Utility Cost Estimation Model Development and Decisions for the 2015 American Housing Survey and Beyond

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Purpose

The purpose of this paper is to summarize the results of research on utility cost estimation conducted by the U.S. Census Bureau and the U.S. Department of Housing and Urban Development (HUD) as part of the redesign of the American Housing Survey (AHS) for 2015. Utility costs are an important component of housing costs, which also include rent or mortgage payments; garbage, trash, water, and sewage costs; real estate taxes; and other housing-related fees. Accurate estimation of housing costs is crucial to monitoring trends in affordable housing supply over time. Housing costs are incorporated into measures of housing burden that examine the percentage of a household's income spent on housing. Housing burdens are a component of HUD's *Worst Case Needs* measure,[1] which is used to estimate the number of households in the United States with the greatest housing needs. Since 1993, utility cost data collected in the AHS have been adjusted and imputed using regression models developed from the Residential Energy Consumption Survey (RECS).

The research discussed in this white paper analyzes the implications of estimating utility costs in the AHS in the absence of billing data provided by respondents. The results of the research informed the decision to not collect billing data for electricity, natural gas, and bottled gas for most households (around 99 percent of households) and instead to use housing and household characteristics and climate data to model utility consumption and costs for housing units in the 2015 AHS.

1. The American Housing Survey

The AHS is a key source for housing and utility cost data in the United States. The AHS is the largest, most comprehensive, longitudinal housing survey in the United States and is collected by the Census Bureau on the behalf of HUD. The AHS employs two types of housing unit samples—a national sample and metropolitan area samples, with the metropolitan area samples surveyed on a rotating basis. In both types of sample, the same housing units are followed over time until a new sample is collected. Between 2 and 29 metropolitan area samples have been surveyed in the years the metropolitan AHS has been fielded, depending on funding availability. The national AHS started in 1973 and has surveyed the same housing units since 1985, drawing additional samples to account for new construction, improve coverage, and oversample subpopulations. From 1973 and 1981, the national AHS was conducted annually. Since 1983, the national AHS has collected data in every odd-numbered year. Since 2007, national and metropolitan area samples have been surveyed in the same year. Since 1997, the AHS has been collected via in-person and telephone interviews using an electronic questionnaire.

1.1 2015 AHS Redesign

In 2015, the AHS retired the national sample it had surveyed since 1985 and all metropolitan samples, and it drew a new sample from the Census Bureau's Master Address File. Along with the introduction of a new sample, the AHS underwent a redesign for 2015, balancing the goals of increasing data quality and reducing respondent burden. As part of the 2015 AHS redesign, HUD and the Census Bureau reevaluated all the questions in the AHS. Related to the goal of reducing respondent burden, HUD and the Census Bureau conducted research on the implications of collecting less data on electric and gas utility costs in the AHS and relying more on modeling for the estimation of utility costs. This research informed the decision to stop collecting most utility billing data on the AHS and to estimate utility costs through regression model-based imputation.[2]

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[1] One criterion for classification of Worst Case Needs household is being an unassisted renter household with very low income (income not more than 50 percent of area median income) having "severe rent burden," paying more than one-half of their income on housing costs (Steffen et al., 2015).

[2] Appendix table J1 presents the distribution of 2015 AHS cases by type of electric and natural gas model (modeled with housing and household characteristics, modeled with billing data, and estimated using self-reported estimates of average monthly utility costs).

1.2 Utility Cost Data Collection Prior to 2015

Before 2015, the AHS asked respondents to refer to their utility bills when reporting monthly electric and gas costs. In addition to electric and gas costs, the survey asked questions about other utility costs, including fuel oil, other fuels (that is, coal, kerosene, wood, and solar), garbage and trash, and water and sewage. The series of utility questions in the AHS was highly burdensome, requiring respondents to locate and report their utility bills and to estimate costs when they did not have bills. To prepare respondents for the survey, a letter sent in advance of the interview contained a worksheet with questions about utility costs.

1.3 Electric and Gas Cost Data Collection Prior to 2015

Prior to 2015, the electric and gas cost questions in the AHS collected billing data for the months of January, April, August, and December—months that Gorsak and Schwanz (2004) found most predictive of average monthly utility costs. Gorsak and Schwanz reported that, historically, one-third of AHS respondents provided billing data, and the majority of those who did provided data for all 4 months. Using 2007 AHS data, Carter (2010) found that 39.5 percent of respondents reported at least 1 month and 35.9 percent reported all 4 months of electric bills, and 39.9 percent of respondents reported at least 1 month and 36.5 percent reported all 4 months of gas bills. Increasingly, online billing and automatic bill pay options present barriers to respondents possessing physical bills. Even though respondents are asked to use their bills during the interview, it was not until 2011 that the AHS asked respondents explicitly if they used bills or the worksheet in the interview. The 2011 AHS recorded 20 percent of respondents as using an electric bill, 18 percent as using a gas bill, and 10 percent as using the worksheet to answer the survey. Of those using the worksheet, it is not known whether respondents filled out the utility bill information.

Respondents without 4 months of billing data were asked other questions to allow for the estimation of utility costs. If respondents did not have bills, did not know the billing amount, refused to answer, or provided fewer than two valid

monthly amounts, the survey asked: "How much was your most recent bill?" and "What month was the bill for?" The AHS asked a subset of respondents to estimate their average monthly electricity costs. Respondents who used gas were asked similar cost questions and whether their gas comes from underground pipes or bottled gas.

1.4 Other Utilities

In addition to electric and gas costs, the AHS collected (and still collects) information for fuel oil, other fuels, garbage and trash collection, and water supply and sewage disposal. The level of detail collected for these costs is less than that for electric and gas costs. Monthly billing data were not collected for these items. However, the AHS collected (and still collects) whether the utility was used, whether it was billed separately or combined with another bill, and the total costs for the year. In addition to reevaluating the estimation of electric and piped natural gas costs, HUD and the Census Bureau explored using modeling to estimate bottled gas and fuel oil costs for the 2015 AHS.

2. Utility Data Editing, Estimation, and Imputation

After data collection, consistency edits are performed to check the utility data against relevant use (that is, if electricity is used) and equipment (that is, electricity is used as the heating equipment fuel) variables and to identify if utilities are billed separately. Because the AHS did not ask for billing data for all months, and respondents' recall of utility costs is not always accurate, the utility estimation system (UES) was created to estimate annual utility costs using regression models developed from the RECS. This estimate was divided by 12 to calculate average monthly utility costs. The advantage of using the RECS to model utility costs is that the RECS collects administrative data from suppliers on actual billing amounts. The RECS also collects some housing characteristics similar to those the AHS collects, which allows for the construction of models that can then be applied to the AHS. Table 1 lists the 25 regression models that comprise the UES.

Table 1. Billing Data for Each Model

Model	Month				Model	Month				
1	January	April	August	December	12	January				
2	January		August	December	13		April			
3	January	April		December	14			August		
4	January	April	August		15				December	
5		April	August	December	16					March
6	January	April			17					May
7	January		August		18					June
8	January			December	19					July
9		April	August		20					February
10		April		December	21					September
11			August	December	22					October
					23					November
					24	Self-reported average monthly costs				
					25	No monthly data				

2.1 The Utility Estimation System

From 1993 to 2013, the UES was used to calculate annual estimates for households that use electricity and households that use underground piped natural gas. The calculation process consisted of three steps: (1) calculating the utility cost estimate, (2) comparing the cost estimate with a cutoff value, and (3) aligning cost estimates to the RECS.

In the first step, cost estimates were calculated by applying one of a set of regression models to data collected from the respondents. Utility cost regression models were created with the RECS. Because the RECS collects respondent monthly billing data directly from suppliers and asks respondents questions that are also asked on the AHS, the Census Bureau was able to create regression models with the RECS and apply AHS responses to the regression parameters to obtain a total utility cost estimate for AHS respondents.

In the second step, each cost estimate was compared to a set of values to avoid extremely low or high estimates. These cutoff values were calculated at the census division level. If a cost estimate was out of the range of cutoff values, extreme AHS-reported individual bills were dropped and a new cost estimate was calculated with the appropriate model. If no extreme individual bills were identified for cases exceeding the cutoff, the cost estimate was obtained through hot deck imputation.

In the final step, cost estimates were adjusted to align with the RECS total utility cost. An adjustment factor was calculated, such that the AHS cost estimates that were calculated with billing data plus the adjusted sum of the AHS cost estimates that were calculated without billing data was equal to the RECS average monthly cost multiplied by the AHS sample size. Cost estimates calculated with billing data were assumed to be correct; therefore, the adjustment factor was applied only to estimates calculated without billing data.

2.2 History of Model Development

The electricity and gas models evolved over time. The Census Bureau developed the UES in 1993 based on a recommendation from the Office of Management and Budget. In the initial version, 15 models were developed for each census division;[3] each model contained parameter estimates for the billing months of January, April, August, and December, corresponding with the amount of billing data obtained from the respondent. If a respondent had only 1 month of billing data, electric bills from only January and December, or gas bills from only April and August, the model added parameter estimates corresponding with home heating equipment, water heating equipment, and housing and household characteristics. Parameter estimates were calculated from the 1990 RECS and inflated to reflect 1993 utility cost. Separate inflation factors were calculated for electric costs and natural gas costs. Both inflation factors were calculated at the national level. After 1993, each AHS survey updated the inflation factors and average monthly costs.

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[3] Alaska was assigned to the New England division. Hawaii was assigned to the West South Central division.

In 2003, based on research by Gorsak and Schwanz (2004), parameter estimates were updated using data from the 1997 RECS. Also, two regression models were added—one using average electric and gas costs estimated by respondents and the other assigning zero to all regression parameters, thereby forcing the case through the hot deck imputation method.[4]

In 2007, the parameter estimates were updated with data from the 2001 RECS. Four models were added. These models used billing data for March, May, June, and July to allow for modeling of costs for respondents who provided the past month's bill.

