# APPENDIX B. DETAILED METHODOLOGY

This appendix to the New York State Energy Research and Development Authority (NYSERDA) 2019 *Residential Building Stock Assessment* (RBSA) report provides more information about the study methodology than would reasonably fit in the main body of the report. This appendix is intended for readers who use the study and need a deeper understanding of the study methodology.

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# B.1 PROJECT SUMMARY

## B.1.1 Background and Study Objectives

The NYSERDA 2019 RBSA provides the first update to the 2015 *Residential Statewide Baseline Study* (RSBS) of New York State. NYSERDA, in coordination with lead contractor Cadmus and subcontractors Performance Systems Development (PSD) and Honeywell, developed and implemented a work plan that allowed key study components to be completed in time to inform the State energy plan.

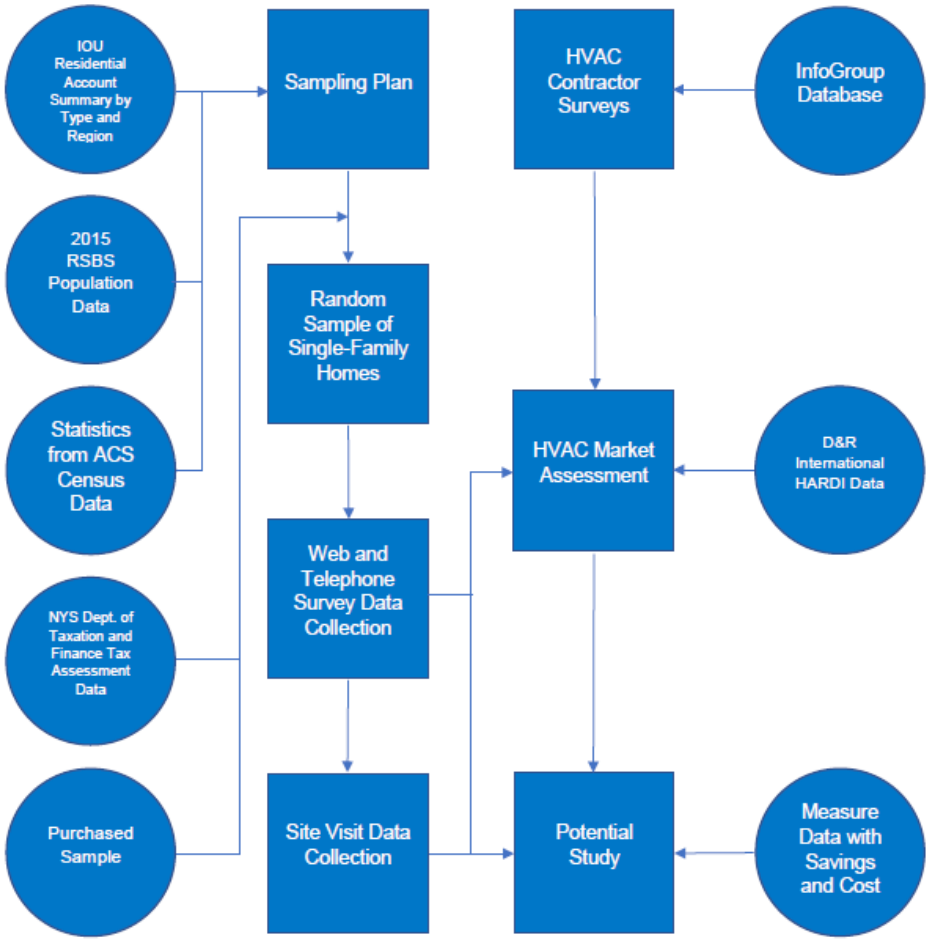
The project team characterized single-family homes throughout the State, with a single-family home defined as a residential structure containing one to four living units, including manufactured homes. Primary data collection included surveys of 2,419 respondents and site visits at 456 homes.

In addition to the building stock assessment, the RBSA included an HVAC market assessment to update baseline conditions for high-efficiency heating equipment in the State and a potential study to estimate three-, five-, and 10-year energy efficiency potential in the State. This appendix provides documentation of methods for the building assessment component only; separate reports and methodology documentation will be made available for the HVAC market assessment and potential study components.

The primary objectives of the RBSA are to provide a profile of new and existing homes in the State based on data from a representative sample of homes and to determine changes in building and equipment stock since the 2015 RSBS, including changes in the saturation of energy-consuming equipment (that uses electric, natural gas, and other fuels); key building characteristics such as insulation, windows types, and air leakage rates; and energy management practices. The RBSA also collected customer household and demographic information.

Information provided in this study will be used by NYSERDA, the New York State Department of Public Service, energy efficiency program administrators throughout the State, and others for a variety of purposes, such as informing program planning and setting baselines for savings calculations. This information also provided necessary inputs to the HVAC market assessment and potential study components of the study, as shown in Figure 1.

FIGURE 1. RESIDENTIAL BUILDING STOCK ASSESSMENT PROJECT FLOW CHART




## B.1.2 Market Segment Definitions

The RBSA characterized single-family homes, which are defined for the study as residential structures comprising one to four living units. While single-family detached homes are by far the most common type of single-family home in the State, the study also collected data on single-family attached homes, such as townhouses, manufactured or mobile homes, and multi-unit buildings.

The study characterized both existing and new homes, with homes classified as new if they were constructed in 2015 or later.

## B.1.3 Building Assessment Project Team

The project team for the building assessment component included NYSERDA, Cadmus as the lead contractor, and PSD and Honeywell as subcontractors.

As the lead contractor working under the direction of NYSERDA, Cadmus completed the following tasks:

- Managed all aspects of the project.

- Developed the work plan and sampling plan.
- Developed the sample frame used for recruiting.
- Developed study protocols with input from PSD.
- Conducted all analysis and generated all data tables.
- Designed and created the primary building assessment report.
- Provided all reporting, including designing and creating the primary building assessment report and generating this detailed documentation of the methodology.

Under the leadership and guidance of NYSERDA and Cadmus, PSD completed the following tasks:

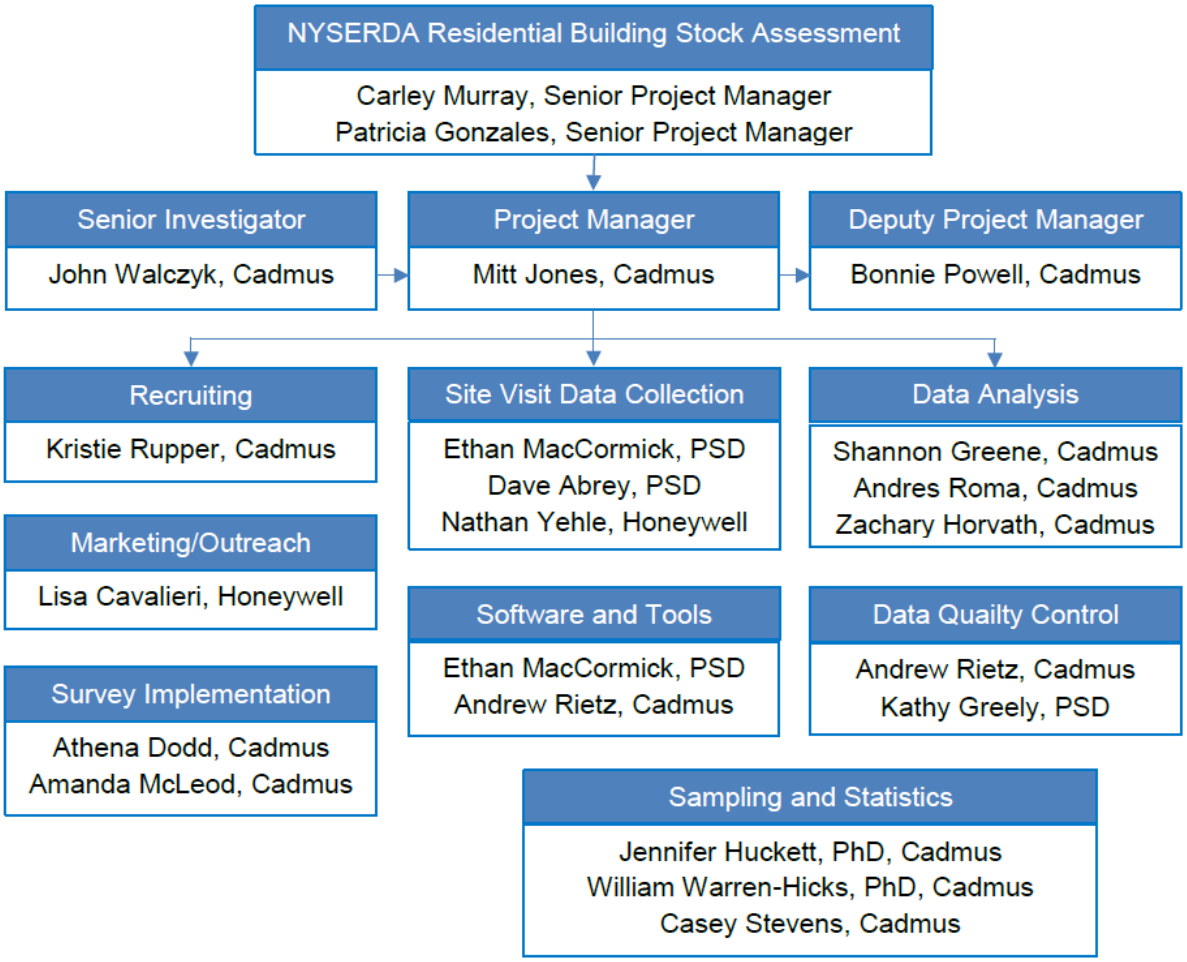
- Updated and deployed the iPad-based data collection tool it provided for the 2015 RSBS, which was used to collect data during site visits.
- Modified its internal scheduling software to accommodate project needs, including providing cloud-based access for Cadmus and Honeywell.
- Conducted project training for PSD and Honeywell field staff.
- Conducted site visits for 95 new homes and 170 of the 361 existing homes in the study.
- Performed initial data cleaning and data quality control (QC) of all site visit data.

