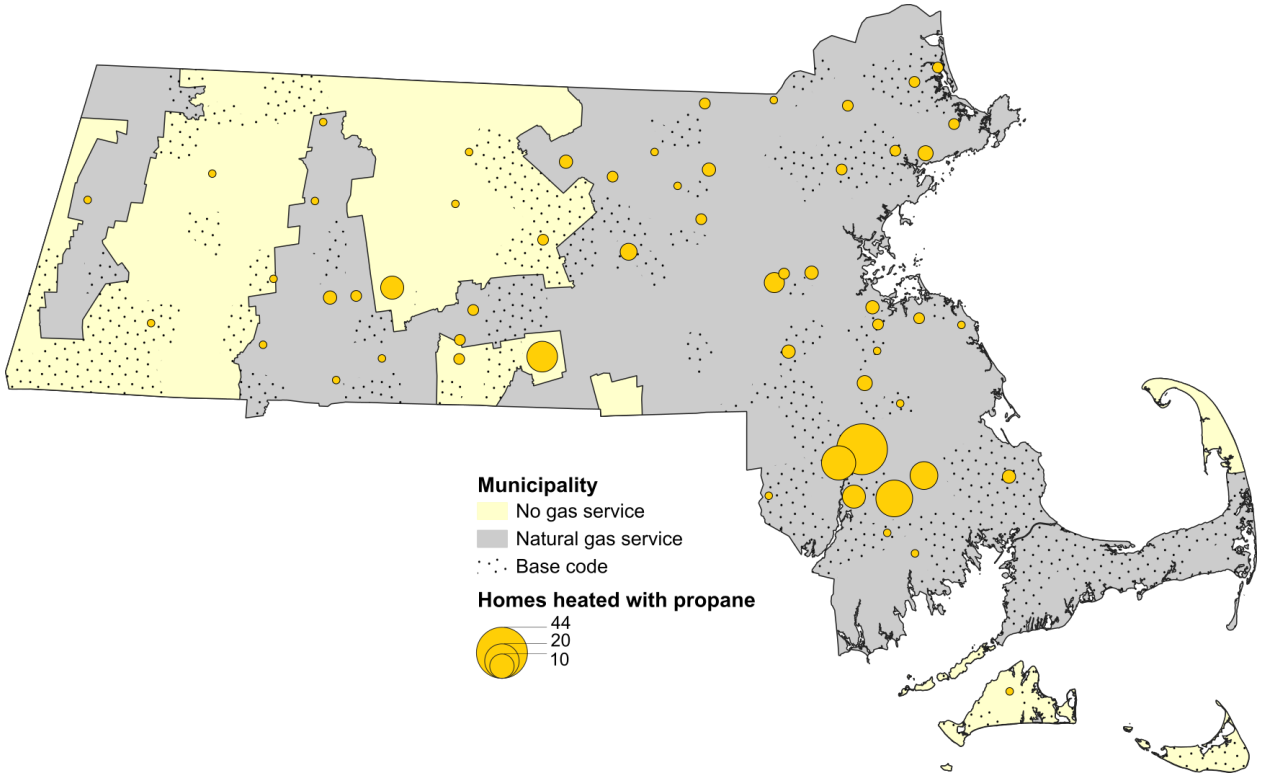
* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

[11]NMR Group, Massachusetts 2011 Baseline Study of Single-family Residential New Construction, (August 16, 2012), http://ma-eeac.org/wordpress/wp-content/uploads/Massachusetts-2011-Baseline-Study-of-Single-Family-Residential-New-Contruction-Final-Report.pdf

[12] NMR Group, 2015-16 Massachusetts Single-Family Code Compliance/Baseline Study: Volumes 1 & 2, (August 30, 2016), http://ma-eeac.org/wordpress/wp-content/uploads/Single-Family-Code-Compliance-Baseline-Study-Volume-1.pdf#page=12 http://ma-eeac.org/wordpress/wp-content/uploads/Single-Family-Code-Compliance-Baseline-Study-Volume-2.pdf#page=16

Figure 3 shows the geographic distribution of Ekotrope non-participant homes heated with propane (by ZCTA) vs. building code and the municipal-level availability of natural gas. This reveals that many of the Ekotrope non-participant base code homes recorded as propane heat were constructed in municipalities with natural gas service – particularly Raynham (44), Taunton (20), and Berkley (9) – although it is possible that gas was simply not available in some neighborhoods.

Figure 3: Ekotrope Non-participant Propane Heating vs. Natural Gas Service and Code



2.2 AVERAGE HOME OVERVIEW

The average values for key metrics among Ekotrope non-participant homes are shown in Table 6. Detached and attached homes are similar overall, with only a few statistically different details.

Due to the low representation of attached homes in the baseline study (Table 4) and the overall similarity between detached and attached homes in the Ekotrope non-participant sample (Table 6), we limit further comparisons between the baseline and Ekotrope non-participant sample to detached Ekotrope non-participant homes. Table 7 compares the same set of key values as above for both samples, split by building code.

Table 6: Average Ekotrope Non-participant Home by Style

Measure	Detached	Attached	Combined
Homes, see Counts button below	291	81	372
HERS Index	53.5	54.2	53.7
Conditioned Floor Area (CFA) ft2	2,868*	1,724	2,621
Building Shell			
Air Leakage ACH50	2.5*	3.2	2.7
Ambient Wall R-value	21.1	21.4	21.2
Window U-factor	0.28*	0.29	0.28
Flat Ceiling R-value	46.7*	45.9	46.6
Sealed Attic/Vaulted Ceiling R-value	40.4*	37.2	39.5
Frame Floor R-value	29.6*	29.7	29.6
Conditioned foundation wall R-value	14.00	14.8	14.1
Mechanical Equipment			
Duct LTO CFM25/100 ft2 CFA	4.14*	2.23	3.59
Heating System AFUE	94.8	94.8	94.8
Heat Pump HSPF	10.8	9.9	10.7
ASHP/MSHP SEER	19.8	16.5	19.5
CAC SEER	13.8	13.6	13.8
Water Heater EF	1.49	1.62	1.52
Lighting and Appliances			
Dishwasher kWh/yr	269.4	266.9	268.9
Refrigerator kWh/yr	684.8	640	676.5
Clothes Washer IMEF	2.63	2.58	2.66
Clothes Dryer EF	3.57*	3.47	3.55
Electric Clothes Dryer %	90.1	84.0	89
Electric Cooking %	25.3	30.8	27
Interior Efficient Lighting %	96.8	98.1	97.1
Garage Efficient Lighting %	90.0	86.4	89.2
Exterior Efficient Lighting %	96.0	96.3	96.1

* Significantly different from attached at the 90% confidence interval.

Counts ►

While there are significant differences between ambient walls and ceiling R-values for some segments, because of the reciprocal relationship between R-value and heat flow, the actual impacts are less than 8% of the heating and cooling loads for those measures.

Table 7: Average Home – Detached Ekotrope Non-participant vs. Baseline by Code

	Ekotrope Non-participant		Baseline	
Measure	**Base**	**Stretch**	**Base**	**Stretch**
Homes, see Counts button below	79	212	51	49
HERS Index	55.4*	52.8	55.5	53.7
Conditioned Floor Area (CFA) ft^2	2,557*	2,976	2,883	3,045
MA-REC %	99.3	98.4	86.7	89.0
Building Shell				
Air Leakage ACH50	2.5	2.6	3.2†	3.0†
Ambient Wall R-value	20.5*	21.3	21.9†	21.8
Window U-factor	0.29*	0.28	0.30	0.28
Flat Ceiling R-value	47.7	46.2	44.0	45.2
Sealed Attic/Vaulted R-value	41.2	40.2	40.5	43.7†
Frame Floor R-value	29.7	29.6	31.1	29.2
Cond. foundation wall R-value	13.6	14.11	16.2	13.6
Mechanical Equipment				
Duct LTO CFM25/100 ft2 CFA	4.22	3.54	5.0	3.9
Combustion Heating AFUE	94.3*	95.1	94.3	94.1†
Heat Pump HSPF	11.0	11.0	10.3	10.7
ASHP/MSHP SEER	18.0a	19.9	19.1	19.3
CAC SEER	14.2*	13.6	14.1	14.2†
Water Heater EF	1.48	1.49	1.21	1.40
Lighting and Appliances				
Dishwasher kWh/yr	270.7	268.9	264.1†	265.2†
Refrigerator kWh/yr	683	689.8	646.3†	653.0†
~ Freezers and Coolers kWh/yr	–	–	931.2	1,094.9
Clothes Washer IMEF	2.69	2.61	2.47	2.37†
Clothes Dryer EF	3.26*	3.67	3.28	3.26†
Electric Dryer %	96.2	87.8	78†	85
Electric Range %	15.2	29.1	13	25
Interior Efficient Lighting %	98.6	96.1	93.6	93.6
Garage Efficient Lighting %	95.5*	88.0	86.9†	91.6
Exterior Efficient Lighting %	98.0	95.2	85.3†	89.1†

a. Only one home in this category; therefore, no test for significance.