In 2009, four models corresponding with the remaining billing months (February, September, October, and November) were added to the system. The 2003 model, which assigned zero to all regression parameters, was updated with 2001 RECS-based parameters for the housing and household characteristics data. This housing and household characteristics (HHC) model was applied to cases with no billing data and no estimate of average monthly costs. In this update to the system, the Census Bureau also split the electric universe into two smaller universes—housing units that use electric only and those that use both electricity and gas—to better estimate the costs of units using different combinations of electric and gas. This update also saw the introduction of division-level inflation factors. The 2009 system update was used through 2013, with inflation factors and average monthly costs reflecting the current year of enumeration.

2.3 Strengths and Limitations of Using the RECS

The RECS was chosen to derive regression parameter estimates that could be applied to AHS data to estimate utility costs because it collects housing and household variables similar to AHS variables and collects high-quality utility data. Rather than collecting self-reported utility billing data, the RECS collects billing data directly from suppliers, who are mandated to provide the data to the U.S. Department of Energy. These factors help maintain the high quality and low nonresponse rates of RECS data. One limitation of using the RECS to model utility costs is that the models are dependent on getting current RECS data. Inflation factors are applied to the models to adjust

costs to the year of the AHS data collection. In the past, the RECS released data at only the regional and census division levels. The 2009 RECS,[5] used to model costs and consumption in our research, includes geography at the reportable domain level (states and groups of states), which improved the models' level of geographical precision.

The RECS underwent a redesign and was the subject of a National Research Council review panel, which published its findings in *Effective Tracking of Building Energy Use* in 2012. The panel made several recommendations to improve the RECS, including improving timeliness, revising edit procedures, releasing prepublication estimates, increasing sample size to make more state data available, working more closely with suppliers, introducing a multimode approach for data collection (the RECS already uses a web survey for suppliers), and conducting ongoing evaluations of administrative record use for data and imputation (for example, square footage can be used to replace self-reported data or to impute missing data from self-reported items) (NRC, 2012). In Spring 2017, data from the 2015 RECS will be released (https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata) that will be used to update future AHS utility estimation models.

3. Changes for 2015 Evaluated in Research

The utility cost questions in the AHS are complicated, and many respondents do not have the billing information available to answer them. Because the utility questions are burdensome to respondents and costly to collect, the Census Bureau and HUD conducted simulation studies to evaluate the impact of estimating utility costs with less or no billing data. The research explored several options for redesigning the 2015 AHS utility cost models.

1. *Continue with the current AHS approach*. Ask respondents for 4 months of billing information and update the UES as new RECS data become available.

2. *Collect no utility data for electric and natural gas costs*. Model utility costs with a revised housing and household characteristics (HHCR) model.

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[4] The hot deck imputation method includes 180 cells for each utility: nine census divisions, electric or natural gas home heating, electric or natural gas water heating, and five categories for total rooms—less than four, four, five, six, and seven or more (Gorsak and Schwanz, 2004).

[5] The 2009 RECS had a sample size of 12,083 cases. Sample and methodology documentation for the 2009 RECS is at https://www.eia.gov/consumption/residential/data/2009/. Information on all RECS surveys is at https://www.eia.gov/consumption/residential/index.php.

3. *Adopt the American Community Survey approach.* Collect only costs for the past month and model utility costs using the UES for the past month's bill.

4. *Collect average monthly costs.* Model utility costs using the UES for average monthly costs (we did not have the data to explore this option, as not all cases provided average monthly cost information).

We present evaluations of options 1, 2, and 3 in this paper. For option 3, we chose to test with households that provided April billing information, because that was the month with the most 2009 AHS data available. We ran the model only on cases with April bills. We did not have enough data to test option 4, as many respondents are not asked to estimate average monthly costs. In addition, Gorsak and Schwanz (2004) questioned the validity and reliability of self-reported average monthly cost estimates, because they are highly burdensome for respondents to answer. The task of estimating average monthly costs requires respondents to quickly remember all their bills from the past year and convert them into a monthly value.

3.1 Study Design

We estimated regression models for electric and gas costs and consumption with public use data from the 2009 RECS.[6] We applied the models to data from the 2009 AHS internal use file to yield estimates for monthly electric and gas consumption

and costs. We compared median estimates and frequency distributions of monthly electric and gas costs from our models and published estimates from the 2009 AHS with estimates from the 2009 RECS to assess how closely the models approximated costs at national and regional levels. As the RECS is the gold standard for utility costs, we benchmarked our estimates to the 2009 RECS estimates.

3.2 Models

The models used in the research are described in table 2, and the variables in the initial HHC model and the final HHC (HHCFIN) model are in table 3. All models exclude cases in

Table 2. Models

UES	Approach used in 2009 AHS.
HHC	Applies housing and household characteristics cost model to all units using electric, gas, or both.
HHCR	Revised HHC model. Changed to consumption model. Degree days added.
UESR	Revised UES model. Updated with monthly billing data from 2009 RECS.
HHCR2	Revised HHCR model. Adds presence of steam heat to gas model, collapses geographies with small sample sizes, and adds household income.
ONE BILL	HHCR2 model plus April utility bill.
HHCFIN	HHCR2 with degree day normals.

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table 3. Variables in Models

	HHC	HHCFIN
Response variable	Cost	ln (Consumption + 1)
Independent variables	Electric heat	Heating degree days (if electric heat)
	Gas heat	Heating degree days (if gas heat)
		Cooling degree days (if central air)
		Cooling degree days (if wall air unit)
	Electric hot water	Electric hot water
	Gas hot water	Gas hot water
	Year built	Year built
	Type of housing unit (single-family = 1, multifamily = 2, mobile = 3)	Single unit (indicator)
		Multiunit (indicator)
		Mobile home (indicator)
	Total rooms	Total rooms
	Total bathrooms	Total bathrooms
	Total major appliances	Total major appliances
	Number of household members	Number of household members
		Household income

ln = natural log.

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[6] For more on regression techniques and the use of regression in imputation, see Little and Rubin (2002), Myers (1990), and Raghunathan (2015).

which the given utility costs are included in rent or condominium fees. Both the RECS and the AHS required recoding variables so that regression parameters could be applied across surveys. Appendix A contains a full list of variables in all models and a crosswalk between RECS and AHS variables.[7] The UES model is the billing model used to produce published estimates for the 2009 AHS, which uses data from the 2001 RECS, adjusted for inflation to reflect 2009 values. The model uses billing data primarily for estimation and incorporates some housing and household characteristics for units with less billing data. Because the HHC model was developed for the 2009 AHS public use file using only housing and household characteristics, we evaluated the predictive capability of this model when applied to all cases in the 2009 AHS national sample. The HHC model was developed with 2001 RECS data, and because 2009 RECS data are now available, we created the HHCR model with the 2009 RECS data. The HHCR model incorporates heating degree days (HDD) and cooling degree days (CDD) to account for variability in consumption.[8] The model uses degree days available on the 2009 AHS internal use file. HDD affect heating equipment usage, and CDD affect air conditioning usage; therefore, we apply this information depending on the presence of specific types of heating and cooling equipment.

We attempted several enhancements in HHCR model development to create a model with high predictive capabilities that would not require applying cutoffs or aligning to the RECS cost totals, as required with pre-2015 models. First, we attempted to develop models at a more-refined geographic level than the census division. The RECS publishes data at the state (or group of states) level, which the U.S. Energy Information Administration (EIA) calls "reportable domain." Because some census divisions cover relative large geographic areas, analysis at the reportable domain level can account for some cost variability at smaller geographic levels.

Second, cost data are skewed. To address skewed data, we explored modeling the natural logarithm of monthly cost as a function of the independent variables; more specifically, the natural log of cost + 1, to account for units that reported 0. During the evaluation, we noticed differences in average costs from state to state. Therefore, we estimate consumption (natural log of consumption + 1, because consumption data are also skewed) with independent variables.

After iteratively removing outliers,[9] we used stepwise regression to determine which variables to include and which variables to remove from each reportable domain model.

We applied the new regression parameters to the recoded 2009 AHS data. After transforming our estimates from the natural log scale back to our base consumption, we multiplied our monthly consumption estimates by each state's average price per unit of consumption to obtain the unit's average monthly cost. For fuel prices, we obtained price and consumption data from EIA's website for each state.[10] We then calculated a weighted average across the 12 months prior to the 2009 AHS enumeration, or May 2008 through April 2009. Next, we multiplied the average by a factor to put the value into a unit of measure equivalent to the RECS public use data. For electricity, the factor was 0.01 to convert cents to dollars. For gas, the factor was 0.1 to convert dollars per 1,000 cubic feet to dollars per 100 cubic feet. Finally, we summarized our results and compared them with the RECS.

We requested 2009 RECS internal use billing data from EIA and used the data to reestimate the UES with the same parameters as in the 2009 UES. This model is referred to as UESR. The HHCR2 model is a revision of the HHCR model that incorporates household income to more accurately estimate consumption across the income distribution. The HHCR2 model is weighted, uses degree days from the 2009 AHS internal file, adds a variable to the gas model for the use of steam or hot water radiators or other hot water heating systems, and collapses some geographies with small samples sizes. The ONE BILL model explores the option of collecting one bill and incorporating that one bill into a consumption model. Because April was the month with the most 2009 AHS cases, we ran the ONE BILL model on cases with an April bill. The final model (the model chosen for electric and gas estimates in 2015), the HHCFIN model, is a revision of the HHCR2 model that uses HDD and CDD data obtained from a National Oceanic and Atmospheric Administration (NOAA) 30-year climate normals file from 1980 to 2010.

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[7] Independent variable cumulative distribution functions (CDFs) that compare the distribution of the 2009 RECS variables with distributions of the 2009 HHCFIN AHS variables is in appendix M. Appendix N shows the extent of imputation in the RECS variables used in different models.