Under the leadership and guidance of NYSERDA and Cadmus, Honeywell completed the following tasks:

- Designed the postcard used for recruitment.
- Managed the mailing and printing of postcards to addresses provided by Cadmus and following a timeline determined by NYSERDA and Cadmus.
- Provided phone staff to administer the survey to RBSA postcard recipients who called the toll-free number provided on the postcards.
- Provided phone staff to recruit additional respondents by contacting postcard recipients who had not responded.
- Conducted site visits for 191 of the 361 existing homes in the study.

Figure 2 shows many key members of the building assessment project team at NYSERDA, Cadmus, PSD, and Honeywell. Other project staff at each organization made important contributions such as providing guidance, providing additional project management support, or carrying out essential tasks such as scheduling and completing site visits.

FIGURE 2. BUILDING ASSESSMENT PROJECT TEAM




## B.1.4 Overall Approach

As with the 2015 RSBS, providing results representative of homes throughout New York State was a key priority. It was essential to retain the ability to compare results against those of the 2015 RSBS. Finally, to provide results soon enough to meet NYSERDA's required timeline, all data collection had to be complete in fall 2018, less than four months after the project kickoff. These requirements led to three decisions:

- The 2019 RBSA sampled by 10 Economic Development Region (EDRs) to ensure that homes were sampled throughout the State and to provide stratified sampling similar to that of the 2015 RSBS.
- As with the 2015 RSBS, the 2019 RBSA also included separate stratified samples for new and existing homes across the 10 EDRs.
- The 2019 RBSA leveraged data collection methods and tools used in the 2015 RSBS as practical, though the team improved those tools to overcome some previous limitations and to adapt to current trends and priorities.

With the nested design employed by the 2019 RBSA (and the 2015 RSBS before it), the project team first recruited respondents to complete an extensive telephone or online survey, which

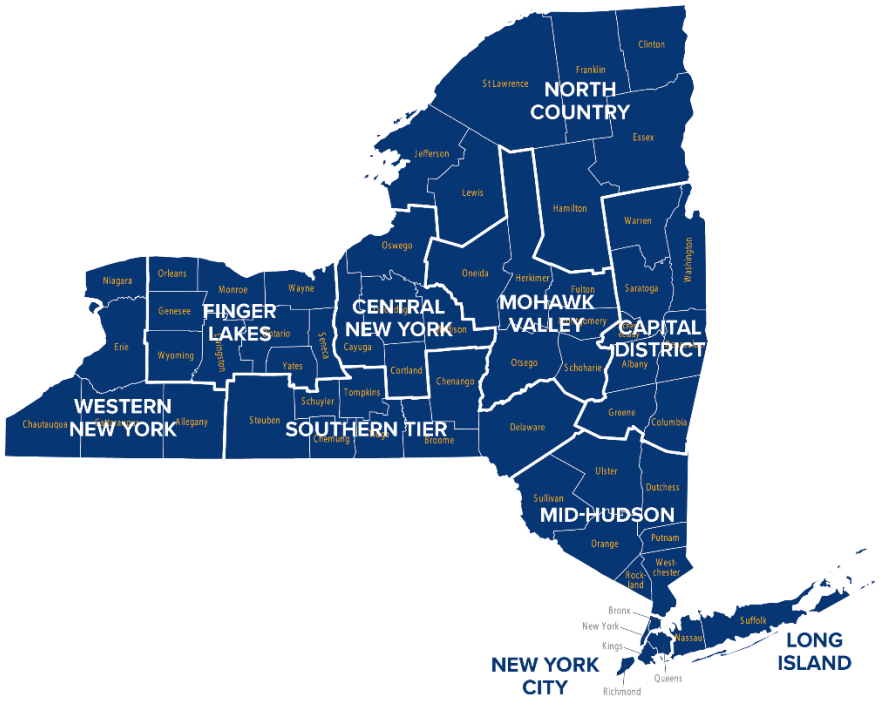
collected a variety of data essential to characterizing single-family homes. The survey also asked respondents whether they would be interested in participating in a site visit. Respondents who agreed to the site visit made up the sample frame for recruiting site visit participants.

## B.1.5 Sample Design

Cadmus developed the initial sampling plan during the proposal phase of the project with the goal of achieving 90% confidence and ±10% precision for most parameters of interest statewide and 90% confidence and ±20% precision within each of the 10 EDRs, shown in Figure 3. Based on coefficients of variation for a variety of metrics calculated from the 2015 RSBS data, Cadmus designed a nested approach that called for surveying approximately 2,400 households and visiting 486 homes to collect detailed information from 120 new homes and 366 existing homes.

After project award and further work with the 2015 RSBS data, Cadmus apportioned site visit targets for new and existing homes within each EDR using a combination of EDR population sizes and coefficients of variation calculated from 2015 RSBS data for two key metrics—Home Energy Rating System (HERS) scores for new homes and blower door test results in air changes per hour for existing homes. Cadmus used these metrics because of their importance in characterizing the efficiency of a home and because generating HERS scores and running blower door tests requires a site visit, making these especially good metrics for determining site visit sample sizes. EDRs with the largest populations and greatest variability were assigned a larger proportion of samples, consistent with standard statistical sampling methods.

FIGURE 3. NEW YORK STATE ECONOMIC DEVELOPMENT REGIONS




Cadmus reviewed the resulting sample size distributions and reallocated sample sizes to achieve sufficient coverage in each EDR and to ensure that the 90% confidence and ±20% precision target would be met within each EDR. Table 1 illustrates the target site visit completions for each home vintage within each EDR.

TABLE 1. TARGET SITE VISIT SAMPLE SIZES

| Economic Development Region | Existing Homes | New Homes | Total |
|---|---|---|---|
| Capital District | 32 | 16 | 48 |
| Central New York | 57 | 8 | 65 |
| Finger Lakes | 42 | 18 | 60 |
| Long Island | 30 | 10 | 40 |
| Mid-Hudson | 23 | 18 | 41 |
| Mohawk Valley | 26 | 5 | 31 |
| New York City | 60 | 13 | 73 |
| North Country | 20 | 13 | 33 |
| Southern Tier | 26 | 5 | 31 |
| Western New York | 50 | 14 | 64 |
| **Total** | **366** | **120** | **486** |

## B.1.6 Sample Frame

Unlike the 2015 RSBS, the 2019 RBSA did not use customer information provided by investor-owned utilities to recruit for the study, largely because the condensed project timeline did not allow enough time, based on prior experience, to request and receive customer information. Instead, Cadmus constructed the study sample frame by randomly selecting single-family homes from New York State Department of Taxation and Finance tax assessment rolls. To reach postcard recipients who did not respond, Cadmus used a third-party data source, Marketing Systems Groups, to append telephone numbers to homes sampled from tax assessment data. Where necessary, such as for new homes in some EDRs, Cadmus purchased qualified mailing lists from a third party, Dynata (formerly Research Now SSI).

## B.1.7 Recruitment Overview

The project team employed a multimode approach to recruiting. This approach used mail, telephone, and email outreach to encourage participation in a phone or online survey, recruiting from a sample of single-family existing and new homes. The survey asked respondents whether they would be interested in participating in a site visit, and those who agreed made up the sample frame for recruiting site visit participants. The project team provided an incentive of $20 to respondents who completed the telephone or online survey and an additional $100 to those who completed a site visit.

This process began by sending postcards (in batches) to a randomly selected set of households, encouraging them to complete the survey using a link to an online version or by calling a field agent using a toll-free number. Approximately 10 days after each mailing, the project team followed up with telephone calls to nonresponders for each record where a telephone number was matched to the sampled address. Additionally, NYSERDA followed up these attempts with an email reminder to a subset of nonresponders where email addresses were available.

As study team members responsible for completing site visits, Honeywell and PSD each handled recruiting and scheduling site visit participants from the group of survey respondents who expressed a willingness to participate. EDRs were divided among the two companies to avoid confusion during recruiting and to allow each company to realize efficiencies by focusing on a smaller geographic area.

## B.1.8 Summary of Data Collection Activities

The 2019 RBSA sample design and recruitment led to completion of 2,419 surveys (2,223 online and 196 phone) between September 28, 2018, and December 3, 2018, as shown in Table 2. The project team completed 456 site visits between October 10 and December 15, 2018.

TABLE 2. SITE VISITS AND SURVEY COMPLETIONS BY HOME VINTAGE

| Respondent Type | Target Survey Completions | Survey Completions | Target Site Visit Completions | Site Visit Completions |
|---|---|---|---|---|
| Existing Homes | 1,825 | 1,835 | 366 | 361 |
| New Homes | 598 | 584 | 120 | 95 |
| **Total** | **2,423** | **2,419** | **486** | **456** |

Table 3 shows survey completions and site visits by EDR.

