Comparing the 2020 RECS with Previous RECS and Other Studies

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Introduction

This document describes:

- Differences between the 2020 *Residential Energy Consumption Survey* (RECS), the 2015 RECS, and previous studies
- Design and process changes between the 2020 RECS and the 2015 RECS
- Differences in weather in the United States between 2015 and 2020
- Differences between RECS and estimates from external sources

Knowing these differences will help readers compare estimates from one round of RECS to another and from the RECS to other studies.

We conduct the RECS periodically to provide detailed information about energy usage in U.S. homes. We conduct the RECS in two phases. Phase one is the cross-sectional *Household Survey* that collects energy-related characteristics and usage patterns from a representative sample of occupied primary housing units. Phase two is the *Energy Supplier Survey* (ESS), which collects billing data for responding households from their energy suppliers to allow us to estimate energy consumption and expenditures. Taken together, the housing characteristics data and the billing data are the basis for individual energy end-use consumption and expenditure estimates.

You can find additional information about RECS design and processes in the technical documentation for the 2020 RECS household characteristics and 2020 RECS consumption and expenditures.

Comparing 2020 RECS and Previous RECS Studies

Design and process changes

Each RECS is an independent, cross-sectional study of residential energy use. We have not sampled the same housing units across cycles (also called the longitudinal component) in the RECS design since the 1990 RECS. Although each RECS shares many design elements with previous rounds, including most questions and processes, each study updates design elements based on program needs, resources available, and process improvements. As such, if you are analyzing multiple rounds of RECS, you should consider where program updates might affect your analysis. Notable changes for the 2020 RECS that may limit comparisons with previous rounds are discussed here.

The following list contains changes between the 2015 and 2020 studies, and because each RECS study is independent, every iteration of this study is slightly different. So, you will find changes between 2020 and 2009 and so on, including earlier RECS that are not listed below. You can find survey forms and documentation for earlier RECS on the RECS website. The overall impact of the changes below, most notably sample size, is that we published estimates for the first time in RECS history for all 50 states and

the District of Columbia (DC). You can find more information on this addition in the household characteristics technical documentation.

- **Shift to web and mail modes for *Household Survey***: The 2020 RECS *Household Survey* relied exclusively on self-administered web and paper questionnaires. We developed instruments for both modes in tandem. We kept content, questions, and response options the same, where possible. As a result of this change in survey methodology, we increased our sample size and included estimates for all 50 states and DC.

- **Three-fold increase in sample size:** We based 2020 RECS estimates on responses from 18,496 households, which is more than three times greater than the 5,686 respondents in the 2015 RECS. Larger sample sizes generally result in smaller standard errors and confidence intervals, especially for estimates of smaller subpopulations. In addition, the 2020 study relied on a much less clustered sampling method because we did not rely on primary sampling unit (PSU) or secondary sampling unit (SSU, or segment) selections like in 2015. As no in-person interviewers are used, clustered samples are not required for entirely self-administered surveys.

- **New questions and improvements to existing questions:** In addition to changing the data collection modes for the 2020 RECS, we also updated and added questions to the *Household Survey* to improve wording, add new questions to account for changes in technology, and remove questions that no longer applied or did not provide high quality responses in past RECS. Questions that are new to the survey or changed from 2015 are marked on the survey form. For example, we added new electric vehicle questions to capture more information about these vehicles and vehicle-charging behaviors.

- **New square footage estimation series**: We consider the new square footage estimates to be a break in series from previous estimates. Prior to the 2020 RECS, trained interviewers conducted in-person interviews at sampled housing units. Part of the interview process included taking square footage measurements of the home. In the 2020 RECS, which moved to entirely self-administered web and paper survey modes, all square footage information was collected from the household respondent. If respondents could not provide an exact estimate, we asked them to categorically classify their home's square footage. If the respondent did not know or left the question blank, we imputed the square footage for the home. We asked additional questions about what spaces (that is, attic, basement, or garage) were included in the square footage estimate. We used these responses to generate a final square footage estimate. You can find more detailed information on square footage in the square footage documentation.

End-use modeling and calibration improvements

We began modeling energy end-use estimates (for example, space heating and air conditioning) as part of the RECS data series in 1980. End-use estimates from the 1980 RECS through 2009 RECS relied on statistical regression models. In the 2015 and 2020 RECS studies, the end-use models used an

engineering approach where end-use estimates were determined by the collected housing characteristics and weather data. The change in approach from 2009 to 2015 was substantive, and although many of the 2020 models have been updated from the 2015 versions, the approaches and coverage of the end-use models are very similar in both studies.