[8] A degree day is an index based on the difference between the daily average temperature and 65 degrees Fahrenheit. HDD are the negative differences, and CDD are the positive differences.

[9] Outliers were determined based on a negative effect on the regression model. We defined an outlier as a value with a large Cook's *D* and a small COVRATIO. See appendix K for the extent of outlier removal.

[10] See appendix O for information on obtaining price and consumption data for 2009 and 2015.

NOAA no longer provides the data product that EIA used to assign HDD and CDD to the RECS, so we experimented with several approaches to assigning HDD and CDD to AHS cases. The 30-year climate normal HDD and CDD were closest to the 2009 RECS and AHS distributions.[11]

Electric models are split into two categories: electric-only models are applied to occupied units that pay for electricity and do not use natural gas, and electric-gas mixed models are applied to occupied units that pay for electricity and use natural gas. Natural gas models are applied to occupied units where households pay for gas that is piped into the unit.

4. Evaluation Methods

The AHS and RECS are independent samples, so we cannot compare each individual unit's estimates of monthly costs between the surveys. Therefore, comparisons must be at the aggregate level. We evaluated the quality of our estimates by how closely AHS distributions matched the medians and distributions calculated from the RECS.

We calculated quantiles for all units, medians for selected characteristics, and categorical percent distributions for AHS models and compared these estimated distributions with distributions from the 2009 RECS. We estimated variation in quantiles, medians, and categorical percent distributions attributed to repeated sampling for each survey using replicate weights. We obtained a pooled standard error estimate and performed t tests on the null hypothesis of zero difference between each distribution and the RECS distribution with a two-sided alpha of 0.1.

4.1 Quantiles for All Units

Tables 4 and 5 show the national electric and natural piped gas quantiles of average monthly costs (in dollars).[12] The UES-derived values were top-coded for publication, and therefore we suppress values at or above the 97.5th percentile for confidentiality. At the national level, all differences between evaluation medians and the RECS median are statistically significant for both electric costs and natural gas costs. However, the national distributions calculated with the models, including the proposed HHCFIN model, visually follow the RECS. The electric medians for the HHCR, HHCR2, and HHCFIN models are lower than the 2009 RECS; the UES, HHC, UESR, and ONE BILL medians are higher than the RECS median. Gas medians for all AHS models are higher than the 2009 RECS gas median, but the HHCFIN model comes closest to the RECS median. Regional Electric Quantiles and Regional Natural Gas Quantiles tables showing average monthly costs are in appendixes B and C, respectively.

Table 4. Average Monthly Cost of Electricity ($), National Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	21	13	14.38	23	26.64	13.92	26.90	17.67
5%	37	42	35.88	39	38.30	38.43	38.80	30.33
10%	48	55	44.89	50	46.08	46.31	46.84	39.58
25% Q1	71	77	62.76	74	63.46	65.51	64.50	62.08
50% median	108	106	89.77	111	90.05	101.27	91.76	96.92
75% Q3	159	147	127.74	167	128.10	158.45	129.53	144.33
90%	224	193	168.91	237	169.51	257.22	171.34	203.50
95%	273	220	198.45	295	199.29	367.69	200.70	245.08
99%	*	273	267.96	456	267.67	1,026.39	269.88	356.33

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

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[11] See appendix M for CDFs of HDD and CDD for differences between our original approach (Original Match) and the 30-year climate normals (Norms).

[12] See appendix L for consumption and cost estimate CDFs for electric, piped natural gas, and bottled natural gas in our final AHS models and the 2009 RECS. The CDFs show the probability that consumption and cost estimates have values less than or equal to the argument of the function. Although each of the CDFs exhibit similarly shaped distributions, all Kolmogorov-Smirov tests yielded a statistically significant difference at the maximum distance between each CDF at $p < .0001$.

Table 5. Average Monthly Cost of Natural Gas ($), National Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	11	3	6.66	12	8.04	0.16	7.47	3.50
5%	22	32	21.78	23	22.70	15.24	20.83	11.33
10%	31	47	31.45	31	32.62	24.96	30.11	20.42
25% Q1	48	68	47.54	46	47.40	42.65	44.67	38.08
50% median	73	90	71.46	70	69.93	67.22	66.60	60.58
75% Q3	111	119	98.24	107	97.44	111.48	94.26	90.25
90%	162	149	129.55	156	130.41	188.22	122.71	125.67
95%	203	165	153.89	200	155.84	275.43	145.10	155.00
99%	*	200	209.85	334	218.74	812.71	192.15	225.92

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

4.2 Medians for Selected Housing and Household Characteristics

Even if the AHS model quantile estimates were to match the 2009 RECS perfectly at the national level, we would want to know if average utility cost medians were similar across different types of housing units. For this reason, we compared electric and natural gas monthly costs for subsets of the total housing population. We calculated median electric and natural gas average monthly costs (in dollars) for the AHS models and compared them with the 2009 RECS, based on the following housing and household characteristics—

- Housing unit type (one unit attached, one unit detached, building with two or more units, and manufactured or mobile home).

- Tenure (owner or renter).

- Year built.

- Square feet.

- Total number of rooms.

- Bedrooms.

- Complete bathrooms.

- Householder characteristics (Black, White, Hispanic, elderly, and married).

- Education level of householder.

- Number of household members.

- Household income.

- Below poverty.

- Subsidized housing (owned by public housing authority or receives government subsidy).

Altogether, 75 categories exist across the aforementioned characteristics.[13]

Electric

Table 6 summarizes the number of electric medians for the 75 categories produced by different models that are not significantly different from the RECS medians. The UES and the HHC models overestimate the medians of most characteristics if the difference is significant. The HHCR, HHCR2, and HHCFIN models underestimate the medians.

Table 6. Electric Medians for Selected Housing and Household Characteristics

Model	Categories Not Significantly Different From the RECS (out of 75)
UES	7
HHC	14
HHCR	27
UESR	2
HHCR2	26
ONE BILL	31
HHCFIN	36

RECS = Residential Energy Consumption Survey.

Natural Gas

Table 7 summarizes the number of natural piped gas medians for 74 categories produced by different models that are not significantly different from the RECS medians. The 0 bedrooms characteristic is not evaluated, because the RECS contains only two units using natural gas with zero bedrooms. AHS natural gas models consistently overestimate the RECS medians.

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[13] See appendixes H and I for tables with complete information on average monthly cost medians by selected housing and household characteristics for electric and piped gas.

Table 7. Natural Gas Medians for Selected Housing and Household Characteristics

Model	Categories Not Significantly Different From the RECS (out of 74)
UES	0
HHC	0
HHCR	5
UESR	3
HHCR2	8
ONE BILL	19
HHCFIN	19

RECS = Residential Energy Consumption Survey.

4.3 Categorical Percent Distributions

The AHS national publication provides categorical distributions of the number of housing units paying different monthly costs for electricity and for gas (HUD and Census Bureau, 2009). Each table contains seven groups to show the distribution of housing units' monthly utility expenses, grouped into the following categories: less than $25, $25 to $49, $50 to $74, $75 to $99, $100 to $149, $150 to $199, and $200 or more.

For our analysis, we converted the counts to percentages to account for differences in the number of housing unit estimates by RECS and those estimated by AHS. We then performed statistical tests on the differences in percentages between our AHS models and the RECS. Groups with nonsignificant differences are highlighted in tables 8 and 9. Overall, no one model for electric (table 8) outperforms the others in replicating the RECS distribution. Although all natural gas models (table 9) outperform the HHC model, none consistently outperforms the others in matching the RECS distribution.

4.4 Regional Distribution Comparisons—Electric and Natural Gas

We performed significance testing at the regional level and identified how closely the AHS estimates matched the RECS distribution. Table 10 summarizes the electric comparisons, and table 11 summarizes the natural gas comparisons. Tables with detailed regional electric cost distributions are in appendix D. Tables with regional piped natural gas distributions are in appendix E.

Table 8. National Electric Cost Distributions (%)

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	1.6	2.2	1.8	1.2	0.7	1.6	0.7	2.7
$25 to $49	9.4	5.1	11.6	8.7	11.9	10.7	11.3	13.4
$50 to $74	16.7	16.5	22.9	15.8	23.2	19.7	22.7	18.2
$75 to $99	17.6	21.2	21.5	17.2	21.6	17.0	21.7	17.4
$100 to $149	26.6	31.1	26.3	26.1	26.6	23.4	27.3	25.3
$150 to $199	14.3	15.4	11.0	14.6	10.9	11.2	11.2	12.3
$200 or more	13.8	8.6	4.9	16.4	5.0	16.4	5.2	10.7

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.
Note: Highlighted cells indicate nonsignificant differences between model and RECS.

Table 9. National Natural Gas Cost Distributions (%)

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	6.3	3.2	6.4	5.9	5.9	9.6	7.2	13.1
$25 to $49	20.4	8.1	20.5	22.3	21.7	22.9	23.7	25.1
$50 to $74	24.3	20.5	26.0	25.2	27.0	22.9	26.4	25.0
$75 to $99	17.5	27.3	22.9	17.5	21.7	14.7	21.5	16.9
$100 to $149	19.0	31.1	18.6	17.6	17.8	14.9	16.9	14.2
$150 to $199	7.1	8.7	4.3	6.2	4.3	6.1	3.5	3.9
$200 or more	5.3	1.1	1.4	5.3	1.6	8.9	0.8	1.8

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.
Note: Highlighted cells indicate nonsignificant differences between model and RECS.

Table 10. Regional Electric Categorical Percent Distributions

Model	Categories Not Significantly Different From the RECS (out of 28)
UES	8
HHC	7
HHCR	5
UESR	7
HHCR2	5
ONE BILL	4
HHCFIN	5

RECS = Residential Energy Consumption Survey.