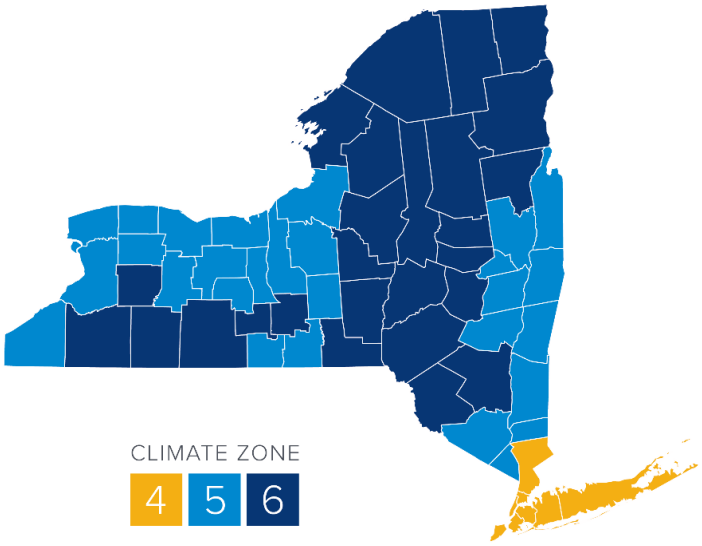
TABLE 3. SURVEY COMPLETIONS AND SITE VISITS BY ECONOMIC DEVELOPMENT REGION

| Economic Development Region | Survey Completions | Target Site Visits Completions | Site Visits Completions |
|---|---|---|---|
| Capital District | 258 | 48 | 48 |
| Central New York | 304 | 65 | 64 |
| Finger Lakes | 289 | 60 | 62 |
| Long Island | 243 | 40 | 33 |
| Mid-Hudson | 194 | 41 | 41 |
| Mohawk Valley | 142 | 31 | 32 |
| New York City | 287 | 73 | 55 |
| North Country | 148 | 33 | 29 |
| Southern Tier | 205 | 31 | 28 |
| Western New York | 349 | 64 | 64 |
| **Total** | **2,419** | **486** | **456** |

## B.1.9 Climate Zones

The 62 counties within the State vary in climate from Climate Zone 4 to Climate Zone 6, as shown in Figure 4 and as defined in the 2009 and 2015 International Energy Conservation Code. Consistent with the 2015 RSBS, for the purpose of analyzing and presenting results, the 2019 RBSA project team grouped survey and site visit participants into the three climate zones by county, as shown in Figure 5.

## FIGURE 4. NEW YORK STATE CLIMATE ZONE MAP




## FIGURE 5. NEW YORK STATE CLIMATE ZONE BY COUNTY

| CLIMATE ZONE 4 | | | |
|---|---|---|---|
| Bronx | Nassau | Queens | Suffolk |
| Kings | New York | Richmond | Westchester |
| **CLIMATE ZONE 5** | | | |
| Albany | Erie | Ontario | Saratoga |
| Cayuga | Genesee | Orange | Schenectady |
| Chautauqua | Greene | Oswego | Seneca |
| Chemung | Livingston | Orleans | Tioga |
| Columbia | Monroe | Putnam | Washington |
| Cortland | Niagara | Rensselaer | Wayne |
| Dutchess | Onondaga | Rockland | Yates |
| **CLIMATE ZONE 6** | | | |
| Allegany | Franklin | Montgomery | Sullivan |
| Broome | Fulton | Oneida | Tompkins |
| Cattaraugus | Hamilton | Otsego | Ulster |
| Chenango | Herkimer | Schoharie | Warren |
| Clinton | Jefferson | Schuyler | Wyoming |
| Delaware | Lewis | St. Lawrence | |
| Essex | Madison | Steuben | |

Table 4 shows survey and site visit completions by climate zone for new and existing homes.

TABLE 4. SURVEY AND SITE VISIT COMPLETIONS BY HOME VINTAGE AND CLIMATE ZONE

| Climate Zone | Survey Completions | | Site Visit Completions | |
|---|---|---|---|---|
| | Existing Homes | New Homes | Existing Homes | New Homes |
| Climate Zone 4 | 515 | 38 | 85 | 5 |
| Climate Zone 5 | 913 | 420 | 206 | 68 |
| Climate Zone 6 | 407 | 126 | 70 | 22 |
| **Total** | **1,835** | **584** | **361** | **95** |

## B.1.10 Weights

The basic function of a weight is to estimate the number of homes each home represents. If 50 out of 1,000 homes are sampled in a given stratum, the resulting weight would be 20 (Population (N)/sample size (n)). For example, if a single ground-source heat pump is observed in one home (which represents 20 homes), you can estimate that 20 homes in the population have a ground-source heat pump. If you observe an average of eight LEDs in each home, you can estimate that the population of 1,000 homes includes 8,000 LEDs (50 homes * 8 bulbs * 20 weight, or 8 bulbs * 1,000 homes).

For the 2019 RBSA, stratifying by climate zone within each home vintage—new and existing—results in six distinct strata:

- Climate Zone 4 Existing Homes.
- Climate Zone 5 Existing Homes.
- Climate Zone 6 Existing Homes.
- Climate Zone 4 New Homes.
- Climate Zone 5 New Homes.
- Climate Zone 6 New Homes.

The study assumed that the random sampling within each EDR resulted in representative samples of the populations in each of these six strata. Accordingly, when characterizing specific parameters within each stratum, applying sampling weights to the results is unnecessary.

When calculating totals, means, proportions, or other summary statistics for a population that encompasses more than one of the six strata, a sample weight must be applied to each observation to give it the appropriate contribution for the population. Cadmus calculated a weight for each of the six strata and for each primary data collection method—survey and site visit—by dividing the estimated population of single-family homes in that stratum by the achieved sample size in that stratum.

The analysis for a given characteristic often involved recalculating stratum weights to account for a smaller sample size, because in many cases values for a given characteristic were not known for some of the sampled homes. The project team calculated a new weight for each stratum as the stratum population (which was always the same for that stratum) divided by the number of homes in the sample with observed values. Cadmus recalculated weights only when the subset of homes with observed values were meant to be representative of the population of

that stratum. Site weights that assume a full sample size for each stratum are provided for each observation in the 2019 RBSA survey and site visit datasets.

Cadmus used 2016 American Community Survey (ACS) *5-Year Estimates* to estimate the total population of homes in each climate zone and used "Building Permits Survey" data from census.gov to estimate new homes populations. Cadmus subtracted the new homes population from the total population to arrive at estimates for existing homes. Table 5 shows the population estimates used in the weighting calculations for survey and site visit observations. The *B.2 Web and Telephone Survey* and *B.3 Site Visits* sections provide tables with the survey weights for observations in both data collection methods.

TABLE 5. 2019 RESIDENTIAL BUILDING STOCK ASSESSMENT POPULATION ESTIMATES

| Climate Zone | Population | |
|---|---|---|
| | Existing Homes | New Homes |
| Climate Zone 4 | 2,516,613 | 12,105 |
| Climate Zone 5 | 1,945,375 | 18,451 |
| Climate Zone 6 | 807,178 | 7,169 |
| **Total** | **5,269,166** | **37,725** |

## B.1.11 Estimation Methods

Cadmus used SAS statistical software to calculate weighted mean and proportion tables presented in Appendix A. For tables presenting proportions and distributions, Cadmus used the SAS procedure PROC SURVEYFREQ. For tables presenting means, Cadmus used the SAS procedure PROC SURVEYMEANS. Inputs to these procedures are outlined in Table 6.

TABLE 6. SAS PROCEDURES USED IN RESIDENTIAL BUILDING STOCK ASSESSMENT ANALYSIS

| Procedure | Statement | Input |
|---|---|---|
| PROC SURVEYFREQ[a] | TABLE | Grouping variables used in the rows and columns for the tables. These could include either a stratification variable or any variable used to report results. |
| | WEIGHT | If reporting whole-home results, WEIGHT is specified as the case weight. If reporting component-level results, WEIGHT is specified as the case weight multiplied by the number of components within the home. |
| PROC SURVEYMEANS[b] | VAR | Grouping variable used in the rows for the tables. This could include either a stratification variable or any variable used to report results. |
| | STRATA | Grouping variable used in the columns for the tables. This could be a stratification variable or any variable used to report results. |
| | BY | Grouping variable used in the columns for the tables, such as home vintage or climate zone. Using the BY statement provides completely separate analyses of the BY groups for each column. |
| | WEIGHT | If reporting whole-home results, WEIGHT is specified as the case weight. If reporting component-level results, WEIGHT is specified as the case weight multiplied by the number of components within the home. |

[a] *https://support.sas.com/documentation/cdl/en/statug/63347/HTML/default/viewer.htm#statug_surveyfreq_sect003.htm*
[b] *https://support.sas.com/documentation/cdl/en/statug/63033/HTML/default/viewer.htm#statug_surveymeans_sect006.htm*

Estimates and standard errors produced using the methods outlined above are weighted estimates using stratified estimation methods and are representative of what is expected in the population based on the sample. To understand the methodology of the SAS procedures used in this analysis, or to perform this analysis with a different program, please see *the B.1.11.1 Formulas* section below.

### *B.1.11.1 Formulas*

Formulas in this section allow estimation of whole-home metrics. If estimating at a component level, replace the population of homes ($N$) and sample size of homes ($n$) with the estimated population of components ($\widehat{M}$) and number of sampled components ($m$). The formulas in this section use the notations provided in Table 7 for stratified estimation.

TABLE 7. NOTATION FOR STRATIFIED ESTIMATION

| Symbol | Description |
|---|---|
| $Y, y$ | Observation within population (upper case) or sample (lower case) |
| $i$ | Home identifier |
| $l$ | Stratum defined by a unique combination of climate zone and building type |
| $N, n$ | Population of homes (upper case) and sample size (lower case) of homes |
| $\widehat{M}, m$ | Estimated population of components (upper case) and sample size of components (lower case), where $\widehat{M} = N * m$ |

Note that all estimates are parameter-level metrics but will use building-level population stratified estimation formulas. The population sizes, $Nl$, correspond to building population sizes in each of the six strata.