We produce final end-use consumption estimates by taking a home's engineered end-use model outputs and comparing them with calendar year 2020 billing data. We adjust the initial end-use outputs so that the total sum of the end-use estimates matches the billing data. This process is known as calibration.

In RECS studies prior to 2015, the calibration procedure used was simple normalization, wherein every individually modeled end-use value for a household was multiplied by the same factor to ensure the scaled estimates summed to the billing total. In the 2015 RECS, we introduced a new calibration method, known as minimum variance estimation, which uses estimates of the models' likely errors, or uncertainties, to produce unique factors for each end use. Because models vary in complexity and use of RECS data, the various model outputs have varying levels of uncertainty. Further, certain end-use pairs are also likely to be correlated. For example, housing units that use clothes washers more than average are likely to use clothes dryers more than average as well. We use the uncertainties associated with the end-use estimates and the correlations between certain end-use pairs to make the calibration adjustments information-based and internally consistent.

In previous RECS studies, we produced annual end-use estimates and compared these estimates with annualized billing totals. Beginning with the 2020 RECS, we produced engineered daily end-use modeling outputs. Daily outputs can be aggregated and matched to any arbitrary period within 2020. We made this improvement to allow for billing-level calibration, which is explained in further detail in the next paragraph. For end uses with no expected seasonal variation, such as toasters or laptops, every daily estimate is equal to the annual estimate divided by 366. We modeled other end-uses, such as space conditioning, with expected seasonal variation using daily-varying inputs, such as temperature, to allow for daily estimates that vary throughout the year. You can find more detail regarding inputting seasonality into end-use modelling in the full consumption and expenditure documentation.

For 2020, we calibrated electricity and natural gas at the billing level rather than at the annual level. This change allowed temporal patterns to be more accurately reflected in the final annual total than would otherwise be estimated. If a home has 13 bills that span calendar year 2020, the 2015 method would input the single annualized total and output one estimate for every end use in the home. The 2020 method produces the same number of outputs but inputs 13 separate bills, each of which is associated with a non-overlapping time period during 2020.

In 2015 and previous years, if the annualized billing total exactly matched the sum of the end-use estimates, then calibration would not change any estimates. Although 2015 no longer used simple normalization, we could not change end-use estimates in the case of a perfect match between billing totals and end-use modeling. Table 1 shows consumption in a single-family home in the Marine climate

zone. Although the annual billing total almost exactly matches the annual estimated total, our end-use modeling underestimates summertime consumption and overestimates wintertime consumption. For example, from January 28 to February 25, bills show this home consumed 562 kilowatthours (kWh), but our modeled consumption was considerably greater, at 694 kWh. During the summer, from June 25 to July 24, this home consumed 787 kWh, but our modeled consumption was far less, at 607 kWh. This discrepancy indicates that our model is likely assigning too much consumption to end uses used mostly in winter (for example, space heating), and assigning too little consumption to end uses used mostly in summer (for example, air conditioning).

Because our modeled estimates are sometimes greater or sometimes lesser than the bills, the annual total of our modeled estimates balances out at 7,546 kWh, which is close to the billing total of 7,458 kWh. Without looking at individual bills, we would not be aware that our model's accuracy varies seasonally.

Table 1. Example electricity billing data and end-use model outputs prior to calibration

Billing end date	Billing days	Monthly consumption from bills (kWh)	End-use modeling total (kWh)	End-use modeling—space heating (kWh)	End-use modeling—air conditioning (kWh)	End-use modeling—refrigerators (kWh)	End-use modeling—other (kWh)
Jan 27, 2020	27	554	627	279	0	33	315
Feb 25, 2020	29	562	694	324	0	36	334
Mar 26, 2020	30	605	686	306	0	38	342
Apr 24, 2020	29	439	487	110	5	37	335
May 26, 2020	32	502	485	12	52	43	377
Jun 24, 2020	29	575	508	0	105	40	363
Jul 24, 2020	30	787	607	0	167	42	399
Aug 24, 2020	31	1,015	685	0	220	43	422
Sep 24, 2020	31	752	618	0	157	43	418
Oct 23, 2020	29	431	511	25	79	39	368
Nov 23, 2020	31	456	690	284	4	40	361
Dec 24, 2020	31	650	760	362	0	39	359
Dec 31, 2020	7	130	187	98	0	9	81
2020 totals	**366**	**7,458**	**7,546**	**1,801**	**789**	**482**	**4,475**

Data source: U.S. Energy Information Administration, *Residential Energy Consumption Survey*
Note: kWh=kilowatthours. End-use modeling total might not exactly match sum of its components due to rounding.