Table 11. Regional Natural Gas Categorical Percent Distributions

Model	Categories Not Significantly Different From the RECS (out of 28)
UES	6
HHC	3
HHCR	8
UESR	4
HHCR2	7
ONE BILL	7
HHCFIN	14

RECS = Residential Energy Consumption Survey.

4.5 Propane Model

After developing consumption and cost models for electric and natural piped gas, we explored models to estimate propane and oil consumption and costs. The propane model includes the following variables: census division; (use of bottled gas for heat)*(heating degree days); use of bottled gas for water heating; (use of bottled gas for cooking)*(number of people in the household); (use of bottled gas for clothes drying)*(number of people in the household); household income; built date of unit; unit type; total number of rooms; and housing tenure. Table 12 presents statistics from the original 2009-published AHS propane estimates and propane model estimates compared with the RECS. At the national level, average monthly cost medians for propane from the 2009 AHS and the model are not significantly different from the RECS. At the census division level, the 2009 AHS estimates for four divisions are significantly different from the RECS, whereas only one division estimate based on the model is statistically different from the RECS. Propane cost quantiles by census division are in appendix F.

Propane models are converted from consumption estimates to costs using prices estimated from the 2009 RECS. After discussions with EIA and comparisons of propane price data with RECS

Table 12. Average Monthly Cost of Propane, National Quantiles ($)

Quantile	2009 AHS	Model	2009 RECS
1%	11	13.23	4.42
5%	17	18.88	9.92
10%	24	22.09	15.17
25% Q1	42	33.11	32.75
50% median	62	69.54	65.25
75% Q3	94	124.17	115.75
90%	142	172.88	167.50
95%	182	214.40	217.00
99%	*	323.12	337.92

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

price estimates, we decided to use actual price data for the 38 states that currently have price data and EIA's Annual Energy Outlook price data for the remaining states (EIA, 2009).[14] Prices from both sources are close to the RECS-derived estimates.

4.6 Fuel Oil Model

Table 13 presents statistics on published 2009 AHS estimates and model estimates for fuel oil compared with the 2009 RECS. Fuel oil model variables include: use of fuel oil for heating fuel; use of fuel oil for water heating fuel; built date; total number of rooms; housing tenure; household income; and heating degree days. At the national level, medians for annual costs of fuel oil from published 2009 AHS estimates are significantly different from the RECS, but medians from the model are not. At the regional level (we did not examine fuel oil at the census division level because of small sample sizes for oil in some divisions), 2009 AHS published estimates are statistically different from the RECS in two out of four regions. Fuel oil model medians are not statistically different from the RECS at the regional level.[15]

Table 13. Annual Cost of Fuel Oil ($), National Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	80	1.25	191
5%	350	2.71	367
10%	600	260.99	571
25% Q1	1,000	1,083.17	847
50% median	1,600	1,465.05	1,245
75% Q3	2,500	1,712.43	1,871
90%	3,500	1,917.54	2,641
95%	4,162	2,097.44	2,985
99%	*	2,879.65	3,955

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

[14] See appendix O for information on obtaining price data.

[15] See appendix G for fuel oil quantiles by region.

Oil costs are converted from consumption estimates to costs using prices estimated from the 2009 RECS. After consulting with EIA, we concluded that adequate price data did not exist to convert consumption estimates into costs. Additionally, although the model does predict median oil costs well, it does not follow the RECS distribution in the tails of the distribution very well. This result is likely influenced by the small number of variables on fuel oil usage available in the AHS. For these reasons, we decided not to implement oil models in the 2015 AHS.

4.7 Effect of Modeled Estimates on Housing Burden Estimates (an Element of Worst Case Needs)

We adopted the HHCFIN models for electric and natural gas and the propane model for bottled gas in the 2015 AHS. Housing costs are part of the housing burden calculation used in identifying worst case needs households; therefore, we wanted to assess the impact of adopting the models on housing burden estimates for very low-income renters (in particular, those spending more than 50 percent of household income on housing costs, who are defined as having "worst case needs").

Tables 14 and 15 show percentages and counts of renter-occupied housing units with household incomes of not more than 50 percent of area median income that spend more than half of their household income on housing costs. We see declines

Table 14. Households With Housing Costs of More Than 50 Percent of Household Income, Very Low-Income Households, 2009 AHS (Weighted Percentages)

	Percentage	Standard Error	LCL95	UCL95
Old burden	41.5	0.6	40.2	42.7
New burden	39.8	0.7	38.5	41.2

AHS = American Housing Survey.

Table 15. Households With Housing Costs of More Than 50 Percent of Household Income, Very Low-Income Households, 2009 AHS (Weighted N, 1,000s)

Model	Count	Standard Error	LCL95	UCL95
Original estimate	7,096	129	6,843	7,350
New estimate	6,821	129	6,567	7,074

AHS = American Housing Survey.

in the percentage and count of burdened households at the national level using the new models. This finding is based on a significance test on the differences between burden estimates calculated using published 2009 cost estimates (old burden) and those calculated using the HHCFIN models (new burden). Looking at the comparison of the published 2009 AHS UES estimates with the RECS, evidence suggests that the UES was overestimating electric and natural gas costs compared with the RECS. This overestimation partially explains higher housing burden in the old burden calculations.

5. Decisions for 2015 AHS Utility Data Collection

Based on the research findings, we stopped collecting monthly bills for electric, piped natural gas, and bottled gas when those utilities are billed separately or when combined (that is, electric is billed with gas or gas is billed with electric; but not electric or gas billed with oil, other fuels, trash, or water). For 2015, we modeled average monthly costs for electric, natural piped gas, and bottled gas using final models developed from the RECS. We concluded that the fuel oil model does not adequately estimate fuel oil consumption and that no price data were adequate to convert consumption estimates into costs. For that reason, we continued to collect data on annual fuel oil costs in the 2015 AHS.

5.1 Combined Bills

In the 2015 AHS, when utility bills were combined with utilities that could not be modeled separately (such as fuel oil, other fuels, trash, water, and sewage), we prioritized the bills and recorded the cost in the bill of highest priority (highest to lowest priority: electricity, gas, oil, other fuel, trash, water). For combined bills that could not be separated and were combined with electric or gas, we asked respondents to provide the amounts of the most recent electric and gas bills. If they did not have those bills, we asked them to estimate the average monthly costs of electricity and gas. If respondents provided the most recent bill, the cost was estimated with the appropriate individual monthly model from the UESR model adjusted for inflation (see table 1).[16] If respondents provided average monthly cost estimates, we put the estimates through the self-reported average monthly costs

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[16] For model assignment for the last bill models, we needed to determine the billing month. For cases billed monthly, we asked respondents for the month of the bill. We used the month respondents provided. If respondents did not provide a month, we selected the month prior to their interview. If the billing cycle is every 2 months, we divided the amount by 2 and assigned the month prior to respondent interview. A 1-month difference does not affect the estimates much. Cases reporting multiple payments per month were run through the HHCFIN model for the bill with the highest priority, because we could not tell how many times they pay per month and thus cannot calculate the monthly payment.

model, or model 24 in table 1, which uses only the average monthly costs provided by respondents as the estimate of costs. If a respondent provided no bill or average monthly estimate, we put the case through the HHCFIN model of the utility with the highest priority. These procedures are in line with the procedures used in the 2013 AHS for handling these types of bills. For bills not combined with electric or gas, the utility bill's priority is determined and the cost is recorded with the utility of highest priority.

5.2 Post-Model Imputations

Average monthly costs for electric, piped gas, and bottled gas are calculated from either HHCFIN models, cost models based on the last bill, or self-reported average monthly costs. For the other utilities, (fuel oil, other fuels, garbage and trash, and water and sewage), we did not propose any changes to the pre-2015 hot deck imputation methods.

6. Conclusions

The HHCFIN electric models underestimate the median electric average monthly cost at the national level, but the median value using the HHCFIN models is closer to the RECS than the UES value.[17] Using a natural logarithm transformation on consumption helped us to capture a skewed consumption distribution. Adding household income and degree day normals in the models helped us more closely mirror the RECS electric distribution. Like the UES, the HHCFIN model overestimates the median natural gas average monthly cost, but the HHCFIN comes closer to the RECS estimate. We developed propane and fuel oil models. Both models yield medians not statistically different than the RECS. We did not adopt the fuel oil models, because we lacked adequate residential fuel oil price data for the whole country, and the model did not adequately predict costs across the distribution. We adopted the HHCFIN models for electric and natural gas and the propane model and did not implement the fuel oil model. For 2017, recently released RECS data for 2015 will be used to update model parameters, and we are exploring adding a random contribution from the error term to the utilities consumption estimates.[18]

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[17] Aggregate electric costs with the UES were higher than RECS aggregate electric costs, whereas aggregate electric costs using the HHCFIN models were lower but closer to the RECS estimates. Aggregate natural gas costs using HHCFIN models were also closer to the aggregate RECS natural gas cost estimates than the aggregate UES natural gas estimates to the RECS.

[18] A possible way to add a random contribution to the error term is to: (1) produce a regression-based prediction interval variance term, which incorporates the uncertainty in the parameter estimates and the residuals; and (2) using a random number generator, assuming a normal distribution with mean = y-hat and the variance previously described, produce the imputed consumption value.