#### B.1.11.1.1 Estimation within a Single Stratum

Calculating means or proportions within a single stratum, such as for one climate zone and home vintage, does not require stratification weighting. Use the formulas for mean and proportion estimates in Equation 1 through Equation 4. *These equations should be used only within a single stratum and, in most cases for the NYSERDA RBSA, Equation 5 through Equation 8 will also be necessary when conducting the analysis on a given characteristic.*

***Equation 1: Means***

Means should be calculated using Equation 1, where $y_{il}$ represents the observed metric for home *i* in stratum *l*, $n_l$ represents the number of instances in the sample in stratum *l* with that metric observed, and $\bar{y}_l$ represents the estimated mean of the observed metric in stratum *l*.

$$\bar{y}_l = \frac{1}{n_l} \sum_{i=1}^{n_l} y_{il}$$

***Equation 2: Stand Errors of Estimated Means***

Standard errors of the estimated means should be calculated using Equation 2, where the $y_{il}$ and $n_l$ are the same as in Equation 1, $N_l$ represents the population size of homes in stratum *l*, and $SE(\overline{yl})$ represents the standard error of the estimated mean in stratum *l*. Again, this equation is valid only for results within a given stratum and additional equations will be needed when results span two or more strata.

$$SE(\bar{y}_l) = \sqrt{\left(1 - \frac{n_l}{N_l}\right)\left(\frac{1}{n_l}\right)\left(\frac{1}{n_l - 1}\sum_{i=1}^{n_l}(y_{il} - \bar{y}_l)^2\right)}$$

***Equation 3: Proportions***

Proportions should be calculated using Equation 3, where $n_{l^*}$ represents the number of observations with the characteristic of interest (for example, homes of a certain height) and $n_l$ represents the number of homes in the sample in stratum *l* with a known value for that characteristic. For example, to estimate the proportion of doors within each weatherstripping category, calculate $n_{l^*}$ by counting the number of doors in stratum *l* with known values, such as good, fair, poor, or none, then divide each $n_{l^*}$ by $n_l$, the total number of doors with weatherstripping observed in the stratum. The result will be one $\hat{p}_l$ value for each characteristic (good, fair, poor, and none).

$$\hat{p}_l = \frac{n_l^*}{n_l}$$

***Equation 4: Standard Errors of Estimated Proportions***

Standard errors of estimated proportions should be calculated using Equation 4, where $nl$ is the same as above and $Nl$ represents the population size of observations in stratum *l*. The estimate from Equation 3 results in $\hat{p}l$, and $SE(\hat{p}l)$ represents the standard error of the estimated proportion in stratum *l*.

$$SE(\hat{p}_l) = \sqrt{\left(1 - \frac{n_l}{N_l}\right)\frac{\hat{p}_l(1 - \hat{p}_l)}{n_l}}$$

### B.1.11.1.2 Stratified Estimation: Combining Multiple Strata

Estimating means or proportions for populations that include multiple combined strata requires stratification weighting. Equation 5 through Equation 8 should be used to estimate values that represent more than one stratum, such as statewide values and values that represent all homes (new and existing) within each climate zone. These build on Equation 1 through Equation 4 above.

***Equation 5: Combined Means***

Means should be calculated using Equation 5, where $\bar{y}_l$ is the mean within stratum *l* and $N_l$ is the population size of homes in stratum *l*. The products of the population sizes and mean estimates should be summed, then divided by the sum of the population sizes. In the summation notation, *L* represents the total number of strata. The result is a combined mean estimate, $\bar{y}$. For example, to estimate the mean conditioned floor area for the State, the user should assign *l*=1 to 6 to represent the six strata defined for the study. The user should sum the population sizes from the six strata to calculate the denominator in Equation 5 and divide the sum of the product of each stratum population size $Nl$ with the stratum mean estimate $\bar{y}l$ by the summed population sizes.

$$\bar{y} = \frac{\sum_{l=1}^{L} N_l * \bar{y}_l}{\sum_{l=1}^{L} N_l}$$

***Equation 6: Standard Errors of Estimated Means***

Standard errors of estimated means should be calculated using Equation 6 with the standard error of the estimated mean in each stratum *l*, $SE(\bar{y}_l)$, defined above in Equation 2. The products of the squared population sizes, $N_l$, should be summed with the squared mean standard errors, $SE(\bar{y}_l)$, then the square root of the sum should be divided by the sum of the population sizes.

$$SE(\bar{y}) = \frac{1}{\sum_{l=1}^{L} N_l} \sqrt{\sum_{l=1}^{L} N_l^2 * SE(\bar{y}_l)^2}$$

***Equation 7: Proportions***

Proportions should be calculated using Equation 7, where $\hat{p}_l$ represents the proportion in each stratum *l* and is defined above in Equation 3. The population size, $N_l$, represents the number of homes in each stratum *l*. Similar to the combined mean estimate, the product of the population sizes and the strata proportions should be summed, then divided by the sum of the strata population sizes.

$$\hat{p} = \frac{\sum_{l=1}^{L} N_l * \hat{p}_l}{\sum_{l=1}^{L} N_l}$$

***Equation 8: Standard Errors of Combined Proportion Estimates***

Standard errors of the combined proportion estimates should be calculated using Equation 8, with the standard error of the estimated proportion in each stratum, $\hat{p}_l$, calculated using Equation 4 and the strata population sizes $N_l$. The product of the squared population sizes, $N_l$, and squared standard errors, $SE(\hat{p}l)$, should be summed in each stratum, then square root of the sum should be divided by the sum of the population sizes.

$$SE(\hat{p}) = \sqrt{\frac{\sum_{l=1}^{L} N_l^2 * SE(\hat{p}_l)^2}{\sum_{l=1}^{L} N_l}}$$

## B.1.12 Comparisons of Weighted Data to Other Data Sources

Cadmus compared weighted results from survey and site visit data to numerous sources, including the following:

- 2013-2017 ACS *5-Year Estimates*.
- 2016 U.S. Energy Information Administration *Electric Sales, Revenue, and Average Price*, Table 5.a.
- U.S. Energy Information Administration *2009 Residential Energy Consumption Survey.*
- D&R International and the Heating Air-Conditioning & Refrigeration Distributors International data for 2017.

Table 8 shows a comparison of weighted 2019 RBSA statewide results for several key characteristics. Most of the values in the Other State Data Sources column are available only for single-family and multifamily homes combined, making direct comparisons between the 2015 RSBS and 2019 RBSA study results difficult. In addition, the annual energy consumption results for the 2019 RBSA are not directly comparable with those shown for the 2015 RSBS, because the 2019 estimates are based on data taken from bills during site visits; in contrast, the 2015 RSBS results were calculated for survey respondents' using billing data provided by utilities, which was not practical for the 2019 RBSA given its accelerated timeline.

While Table 8 shows statistically significant differences between the 2019 RBSA and 2015 RSBS studies for several characteristics, values for key parameters such as home size, annual energy consumption, and number of occupants speak well for the representativeness of the sample. As noted in Volume 5 of the 2015 RSBS report, most metrics that may indicate bias in the sample, such as high educational attainment and relatively high income, apply to the home occupants rather than to the home itself, which was the sampling unit for the study. In addition, it is possible that survey respondents may exaggerate their household income and educational attainment.

As noted in reporting for the 2015 RSBS, some of the observed differences in demographic data between the current study and benchmark sources, such as the differences in education, could be explained by differences in methodology. The 2019 RBSA estimates that 39% of households or building units have at least one household member with a graduate degree. In comparison, about 15.4% of respondents to the ACS reported that they have a graduate degree. Note that the 2019 RBSA survey collected the highest level of educational attainment for *anyone* in household, which may have been interpreted to include grown children who had moved away, while the ACS collected the highest level of education of only the *respondent*.

TABLE 8. TYPICAL SINGLE-FAMILY EXISTING HOMES PROFILE

| Characteristic | 2015 RSBS Statewide | 2019 RBSA Statewide | Other State Data Sources (Single-Family and Multifamily) |
|---|---|---|---|
| Home age—built in 1939 or earlier[a] | 28.0% | 25.2% | 32.3%[b] |
| Home square footage less than 2,000[a] | 65.3% | 58.6%▼ | 1,832 sq ft average[c] |
| Average number of bedrooms[a] | 3.1 | 3.4▲ | 31.7% three bedrooms[b] |
| Most common house type—single-family detached house[a] | 71.7% | 87.7%▲ | 65%[b] |
| Annual energy consumption between 6,000 kWh and 12,000 kWh[d] | 40.4% | 50.5%▲ | 6,864 kWh average[e] |
| Occupancy—own/buying[a] | 81.2% | 97.4%▲ | 54% owner-occupied[b] |
| Average number of occupants[a] | 2.8 | 2.8 | 2.6[b] |
| Annual household income of $75,000 or more[a] | 46.0% | 52.9%▲ | 43%[b] |
| Highest education level in household of graduate degree[a] | 33.9% | 39.5%▲ | 15.4% of respondents age 25 and over[b] |

[a] From survey data.
[b] From 2013-2017 ACS *5-Year Estimates*;
[c] From U.S. Energy Information Administration *2009 Residential Energy Consumption Survey*.
[d] From site visit data.
[e] From U.S. Energy Information Administration 2016 *Electric Sales, Revenue, and Average Price.*

Table 9 shows a comparison of the new home samples for the 2019 RBSA and 2015 RSBS. With the 2019 RBSA, a smaller percentage of homes appear to have less than 2,000 square feet of living space, reported household income is better aligned with that of existing homes than with the 2015 RSBS sample, and a significantly lower percentage of homes are single-family detached houses.