In Table 2, using the 2015 method, calibration has little effect on the individual end-use estimates and is similar to the simple normalization used in 2009 and earlier RECS. The changes introduced in the 2020 calibration process still preserve the annual total but decrease space heating while simultaneously increasing air conditioning. Although the three methods all output the same annual total, the 2020 estimates more accurately reflect individual end uses within a home.

Because propane and fuel oil are delivered rather than metered with regular billing periods like electricity and natural gas, the calibration process for propane and fuel oil remains unchanged from 2015. However, our initial model outputs are still daily, which allows for more accurate annualization.

Table 2. Example total consumption and end-use consumption estimates after calibration, current and previous methods

Method	Total (kWh)	Space heating (kWh)	Space cooling (kWh)	Refrigerators (kWh)	Other (kWh)
End-use modeling outputs	7,546	1,801	789	482	4,475
Billing-level calibration, minimum variance estimation (2020 method)	7,458	1,019	1,291	487	4,660
Annual-level calibration, minimum variance estimation (2015 method)	7,458	1,754	775	481	4,447
Annual-level calibration, simple normalization (2009 and previous method)	7,458	1,780	780	476	4,423

Data source: U.S. Energy Information Administration, *Residential Energy Consumption Survey*
Note: kWh=kilowatthours. Total might not exactly match sum of its components due to rounding.

The updated modeling and calibration methods are an improvement over previous RECS end-use estimation methods because:

- End-use estimates are produced at the daily level and can be aggregated to arbitrary billing periods, allowing for more accurate billing-level calibration.
- We calibrate electricity and natural gas in the 2020 RECS on billing-level data rather than on a single annualized total. This method allows estimates to better reflect individual end-use consumption at the time during the year they are most likely to occur.
- Daily end-use estimates allow end-use estimates to be matched to fuel oil and propane delivery dates. This ability provides more accurate annualized estimates of 2020 consumption for these fuels.

The next three graphics show end-use estimate comparisons across selected RECS cycles for all fuels combined (Figure 1), electricity only (Figure 2), and natural gas only (Figure 3). Notably, the updated RECS end-use and calibration methods used in 2020 produced estimates of electricity consumption for space heating and water heating that are lower than the 2015 RECS but similar to those in previous RECS. It also produced estimates of refrigerators and *other* electricity consumption that are higher than in previous rounds. Note, *refrigerators* do not include freezers. Freezers are included in the *other* category.