* Significantly different from Ekotrope non-part. stretch code at 90% confidence interval.

† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

Counts ►

2.2.1 MA-REC

MA-REC is a methodology for measuring code compliance that our team developed for the 2015 Massachusetts Baseline and Code Compliance Study.[13] A score of 100% for a measure indicates equivalent performance to a prescriptive code compliant home. Weighting the Ekotrope non-participant sample by code (0.4805 for stretch code and 2.3941 for base code) yields the modeled code compliance results in Table 8,[14] which shows that the baseline and Ekotrope non-participant samples are significantly different in terms of overall compliance and for each measure included in the MA-REC methodology.

Table 8: MA-REC – Detached Ekotrope Non-participant vs. Baseline by Code

Measure	Ekotrope Non-participant		Baseline	
	Mean	Std. Dev.	Mean	Std. Dev.
n	*291*		*100*	
Fenestration U-factor	99.0%	4.2%	87.7%†	14.8%
Above Grade Wall Insulation	99.4%	3.8%	94.9%†	12.3%
Air Leakage	98.7%	6.8%	87.6%†	19.8%
Ceiling Insulation	99.3%	3.7%	86.6%†	20.1%
Frame Floor Insulation	97.4%	9.0%	86.7%†	19.4%
Foundation Wall Insulation	98.3%	7.2%	95.5%†	14.3%
Slab Insulation	98.8%	5.0%	97.4%†	6.5%
Overall	**99.0%**	**3.1%**	**89.9%†**	**10.8%**

† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

Measure weights for overall compliance scores are available in Table 29.

[13] Methodology available in: NMR, "2015 Single-Family Stretch Code Update Compliance and Potential" (May 2017) http://ma-eeac.org/wordpress/wp-content/uploads/Single-Family-Stretch-Code-Update-Compliance-and-Potential.pdf

[14] The Ekotrope non-participant sample is weighted, so that the statewide summary values would represent the same 50:50 mix of stretch code and base code as the baseline.

2.3 SELECT IN-DEPTH MEASURES

In this section, we compare the efficiencies for select measures between the Ekotrope non-participant and baseline samples. The comparisons here are limited to those with statistical differences or those that were of particular interest in the final work plan.

2.3.1 HERS Ratings

Table 9 features summary statistics for HERS ratings of both samples. While the means do not differ significantly from each other due to the high degree of variance for baseline homes, the medians are significantly different. Disparities in HERS ratings are a result of the cumulative effect of any differences in rated performance across all measures. Other factors that could contribute to differences between baseline and Ekotrope non-participant HERS ratings include the proportion of custom homes (which is only known for the baseline) and rater practices for classification of basements. Although basements are frequently presented in a binary conditioned/unconditioned manner, they exist on a spectrum between these two extremes. Furthermore, delineation between conditioned, unconditioned, and a third category of "partially conditioned" or "conditioned volume only" can be subjective,[15] yet this classification impacts the calculations of conditioned floor area, internal heat gains from equipment, and more.

Table 9: HERS Ratings – Detached Ekotrope Non-participant vs. Baseline by Code

	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*79*	*213*	*51*	*49*
Minimum	40	16	-3	-13
Mean	55.4	52.8	55.5	53.7
Median	53.5	54	59†	55†
Maximum	71	70	97	129
Standard Deviation	4.3	5.0	19.3	22.3

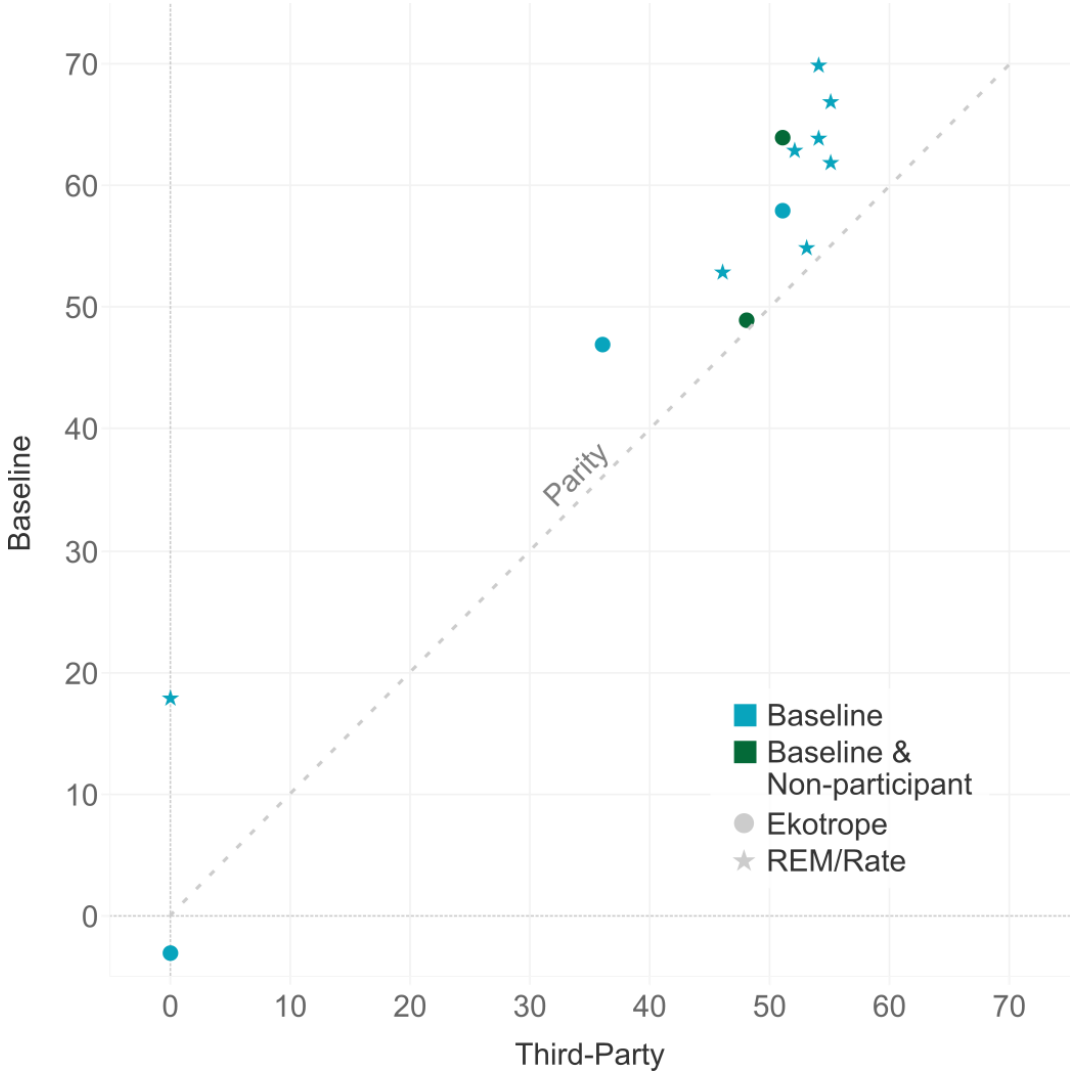
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

[15] For example, there is evidence that a site excluded from the Ekotrope non-participant sample was visited as part of the baseline. One auditor classified the basement as fully conditioned, while another auditor classified it as partially conditioned.