Appendix A. Variables in Models

Table A1. Variables in Models

	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN
Input data	2001 RECS (inflated to 2009)	2001 RECS (inflated to 2009)	2009 RECS	2009 RECS	2009 RECS	2009 RECS	2009 RECS
Response variable	Cost	Cost	ln (consumption+1)	Cost	ln (consumption+1)	ln (consumption+1)	ln (consumption+1)
Independent variables	Monthly billing data and some housing and household characteristics (similar to HHC model) for units with less billing data	Electric heat	Heating degree days (if electric heat)	Same as UES	Same as HHCR models, used degree days from 2009 AHS file, household income, weighted, some collapsed geographies compared with HHCR	Same as HHCR2, but run only on cases with April bills and including the April bill as a predictor.	Same as HHCR2, but using heating degree days and cooling degree days from 30-year (1980–2010) climate normals from NOAA
		Gas heat	Heating degree days (if gas heat)				
			Cooling degree days (if central air)				
			Cooling degree days (if wall air unit)				
		Electric hot water	Electric hot water				
		Gas hot water	Gas hot water				
		Year built	Year built				
		Type of housing unit (single = 1, multi = 2, mobile = 3)	Single unit (indicator)				
			Multiunit (indicator)				
			Mobile home (indicator)				
		Total rooms	Total rooms				
		Total bathrooms	Total bathrooms				
		Total major appliances	Total major appliances				
		Number of household members	Number of household members				

AHS = American Housing Survey. ln = natural log. NOAA = National Oceanic and Atmospheric Administration. RECS = Residential Energy Consumption Survey.

Table A2. Electric Final Models—Variable Recoding (1 of 2)

Model	Estimating	Universe	RECS Input Variable	Definition Using AHS Variables	Levels	Notes
Electric-only	Average monthly costs of electricity	status in ('1') and uselect = '1' and buye not ('1','2','3') and usegas ne '1'	RDCOLL (reportable domain)	FIPSTATE coded into Reportable domain categories	14	'BY' VARIABLE—Started with 27 levels, but collapsed to 14 to bring sample size to 100
			EHDEMAND	(hfuel='1')*HEATDAY		HEATDAY is the heating degree days variable.
			EH20	(wfuel='1')		
			YRBUILT	BUILT	7	RECS YEARMADERANGE collapsed to link to AHS
			NU1	nunit2 in ('1','2')		
			NU2	nunit2 = '3'		
			NU3	nunit2 = '4'		
			TOTROOMS	min (bedrms + kitch + living + dining + famrm + recrm +dens + othfn,25)		RECS ranges are capped at 25
			BATHRMS	min (baths + (0.5*halfb),7)		RECS ranges went to 9 each, we capped at 7
			MAJAPPL	(refr='1') + (2*(cook+'1')) + (oven='1') + (burner='1') + (dish='1') + (wash='1') + (dry='1')		
			PEOPLE	min(curper,12)		RECS ranges went to 15, we capped them at 12
			CENAIR	(airsys='1') * COOLDAY		COOLDAY is the cooling degree days variable
			WALL	(airsys='2' and numair ge 1) * COOLDAY		COOLDAY is the cooling degree days variable
			MONEY_R	ZINC2		RECS ranges collapsed to $10,000 groups
Electric-gas mixed	Average monthly cost of electricity	status in ('1') and uselect='1' and buye not in ('1','2','3') and usegas = '1'	RDCOLL (Reportable Domain)	FIPSTATE coded into Reportable Domain categories	17	'BY' VARIABLE—started with 27, collapsed to bring sample size 100
			EHDEMAND	(hfuel='1') * HEATDAY		HEATDAY is heating degree days
			GHDEMAND	(hfuel='2' and gaspip='1')*HEATDAY		HEATDAY is heating degree days
			EH20	(wfuel='1')		
			GH20	(wfuel='2' and gaspip='1')		
			YRBUILT	BUILT	7	RECS YEARMADERANGE collapsed to link to AHS
			NU1	nunit2 in ('1','2')		

Table A2. Electric Final Models—Variable Recoding (2 of 2)

Model	Estimating	Universe	RECS Input Variable	Definition Using AHS Variables	Levels	Notes
			NU2	nunit2='3'		
			NU3	nunit2='4'		
			TOTROOMS	min (bedrms + kitch + living + dining + famrm + recrm + dens + othfn,25)		RECS ranges are capped at 25
			BATHRMS	min (baths+ (0.5*halfb),7)		RECS ranges, I capped at 7
			MAJAPPL	(refr='1') + (2*(cook+'1')) + (oven='1') + (burner='1') + (dish='1') + (wash='1') + (dry='1')		
			PEOPLE	min(curper,12)		RECS ranges went to 15, I capped at 12
			CENAIR	(airsys='1') * coolday		COOLDAY is cooling degree days
			WALL	(airsys='2' and numair ge 1) * coolday		COOLDAY is cooling degree days
			MONEY_R	ZINC2	12	RECS ranges collapsed to $10,000 groups

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table A3. Gas Final Models—Variable Recoding (1 of 2)

Model	Estimating	Universe	Input	Definition Using	Levels	Notes
Natural gas	Average monthly cost of piped natural gas	status in ('1') and usegas='1' and buyg not in ('1','2','3') and gaspip = '1'	RDCOLL	FIPSTATE coded into reportable domain categories	17	'BY' VARIABLE—Started with 27 levels, but collapsed to 14 to bring sample size to 100
			EHDEMAND	(hfuel = '1') * HEATDAY		HEATDAY is heating degree days
			EH2O	(wfuel = '1')		
			NOSTEAM	(hequip ne 2) * (hfuel = '2' and gaspip = '1')		/*removed degree days because distributions were adversely affected*/
			STEAM	(hequip = 2) * (hfuel = '2' and gaspip = '1')		/*removed degree days because distributions were adversely affected*/
			GH2O	(wfuel = '2' and gaspip = '1')		
			YRBUILT	BUILT	7	RECS YEARMADERANGE collapsed to link to AHS
			NU1	nunit2 in ('1','2')		
			NU2	nunit2 = '3'		
			NU3	nunit2 = '4'		
			TOTROOMS	min (bedrms + kitch + living + dining + famrm + recrm + dens + othfn,25)		RECS ranges are capped at 25

Table A3. Gas Final Models—Variable Recoding (2 of 2)

Model	Estimating	Universe	Input	Definition Using	Levels	Notes
			BATHRMS	min (baths + (0.5 * halfb),7)		RECS ranges went to 9 each, I capped at 7
			MAJAPPL	(refr = '1') + (2 * (cook = '1')) + (oven = '1') + (burner = '1') + (dish = '1') + (wash = '1') + (dry = '1')		
			PEOPLE	min (curper,12)		RECS ranges went to 15, I capped at 12
			CENAIR	(airsys = '1') * coolday		COOLDAY is cooling degree days.
			WALL	(airsys = '2' and numair ge 1) * coolday		COOLDAY is cooling degree days.
			MONEY_R	ZINC2	12	RECS ranges collapsed to $10,000 groups
Propane	Average monthly cost of bottled natural gas	status in ('1') and usegas='1' and (buyg not in ('1','2','3') or (buyg in ('1','2','3') and jbuyg = '2')) and gaspip='2'	DIV	DIV	9	'BY' VARIABLE—smallest sample size 56—opted to use instead of REGION
			GASHEAT	(hfuel = '2' and gaspip = '2') * heatday		HEATDAY is heating degree days
			GASH2O	(wfuel = '2' and gaspip = '2')		
			GCOOK	(cfuel = '2' and gaspip = '2') * min (curper,12)		RECS ranges went to 15, I capped at 12
			GDRY	(dfuel = '2' and gaspip = '2') * min(curper,12)		RECS ranges went to 15, I capped at 12
			MONEY_R	ZINC2	12	RECS ranges collapsed to $10,000 groups
			YRBUILT	BUILT	7	RECS YEARMADERANGE collapsed to link to AHS
			NU1	nunit2 in ('1','2')		
			NU2	nunit2 = '3'		
			NU3	nunit2 = '4'		
			TOTROOMS	Min (bedrms + kitch + living + dining + famrm + recrm + dens + othfn,25)		
			OWNER	(tenure='1')		

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Appendix B. Regional Electric Quantiles

Table B1. Average Monthly Cost of Electricity ($), Northeast Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	24	44	0.06	26	32.33	25.55	33.15	20
5%	26	55	40.76	41	41.62	37.52	42.83	34
10%	45	57	46.43	50	46.76	43.91	48.57	42
25% Q1	63	77	61.13	70	61.12	58.50	63.26	59
50% median	94	97	87.70	101	87.06	85.65	89.58	93
75% Q3	144	119	122.50	155	124.03	133.74	127.22	143
90%	218	144	161.39	231	166.35	210.69	171.01	204
95%	276	163	194.34	300	197.34	301.57	201.35	243
99%	*	207	273.51	484	273.72	728.51	277.73	337

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

Table B2. Average Monthly Cost of Electricity ($), Midwest Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	20	4	0.10	24	22.73	0.02	23.03	20
5%	34	29	27.56	35	32.50	33.28	32.78	31
10%	44	44	37.99	45	40.71	39.56	41.10	38
25% Q1	64	62	53.73	64	54.98	50.78	55.31	57
50% median	93	83	72.71	92	73.68	68.96	73.94	84
75% Q3	134	112	98.64	132	99.71	108.18	100.08	115
90%	187	145	133.81	189	133.38	174.74	133.38	156
95%	230	165	165.47	236	162.01	269.21	162.03	190
99%	*	201	229.08	350	219.36	666.30	220.15	260

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

Table B3. Average Monthly Cost of Electricity ($), South Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	38	42	27.34	35	35.94	15.75	36.45	29
5%	57	70	52.72	57	55.86	48.76	56.47	48
10%	70	86	65.51	71	67.11	62.45	67.69	59
25% Q1	98	115	88.02	100	87.78	88.78	88.54	85
50% median	136	151	119.95	141	118.58	129.67	119.30	124
75% Q3	189	192	155.06	197	154.85	200.41	155.48	174
90%	248	228	194.73	262	195.77	316.83	196.12	229
95%	298	250	223.17	315	224.98	446.33	225.97	271
99%	*	303	286.57	460	289.28	1,491.22	291.52	374