Figure 1. Total site consumption by end use, 2009–2020

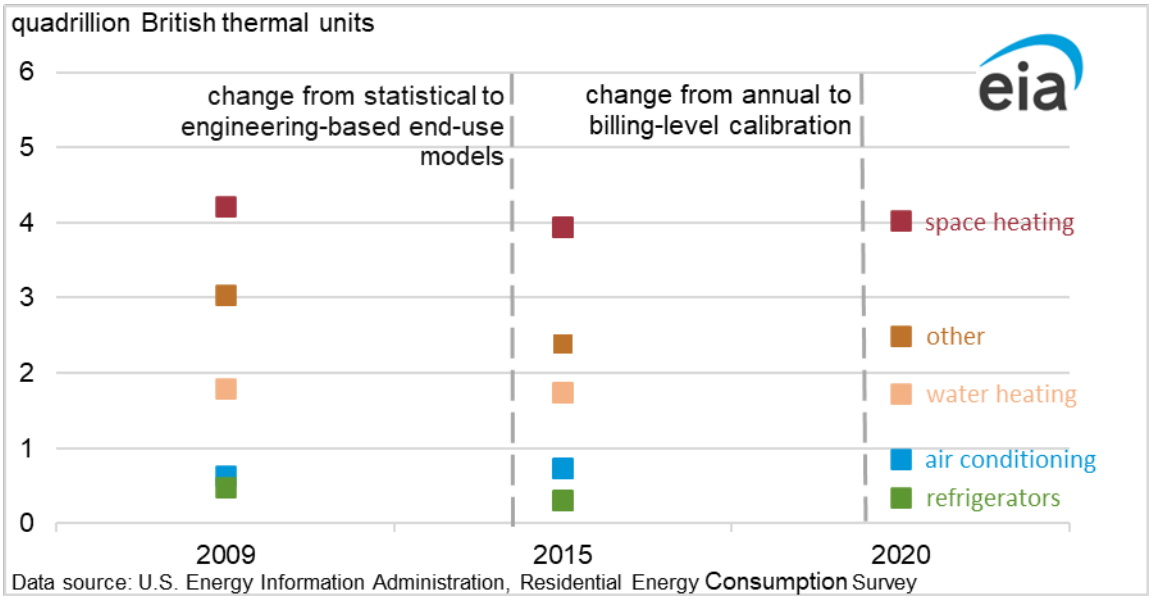


Figure 2. Electricity site consumption by end use, 2009–2020

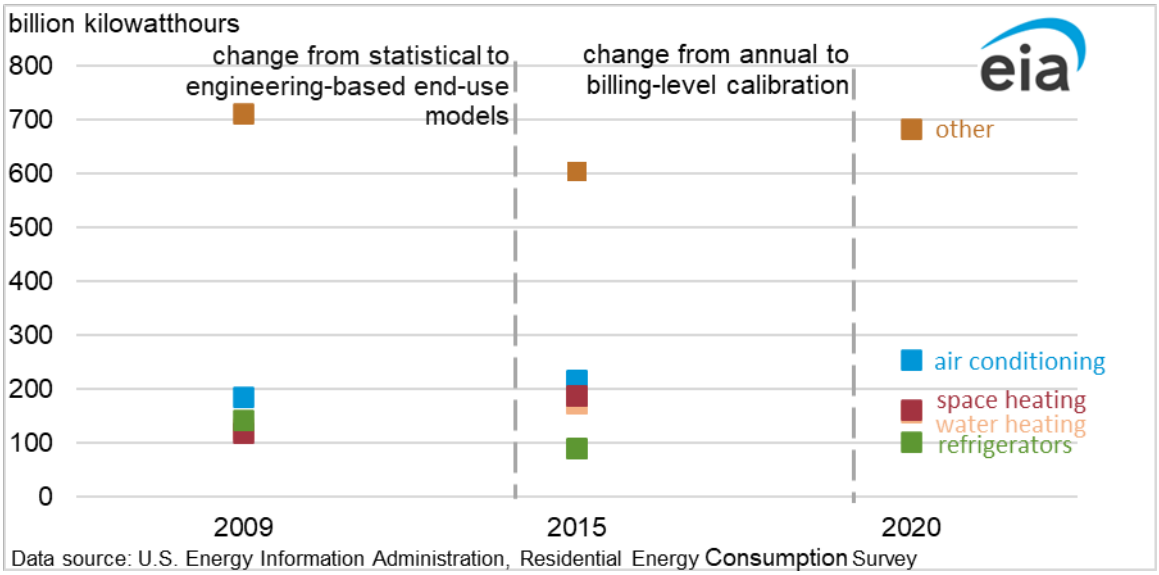
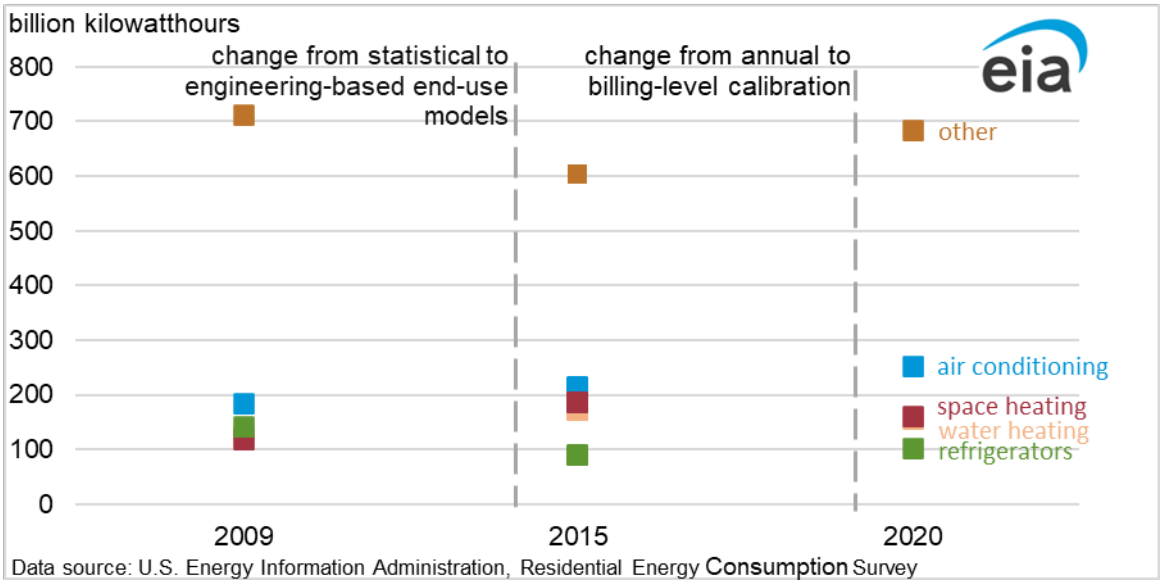


Figure 3. Natural gas site consumption by end use, 2009–2020



Weather

When comparing estimates from different RECS survey cycles, some of the differences can be attributed to different temperature and weather patterns. Weather varies from year to year, but RECS energy consumption and expenditures estimates are not weather-normalized. That is, the reported consumption in RECS is for the actual weather conditions in 2020 rather than the energy that would have been consumed under average conditions (climate normals). In 2020, the U.S. household-weighted heating degree day (HDD) and cooling degree day (CDD) averages were both 1% lower than the HDD and CDD averages in 2015.