Figure 4 compares baseline HERS ratings to third-party ratings for a dozen homes, including two homes (in green) that were in the initial sample provided by Ekotrope. Ratings for the remaining homes (in blue) are from documentation found on site, except for the home with a third-party rating of 0, which was advertised on a real estate website as net-zero and is shown with both REM/Rate and Ekotrope baseline scores since it is not clear which software was used by the builder. Many factors could contribute to the 8.8-point higher average score of baseline ratings, but three differences between the two ratings that are likely to play a role are:

1. Difficulty assessing grade of above grade walls in post-occupancy evaluator ratings (Section 2.3.3)
2. Difficulty determining window properties during baselines audits without National Fenestration Rating Council labeling, and subsequent use of default values (Section 2.3.7)
3. Higher post-occupancy plug-loads from additional major appliances (Section 2.3.10)

Figure 4: Third-party HERS Ratings vs. Baseline HERS Ratings



2.3.2 Infiltration

Ekotrope non-participant homes have significantly lower air leakage than the baseline sample, and the average Ekotrope non-participant base code home complies with air leakage requirements (3 ACH50), unlike those in the baseline. Some possible sources of the disparity include (1) differing prevalence of conditioned basements and (2) the inconsistent application of the air density adjustments adopted by RESNET in July 2018, which account for the impact of temperature and altitude on equipment readings.[16]

Table 10: Air Leakage – Detached Ekotrope Non-participant vs. Baseline by Code

ACH50	Ekotrope Non-Participant		Baseline	
	Base	Stretch	Base	Stretch
n	*79*	*213*	*51*	*49*
Minimum	0.8	0.6	0.7	0.9
Mean	2.5	2.0	3.2†	3.0†
Maximum	4.2	9.5	8.8	6.5
Standard Deviation	0.5	2.1	1.8	1.4

† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

2.3.3 Ambient Wall

There is a small but statistically significant difference in the average R-value of ambient walls between samples for base code homes; however, the Ekotrope non-participant sample includes at least two log cabin homes that have depressed the minimum and average R-values of the sample. The significance persists for the slightly higher average value of R-20.7 when the identifiable base code log cabin home is excluded; the minimum increases to R-19.3. The stretch code minimum increases to R-15.0 and its average is unaffected when excluding the other log cabin home.

Table 11: Ambient Wall R-value – Detached Ekotrope Non-participant vs. Baseline by Code

R-value	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*79*	*212*	*51*	*49*
Minimum	7.4[a]	12.2[a]	17.0	19.0
Mean	20.5*	21.3	21.9†	21.8
Maximum	24.0	46.0	33.9	42.0
Standard Deviation	1.6	2.9	3.7	3.7

[a] These minima appear to be from log cabins, which have different code requirements.
* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

[16] RESNET, "ANSI/RESNET/ICC 380 Blower Door Test Correction Calculations", (July 24, 2018), http://www.resnet.us/wp-content/uploads/archive/resblog/2018/07/Blower-Door-Test-Correction-Calculation-Procedures_rev051.pdf

Due to the difficulties inherent in observing installation grade once insulation has been sealed behind drywall or plaster, our team employs a default assumption of Grade II installation for post-occupancy audits of new construction in the absence of other evidence. This assumption likely accounts for the significant differences in Grade I and Grade II insulation in Table 12. There are also significant differences in continuous insulation between the two samples, which are unaffected by cavity grade assumptions.

Table 12: Dominant Ambient Wall Ins. Cavity Grade and Continuous Ins. Penetration

	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*79*	*211*	*51*	*49*
Grade 1	84%*	69%	37%†	41%†
Grade 2	5%*	14%	55%†	55%†
Grade 3	10%	16%	0%†	4%†
Continuous only	1%	1%	8%†	0%
Majority of walls have cont. ins.	1%	6%	16%†	6%

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

2.3.4 Flat Attic

Although one might expect the difference in average flat attic R-values for base code homes between samples to be statistically significant, this is not the case due to dissimilar variance. Furthermore, the baseline average is depressed due to a home with a sealed attic that was compromised during the installation of a non-condensing furnace, resulting in a rated value of R-0. Excluding this outlier, the minimum base code baseline is R-29. Similarly, the minimum Ekotrope non-participant stretch code R-value may represent a data-entry error and would otherwise be R-29.

Table 13: Flat Attic R-value – Detached Ekotrope Non-participant vs. Baseline by Code

R-value	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*71*	*167*	*38*	*35*
Minimum	34.1	19.6[a]	0.0[b]	30.0
Mean	47.7	46.2	44.0	45.2
Maximum	61.2	65.7	66.6	69.3
Standard Deviation	4.77	6.8	11.4	9.9

a. This appears to be due to an errant entry at a site where one portion of the roof has a description of R-49 but is entered as R-13.3. The next smallest R-value for a home is R-29.
b. This is the home mentioned above with a sealed attic that was compromised to provide combustion supply air for a furnace. The next smallest R-value for a home is R-29.4.

Post-occupancy observation of flat attic insulation grade is usually straightforward and, unlike ambient walls, requires no assumptions. Nevertheless, significant differences exist between the samples in the prevalence of each grade, as well as the presence of continuous insulation. This is likely because only 8% of Ekotrope non-participant flat attic area was insulated with batt insulation, whereas 33% of flat attics in baseline homes were predominantly insulated with batts.

Table 14: Dominant Flat Ceiling Cavity Ins. Grade and Continuous Ins. Penetration

	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*71*	*166*	*38*	*35*
Grade 1	100%*	87%	61%†	49%†
Grade 2	0%*	10%	29%†	40%†
Grade 3	0%	2%	8%†	11%†
Continuous only	0%	1%	3%	0%
Majority of ceilings have cont. ins.	96%	89%	53%†	74%†

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

2.3.5 Vaulted Ceiling

Vaulted ceiling R-values in Ekotrope non-participant stretch code homes were significantly lower than in the baseline, due in part to smaller features, such as attic bump-outs.

Table 15: Vaulted R-value – Detached Ekotrope Non-participant vs. Baseline by Code

R-value	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*24*	*100*	*30*	*31*
Minimum	30.5	13.0[a]	19.0	25.4
Mean	41.2	40.2	40.7	43.7†
Maximum	53.6	72.0	69.0	73.5
Standard Deviation	6.3	7.4	9.1	10.3

[a] This is the ceiling over a basement bump-out.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

Vaulted ceilings in baseline homes were significantly more likely to be rated Grade II than Ekotrope non-participant homes. In addition, base code baseline homes were more likely to have continuous insulation than Ekotrope non-participant base code homes.

Table 16: Dominant Vaulted Ceiling Cavity Grade and Continuous Ins. Penetration

	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*24*	*99*	*30*	*31*
Grade 1	83%	84%	73%	71%
Grade 2	4%	8%	20%†	19%†
Grade 3	13%	8%	0%†	10%
Continuous only	0%*	0%	7%	0%
Majority of ceilings have cont. ins.	29%	35%	50%†	39%

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

2.3.6 Frame Floor

Raters of Ekotrope non-participant homes were significantly more likely to input frame floor insulation as Grade I, whereas the baseline sample is primarily Grade II and Grade III. Given the installation practices regarding insulation, ductwork, and plumbing observed in the baseline, the level of Grade I installations in the Ekotrope non-participant data would require major differences in practice by these contractors compared to baseline builders.

Table 17: Dominant Frame Floor Cavity Grade

	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*61*	*111*	*40*	*29*
Grade 1	97%*	70%	12%†	3%†
Grade 2	2%*	19%	48%†	48%†
Grade 3	2%*	11%	38%†	45%†
Uninsulated	0%	0%	2%	3%

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

2.3.7 Windows

It is difficult to obtain window details, such as U-factor and Solar Heat Gain Coefficient (SHGC), during post-occupancy baseline visits since homeowners typically remove manufacturers' specification stickers and few homeowners have copies of blueprints with window schedules. Baseline study auditors were only able to confirm the window properties for fewer than 250 windows across 25 homes, with an average U-factor of 0.29. However, most new construction HERS ratings take place pre-occupancy, permitting more in-depth collection of this information.