TABLE 9. TYPICAL SINGLE-FAMILY NEW HOMES PROFILE

| Characteristic | 2015 RSBS Statewide | 2019 RBSA Statewide |
|---|---|---|
| Average HERS rating[a] | 68.5 | 55.7▼ |
| Home age—built in 2015 or after[b] | 67.0% | 33.8%▼ |
| Home square footage less than 2,000[b] | 36.8% | 44.9%▲ |
| Average number of bedrooms[b] | 3.3 | 3.4 |
| Annual energy consumption between 5,470 kWh and 8,202 kWh[a] | 29.2% | 22.0% |
| Most common home type—single family detached house[b] | 93.6% | 83.8%▼ |
| Occupancy—own/buying[b] | 99.7% | 98.8% |
| Annual household income of $75,000 or more[b] | 75.6% | 56.5%▼ |
| Average number of occupants[b] | 2.9 | 3.1 |
| Highest education level in household of graduate degree[b] | 44.2% | 48.0% |

[a] From site visit data.
[b] From survey data.

## B.1.13 Statistical Confidence, Precision, and Error Bounds

As mentioned in the *B.1.5 Sample Design* section above, Cadmus developed a sampling plan with the goal of achieving 90% confidence and ±10% precision for most parameters of interest statewide. Precision represents uncertainty with a level of confidence. When the study achieves ±10% precision at the 90% confidence level, one can be 90% confident that any random sample of the same population would yield a result within ±10% of the study's result.

Data tables provided in Appendix A include error bounds for all values. Cadmus calculated the error bounds as the standard error multiplied by a t-statistic, and they provide the half-width of the 90% confidence interval. Error bounds are equivalent to absolute precision and have the same units as the estimate. When reporting precision, absolute precision is typically reported for percentages or distributions, while relative precision is typically reported for means or totals. To calculate the relative precision for a given mean or total, divide the error bound by the associated estimate. With percentages, the reported error bound represents the absolute precision.

With a total sample size of 2,419 across the six strata, the precision for survey results easily falls within the target 90/10 for the State and for each stratum except Climate Zone 4 new homes. Even with that stratum, however, the survey sample size of 38 often delivers results within the 90/10 target given the relatively small coefficients of variation for many characteristics in new homes.

Site visit results for key metrics easily fall within the 90/10 target at the statewide level, with a total sample size of 456 sites, and often meet 90/10 within climate zones. For one key metric mentioned above in the *B.1.5 Sample Design* section, average air leakage expressed in air changes per hour (ACH50), analysis showed a relative precision of ±7% statewide at the 90% confidence level, ±13% for Climate Zone 4, ±8% for Climate Zone 5, and ±17% for Climate Zone 6. That said, it is worth keeping in mind that air leakage rates in existing homes are highly variable, making it difficult to obtain good precision for this variable.

With a site visit sample size of only five, results for the Climate Zone 4 new homes stratum generally yield poor precision and should not be considered representative due to the small sample size.

# B.2 WEB AND TELEPHONE SURVEY

## B.2.1 Summary of Approach

The RBSA web and phone survey collected data from September 28, 2018, through December 3, 2018, and allowed participation by telephone or web. Using input from NYSERDA's evaluation and program staff, Cadmus designed the survey to closely align with the 2015 RSBS baseline survey to ensure that results could be compared. The survey and survey programming were reviewed and approved by NYSERDA prior to the launch.

Additional questions for the 2019 RBSA collected information about several factors:

- Connected devices.
- Smart thermostats.
- Number of ductless mini-split heat pumps installed.
- Supplemental heating systems.
- Willingness to pay at various levels for high-efficiency equipment.
- Utility bill payment and assistance.

The key objectives of the survey were to provide up-to-date, self-reported estimates of equipment types, fuel types and uses, vintages, and efficiencies, as well as information about building characteristics, demographics, homeowner energy consumption attitudes and behaviors, participation in energy efficiency programs, and willingness to pay for different types of efficient equipment. Additionally, the survey was used to recruit households for site visits.

Honeywell conducted the telephone surveys. Phone staff made multiple attempts to reach potential respondents on different days of the week and different times of the day.

The project team offered survey respondents the option to receive a $20 Amazon gift card electronically through email or as a physical gift card mailed to them for their participation in the survey. If requested, the survey respondents were provided with an optional pre-paid Visa card. The project team distributed gift cards on a weekly basis.

## B.2.2 Sampling

To identify recipients for RBSA recruiting postcards, Cadmus began by drawing a random sample of single-family households from the 2015 to 2017 New York State Department of Taxation and Finance tax assessment rolls within each EDR. The tax assessment rolls did not include phone numbers or email records. Cadmus matched phone numbers for 85% of the sampled records using a third-party data source, Marketing Systems Groups, to allow outreach to nonresponders by phone.

The tax assessment rolls included ample homes for the existing homes sample (homes built before 2015) for most EDRs but provided too few new homes records to adequately support recruiting for new homes. In addition, the tax assessment roll data included no homes in the New York City EDR and several counties elsewhere in the State. The data included very few new homes in Long Island. After consultation with NYSERDA, Cadmus purchased address lists

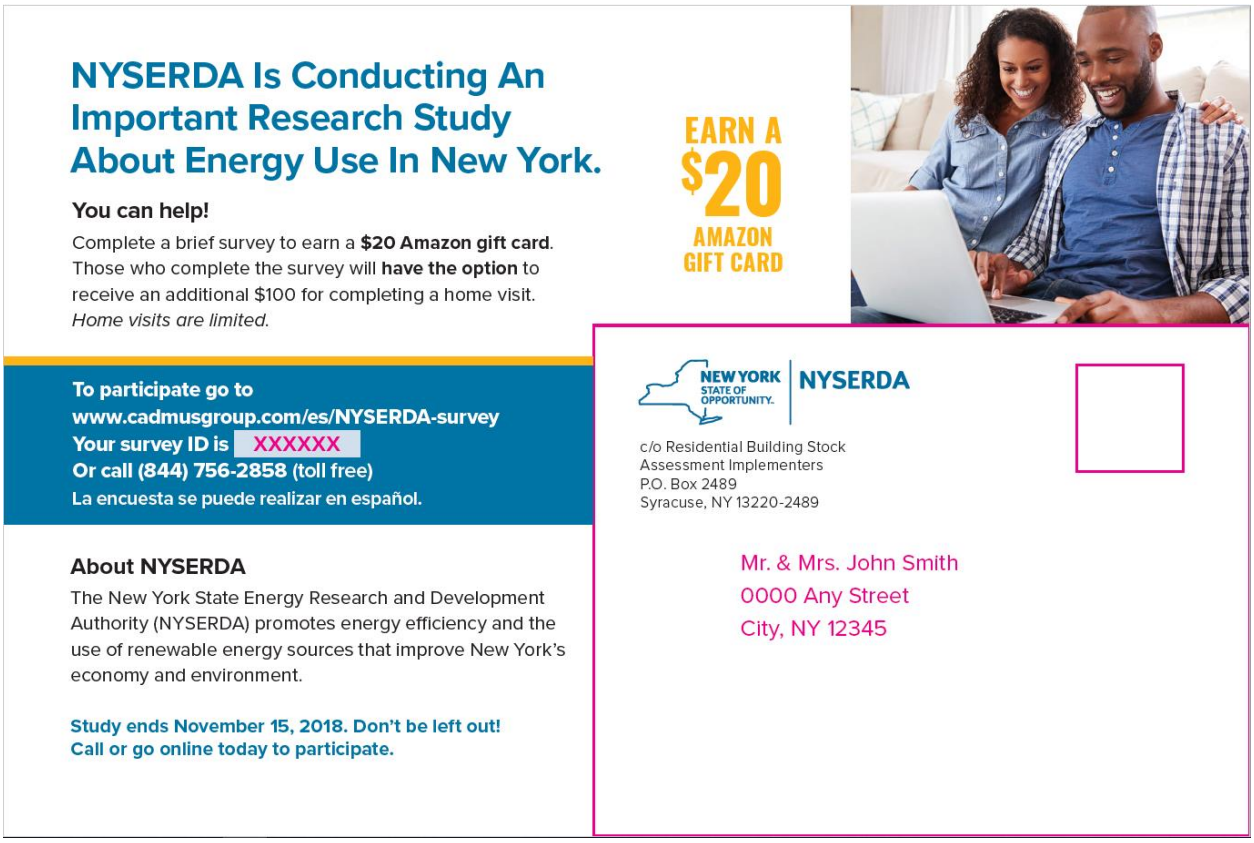
for New York City, new homes, and other segments as needed from a third-party data source, Dynata. Forty-four percent of purchased new homes records included a phone number.

### B.2.3 Response Rates

To recruit survey recipients, the project team mailed postcards to randomly selected homes within each EDR in sufficient numbers to reach the site visit goals, where practical. Designed by Honeywell under the direction of NYSERDA and Cadmus, the postcards (see Figure 6 and Figure 7) invited recipients to complete the survey online or by phone and provided a toll-free number. The postcards noted that the survey was offered in Spanish, and Honeywell provided phone staff to conduct surveys in English or Spanish at a toll-free number. Honeywell phone staff also attempted to contact postcard recipients by phone who had not responded.

FIGURE 6. EXAMPLE OF RECRUITING POSTCARD, FRONT

FIGURE 7. EXAMPLE OF RECRUITING POSTCARD, BACK




Like the 2015 RSBS, the 2019 RBSA offered a $20 gift card to respondents who completed the survey, along with an additional $100 gift card to those who went on to complete a site visit. As a default, Cadmus provided an electronic Amazon gift card, which was delivered by email. Alternatively, physical Visa and Amazon gift cards were available on request.

Cadmus built its initial recruiting plan around the 13.6% response rate reported for the previous study. In practice, given the recruiting methodology available during the short timeline and the timing of the November 2018 elections, the actual response rate proved much lower. The project team mailed postcards in successive batches, adjusting the timing, targeted EDRs, and quantities as necessary, with the goal of meeting site visit targets while also minimizing cost. Overall, the project team mailed 138,281 postcards (in addition to sending an email blast to 3,994 recipients) and achieved a response rate of 2%, as shown in Table 10.