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

Table B4. Average Monthly Cost of Electricity ($), West Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	14	11	0.05	16	22.84	23.69	23.07	11
5%	26	24	31.96	29	32.58	40.67	32.77	21
10%	36	41	38.33	38	38.50	50.39	39.19	27
25% Q1	55	66	51.59	58	51.74	73.38	52.50	43
50% median	86	85	70.79	90	71.29	107.97	73.38	72
75% Q3	134	110	95.41	146	97.06	157.99	101.01	118
90%	199	135	124.34	222	126.82	252.08	131.52	177
95%	253	150	146.75	291	150.71	373.72	155.31	220
99%	*	192	210.18	500	213.54	994.11	218.42	348

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

Appendix C. Regional Natural Gas Quantiles

Table C1. Average Monthly Cost of Natural Gas ($), Northeast Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	10	– 31	5.50	10	5.85	1.22	5.69	4
5%	22	3	7.37	22	7.58	11.73	7.34	8
10%	36	42	22.33	34	17.63	17.44	13.53	17
25% Q1	68	103	79.41	75	78.19	46.15	74.19	64
50% median	106	135	117.74	113	120.17	84.40	107.59	99
75% Q3	153	162	151.19	149	154.38	146.97	137.47	141
90%	212	180	185.25	207	191.00	271.58	166.47	186
95%	263	198	209.98	269	220.89	425.82	185.49	218
99%	*	238	283.91	428	298.88	1,152.18	249.78	311

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

Table C2. Average Monthly Cost of Natural Gas ($), Midwest Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	19	34	13.65	21	29.24	0.00	27.84	5
5%	35	59	43.31	39	42.76	11.59	42.29	31
10%	43	69	53.08	49	51.52	32.10	51.23	41
25% Q1	60	85	68.25	66	67.16	55.36	66.12	56
50% median	89	103	83.72	85	82.31	74.84	81.47	75
75% Q3	126	124	100.90	116	99.67	106.08	98.48	99
90%	173	146	118.02	164	116.71	152.49	116.18	127
95%	212	160	130.04	205	128.42	195.97	130.94	149
99%	*	188	164.00	326	160.86	433.94	173.59	196

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

Table C3. Average Monthly Cost of Natural Gas ($), South Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	11	28	11.86	14	21.91	0.35	19.27	3
5%	23	45	25.73	25	30.83	23.81	28.94	11
10%	30	56	33.75	32	36.87	30.82	35.81	22
25% Q1	46	70	46.55	46	47.95	45.04	47.42	37
50% median	70	86	63.89	64	62.84	74.85	60.57	54
75% Q3	101	106	86.32	94	86.25	123.84	82.30	80
90%	145	126	107.91	144	111.82	215.03	103.02	105
95%	189	138	121.10	189	126.40	319.91	116.66	120
99%	*	167	155.13	305	153.45	839.65	153.07	168

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.
* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

Table C4. Average Monthly Cost of Natural Gas ($), West Quantiles

Quantile	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
1%	8	7	16.12	10	16.11	0.21	15.63	4
5%	16	23	20.32	18	20.16	14.51	19.16	9
10%	23	32	23.42	23	23.50	21.60	22.02	15
25% Q1	36	50	37.17	35	37.28	32.44	34.44	25
50% median	54	68	48.58	48	48.22	45.08	44.06	40
75% Q3	73	83	66.13	66	64.25	68.60	58.09	58
90%	104	102	87.14	100	84.59	145.78	81.38	82
95%	136	117	103.69	131	95.74	226.31	99.42	101
99%	*	160	141.10	237	132.40	621.03	147.94	160

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

* The value at the 99% quantile is suppressed, because UES data on the public use file are suppressed at the 97.5th percentile.

Appendix D. Regional Average Monthly Cost for Electricity Distributions

Table D1. Regional Electric Cost Distributions (%), Northeast

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	1.0	—	1.1	0.9	—	1.0	—	2.1
$25 to $49	12.3	3.7	12.1	8.7	12.8	14.2	11.0	14.5
$50 to $74	21.7	20.5	24.4	18.8	25.6	25.3	25.1	20.4
$75 to $99	18.9	28.3	22.4	19.3	21.4	19.4	22.1	17.4
$100 to $149	22.8	38.9	26.7	25.0	25.8	20.6	26.0	23.0
$150 to $199	10.8	7.1	8.9	12.0	9.6	8.4	10.6	11.7
$200 or more	12.5	1.4	4.5	15.3	4.7	11.2	5.2	10.8

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.
— Less than 5 cases in cell.

Table D2. Regional Electric Cost Distributions (%), Midwest

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	2.2	4.0	3.7	1.0	1.6	2.6	1.5	2.1
$25 to $49	11.6	9.2	16.2	12.4	17.5	20.5	17.1	16.8
$50 to $74	20.5	28.4	32.2	21.4	32.0	32.1	32.1	22.6
$75 to $99	20.7	24.6	23.4	22.1	23.8	16.4	23.9	22.7
$100 to $149	26.6	25.1	17.2	24.3	18.4	14.7	18.6	24.2
$150 to $199	10.7	7.6	5.2	10.2	5.0	6.2	4.9	7.6
$200 or more	7.7	1.1	2.1	8.5	1.8	7.6	1.9	3.9

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table D3. Regional Electric Cost Distributions (%), South

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	0.2	0.5	0.9	0.4	0.2	1.4	0.2	0.6
$25 to $49	2.5	1.0	3.5	2.7	3.0	3.8	2.8	5.0
$50 to $74	9.5	4.5	11.1	8,7	11.7	10.8	11.4	12.3
$75 to $99	14.8	10.1	18.9	13.0	19.6	16.0	19.6	15.8
$100 to $149	31.9	32.6	36.9	30.4	37.4	27.6	37.4	31.4
$150 to $199	20.4	30.3	19.7	20.9	19.2	15.3	19.2	17.9
$200 or more	20.7	21.1	9.1	24.0	9.2	25.1	9.4	16.9

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table D4. Regional Electric Cost Distributions (%), West

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	4.0	5.0	2.0	3.2	1.3	1.2	1.3	7.5
$25 to $49	16.7	9.0	20.4	15.2	20.9	8.4	20.0	23.2
$50 to $74	21.3	21.7	32.3	19.9	31.7	16.2	30.2	21.6
$75 to $99	18.1	30.9	23.5	17.5	23.0	17.3	22.4	14.7
$100 to $149	20.4	28.2	16.9	21.2	17.7	28.8	20.1	17.9
$150 to $199	10.3	4.4	3.6	10.5	3.9	12.3	4.5	8.2
$200 or more	9.3	0.7	1.2	12.5	1.4	15.9	1.5	6.8

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Appendix E. Regional Average Monthly Cost for Piped Gas Distributions

Table E1. Regional Natural Gas Cost Distributions (%), Northeast

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	5.9	7.9	10.3	5.9	11.9	12.8	14.0	12.4
$25 to $49	9.4	3.1	5.3	10.2	6.3	14.3	5.1	7.0
$50 to $74	12.3	4.0	6.2	8.8	5.0	16.6	6.1	13.3
$75 to $99	16.3	8.7	14.7	14.7	12.7	14.1	18.1	17.7
$100 to $149	29.8	40.5	37.3	35.7	36.0	18.0	39.4	28.9
$150 to $199	14.2	31.0	19.0	12.8	19.9	8.3	14.0	13.2
$200 or more	11.8	4.7	7.0	11.9	8.3	15.9	3.4	7.6

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table E2. Regional Natural Gas Cost Distributions (%), Midwest

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	1.7	0.5	1.3	1.4	0.5	8.2	0.8	3.4
$25 to $49	13.4	2.5	6.7	8.8	8.1	10.5	8.0	14.1
$50 to $74	22.4	10.3	26.3	26.1	27.9	30.8	29.5	31.7
$75 to $99	20.5	31.2	39.0	29.2	38.3	21.9	37.9	26.4
$100 to $149	26.4	47.0	24.8	21.2	23.4	17.7	21.4	19.6
$150 to $199	9.5	8.0	1.6	7.6	1.5	6.3	2.0	3.9
$200 or more	6.1	0.5	0.3	5.7	0.2	4.7	0.5	0.9

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table E3. Regional Natural Gas Cost Distributions (%), South

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	5.9	0.8	4.1	4.5	1.7	5.4	2.5	12.5
$25 to $49	22.7	5.7	23.8	25.5	25.3	24.0	25.6	30.9
$50 to $74	25.7	24.7	34.6	31.1	36.8	20.4	39.4	28.0
$75 to $99	20.4	35.8	22.3	16.4	20.0	14.6	20.6	16.6
$100 to $149	16.2	30.4	13.8	13.5	14.9	17.4	10.6	10.2
$150 to $199	5.2	2.4	1.1	4.8	1.1	7.1	1.0	1.3
$200 or more	4.0	0.2	0.2	4.1	0.2	11.2	0.2	0.6

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table E4. Regional Natural Gas Cost Distributions (%), West

	2009 AHS							2009 RECS
	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	
Less than $25	11.7	5.1	11.3	11.7	11.4	13.8	13.6	23.8
$25 to $49	32.1	19.1	40.5	40.4	41.5	43.6	49.3	41.3
$50 to $74	32.3	37.2	30.0	29.0	30.8	20.6	24.2	22.4
$75 to $99	12.6	27.2	12.4	8.7	12.2	6.3	8.0	7.1
$100 to $149	7.5	10.1	5.0	6.5	3.6	6.1	4.1	4.1
$150 to $199	2.1	1.2	0.6	1.9	0.4	3.0	0.7	0.9
$200 or more	1.6	0.2	0.2	1.7	0.1	6.6	0.2	0.4

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Appendix F. Census Division Propane Quantiles

Table F1. Average Monthly Cost of Propane ($), New England Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	9	—	6.25
5%	18	—	8.50
10%	—	20.31	13.00
25% Q1	28	25.72	21.25
50% median	48	34.31	39.25
75% Q3	59	104.31	107.42
90%	79	205.43	182.67
95%	79	250.03	201.17
99%	*	—	243.58