Figure 5: Area-weighted Average Ekotrope Non-participant Window Values per Home

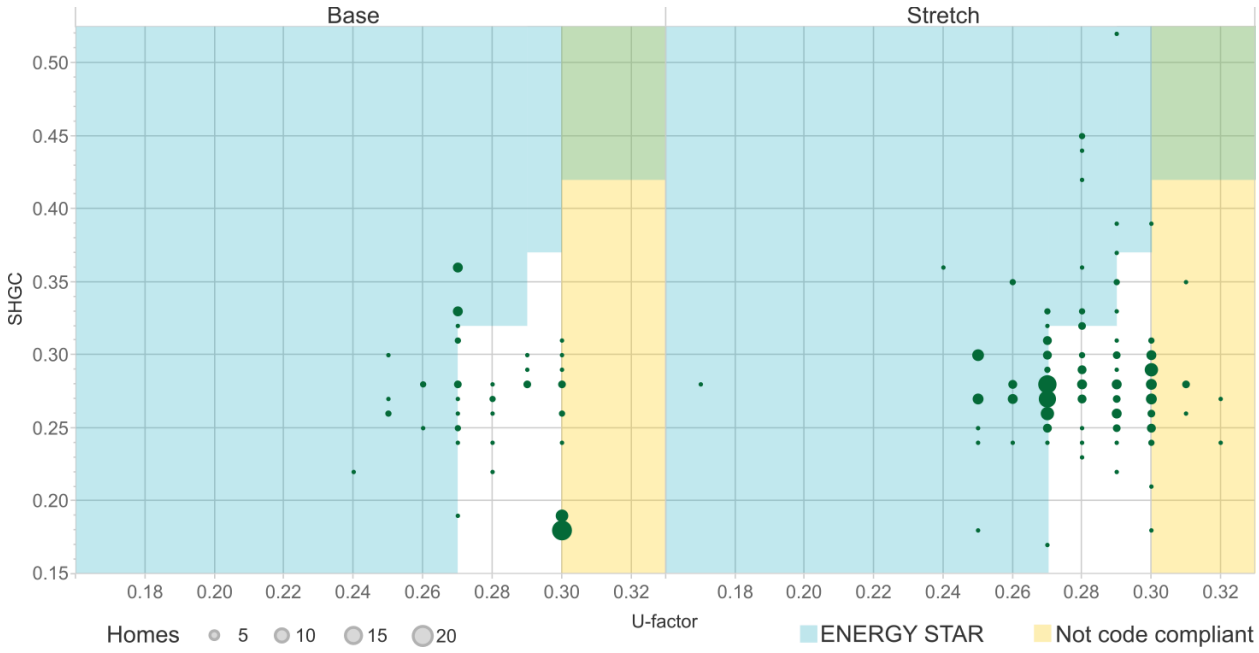


Figure 5 plots the distribution of window properties among Ekotrope non-participant homes, while Table 18 summarizes these values and the proportion that comply with building code or ENERGY STAR requirements. Both use the average area-weighted properties for above grade wall windows, excluding entries with REM/Rate default values. Note that the figure shadings are transparent; in other words, the top-right corner represents non-code compliant ENERGY STAR windows,[17] while the uncolored region contains compliant non-ENERGY STAR windows.

Table 18: Area-weighted Average Ekotrope Non-participant Window Values by Code

	Base		Stretch	
	U-factor	SHGC	U-factor	SHGC
n Homes	*78*	*78*	*212*	*194*
n Windows	521	521	1,762	1,630
ENERGY STAR	44%		45%	
Minimum	0.24	0.18	0.17	0.17
Mean	0.29*	0.25*	0.28	0.29
Maximum	0.30	0.36	0.32	0.52
Code Compliant	100%	–	97%	–

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.

[17] The ENERGY STAR standards for windows indicate that all acceptable windows with a U-factor greater than 0.27 have "equivalent energy performance;" U.S. EPA, https://www.energystar.gov/products/building_products/residential_windows_doors_and_skylights/key_product_criteria (Accessed February 25, 2020).

2.3.8 Duct Leakage and Insulation

There are no significant differences in duct leakage between the Ekotrope non-participant and baseline samples in Table 19, despite the higher proportion of rough-in tests among Ekotrope non-participant homes.[18]

Table 19: Duct Leakage and Testing Conditions – Detached Ekotrope Non-participant vs. Baseline by Code

Testing Condition	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*76*	*187*	*42*	*39*
Post Construction	71%*	92%	100%†	100%†
Rough-in	29%*	8%	0%†	0%†
Duct LTO CFM25/100 ft2 CFA	4.22	3.53	5.0	3.9

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

In Table 20, the base code homes studied for the baseline report are more likely to have ductwork that is partially in conditioned space than the Ekotrope non-participant sample. In the latter group, one-half of homes (48%) do not have ducts in conditioned space. The similarity in leakage rates is somewhat unexpected given the differences in duct location.

Table 20: Duct Location – Detached Ekotrope Non-participant vs. Baseline by Code

Location	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
n	*79*	*213*	*51*	*49*
All Ducts in Conditioned Space	13%*	23%	12%	22%
Some Ducts in Conditioned Space	37%*	49%	61%†	55%
No Ducts in Conditioned Space	48%*	16%	20%†	8%
No Ducts	3%*	12%	8%	14%

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

Ekotrope non-participant attic and basement ductwork in Table 21 appears to be more heavily insulated than the baseline; however, small sample sizes in the baseline study population preclude significance testing. Furthermore, the lack of insulation material details in the Ekotrope non-participant sample prevent the exploration of some plausible causes for any difference, such as the relative prevalence of metalized bubble wrap insulation and the R-value attributed to it.

[18] Code allows for duct tightness to be tested either once the ductwork has been installed but the home is unfinished (e.g., the air handler may not yet be installed) or post-construction. The testing standards for either scenario are very similar; however, it is best practice to note the testing conditions since they can influence the results. For example, a system that passes the rough-in test might later fail a post-construction test if additional holes, such as nail penetrations, were introduced into the ductwork as the home was being finished. Conversely, a home that passes a post-construction test may have marginally failed the rough-in test, but due to back-pressure from being sealed in the structure, the post-construction leakage rate is reduced.

Table 21: Duct Insulation in Detached Ekotrope Non-participant vs. Baseline

Location	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
Attic Supply R-value	10.0	8.5	6.6	6.5
Attic Supply *n*	*55*	*114*	*22*	*22*
Attic Return R-value	9.2	7.9	6.6	5.9
Attic Return *n*	*55*	*112*	*22*	*20*
Unconditioned Basement R-value	7.1	7.2	5.6	5.6
Unconditioned Basement *n*	*67*	*105*	*34*	*22*
Garage R-value	6.9	7.3	6.8	5.1
Garage *n*	*4*	*21*	*4*	*4*

2.3.9 Lighting

There are several factors that complicate the comparison of lighting between the baseline and the Ekotrope non-participant samples. First, the RESNET algorithm for determining efficient lighting levels in a home contains several special cases and was revised in February 2018, potentially contributing to differences in practice.[19] Another complicating factor is due to the recording of efficient saturation figures for broad locations (interior, exterior, garage),[20] which precludes the calculation of site-level saturation numbers. Furthermore, unlike a typical baseline visit, none of the certified packages can unambiguously represent the absence of permanent exterior or garage lighting. On the other hand, the NMR baseline audits were conducted post-occupancy, meaning homeowners could have replaced some bulbs post-construction, perhaps for a more amber-colored light from exterior fixtures, which differ significantly between samples.

Table 22: Average Lighting – Detached Ekotrope Non-participant vs. Baseline by Code

Measure	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
Homes	*79*	*213*	*51*	*49*
Interior Efficient Lighting %	98.6	96.1	93.6	93.6
Garage Efficient Lighting %	95.5*	88.0	86.9†	91.6
Exterior Efficient Lighting %	98.0	95.2	85.3†	89.1†

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

[19] RESNET, "ANSI/RESNET/ICC 301-2014 Addendum G-2018, Solid State Lighting", (February 2, 2018), https://www.resnet.us/wp-content/uploads/ANSIRESNETICC-301-2014-Addendum-G-2018-Solid-State-Lighting-February-2-2018.pdf

[20] Two of the three RESNET-certified software packages only collect the fraction of specific efficient lighting rather than a count of efficient bulbs or fixtures.

2.3.10 Appliances

The type and number of appliances installed by a builder varies: one home may come with all major appliances, another may only have a dishwasher, and another with a dishwasher and refrigerator but no laundry. Consequently, pre-occupancy audits may use dated, default values for some appliances. For example, a 0.331 IMEF clothes washer was entered for 84 Ekotrope non-participant homes. Our team excluded obvious defaults such as this from the analysis of Ekotrope non-participant data, but other non-verified values may still be present in the dataset. In addition, homeowners may replace or add new appliances when they move in, as evidenced by the similarity between primary refrigerator energy consumption of the two samples in Table 23 (approximately 685 kWh/yr for Ekotrope non-participant homes vs. 650 kWh/yr for the baseline) compared to the nearly 50% larger average consumption for all refrigerators, freezers, and coolers (1,011 kWh/yr) observed during the baseline.