Comparing RECS with Other Studies

Other federal studies, including EIA's supply-side data collection programs, provide additional insight into residential energy demand. For example, we conduct monthly and annual surveys of electricity suppliers which we use to report estimates of aggregate electricity retail sales for the residential sector. In addition, independent measures from other federal household studies help relate the RECS estimates to key benchmarks, enhancing our understanding of energy consumers, housing units, and households.

The scope and purpose of RECS differ slightly from similar EIA products that report residential energy data. RECS samples homes occupied as a primary residence, which excludes secondary homes, vacant homes, military barracks, and common areas in apartment buildings. As a result, RECS estimates do not represent sector-level totals defined in our other products, but they are best suited for comparisons across different characteristics of homes within the residential sector.

- **EIA supply-side surveys (Forms EIA-176, EIA-857, EIA-861, EIA-861M, EIA-821, and EIA-877):** Our electricity, natural gas, and petroleum offices conduct monthly, seasonal, and annual data collections to produce estimates of supply for these fuels disaggregated by energy demand sectors—residential, commercial, industrial, and transportation. These supply-side estimates reflect delivered consumption to each of these demand sectors. Although the supply-side surveys provide insight into total energy delivered to customers in specific sectors, consumption surveys such as RECS provide the view of demand within consuming units (for example, housing units). RECS does not collect data or produce estimates for portions of the residential sector that are difficult or costly to survey, including vacant homes, seasonal homes, and common areas in apartment buildings. RECS total consumption and expenditures estimates, therefore, are expected to be lower than our supply-side sector estimates.
- ***Annual Energy Outlook* (AEO)**: We publish projections of energy consumption for each fuel and sector using the National Energy Modeling System (NEMS) in our *Annual Energy Outlook* (AEO). The most recent RECS data, as well as a number of auxiliary data sources and technology reports, are used as inputs to the AEO's Residential Demand Module of NEMS. The AEO residential projections are estimates at the sector level, and RECS estimates are of occupied, primary housing units only. For these reasons, RECS and AEO estimates will differ.
- **State Energy Data System (SEDS):** We publish historical estimates of energy production, consumption, prices, and expenditures by state and sector in SEDS. The residential sector in SEDS includes vacant homes, secondary homes, and common spaces in residential buildings. Total energy estimates in RECS only include electricity, natural gas, propane, and fuel oil. SEDS includes these same fuels as well as electrical system losses and other fuels, such as wood; RECS displays wood estimates in a separate tables n. So, SEDS estimates are often higher than RECS estimates. In some cases, RECS estimates may be higher due to sampling and other methodological differences.

The U.S. Census Bureau's *American Community Survey* (ACS) and the U.S. Department of Housing and Urban Development's *American Housing Survey* (AHS) collect energy characteristics about a few items similar to those in the RECS *Household Survey*. Each of these external studies is optimized to serve a different purpose from the RECS, and so their results for similar items may vary from the RECS. Below is a summary of comparisons with these external studies.

- ***American Community Survey* (ACS)**: The U.S. Census Bureau's ACS is an annual survey of more than three million U.S. households. The ACS questionnaire includes demographic and basic structural characteristics questions similar to those found on the RECS. Both surveys, for example, ask about housing unit type, age of home, main heating fuel, and household income. The final RECS counts of households by geographic region, housing type, and age are poststratified using ACS estimates. Estimates for main heating fuel, however, will differ as a result of differences in question wording and additional quality checks that we conducted.

- ***American Housing Survey* (AHS):** The U.S. Department of Housing and Urban Development's AHS is a comprehensive, longitudinal study of the quality of living conditions and the housing stock. In addition to questions about fuel use and devices in homes, the AHS produces estimates of utility costs. Although these utility cost estimates are similar to RECS fuel expenditure estimates, AHS does not include costs for electricity, natural gas, and other fuels that are included in rents or condo fees.

You can direct your specific questions to the Residential Energy Demand Team.