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Table F2. Average Monthly Cost of Propane ($), Middle Atlantic Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	17	—	4.92
5%	21	15.19	8.83
10%	31	16.76	11.75
25% Q1	43	21.09	27.25
50% median	72	28.04	67.75
75% Q3	128	132.32	135.00
90%	156	199.22	227.33
95%	182	229.21	280.83
99%	*	295.95	398.25

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Table F3. Average Monthly Cost of Propane ($), East North Central Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	19	—	4.33
5%	42	53.91	8.50
10%	48	58.57	15.67
25% Q1	64	96.01	69.17
50% median	91	123.81	115.33
75% Q3	132	147.31	154.17
90%	440	194.87	217.00
95%	440	223.60	271.17
99%	*	308.22	396.58

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Table F4. Average Monthly Cost of Propane ($), West North Central Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	20	—	5.00
5%	—	41.99	28.25
10%	28	52.44	50.08
25% Q1	51	73.46	68.33
50% median	62	104.35	102.33
75% Q3	96	134.40	132.67
90%	185	164.15	189.00
95%	185	179.86	244.83
99%	*	212.13	448.17

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Table F5. Average Monthly Cost of Propane ($), South Atlantic Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	14	—	6.17
5%	17	17.16	10.75
10%	34	19.95	14.08
25% Q1	43	26.49	25.67
50% median	63	41.25	40.42
75% Q3	103	83.82	74.75
90%	122	141.67	121.00
95%	196	180.15	155.92
99%	*	323.12	337.17

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Table F6. Average Monthly Cost of Propane ($), East South Central Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	9	—	2.25
5%	13	33.64	8.58
10%	14	33.64	28.83
25% Q1	31	47.66	38.50
50% median	60	63.30	53.67
75% Q3	88	76.41	83.33
90%	133	96.62	133.92
95%	157	117.43	151.83
99%	*	156.33	191.50

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

**Table F7. Average Monthly Cost of Propane ($),
West South Central Quantiles**

Quantile	2009 AHS	Model	2009 RECS
1%	16	—	8.17
5%	18	20.21	9.58
10%	23	21.03	13.50
25% Q1	31	25.63	22.92
50% median	49	48.51	53.42
75% Q3	73	75.67	87.00
90%	96	118.60	136.58
95%	—	139.22	172.00
99%	*	162.55	273.33

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy
Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because
the 2009 AHS estimate on the public use file are suppressed at the 97.5th
percentile.

**Table F8. Average Monthly Cost of Propane ($),
Mountain Quantiles**

Quantile	2009 AHS	Model	2009 RECS
1%	11	—	9.917
5%	—	20.53	9.917
10%	24	—	15.167
25% Q1	32	39.92	35.250
50% median	46	112.07	88.917
75% Q3	60	191.65	121.917
90%	66	279.57	168.167
95%	—	396.09	242.500
99%	*	699.33	303.833

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy
Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because
the 2009 AHS estimate on the public use file are suppressed at the 97.5th
percentile.

**Table F7. Average Monthly Cost of Propane ($),
Pacific Quantiles**

Quantile	2009 AHS	Model	2009 RECS
1%	8	—	1.583
5%	—	—	13.833
10%	—	—	14.917
25% Q1	36	40.07	33.333
50% median	60	78.11	66.917
75% Q3	89	118.51	100.917
90%	128	164.92	137.500
95%	—	—	150.917
99%	*	—	198.917

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy
Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because
the 2009 AHS estimate on the public use file are suppressed at the 97.5th
percentile.

Appendix G. Regional Oil Quantiles

Table G1. Annual Cost of Fuel Oil ($), Northeast Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	175.00	1.09	256.00
5%	500.00	2.16	381.00
10%	700.00	967.60	651.00
25% Q1	1,199.00	1,302.36	959.00
50% median	1,876.00	1,534.51	1,364.00
75% Q3	2,765.00	1,740.68	2,002.00
90%	3,800.00	1,891.55	2,783.00
95%	4,566.00	2,029.07	3,241.00
99%	*	2,373.91	4,085.00

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

* The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Table G2. Annual Cost of Fuel Oil ($), Midwest Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	50.00	—	262.00
5%	65.00	—	319.00
10%	220.00	112.32	618.00
25% Q1	650.00	317.33	730.00
50% median	1,200.00	648.70	905.00
75% Q3	1,663.00	1,244.96	1,205.00
90%	2,500.00	2,034.83	1,674.00
95%	3,000.00	2,939.96	1,811.00
99%	*	5,889.82	2,760.00

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Table G3. Annual Cost of Fuel Oil ($), South Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	96.00	—	133.00
5%	225.00	108.44	268.00
10%	400.00	249.83	392.00
25% Q1	770.00	445.16	636.00
50% median	1,200.00	973.87	841.00
75% Q3	1,700.00	1,495.01	1,473.00
90%	2,400.00	2,109.86	1,822.00
95%	3,360.00	—	2,323.00
99%	*	3,168.23	2,907.00

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Table G4. Annual Cost of Fuel Oil ($), West Quantiles

Quantile	2009 AHS	Model	2009 RECS
1%	60.00	—	298.00
5%	190.00	—	298.00
10%	400.00	—	544.00
25% Q1	800.00	—	708.00
50% median	1,200.00	621.30	859.00
75% Q3	1,637.00	1,166.06	1,087.00
90%	2,040.00	—	1,236.00
95%	3,300.00	—	1,258.00
99%	*	—	1,533.00

AHS = American Housing Survey. Q = quantile. RECS = Residential Energy Consumption Survey.

— Less than 10 cases. * The value at the 99% quantile is suppressed, because the 2009 AHS estimate on the public use file are suppressed at the 97.5th percentile.

Appendix H. Medians for Average Monthly Cost of Electricity by Selected Housing and Household Characteristics

Table H1. Electric Medians by Selected Housing and Household Characteristics (1 of 2)

Median Monthly Electric Costs	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	2009 RECS
Housing unit type								
One unit building detached	120	112	100	124	101	114	103	113
One unit building attached	98	104	87	101	86	95	90	82
Building with two or more apartments	71	73	60	74	59	67	60	59
Manufactured/mobile home	122	133	106	128	110	111	109	110
Tenure								
Owned	118	113	99	122	100	111	102	110
Rented	84	84	68	87	68	76	68	70
Year built								
2005 to 2009	124	135	115	129	114	127	115	112
2000 to 2004	125	129	110	129	110	124	111	118
1995 to 1999	124	127	106	127	107	116	108	117
1990 to 1994	122	123	103	125	104	119	106	113
1984 to 1989	114	119	99	117	101	109	103	106
1980 to 1984	115	120	102	120	103	115	104	98
1975 to 1979	113	110	94	116	94	107	96	101
1970 to 1974	106	105	88	109	89	97	90	89
1960 to 1969	102	101	85	106	85	97	86	87
1950 to 1959	98	92	80	101	80	93	81	84
1940 to 1949	96	89	75	100	76	88	77	82
1930 to 1939	93	88	72	97	72	84	74	83
1929 or earlier	90	88	70	93	71	74	73	81
Square feet								
Less than 500	82	86	70	89	69	72	71	45
500 to 749	68	69	58	71	58	64	58	55
750 to 999	82	80	67	84	67	74	68	71
1,000 to 1,499	102	101	85	105	84	94	85	88
1,500 to 1,999	116	111	97	119	98	113	100	102
2,000 to 2,499	127	121	106	131	106	122	109	108
2,500 to 2,999	140	132	115	143	116	134	118	109
3,000 to 3,999	145	135	119	150	121	138	123	117
4,000 or more	150	136	120	159	122	146	124	146
Total number of rooms								
1 to 2	47	39	41	49	42	50	42	44
3 to 4	73	71	61	76	60	70	61	64
5 to 6	109	103	89	112	89	102	91	96
7 or more	139	130	117	143	118	133	121	127
Bedrooms								
0	43	39	40	45	39	46	40	36
1	58	57	51	60	51	57	52	52
2	87	85	70	89	70	79	71	75
3	117	111	97	121	98	112	100	107
4 or more	146	135	122	150	123	144	125	134

Table H1. Electric Medians by Selected Housing and Household Characteristics (2 of 2)

Median Monthly Electric Costs	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	2009 RECS
Complete bathrooms								
None	69	67	60	77	60	58	60	24
1	80	76	64	82	64	71	65	67
1 ½	103	95	83	105	83	89	85	91
2 or more	129	129	112	134	112	127	114	122
Householder characteristics								
Black	113	108	85	115	84	99	85	95
White	108	106	91	111	92	102	93	99
Hispanic	98	98	88	103	89	109	91	84
Elderly (65+)	96	96	82	99	80	88	81	84
Married	126	119	106	130	108	122	110	116
Education								
Up to 12th grade, no diploma	102	100	83	105	82	95	83	82
High school graduate	107	103	87	110	87	95	88	95
Some college, no degree	109	102	88	112	88	104	89	98
Associate's degree	108	109	93	110	93	101	95	101
Bachelor's degree	110	110	95	113	96	107	98	101
Graduate or professional degree	113	112	97	116	100	110	102	103
Number of household members								
1	77	80	67	78	66	72	67	65
2	107	102	86	109	86	100	88	97
3	123	115	99	128	100	119	102	112
4	134	126	115	140	115	137	118	124
5	143	135	129	150	131	152	134	128
6	154	143	136	156	138	171	141	139
7 or more	147	153	165	158	162	183	168	134
Household income								
Less than $5,000	85	89	72	89	67	77	69	75
$5,000 to $9,999	85	85	70	87	66	73	66	69
$10,000 to $14,999	85	86	70	88	68	78	68	73
$15,000 to $19,999	93	93	75	94	74	76	74	78
$20,000 to $24,999	94	95	78	95	75	83	76	79
$25,000 to $29,999	100	101	84	103	81	89	82	85
$30,000 to $39,999	99	102	82	102	81	90	82	84
$40,000 to $49,999	104	102	86	107	84	92	85	99
$50,000 to $59,999	107	105	91	111	90	99	92	97
$60,000 to $79,999	114	108	95	117	96	108	97	104
$80,000 to $99,999	119	112	99	122	104	119	105	115
$100,000 to $119,999	129	118	109	134	115	133	118	120
$120,000 or more	140	126	113	146	120	144	124	144
Poverty								
Income below 100% poverty line	94	95	76	97	72	84	74	83
Subsidized housing								
Owned by a public housing authority	70	71	58	73	55	59	56	62
Government subsidy	79	79	63	78	61	65	61	56

RECS = Residential Energy Consumption Survey.