Table 23: Average Appliances – Detached Ekotrope Non-participant vs. Baseline by Code

Measure	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
Homes	*79*	*213*	*51*	*49*
Dishwasher kWh/yr	270.7	268.9	264.1†	265.2†
Refrigerator kWh/yr	682.7	686.8	646.3†	653.0†
~, Freezers and Coolers kWh/yr	–	–	931.2	1,094.9
Clothes Washer IMEF	2.69	2.61	2.47	2.37†
Clothes Dryer EF	3.26*	3.67	3.28	3.26†
Electric Dryer %	96	88	78†	85

* Significantly different from Ekotrope non-participant stretch code at 90% confidence interval.
† Significantly different from corresponding Ekotrope non-participant code at 90% confidence interval.

Laundry equipment in Ekotrope non-participant stretch code homes was significantly more efficient than that in baseline homes. In addition, there are significantly more electric dryers in the Ekotrope non-participant base code homes than in the baseline. However, this may be due to the apparent absence of natural gas in 94% of these homes based on the analysis in Section 2.1.5.

The Ekotrope non-participant data does not include information on oven fuel, which may become an important data point as energy optimization efforts progress. Although the Ekotrope non-participant data includes range fuel, this does not correlate with oven fuel; only 16% of baseline ranges were electric compared to 40% of ovens.

Section 3 Comparison of Data Collection Methods

In this report, we are primarily concerned with comparing two sources of full HERS-rating audit data: conventional baseline audits and registered HERS ratings. However, the approaches used to collect information about home efficiency can range in complexity – from phone surveys to HERS ratings. This section includes three additional methods as points of comparison: residential appliance saturation study (RASS) audits, smartphone web surveys, and conventional phone or web surveys. These methods are described in Table 24, and their relative merits are discussed in the following sub-sections of the same name. Depending on the goals and budget of a study, only a single technique may be employed, or multiple methods may be used in concert.

Table 24: Data Collection Methods

Method	Description
Conventional Baseline Audit	A HERS rating grade-audit (collection of complete measure-level data) with supplementary details.
RASS Audit	A basic energy audit including full lighting, appliance, and HVAC details, plus basic shell insulation information.
Registered HERS Ratings	Purchase third-party HERS rating grade audit data and extract measure-level information.
Smartphone Web Survey	A new technique in which homeowners use their smartphone to submit photographs of equipment and model nameplates, along with responses to conventional web survey questions.
Conventional Web Survey	A guided survey of basic demographic, home, and appliance information.

The approximate cost per home for each of these methods are presented in Table 25, roughly in order of decreasing thoroughness. For example, the amount of data that can be acquired during a typical web survey is much less than in a full baseline audit. The costs presented here are the costs associated with data acquisition and data cleaning – they do not include analysis and reporting costs. Please note that all of the costs outlined below are variable based on the amount of data acquired. These are ranges based on costs we have seen for typical studies. The Ekotrope data was purchased for $25,000 as part of this study, but there is no guarantee that the price will be the same in the future. As such, these costs should be considered estimates intended to guide future study decisions.

Table 25: Approximate Cost per Home

	Full Audit	RASS	Ekotrope	Smartphone Self-Audit	Web Survey
$ per home	$2,000-$3,000	$1,000-$2,000	$125-$150	$100-$200	$50-$100

3.1.1 Conventional Baseline Audit

Pros	Cons
• Full energy model and shell details • Thorough quality control checks for 100% of sites • Post-occupancy thermostat schedules • Ability to collect a wide variety of data points, (see Section 3.2) and ability to customize • Photographic evidence • Sample design flexibility	• Smaller sample size • Extended timeline • Difficulty reaching homeowners and scheduling protracted visits • Minimal availability of window details • Higher incentive cost

Neutral
• Post-occupancy lighting data, which might not capture builder practices, but does reflect usage

3.1.2 RASS Audit

Pros	Cons
• Collect wide variety of data points (see Section 3.2) and ability to customize • Photographic evidence • Post-occupancy thermostat schedules	• Smaller sample size • Narrower data set • Minimal shell data • No diagnostic data, energy models, or compliance results

3.1.3 Registered HERS Ratings

Pros	Cons

• Larger sample size
• Full energy model and shell details
• Pre-finish wall insulation grading
• Slab and exterior foundation wall insulation verification
• Extensive window U-factor and SHGC data
  ○ Potential for greater geographic breadth (e.g., ratings from the outer Cape and islands)
• No recruitment required
	• Selection bias:
	  ○ Required by stretch code or program
	  ○ Opt-in for non-program base code
	• Unable to reliably stratify by builder type (custom vs. spec) or utility company
	• Inconsistency in rater technique:
	  ○ Measurement precision
	  ○ Insulation details and grading
	  ○ Basement condition designation
	  ○ Shell location (e.g., "Unconditioned Basement" foundation described as "Conditioned to Garage")
	• No explicit distinction between ASHP and MSHP
	• MA-REC does not include breakouts for ductwork or lighting and appliances
	• Absence of some appliances, notably laundry, freezers, and coolers
	• May include pre-finish duct testing
	• Unable to distinguish between N/A and 0% efficient lighting

3.1.4 Smartphone Web Survey

Pros	Cons
• Larger sample size • Ability to collect custom data points • Photographic evidence • Ease of recruitment	• Self-selection bias, correctable with inclusion of demographic questions

3.1.5 Conventional Web Survey

Pros	Cons
• Larger sample size • Ability to collect custom data points • Ease of recruitment	• Limited to non-technical inquiries for most accurate results[21]

[21] NMR, "Do You Know What's in Your Basement? Comparing Knowledge with Reality" (August 2019) http://www.nmrgroupinc.com/wp-content/uploads/2019/09/IEPEC-Abstracts-2019-David.pdf

3.2 HERS Rating Data Field Comparison

A cross-tabulation of the availability of data points in the NMR and Ekotrope data collection forms (DCF) is presented in Table 26. The DCF used for site visits by NMR covers 92% of the items used in the Ekotrope non-participant sample ratings spanning the categories below. The NMR data collection form covers a total of 371 items. The items cover all but 15 of the 190 data collection items in the Ekotrope DCF. A complete list of the relevant data points is included in Appendix B.

- Air Leakage
- Appliances
- Battery Storage‡
- Ceilings
- Code Compliance
- DHW
- Doors
- Electric Vehicle†
- Electronics†
- Foundation Wall
- Frame Floor
- HVAC
- HVAC Distribution
- Joists
- Lighting
- Pools and Hot Tubs†
- Site Information
- Skylights
- Slabs
- Solar
- Thermostats
- Walls
- Windows

‡ NMR DCF only, not required for HERS rating.

Table 26: Data Points in NMR vs. Ekotrope Rating DCFs

	Required	Optional	N/A	TOTAL
In NMR DCF	97	78	196	371
Not in NMR DCF	6	9	–	15
TOTAL	**103**	**87**	**196**	**386**

Furthermore, the app used by NMR for data collection is extremely flexible. In addition to the ability to collect twice as many data points as a conventional HERS rating, such as more detailed lighting inventory data, it allows for photos to be uploaded for every category of data in a home. It also includes a mechanism to include custom data points, such as occupant surveys to be administered in the field. For example, the baseline report added entries for the presence of radon mitigation systems, air filter MERV ratings, etc. The NMR DCF also includes facilities to record the compliance status for 25 separate code requirements, whereas rating software includes a single checkbox indicating full compliance.

Section 4 Conclusions

Although there are differences between the Ekotrope non-participant and baseline samples, registered HERS ratings as represented by the Ekotrope non-participant sample explored in this report offer a potentially cost-effective mechanism of collecting extensive data on new homes. In the future, supplementing Ekotrope non-participant HERS ratings with selective audits could provide a lower-cost approach with higher confidence. For example, Ekotrope non-participant ratings include more extensive information about window properties but frequently lack appliance information; the opposite situation is true for conventional post-occupancy audits. This hybrid method might include a smaller number of full HERS ratings, alongside more targeted, less-intensive home audits, such as the mini-baseline or RASS audits intended to collect verified data for key measures. Given the partial incompleteness of appliance data for many pre-occupancy HERS ratings, the dataset could be further augmented with a smartphone survey. On the other hand, baseline audits can capture details about builder practices not available in HERS ratings, such as duct panning, sealant, and insulation materials.

Any use of Ekotrope non-participant data in the future should consider the fact that the data only covers HERS-rated non-program homes. HERS raters theoretically enhance the efficiency of new homes by providing energy-efficiency consulting services to builders. As such, there may be a bias towards higher-efficiency construction in the Ekotrope non-participant sample. Future studies should account for this potential bias. For example, a future study might leverage the Ekotrope non-participant data to offset the majority of site visits in stretch code communities, where HERS ratings are required, but rely more heavily on traditional site visits to measure baseline efficiencies in base code communities.