Table 10 also shows disposition and response rate by EDR, which ranged from 1% for New York City and Long Island to 3% for Capital District, Finger Lakes, and North Country. Despite rigorous call attempts to postcard recipients who had not responded, an unexpectedly small number of survey respondents—196 of 2,419—opted to complete the survey by phone.

## TABLE 10. WEB AND TELEPHONE SURVEY DISPOSITION AND RESPONSE RATE BY ECONOMIC DEVELOPMENT REGION

| Disposition | Capital District | Central New York | Finger Lakes | Mid-Hudson | Long Island | Mohawk Valley | New York City | North Country | Southern Tier | Western New York | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total sampled (mailed) | 7,791 | 17,322 | 10,635 | 10,720 | 23,850 | 7,215 | 29,085 | 5,529 | 8,395 | 17,739 | 138,281 |
| Completed by phone | 17 | 26 | 6 | 11 | 22 | 16 | 44 | 10 | 17 | 27 | 196 |
| Completed via web | 241 | 278 | 283 | 183 | 221 | 126 | 243 | 138 | 188 | 322 | 2,223 |
| Partially completed | 16 | 26 | 16 | 12 | 27 | 9 | 26 | 7 | 8 | 30 | 177 |
| Active sample (received postcard but did not begin survey) | 6,849 | 16,179 | 9,960 | 10,155 | 23,107 | 6,794 | 27,832 | 5,174 | 7,891 | 16,904 | 130,845 |
| Refused to complete | 165 | 173 | 112 | 85 | 106 | 58 | 171 | 55 | 58 | 95 | 1,078 |
| Invalid phone number (disconnected) | 482 | 609 | 231 | 224 | 330 | 192 | 656 | 115 | 211 | 325 | 3,375 |
| Business line (wrong number) | 1 | 0 | 1 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 18 |
| Language barrier | 1 | 0 | 0 | 2 | 0 | 6 | 0 | 18 | 1 | 0 | 28 |
| Ineligible - wrong address | 3 | 10 | 7 | 5 | 3 | 7 | 9 | 5 | 12 | 11 | 72 |
| Ineligible - invalid utility | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Ineligible - do not occupy home | 1 | 7 | 10 | 5 | 5 | 2 | 7 | 4 | 2 | 7 | 50 |
| Ineligible - invalid housing type | 12 | 12 | 8 | 31 | 10 | 4 | 64 | 3 | 7 | 16 | 167 |
| Ineligible - invalid number of units | 3 | 2 | 1 | 7 | 3 | 0 | 33 | 0 | 0 | 2 | 51 |
| **Response rate[a]** | **3%** | **2%** | **3%** | **2%** | **1%** | **2%** | **1%** | **3%** | **2%** | **2%** | **2%** |
| **Cooperation rate[b]** | **4%** | **2%** | **3%** | **2%** | **1%** | **2%** | **1%** | **3%** | **3%** | **2%** | **2%** |

[a] The response rate was calculated as the number of completed telephone and web surveys divided by the total sampled.
[b] The cooperation rate was calculated as the number of completed telephone and web surveys divided by the total sampled minus invalid phone numbers, business lines, language barriers, and ineligible cases.

## B.2.4 Data Cleaning

Cadmus performed mostly minimal cleaning of the survey data, largely in the spirit of preserving participant responses, but did make two substantive changes to the survey data.

- Consistent with the 2015 RSBS, the 2019 RBSA survey included "baseboard heat" as an option for the primary heating system, without specifying what type of baseboard heat. Cadmus noted that 200 survey respondents identified their primary heating fuel as something other than electricity and identified their primary heating type as baseboard heat. Cadmus changed the primary heating system for these respondents to "Steam/hot water system with radiators or pipes in each room (central boiler)."
- An unrealistically large number of survey respondents—340—identified their water heating equipment as a heat pump water heater. Roughly 60% of these identified their water heating fuel as natural gas or another fossil fuel rather than electricity. For the 61 sites that were also included in the site visit sample, site visit data showed that only eight had heat pump water heaters, and roughly 80% of the 61 had correctly identified their water heating fuel type. After consultation with NYSERDA, Cadmus changed water heater type to "Don't know" for 208 survey respondents who identified their water heater as a heat pump water heater but identified their water heater fuel as something other than electricity.

Data cleaning and QC entailed making the styling, capitalization, and spelling of entered values (such as utility names) consistent and categorizing "Other" responses within predefined categories as appropriate.

## B.2.5 Stratification Weights

When calculating totals, means, proportions, or other summary statistics for a population that encompasses more than one of the six strata, a sample weight must be applied to each observation to give it the appropriate contribution for the population. Cadmus calculated a weight for each of the six strata by dividing the estimated population of single-family homes in that stratum by the achieved sample size. Table 11 shows the population, survey completion, and calculated survey weight for each of the six strata.

TABLE 11. SURVEY STRATIFICATION WEIGHTS

| Climate Zone | Population | | Survey Completions | | Survey Weights | |
|---|---|---|---|---|---|---|
| | Existing Homes | New Homes | Existing Homes | New Homes | Existing Homes | New Homes |
| Climate Zone 4 | 2,516,613 | 12,105 | 515 | 38 | 4,886.63 | 318.55 |
| Climate Zone 5 | 1,945,375 | 18,451 | 913 | 420 | 2,130.75 | 43.93 |
| Climate Zone 6 | 807,178 | 7,169 | 407 | 126 | 1,983.24 | 56.90 |
| **Total** | **5,269,166** | **37,725** | **1,835** | **584** | **N/A** | **N/A** |

## B.2.6 Limitations and Suggestions for Future Studies

The 2019 RBSA survey was an overall success, providing important and useful data for 2,419 respondents throughout the State and creating ample recruits for site visits in most strata. This section highlights the methodologies and choices that worked especially well and then describes challenges and limitations to consider for any future iterations of the project.

Several aspects of the 2019 RBSA survey methodology and process worked well:

- Sampling and recruiting by EDR ensured that the sample included homes throughout the State and provided a convenient geographic structure for organizing and assigning site visits.
- The electronic Amazon gift cards were well-received by most recipients and providing the gift cards to recipients was a relatively easy task to manage. Some people preferred physical gift cards, which increased expense and logistical overhead somewhat.
- Having the 2015 RSBS survey instrument as a starting point was essential to the project team's ability to deploy the 2019 RBSA survey within the allowed timeframe.

The following items summarize limitations of the methodology and data and provide a few suggestions for future iterations of the project:

- The recruiting approach (using utility customer data) for the 2015 RSBS resulted in an impressive response rate of 13.6% and should be used in future efforts if the project timeline will allow. Providing a lengthy enough timeline to allow the sample to be drawn from utility customer data appears to be key, at least partly because it may allow the study to receive accurate names, telephone numbers, and possibly even email addresses. Being able to recruit through mail, telephone calls, and particularly email would help to reduce the cost of contacting potential respondents and help to achieve the most representative sample practical.
- Survey recruiting succeeded in achieving more than adequate survey sample sizes for most strata, but new home survey completes were not high enough for either Climate Zone 4 or Climate Zone 6 to support meeting site visit goals in those climate zones.
- The comparatively small number of new homes in the State makes meeting new homes quotas especially difficult. If characterizing new homes remains a high priority, special care should be taken to construct a new homes sample from all available sources, focusing especially on EDRs in Climate Zone 4 and Climate Zone 6. These sources should include tax assessment data, purchased sample, and possibly even address lists from high-volume builders. Social media may also prove useful. This approach should be combined with a more deliberate recruiting methodology, such as the one used for the 2015 RSBS, to get the most responses from this typically small population of homes.
- Despite thorough investigation of the tax assessment roll data, Cadmus was able to identify only a small number of quadplexes, and these homes may have been underrepresented in the data.
- Survey length likely contributed to the low response rate for the 2019 RBSA. The survey used the 2015 RSBS survey script as a starting point, but numerous questions were added to investigate respondents' willingness to pay for different types of energy efficiency improvements and to collect data on additional types of equipment, such as connected devices and smart thermostats. After removing surveys that took longer than two hours, the average survey length was 38 minutes (n=2,216); after removing surveys that took longer than one hour, the average survey length was 33 minutes (n=1,980).
- The fall 2018 elections likely had a significant effect on both overall response rate and the ability of Honeywell phone staff to reach potential respondents by phone. Election-related postcards and letters made it less likely that RBSA postcards would be noticed, and the high volume of robocalls during that period may have caused many potential respondents to avoid answering the phone. Response rates may be higher in the future if the study can be timed to avoid competing with election-related marketing.
- NYSERDA is moving away from offering financial incentives. To allow for a sampling and recruiting approach that eliminates financial incentives, NYSERDA may want to

consider alternative forms of incentives, such as energy saver kits or home energy reports. The challenge will be to find an alternative to financial incentives that works but does not bias the sample more toward those who most value energy efficiency. Cadmus' experience is that financial incentives are critical to securing homeowner participation in surveys and site visits, and the project team recommends that any alternative approach be tested with surveys only and well in advance of the start of site visits.

- In isolated cases, survey response options (such as for baseboard heat) failed to adequately distinguish between the relevant technologies or choices. Should the study be replicated, the next project team should continue to improve the survey instrument.
- Some survey questions appear to require more knowledge about a given topic than many respondents possess, as evidenced by the 340 respondents mentioned above who reported having a heat pump water heater. While surveys excel at collecting many data points accurately and economically, this example underscores the value of and need to continue having site visits in future updates to the study. Being able to compare data from the two sources—sometimes for the same homes—allows confirmation that results are solid and helps identify cases where one data collection method may not be delivering an accurate result.