Appendix A Additional Details

Table 27 through Table 29 provide supplemental details on the samples that support the findings presented throughout this report.

Table 27: Measure Counts in Ekotrope Non-participant Homes by Style

Measure	Detached	Attached	Combined
HERS Index	291	81	372
Conditioned Floor Area (CFA) ft2	291	81	372
Building Shell			
Air Leakage ACH50	291	82	374
Ambient Wall R-value	290	81	371
Window U-factor	291	81	372
Flat Ceiling R-value	238	54	292
Sealed Attic/Vaulted Ceiling R-value	124	47	171
Frame Floor R-value	172	31	203
Conditioned foundation wall R-value	103	21	124
Mechanical Equipment			
Duct LTO CFM25/100 ft2 CFA	187	75	262
Heating System AFUE	395	89	484
Heat Pump HSPF	18	2	20
ASHP/MSHP SEER	21	2	23
CAC SEER	353	74	427
Water Heater EF	299	82	381
Lighting and Appliances			
Dishwasher kWh/yr	256	72	328
Refrigerator kWh/yr	230	51	281
Clothes Washer IMEF	103	25	128
Clothes Dryer EF	93	24	117
Electric Clothes Dryer %	93	24	117
Electric Cooking %	291	81	372
Interior Efficient Lighting %	291	81	372
Garage Efficient Lighting %	291	81	372
Exterior Efficient Lighting %	291	81	372

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Table 28: Measure Counts – Detached Ekotrope Non-participant vs. Baseline by Code

Measure	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
HERS Index	79	212	51	49
Conditioned Floor Area (CFA) ft2	79	212	51	49
MA-REC %	79	212	51	49
Building Shell				
Air Leakage ACH50	79	212	51	49
Ambient Wall R-value	79	211	51	49
Window U-factor	78	212	–	–
Flat Ceiling R-value	71	166	38	35
Sealed Attic/Vaulted R-value	24	100	30	31
Frame Floor R-value	61	111	40	29
Cond. foundation wall R-value	16	87	17	23
Mechanical Equipment				
Duct LTO CFM25/100 ft2 CFA	74	188	42	39
Heating System AFUE	119	276	70	62
Heat Pump HSPF	1	17	12	19
ASHP/MSHP SEER	1	20	13	19
CAC SEER	115	238	69	56
Water Heater EF	81	218	54	52
Lighting and Appliances				
Dishwasher kWh/yr	73	183	53	49
Refrigerator kWh/yr	58	172	51	49
~, Freezers and Coolers kWh/yr	–	–	84	102
Clothes Washer IMEF	17	86	53	53
Clothes Dryer EF	26	78	52	48
Electric Dryer %	26	78	52	48
Electric Range %	79	212	51	49
Interior Efficient Lighting %	79	212	51	49
Garage Efficient Lighting %	79	212	37	43
Exterior Efficient Lighting %	79	212	50	49

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Table 29: MA-REC Measure-level Weighting

Measure	Ekotrope Non-participant		Baseline	
	Base	Stretch	Base	Stretch
Above Grade Wall Insulation	35.4%	32.3%	26.9%	26.4%
Fenestration U-factor	31.1%	28.8%	30.7%	26.7%
Air Leakage	11.8%	13.4%	20.1%	19.6%
Ceiling Insulation	10.1%	10.4%	11.3%	12.0%
Frame Floor Insulation	6.7%	6.3%	5.7%	7.0%
Foundation Wall Insulation	2.8%	4.8%	3.0%	4.6%
Slab Insulation	2.2%	3.9%	2.3%	3.7%

Appendix B Data Field Comparison

Table 30 presents a detailed comparison of the data fields found in the Ekotrope energy modeling software and the NMR onsite data collection form, which is summarized in Table 24.

Table 30: Data Field Comparison

Category	Item	Ekotrope	NMR
Air Leakage	Baseline Pressure	N/A	Available
Air Leakage	Blower Door Ring	N/A	Available
Air Leakage	CFM50	REQUIRED	Available
Air Leakage	Field Test Status	REQUIRED	Post Const.
Air Leakage	Infiltration Rate	REQUIRED	Available
Air Leakage	Leakage Area	REQUIRED	Calculable
Air Leakage	Manometer ID	N/A	Available
Air Leakage	Specific Leakage Area	REQUIRED	Calculable
Appliances	Air Device Age	N/A	Available
Appliances	Air Device Capacity	N/A	Available
Appliances	Air Device Controls	N/A	Available
Appliances	Air Device Drain	N/A	Available
Appliances	Air Device EnergyStar	N/A	Available
Appliances	Air Device Make	N/A	Available
Appliances	Air Device Model	N/A	Available
Appliances	Air Device Serial	N/A	Available
Appliances	Air Device Type	N/A	Available
Appliances	Dishwasher Age	N/A	Available
Appliances	Dishwasher Capacity	N/A	Available
Appliances	Dishwasher Efficiency	REQUIRED	Available
Appliances	Dishwasher EnergyStar	N/A	Available
Appliances	Dishwasher Make	N/A	Available
Appliances	Dishwasher Model	N/A	Available
Appliances	Dishwasher Place Settings	REQUIRED	Available
Appliances	Dishwasher Primacy	N/A	Available
Appliances	Dishwasher Serial	N/A	Available
Appliances	Dryer Age	N/A	Available
Appliances	Dryer Configuration	N/A	Available
Appliances	Dryer Efficiency	REQUIRED	Available
Appliances	Dryer Fuel	REQUIRED	Available
Appliances	Dryer In-Unit	N/A	Available
Appliances	Dryer Location	N/A	Available
Appliances	Dryer Make	N/A	Available
Appliances	Dryer Model	N/A	Available
Appliances	Dryer Primacy	N/A	Available

Category	Item	Ekotrope	NMR
Appliances	Dryer Properly Vented	N/A	Available
Appliances	Dryer Sensor	REQUIRED	Available
Appliances	Dryer Serial	N/A	Available
Appliances	Dryer Type	N/A	Available
Appliances	Oven Convection	N/A	Available
Appliances	Oven Fuel	REQUIRED	Available
Appliances	Oven/Range Age	N/A	Available
Appliances	Oven/Range Primacy	N/A	Available
Appliances	Range Fuel	REQUIRED	Available
Appliances	Range Induction	N/A	Available
Appliances	Refrigeration Age	N/A	Available
Appliances	Refrigeration Configuration	N/A	Available
Appliances	Refrigeration Consumption	REQUIRED	Available
Appliances	Refrigeration EnergyStar	N/A	Available
Appliances	Refrigeration Ice Maker Present	N/A	Available
Appliances	Refrigeration Location	N/A	Available
Appliances	Refrigeration Make	N/A	Available
Appliances	Refrigeration Model	N/A	Available
Appliances	Refrigeration Plugged-In	N/A	Available
Appliances	Refrigeration Primacy	N/A	Available
Appliances	Refrigeration Serial	N/A	Available
Appliances	Refrigeration Type	N/A	Available
Appliances	Refrigeration Volume	N/A	Available
Appliances	Washer Age	N/A	Available
Appliances	Washer Capacity	REQUIRED	Available
Appliances	Washer Configuration	N/A	Available
Appliances	Washer Efficiency	REQUIRED	Available
Appliances	Washer In-Unit	N/A	Available
Appliances	Washer Labeled Energy Rating	REQUIRED	Available
Appliances	Washer Location	N/A	Available
Appliances	Washer Make	N/A	Available
Appliances	Washer Model	N/A	Available
Appliances	Washer Primacy	N/A	Available
Appliances	Washer Serial	N/A	Available
Appliances	Washer Type	N/A	Available
Battery Storage	Capacity	N/A	Available
Battery Storage	Make	N/A	Available
Battery Storage	Model	N/A	Available
Ceilings	Area	REQUIRED	Available
Ceilings	Assembly U-Factor	REQUIRED	Calculable
Ceilings	Cavity Insulation Grade	Optional	Available
Ceilings	Cavity Insulation Material	Optional	Available
Ceilings	Cavity Insulation Thickness	Optional	Available
Ceilings	Cavity R-value	Optional	Available

Category	Item	Ekotrope	NMR
Ceilings	Clay/Concrete Roof Tiles	REQUIRED	NO
Ceilings	Continuous Insulation Material	Optional	Available
Ceilings	Continuous Insulation Thickness	Optional	Available
Ceilings	Continuous R-value	Optional	Available
Ceilings	Exterior Color	REQUIRED	Available
Ceilings	Framing Depth	Optional	Available
Ceilings	Framing Fraction	Optional	Calculated
Ceilings	Framing Spacing	Optional	Available
Ceilings	Insulation Verification	N/A	Available
Ceilings	In-unit Only	N/A	Available
Ceilings	Location	REQUIRED	Available
Ceilings	Radiant Barrier	Optional	Available
Ceilings	Raised Heel Truss	N/A	Available
Ceilings	Roof Deck Area	Optional	Calculable
DHW	Age	N/A	Available
DHW	Direct Vent	N/A	Available
DHW	EnergyStar	N/A	Available
DHW	Fixture Aerator	N/A	Available
DHW	Fixture Flow Rate	N/A	Available
DHW	Fixture Room	N/A	Available
DHW	Fixture Type	N/A	Available
DHW	Fixtures 100% Low-Flow	REQUIRED	Calculated
DHW	Fuel Type	N/A	Available
DHW	Hot Water Efficiency	REQUIRED	Available
DHW	Hot Water Insulated to R3	REQUIRED	Available
DHW	Location	N/A	Available
DHW	Make	N/A	Available
DHW	Model	N/A	Available
DHW	Percent Load	REQUIRED	Available
DHW	Pipe Length	REQUIRED	Available
DHW	Pipe Wrap	N/A	Available
DHW	Recirculation Branch Length	Optional	NO
DHW	Recirculation Pipe Loop Length	REQUIRED	NO
DHW	Recirculation Pump Power	REQUIRED	NO
DHW	Recirculation System Control	REQUIRED	Available
DHW	Recovery Efficiency	Optional	NO
DHW	Recovery Fixture Factor	Optional	NO
DHW	Recovery Location	Optional	NO
DHW	Spillage	N/A	Available
DHW	Sealed Combustion	N/A	Available
DHW	Tank Capacity	Optional	Available
DHW	Type	N/A	Available
Doors	Area	REQUIRED	Available
Doors	Insulated	N/A	Available

Category	Item	Ekotrope	NMR
Doors	Storm Door	N/A	Available
Doors	U-Factor	REQUIRED	Available
Doors	Wall ID	Optional	Available
Electric Vehicle	Charger Level	N/A	Available
Electric Vehicle	Make	N/A	Available
Electric Vehicle	Model	N/A	Available
Electric Vehicle	Type	N/A	Available
Electronics	Advanced Power Strip Connection	N/A	Available
Electronics	Advanced Power Strip Connection Type	N/A	Available
Electronics	Advanced Power Strip Type	N/A	Available
Electronics	Size	N/A	Available
Electronics	Type	N/A	Available
Foundation Wall	Assembly U-Factor	REQUIRED	Calculable
Foundation Wall	Cavity Insulation Grade	Optional	Available
Foundation Wall	Cavity Insulation Material	Optional	Available
Foundation Wall	Cavity Insulation Thickness	Optional	Available
Foundation Wall	Cavity R-value	Optional	Available
Foundation Wall	Continuous Insulation Material	Optional	Available
Foundation Wall	Continuous Insulation Thickness	Optional	Available
Foundation Wall	Continuous R-value	REQUIRED	Available
Foundation Wall	Depth Below Grade	REQUIRED	Available
Foundation Wall	Distance from Top of Wall to Bottom of Ins.	Optional	Available
Foundation Wall	Distance from Top of Wall to Top of Ins.	Optional	Available
Foundation Wall	Framing Depth	Optional	Available
Foundation Wall	Framing Fraction	Optional	Calculated
Foundation Wall	Framing Spacing	Optional	Available
Foundation Wall	Height Above Grade	REQUIRED	Available
Foundation Wall	Insulation Verification	N/A	Available
Foundation Wall	Length	REQUIRED	Available
Foundation Wall	Location	REQUIRED	Available
Foundation Wall	Type	N/A	Available
Frame Floor	Area	REQUIRED	Available
Frame Floor	Assembly U-Factor	REQUIRED	Calculable
Frame Floor	Cavity Insulation Grade	Optional	Available
Frame Floor	Cavity Insulation Material	Optional	Available
Frame Floor	Cavity Insulation Thickness	Optional	Available
Frame Floor	Cavity Insulation Thickness	Optional	Available
Frame Floor	Cavity R-value	Optional	Available
Frame Floor	Continuous Insulation Material	Optional	Available
Frame Floor	Continuous Insulation Thickness	Optional	Available
Frame Floor	Continuous R-value	Optional	Available
Frame Floor	Framing Depth	Optional	Available
Frame Floor	Framing Fraction	Optional	Calculated
Frame Floor	Framing Spacing	Optional	Available

Category	Item	Ekotrope	NMR
Frame Floor	Insulation Verification	N/A	Available
Frame Floor	In-unit Only	N/A	Available
Frame Floor	Location	REQUIRED	Available
HVAC	Ceiling Fan CFM/W	Optional	NO
HVAC	Cooling Age	N/A	Available
HVAC	Cooling capacity	REQUIRED	Available
HVAC	Cooling Capacity Verification	N/A	Available
HVAC	Cooling Efficiency	REQUIRED	Available
HVAC	Cooling Efficiency Verification	N/A	Available
HVAC	Cooling EnergyStar	N/A	Available
HVAC	Cooling Equipment Type	REQUIRED	Available
HVAC	Cooling Location	Optional	Available
HVAC	Cooling Make	N/A	Available
HVAC	Cooling Model	N/A	Available
HVAC	Cooling Percent Load	REQUIRED	Available
HVAC	Cooling Refrigerant Insulation Coverage	N/A	Available
HVAC	Cooling Refrigerant Insulation R-value	N/A	Available
HVAC	Cooling Sensible Heat Fraction	N/A	Available
HVAC	Cooling Serial	N/A	Available
HVAC	Heat Pump Age	N/A	Available
HVAC	Heat Pump Capacity Verification	N/A	Available
HVAC	Heat Pump Cooling Capacity	N/A	Available
HVAC	Heat Pump Cooling Efficiency	N/A	Available
HVAC	Heat Pump Cooling Efficiency Units	N/A	Available
HVAC	Heat Pump Distribution Type	N/A	Available
HVAC	Heat Pump Efficiency Verification	N/A	Available
HVAC	Heat Pump EnergyStar	N/A	Available
HVAC	Heat Pump Heating Capacity	N/A	Available
HVAC	Heat Pump Heating Efficiency	N/A	Available
HVAC	Heat Pump Location	N/A	Available
HVAC	Heat Pump Make	N/A	Available
HVAC	Heat Pump Model	N/A	Available
HVAC	Heat Pump Refrigerant Ins. Coverage	N/A	Available
HVAC	Heat Pump Refrigerant R-value	N/A	Available
HVAC	Heat Pump Serial	N/A	Available
HVAC	Heat Pump Type	N/A	Available
HVAC	Heating Age	N/A	Available
HVAC	Heating Backdraft	N/A	Available
HVAC	Heating Capacity	REQUIRED	Available
HVAC	Heating Combustion Direct Vent	N/A	Available
HVAC	Heating Combustion Sealed	N/A	Available
HVAC	Heating ECM Motor/Pump	Optional	Available
HVAC	Heating Efficiency	REQUIRED	Available
HVAC	Heating Efficiency Verification	N/A	Available