# B.3 SITE VISITS

## B.3.1 Summary of Approach

The project team conducted all site visits between October 10, 2018, and December 15, 2018, after a two-day in-person training for Honeywell and PSD project field staff. Under the direction of NYSERDA and Cadmus, PSD completed all new homes site visits through contracted HERS Raters. PSD also completed 170 existing homes site visits, while Honeywell staff completed 191 existing home site visits. All existing homes site visits were completed by HERS Raters or professionals holding Building Performance Institute (BPI) credentials.

For the RBSA survey, site visit data collection generally followed 2015 RSBS data scope and methods, including generating a HERS score for each new home and running blower door tests on all homes where allowed under Residential Energy Services Network (RESNET) and BPI standards. New data collected for the 2019 RBSA included several measures:

- Connected devices.
- Smart thermostats.
- LED bulbs.
- Extensive information about heat pump systems.

## B.3.2 Sampling and Recruitment

As study team members responsible for completing site visits, Honeywell and PSD handled recruiting and scheduling of site visit participants from the group of survey respondents who expressed a willingness to participate. EDRs were divided between the two companies to avoid confusion during recruiting and to allow each company to realize efficiencies by focusing on a smaller geographic area. The project team provided site visit participants with an additional $100 gift card. Table 12 shows site visit completions by EDR and home vintage.

TABLE 12. SITE VISIT COMPLETIONS BY ECONOMIC DEVELOPMENT REGION AND HOME VINTAGE

| Economic Development Region | Existing Homes | New Homes | Total |
|---|---|---|---|
| Capital District | 32 | 16 | 48 |
| Central New York | 57 | 7 | 64 |
| Finger Lakes | 44 | 18 | 62 |
| Long Island | 30 | 3 | 33 |
| Mid-Hudson | 23 | 18 | 41 |
| Mohawk Valley | 27 | 5 | 32 |
| New York City | 53 | 2 | 55 |
| North Country | 19 | 10 | 29 |
| Southern Tier | 26 | 2 | 28 |
| Western New York | 50 | 14 | 64 |
| **Total** | **361** | **95** | **456** |

## B.3.3 Response Rates

The percentage of survey respondents willing to schedule a site visit was relatively high, at 18.9%, as shown in Table 13. On the other hand, the site visit response rate calculated as a percentage of mailed postcards was below 1% for every EDR and was 0.3% overall. Recruiting proved most difficult in Long Island, where the site visit response rate from postcards was a mere 0.1%.

TABLE 13. SITE VISIT RESPONSE RATES BY ECONOMIC DEVELOPMENT REGION

| Economic Development Region | Postcards | Surveys | Site Visits | Response Rate from Surveys | Response Rate from Postcards |
|---|---|---|---|---|---|
| Capital District | 7,791 | 258 | 48 | 18.6% | 0.6% |
| Central New York | 17,322 | 304 | 64 | 21.1% | 0.4% |
| Finger Lakes | 10,635 | 289 | 62 | 21.5% | 0.6% |
| Long Island | 23,850 | 243 | 33 | 13.6% | 0.1% |
| Mid-Hudson | 10,720 | 194 | 41 | 21.1% | 0.4% |
| Mohawk Valley | 7,215 | 142 | 32 | 22.5% | 0.4% |
| New York City | 29,085 | 287 | 55 | 19.2% | 0.2% |
| North Country | 5,529 | 148 | 29 | 19.6% | 0.5% |
| Southern Tier | 8,395 | 205 | 28 | 13.7% | 0.3% |
| Western New York | 17,739 | 349 | 64 | 18.3% | 0.4% |
| **Total** | **138,281** | **2,419** | **456** | **18.9%** | **0.3%** |

## B.3.4 Safety

The project team placed the highest priority on the safety of field staff and participants. Field staff were trained to follow strict carbon monoxide and gas leak protocols, which were developed for the 2015 RSBS. An additional, separate safety protocol developed for the 2019 RBSA provided further guidance about general safety in participants' homes, including basics such as ladder safety and removing oneself from unsafe conditions.

## B.3.5 Data Quality

The project team ensured a high level of data quality through multi-layered quality assurance and QC processes:

- Field technician training.
- Data collection tool.
- QC site visits.
- Data collection protocols.
- Weekly meetings.
- Data collection tool completeness checks.
- Phase I data cleaning and QC (conducted by PSD).
- Phase II data cleaning and QC (conducted by Cadmus).

### *B.3.5.1 Field Technician Training*

All field staff deployed by PSD and Honeywell hold BPI certifications or are certified HERS Raters, and all are experienced with blower door equipment and other facets of home energy site visits. With oversight and contributions from NYSERDA and Cadmus, PSD performed the initial, two-day in-person project training for PSD, Honeywell, and Cadmus field staff at the NYSERDA offices and at a residential off-site setting. The presenters recorded each classroom session to allow trainees to review the content later and to support training of technicians who could not attend the in-person training on the scheduled dates.

PSD and Cadmus subsequently completed two additional rounds of training for field staff who could not attend the initial training or who were brought onto the project at a later date. These trainings required that the field staff view all recorded sessions from the in-person training as well as participate in a live webinar training. Field staff were also required to shadow a previously trained field technician on a site visit before conducting a site visit on their own.

### *B.3.5.2 Data Collection Tool*

Field staff captured and submitted site visit data using the iPad-based PSD data collection tool, which was an improved version of the software PSD deployed for the 2015 RSBS. One improvement that helped ensure a high level of data quality was a completeness check, which required that all inputs be provided before the data for a given site could be submitted as final. Cloud-based syncing helped minimize the possibility that collected data would be lost, and more data than for the 2015 RSBS were collected through drop-down menus instead of text entry, which provided consistency in data entry. The data collection tool and all data handling processes were implemented with enhanced security in accordance with NYSERDA protocols.

### *B.3.5.3 Quality Control Site Visits*

Cadmus performed follow-up QC site visits for approximately 10% of the site visits performed by each field technician to identify and correct data collection problems. Cadmus staff scheduled, conducted, and evaluated these visits, providing an additional $100 gift card to each participant. During QC data collection, the Cadmus field technician reviewed a copy of the original site report and noted any differences between that report and their own findings. After each QC site visit, Cadmus sent a summary of any identified data collection errors to the relevant field management staff at PSD or Honeywell, who shared the discrepancies with the field technician. QC site visits occurred during the data collection period to allow Cadmus, PSD, and Honeywell to correct any data collection issues before subsequent site visits. In addition, data corrections

for all 50 QCd sites were incorporated into the database during the data cleaning and QC process.

### *B.3.5.4 Weekly Field Staff Meetings*

With input and participation from Cadmus, PSD conducted weekly meetings with project field staff from PSD and Honeywell during the period of data collection from early October 2018 to mid-December 2018. Field staff were required to attend the meetings if they were not in the field at that time and if they had completed one or more site visits that week or were scheduled to complete at least one site visit the following week. These meetings provided a mechanism for Cadmus and PSD to reinforce key concepts and were often informed by issues noted during the QC site visits. The meetings also gave field staff a weekly forum for asking questions and raising any issues or concerns regarding the data collection tool, data collection protocols, or other topics related to the site visits.

### *B.3.5.5 Data Collection Protocols*

Cadmus created data collection protocols for major data collection categories, such as heating and cooling equipment, building envelope details, and appliances. Given the short project timeline, the data collection protocol documents did not pass through the formal review processes in time to be shared with the field technicians, but the process of generating and reviewing the documents helped ensure that Cadmus and PSD were aligned regarding how data should be collected, which in turn informed communication with field staff and updates to the PSD data collection tool. The data collection protocols will also a valuable resource for those who use the data and need a better understanding of how specific data points were captured, as well as for project staff working on future iterations of the project.

### *B.3.5.6 Quality Control and Data Cleaning*

Project staff ensured a high level of data quality through a multi-layered, two-phase approach to QC. The initial phase of QC, which was performed by PSD, included several tasks:

- An initial completeness review.
- An examination of key fields for technical inconsistencies and identification of apparent discrepancies for deeper, technical review.
- Resolution of identified technical discrepancies.
- Extensive cleaning of successive batches of site data using a combination of automated and manual checks.

PSD implemented the automated checks based on checks it identified and on a list provided by Cadmus, which defined numerous data quality checks related to value ranges and consistency across values.

After receiving each batch of draft, clean data, Cadmus performed additional, in-depth data cleaning and QC. The process comprised multiple layers of tasks and included a combination of automated and manual checks:

- Cadmus checked records for completion, verified that values fell within expected ranges, and checked for internal consistency. Project staff verified internal consistency through a QC punch list for each record type. The punch list outlined checks for specific combinations of information within the record.
  - An example of completion: If a furnace record was missing a key field—such as heating capacity—the record was flagged for deeper review.
  - An example of expected ranges: If a furnace record's heating capacity was entered as "12" and the heating capacity units were entered as "Btuh," the record was

flagged for deeper review, because 12 Btuh is not within the expected range for furnace heating capacities.

  - An example of internal consistency: If a furnace record's fuel type was entered as "Electricity" and the heating capacity units were entered as "Btuh," the record was flagged for deeper review, because capacity for electric HVAC equipment typically is not reported in British thermal units.

- For discrepancies found during the 50 sites where QC site visits were performed, Cadmus updated information collected during the original site visit with data collected during the QC site visit. For the QC site visits, technicians were provided with the original set of information collected on site and were directed to verify that the conditions on were accurately reflected in the data. Where necessary, the QC technicians recorded updates or new information.
- Cadmus performed site-level checks to detect and correct contradictory information that may have been entered on site, as well as to identify potential gaps in the site visit data. As an example, if a home's primary heating system was identified as a gas furnace but no gas utility was entered for the site, that site was flagged for review.