Category	Item	Ekotrope	NMR
HVAC	Heating Electric Auxiliary Energy	Optional	Available
HVAC	Heating EnergyStar	N/A	Available
HVAC	Heating Fuel	REQUIRED	Available
HVAC	Heating Fuel Oil Nozzle Size	N/A	Available
HVAC	Heating Location	Optional	Available
HVAC	Heating Make	N/A	Available
HVAC	Heating Model	N/A	Available
HVAC	Heating Percent Load	REQUIRED	Available
HVAC	Heating Serial	N/A	Available
HVAC	Heating Spillage	N/A	Available
HVAC	Heating Type	REQUIRED	Available
HVAC	Ventilation CFM	Optional	Available
HVAC	Ventilation Control	N/A	Available
HVAC	Ventilation Hours per Day	Optional	Available
HVAC	Ventilation Make	N/A	Available
HVAC	Ventilation Method	N/A	Available
HVAC	Ventilation Model	N/A	Available
HVAC	Ventilation Motor Type	Optional	Available
HVAC	Ventilation Motor Watts	Optional	Available
HVAC	Ventilation Recovery Efficiency	Optional	Available
HVAC	Ventilation Type	Optional	Available
HVAC Distribution	Area Served	Optional	Available
HVAC Distribution	Attached HVAC	REQUIRED	Available
HVAC Distribution	Duct Insulation Material	N/A	Available
HVAC Distribution	Duct Location	Optional	Available
HVAC Distribution	Duct Material	N/A	Available
HVAC Distribution	Duct Return Percentage	Optional	Available
HVAC Distribution	Duct Return R-value	Optional	Available
HVAC Distribution	Duct Sealing	N/A	Available
HVAC Distribution	Duct Supply Percentage	Optional	Available
HVAC Distribution	Duct Supply R-value	Optional	Available
HVAC Distribution	Efficiency	Optional	NO
HVAC Distribution	Filter Condition	N/A	Available
HVAC Distribution	Filter Slot Covered	N/A	Available
HVAC Distribution	HVAC Cooling System	Optional	Available
HVAC Distribution	HVAC Heating System	Optional	Available
HVAC Distribution	Leakage to Outside	Optional	Available
HVAC Distribution	Number of Return Grilles	Optional	Available
HVAC Distribution	Return Duct Area	Optional	Available
HVAC Distribution	Supply Duct Area	Optional	Available
HVAC Distribution	Test Conditions	Optional	Post Const.
HVAC Distribution	Total Duct Leakage	Optional	Available
Joists	Area	REQUIRED	Available
Joists	Assembly U-Factor	REQUIRED	Calculable

Category	Item	Ekotrope	NMR
Joists	Cavity Insulation Grade	N/A	Available
Joists	Cavity Insulation Material	N/A	Available
Joists	Cavity Insulation Thickness	N/A	Available
Joists	Cavity R-value	N/A	Available
Joists	Continuous Insulation Material	N/A	Available
Joists	Continuous Insulation Thickness	N/A	Available
Joists	Continuous R-value	N/A	Available
Joists	Framing	N/A	Available
Joists	Framing Depth	N/A	Available
Joists	Framing Spacing	N/A	Available
Joists	Insulation Verification	N/A	Available
Joists	Location	REQUIRED	Available
Joists	Sealed	N/A	Available
Joists	Type	Rim	Available
Lighting	Bulb Shape	N/A	Available
Lighting	Bulb Type	N/A	Available
Lighting	Exterior Percent CFL	REQUIRED	Calculated
Lighting	Exterior Percent LED	REQUIRED	Calculated
Lighting	Fixture Bulb Count	N/A	Available
Lighting	Fixture Control	N/A	Available
Lighting	Fixture Count	N/A	Available
Lighting	Fixture Hardwired	N/A	Available
Lighting	Fixture Room	N/A	Available
Lighting	Garage Percent CFL	REQUIRED	Calculated
Lighting	Garage Percent LED	REQUIRED	Calculated
Lighting	Interior Percent CFL	REQUIRED	Calculated
Lighting	Interior Percent LED	REQUIRED	Calculated
Pools and Hot Tubs	Covered	N/A	Available
Pools and Hot Tubs	Heated	N/A	Available
Pools and Hot Tubs	Pump Horsepower	N/A	Available
Pools and Hot Tubs	Pump Type	N/A	Available
Pools and Hot Tubs	Type	N/A	Available
Site Information	Address	N/A	Available
Site Information	Area	N/A	Available
Site Information	Basement Drainage	N/A	Available
Site Information	Bedrooms	REQUIRED	Available
Site Information	Builder Type	N/A	Available
Site Information	Builder Type Verification	N/A	Available
Site Information	Building Age	N/A	Available
Site Information	Building Type	REQUIRED	Available
Site Information	Floor Number	Optional	NO
Site Information	Foundation Type	REQUIRED	Available
Site Information	Occupants	N/A	Available
Site Information	Orientation	N/A	Available

Category	Item	Ekotrope	NMR
Site Information	Residence Type	REQUIRED	Available
Site Information	Shelter Class	N/A	Available
Site Information	Stories	REQUIRED	Available
Site Information	Units in Building	REQUIRED	Available
Site Information	Utility	N/A	Available
Site Information	Volume	N/A	Available
Site Information	Walk-out Basement	N/A	Available
Site Information	Wiring Amps	N/A	Available
Site Information	Wiring Amps Source	N/A	Available
Site Information	Wiring Orientation	N/A	Available
Site Information	Wiring Phase	N/A	Available
Site Information	Wiring Smart Meter	N/A	Available
Skylights	Adjacent Summer Shading Factors	REQUIRED	Available
Skylights	Adjacent Winter Shading Factors	REQUIRED	Available
Skylights	Area	REQUIRED	Available
Skylights	Building Orientation	REQUIRED	Available
Skylights	Installed Ceiling Index	REQUIRED	Available
Skylights	Interior Summer Shading Factors	REQUIRED	Available
Skylights	Interior Winter Shading Factors	REQUIRED	Available
Skylights	SHGC	REQUIRED	Available
Skylights	Type	REQUIRED	Available
Skylights	U-Factor	REQUIRED	Available
Slabs	Area	REQUIRED	Available
Slabs	Condition	REQUIRED	NO
Slabs	Depth	N/A	Available
Slabs	Exposed Masonry Area	REQUIRED	NO
Slabs	Exterior Perimeter Length	REQUIRED	Available
Slabs	Full Perimeter Length	N/A	Available
Slabs	Fully Insulated	REQUIRED	Calculated
Slabs	Grade	REQUIRED	Available
Slabs	Insulation Grade	N/A	Available
Slabs	Insulation Material	N/A	Available
Slabs	Insulation Thickness	N/A	Available
Slabs	Insulation Verification	N/A	Available
Slabs	Location	N/A	Available
Slabs	On Grade Perimeter Length	N/A	Available
Slabs	Perimeter Insulation Depth	Optional	Available
Slabs	Perimeter R-value	Optional	Available
Slabs	Radiant Floor	N/A	Available
Slabs	Under Slab Insulation Width	Optional	Available
Slabs	Under Slab R-value	Optional	Available
Solar	Area	N/A	Available
Solar	Azimuth	REQUIRED	Available
Solar	Derating Factor	REQUIRED	NO

Category	Item	Ekotrope	NMR
Solar	DHW Collector Loop	N/A	Available
Solar	Efficiency	REQUIRED	Available
Solar	Name plate Capacity	REQUIRED	Available
Solar	Quantity	N/A	Available
Solar	Tilt	REQUIRED	Available
Solar	Track Mode	Optional	NO
Solar	Type	Optional	Available
Thermostats	Make	Optional	Available
Thermostats	Model	Optional	Available
Thermostats	Schedule	REQUIRED	Available
Thermostats	Serial Number	Optional	NO
Thermostats	Type	REQUIRED	Available
Walls	Area	REQUIRED	Available
Walls	Assembly U-Factor	REQUIRED	Calculable
Walls	Cavity Insulation Grade	Optional	Available
Walls	Cavity Insulation Material	Optional	Available
Walls	Cavity Insulation Thickness	Optional	Available
Walls	Cavity R-value	Optional	Available
Walls	Continuous Insulation Material	Optional	Available
Walls	Continuous Insulation Thickness	Optional	Available
Walls	Continuous R-value	Optional	Available
Walls	Exterior Color	REQUIRED	Available
Walls	Façade Type	N/A	Available
Walls	Framing Depth	Optional	Available
Walls	Framing Fraction	Optional	Calculated
Walls	Framing Spacing	Optional	Available
Walls	Insulation Verification	N/A	Available
Walls	In-unit Only	N/A	Available
Walls	Location	REQUIRED	Available
Walls	Orientation	N/A	Available
Windows	Adjacent Summer Shading Factors	REQUIRED	Available
Windows	Adjacent Winter Shading Factors	REQUIRED	Available
Windows	Area	REQUIRED	Available
Windows	Distance Overhang to Bottom	REQUIRED	Available
Windows	Distance Overhang to Top	REQUIRED	Available
Windows	Wall ID	Optional	Available
Windows	Interior Summer Shading Factors	REQUIRED	Available
Windows	Interior Winter Shading Factors	REQUIRED	Available
Windows	Orientation	REQUIRED	Available
Windows	Overhang Depth	REQUIRED	Available
Windows	SHGC	REQUIRED	Available
Windows	Storm Window	N/A	Available
Windows	U-Factor	REQUIRED	Available