After each site and record was checked for completion and internal consistency, records and sites that had been flagged were reviewed by veteran field staff. Some equipment categories, such as mechanical equipment and building envelope, also received a more rigorous review by subject matter experts. Updates and corrections to the data were validated by reviewing photos and notes from the original site visit, by reviewing photos, notes, and data collected during the QC site visits, by confirming information through online databases, and by comparing site data against the survey or tax assessment data.

Data cleaning continued into the data analysis phase. As preliminary results became available, they were reviewed by a team of subject matter experts. In the case of unusual or unexpected results, the data quality team conducted a detailed review of the information in question using the resources outlined above.

### *B.3.5.7 Inferred Values*

Insulation values such as type and thickness often cannot be collected during site visits when attic or crawlspaces are inaccessible or walls cannot be probed. For certain cases, Cadmus inferred insulation values based on various criteria, including New York State Building Code requirements. Cadmus created a chart for State building code–required R-values and U-factors for floors, walls, ceilings, windows, and slabs. State code insulation values were determined for each home based on an assortment of criteria, including the year the home was built (and the corresponding State code requirements for that year), the county, the heating/cooling equipment efficiency, and the glazing area percentage.

Cadmus also created separate R-value and U-factor tables for general insulation and window values, respectively. The R-value table summarized average R-values per inch for various insulation types. Wherever possible, these values were determined from American Society of Heating, Refrigerating and Air-Conditioning Engineers or U.S. Department of Energy standards. Cadmus also mapped combinations of various window frame and glazing types to window U-factors using National Renewable Energy Laboratory data. Low-e glazing types were assumed to have the same U-factor as non-low-e glazing types, because an accurate and comprehensive U-factor database for low-e glazing types was not available.

To determine inferred inches of insulation, Cadmus divided the State code R-value by the average R-value per inch for the known insulation type. If the insulation type was not known, the

team used an average R-value per inch of 3.0. For wall insulation, where at least two compliance paths were allowed, Cadmus assumed that all insulation was provided in the wall cavities. Insulation type and/or thickness values were inferred for 38 homes in total—23 existing homes and 15 new homes. A data source column in the RBSA site visit dataset indicates whether the insulation values or a given envelope surface were observed or inferred, though in some cases values were inferred by field staff based on other information available on the site.

Window U-factors are not readily available on site, especially in older homes. Cadmus directed field staff to collect only documented U-factor values, but the collected data often included U-factors that appeared to be estimates. To provide U-factors for energy modeling or other purposes, Cadmus inferred window U-factor values based on the State building code requirements in force at the time of the home's construction (if any) and on window frame and glazing type. Cadmus retained U-factors recorded on site only if the building was a new home and the U-factor met State code. For new and existing homes, if the U-factor did not meet State code requirements, the project team replaced the U-factor with a value from either the State code in force at the time of the home's construction or from the window assembly table, using whichever value was smaller. Inferred window U-values were applied to 361 existing homes and 18 new homes. A data source column in the RBSA site visit dataset indicates whether a given U-factor value was inferred or collected.

Where applicable throughout the RBSA site visit dataset, data source columns provide an indication of whether provided values (such as year of manufacture or heating equipment efficiency) were known, estimated, or inferred.

## B.3.6 Stratification Weights

When calculating totals, means, proportions, or other summary statistics for a population that encompasses more than one of the six strata, a sample weight must be applied to each observation to provide the appropriate contribution for the population. Cadmus calculated a weight for each of the six strata by dividing the estimated population of single-family homes in that stratum by the achieved site visit sample size. Table 14 shows the population, site visit completion, and calculated survey weight for each of the six strata.

TABLE 14. SITE VISIT STRATIFICATION WEIGHTS

| Climate Zone | Population | | Site Visit Completions | | Site Visit Weights | |
|---|---|---|---|---|---|---|
| | Existing Homes | New Homes | Existing Homes | New Homes | Existing Homes | New Homes |
| Climate Zone 4 | 2,516,613 | 12,105 | 85 | 5 | 29,607.21 | 2,421.00 |
| Climate Zone 5 | 1,945,375 | 18,451 | 206 | 68 | 9,443.57 | 271.34 |
| Climate Zone 6 | 807,178 | 7,169 | 70 | 22 | 11,531.11 | 325.86 |
| **Total** | **5,269,166** | **37,725** | **361** | **95** | | |

## B.3.7 Limitations and Suggestions for Future Studies

The 2019 RBSA achieved the impressive feat of completing 456 site visits within four months of project award, including assembling the project team, updating necessary project tools and documentation, and implementing all aspects of the required recruiting infrastructure and processes. At the same time, the data quality steps outlined above ensured that the project delivered high-quality data. This section summarizes aspects of the project methodology and processes that worked well, along with areas for improving the next iteration of the study. This section also addresses any notable data reliability issues.

Aspects of the 2019 RBSA site visit methodology and process that worked well include the following:

- With the accelerated timeline of the project, PSD's ability to update the iPad data collection tool used in the 2015 RSBS quickly enough to support October data collection was critical to project success. In addition, though completing upgrades to the tool carried over into the data collection period, the software proved to be an efficient and reliable data collection solution.
- Distributing site visits among PSD and Honeywell allowed enough bandwidth to complete the site visits within the provided amount of time.
- Recruiting for site visits from the pool of survey respondents generally met expectations, with a response rate of nearly 20%.
- The electronic Amazon gift cards were well-received by most recipients, and providing the cards to recipients was a relatively easy task to manage.
- QC site visits proved invaluable for identifying and correcting data collection problems, whether they resulted from misunderstandings or a lack of alignment regarding the required level of effort. Notable isolated problems found early in the project included incorrectly characterized lighting by some field staff, particularly where bulbs were concealed by shades, and insulation values in accessible attic spaces that appeared to have been assumed rather than observed. Quick action by Cadmus, PSD, and Honeywell helped correct these and other early issues.
- As noted above, weekly field staff meetings were helpful for providing essential communication between field staff and management, and developing the data collection protocols ensured that project team members from Cadmus and PSD had the same understanding of how data points would be collected.
- Extensive data cleaning and QC from PSD and Cadmus provided high-quality, useful data. Combining automated checks with intensive site- and measure-level reviews by subject matter expects allowed for discrepancies and other data quality problems to be identified and corrected, often by reviewing field technician notes and photographs.
- Completing all site visits by mid-December avoided most weather-related problems, which helped minimize the need to cancel or reschedule site visits.
- Of 267 site visit participants who responded to questions about customer satisfaction in a follow-up survey, 99% (264) reported being *somewhat* or *very satisfied* with the site visit, and 90% (237) reported being *very satisfied*. The most common feedback was that participants wanted a report summarizing site visit results, which was not a component of this study.

The following items summarize limitations of the methodology and data and include suggestions for future iterations of the project:

- As mentioned in the *B.2.6 Limitations and Suggestions for Future Studies* section for surveys above, the recruiting approach used for the 2015 RSBS resulted in an impressive response rate of 13.6% and should be used in future efforts if practical within the project timeline.  a long enough timeline to allow the sample to be drawn from utility customer data appears to be key, at least partly because it may allow the study to receive accurate names, telephone numbers, and possibly even email addresses. Being able to recruit through mail, telephone calls, and particularly email would help to reduce the cost of contacting potential respondents and help to achieve the most representative sample practical.

- The most notable limitation of project data resulted from the small sample size of only five site visits for new homes completed in Climate Zone 4, which comprises New York City, Long Island, and the Mid-Hudson EDRs. With a sample size of only five homes, results for the Climate Zone 4 new homes stratum cannot be considered representative. After consultation with NYSERDA, Cadmus shaded results for that stratum in data tables that focus on new homes. Further, Cadmus removed observations from those five homes from all other calculations to eliminate the possibility of their introducing significant skew to other results.
- As mentioned in the survey limitations and recommendations above, if characterizing new homes remains a high priority, special care should be taken to construct a new homes sample from all available sources, focusing especially on EDRs in Climate Zone 4 and Climate Zone 6. These sources should include tax assessment data, purchased sample, and possibly even address lists from high-volume builders. Social media may also prove useful. This approach should be combined with a more deliberate recruiting methodology, such as the one used for the 2015 RSBS, to obtain the most responses from this typically small population of homes.
- The accelerated timeline caused many challenges with deploying field staff and the necessary tools and processes. A longer timeline would allow for more flexibility in project planning. Extending the length of time available for completing site visits would also allow the field work to be completed with fewer field staff, which would simplify project planning and support greater consistency in data collection.
- The lower-than-expected response rates caused a slower ramp up in site visits, because fewer survey respondents than expected were available to recruit for site visits. This put further pressure on PSD and Honeywell to complete a high volume of site visits in a short period of time. After consultation with NYSERDA, Cadmus was able to shift the expected timeline to complete site visits by December 15, 2018, instead of November 30. This allowed time for the rapid scale-up in recruiting to take effect, especially for new home participants.
- As expected, surveys and site visits delivered notably different results for some characteristics. While the large discrepancy in the number of reported heat pump water heaters is an obvious example that is difficult to fully explain, less dramatic discrepancies such as different reported percentages of appliances with ENERGY STAR ratings result at least partly from differences in methodology: survey questions ask about ENERGY STAR ratings only for appliances less than 10 years old, while site visits collected that data for appliances of any age. Appendix A provides results for many metrics from both survey and site visit data. Where results differ between survey and site visit data, Cadmus endeavored in the report to identify the more credible source using engineering judgement, available market penetration/saturation benchmarks, and other information.
- Cadmus recommends that in future studies, the project team continue to align survey and site visit methodology where this can be accomplished without losing the ability to compare key findings with results from the previous study.