Appendix I. Median Average Monthly Costs for Piped Gas by Selected Housing and Household Characteristics

Table I1. Natural Gas Medians by Selected Housing and Household Characteristics (1 of 2)

Median Monthly Electric Costs	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	2009 RECS
Housing unit type								
One unit building detached	80	95	76	75	75	72	72	66
One unit building attached	74	90	77	74	77	61	73	56
Building with two or more apartments	46	59	42	45	41	46	39	34
Manufactured/mobile home	58	67	50	60	48	0	45	47
Tenure								
Owned	80	96	77	76	75	71	72	66
Rented	55	70	53	54	52	55	49	44
Year built								
2005 to 2009	70	84	67	67	67	59	64	60
2000 to 2004	69	84	66	68	66	65	64	57
1995 to 1999	68	81	70	67	70	65	66	58
1990 to 1994	72	82	69	69	68	64	66	60
1984 to 1989	69	84	64	65	63	60	60	59
1980 to 1984	63	77	60	60	59	61	57	48
1975 to 1979	66	81	64	64	61	60	58	51
1970 to 1974	67	82	65	64	62	63	60	57
1960 to 1969	74	91	71	70	68	68	65	61
1950 to 1959	75	94	75	72	72	68	69	66
1940 to 1949	71	95	72	71	71	66	68	61
1930 to 1939	85	106	81	82	77	77	76	70
1929 or earlier	95	120	93	91	90	88	89	78
Square feet								
Less than 500	70	93	77	75	74	63	71	21
500 to 749	43	56	41	43	40	35	38	23
750 to 999	53	66	51	53	50	52	47	38
1,000 to 1,499	65	79	64	63	62	59	59	49
1,500 to 1,999	73	87	70	68	68	65	65	58
2,000 to 2,499	83	99	79	79	78	77	75	61
2,500 to 2,999	89	105	84	84	84	85	81	71
3,000 to 3,999	94	113	90	88	89	84	86	78
4,000 or more	107	125	100	100	99	111	96	90
Total number of rooms								
1 to 2	22	31	25	27	25	32	23	15
3 to 4	46	56	45	47	45	43	42	36
5 to 6	70	82	68	68	67	63	63	57
7 or more	92	112	88	86	87	85	84	76
Bedrooms								
0	22	30	25	27	23	32	20	—
1	36	43	37	38	36	32	33	26
2	60	73	59	59	57	57	53	48
3	76	90	74	72	72	67	68	62
4 or more	92	113	88	86	88	88	84	77

Table I1. Natural Gas Medians by Selected Housing and Household Characteristics (2 of 2)

Median Monthly Electric Costs	UES	HHC	HHCR	UESR	HHCR2	ONE BILL	HHCFIN	2009 RECS
Complete bathrooms								
None	65	83	49	66	45	76	51	15
1	62	78	61	61	59	59	56	50
1 ½	84	99	80	82	77	73	75	68
2 or more	77	94	74	72	73	71	69	64
Householder characteristics								
Black	79	90	70	79	69	80	67	66
White	73	90	73	70	71	66	68	61
Hispanic	54	70	48	50	48	45	45	41
Elderly (65+)	75	89	72	73	69	67	66	65
Married	80	98	77	76	76	73	73	65
Education								
Up to 12th grade, no diploma	64	78	58	61	56	55	55	49
High school graduate	74	89	72	72	70	67	68	59
Some college, no degree	71	86	68	67	67	65	65	60
Associate's degree	74	92	74	71	72	67	68	61
Bachelor's degree	75	94	75	71	73	72	70	65
Graduate or professional degree	83	101	79	80	78	77	75	69
Number of household members								
1	62	78	64	61	61	59	57	52
2	73	88	72	70	70	66	66	61
3	76	94	73	73	72	69	68	63
4	83	105	80	80	78	83	76	67
5	82	108	78	78	77	80	75	68
6	81	104	76	80	77	81	73	69
7 or more	80	106	73	77	75	81	73	56
Household income								
Less than $5,000	59	80	57	60	54	60	55	48
$5,000 to $9,999	65	75	62	62	58	57	55	47
$10,000 to $14,999	64	78	62	63	59	61	56	50
$15,000 to $19,999	66	79	64	66	61	67	57	51
$20,000 to $24,999	67	81	66	66	63	59	60	57
$25,000 to $29,999	71	86	69	70	66	63	63	60
$30,000 to $39,999	70	82	67	68	65	64	62	57
$40,000 to $49,999	70	86	69	66	67	66	64	59
$50,000 to $59,999	71	89	71	69	70	66	67	59
$60,000 to $79,999	73	90	73	69	73	66	70	60
$80,000 to $99,999	78	97	77	75	76	74	73	66
$100,000 to $119,999	77	96	77	75	76	70	72	71
$120,000 or more	87	107	82	82	82	81	78	79
Poverty								
Income below 100 percent poverty line	63	78	59	62	57	60	55	50
Subsidized housing								
Owned by a public housing authority	48	54	45	46	44	53	41	34
Government subsidy	55	64	49	54	49	51	47	36

— Too few cases to calculate. RECS = Residential Energy Consumption Survey.

Appendix J. Number of 2015 AHS Cases in Different Models

Model	Number of Cases
Electric only	
Consumption (no bills)	18,095
Cost (combined bills)	153
AMTE (self-reported average monthly costs)	4
Electric mixed	
Consumption (no bills)	38,376
Cost (combined bills)	563
AMTG (self-reported average monthly costs)	6
Natural gas	
Consumption (no bills)	33,515
Cost (combined bills)	123
AMTG (self-reported average monthly costs)	1
Propane	
Consumption (no bills)	3,364
AMTG (self-reported average monthly costs)	10

Appendix K. Count of RECS and AHS Cases in 2009 Models

Table K1. Count of RECS and AHS Cases in 2009 Electric-Only Models

Collapsed Reportable Domains	RECS Cases	Used	Outliers	AHS Cases
1	403	369	34	782
2	315	296	19	1,456
3	207	197	10	887
4	234	227	7	267
5	263	242	21	160
6	257	245	12	889
7	193	180	13	410
8	226	210	16	916
9	783	745	38	2,099
10	353	337	16	1,033
11	489	459	30	1,491
12	186	175	11	465
13	170	165	5	223
14	258	243	15	761

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table K2. Count of RECS and AHS Cases in 2009 Electric and Gas Mixed Models

Collapsed Reportable Domains	RECS Cases	Used	Outliers	AHS Cases
1	451	427	24	1,091
2	632	595	37	2,239
3	304	286	18	3,974
4	490	462	28	4,238
5	211	202	9	2,515
6	191	188	3	671
7	456	435	21	1,216
8	248	239	9	499
9	403	391	12	638
10	219	210	9	1,260
11	484	464	20	1,908
12	249	240	9	1,466
13	675	637	38	2,543
14	235	224	11	760
15	356	340	16	1,375
16	1398	1355	43	3,839
17	181	170	11	769

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table K3. Counts of RECS and AHS Cases in 2009 Natural Gas Models

Collapsed Reportable Domains	RECS Cases	Used	Outliers	AHS Cases
1	380	317	63	741
2	459	398	61	1,666
3	268	242	26	3,376
4	454	430	24	3,602
5	183	171	12	2,162
6	184	170	14	520
7	414	399	15	923
8	240	235	5	442
9	393	355	38	537
10	201	178	23	1,005
11	469	417	52	1,367
12	240	218	22	1,096
13	644	602	42	2,198
14	222	206	16	683
15	350	335	15	1,186
16	1325	1235	90	3,620
17	171	149	22	652

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Table K4. Count of RECS and AHS Cases in 2009 Propane Models

Census Division	RECS Cases	Used	Outliers	AHS Cases
1	86	86	0	257
2	82	81	1	531
3	78	72	6	662
4	177	162	15	348
5	187	178	9	694
6	81	77	4	337
7	56	48	8	281
8	59	57	2	216
9	96	89	7	170

AHS = American Housing Survey. RECS = Residential Energy Consumption Survey.

Appendix L. Consumption and Cost Estimate Cumulative Distribution Functions (CDFs)

Consumption

2009 ahs vs. 2009 recs electric consumption cdfs

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable cons
Classified by Variable survey

survey	N	EDF at Maximum	Deviation from Mean at Maximum
RECS	107852972	0.837276	-326.25750
AHSN	106849315	0.900402	327.78622
Total	214702287	0.868692	

Maximum Deviation Occurred at Observation 22446
Value of cons at Maximum = 18118.0

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)
KS 0.031563 D   0.063126
KSa 462.480012 Pr > KSa <.0001

2009 ahs vs. 2009 recs natural gas consumption cdfs

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable cons
Classified by Variable survey

		EDF at Maximum	Deviation from Mean at Maximum
survey	N	Maximum	
RECS	60006744	0.242840	341.55893
AHSN	61250166	0.155550	-338.07421
Total	********	0.198747	

Maximum Deviation Occurred at Observation 1986
  Value of cons at Maximum = 353.0

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)
KS 0.043643 D   0.087290
KSa 480.579518 Pr > KSa <.0001

2009 ahs vs. 2009 recs propane consumption cdfs
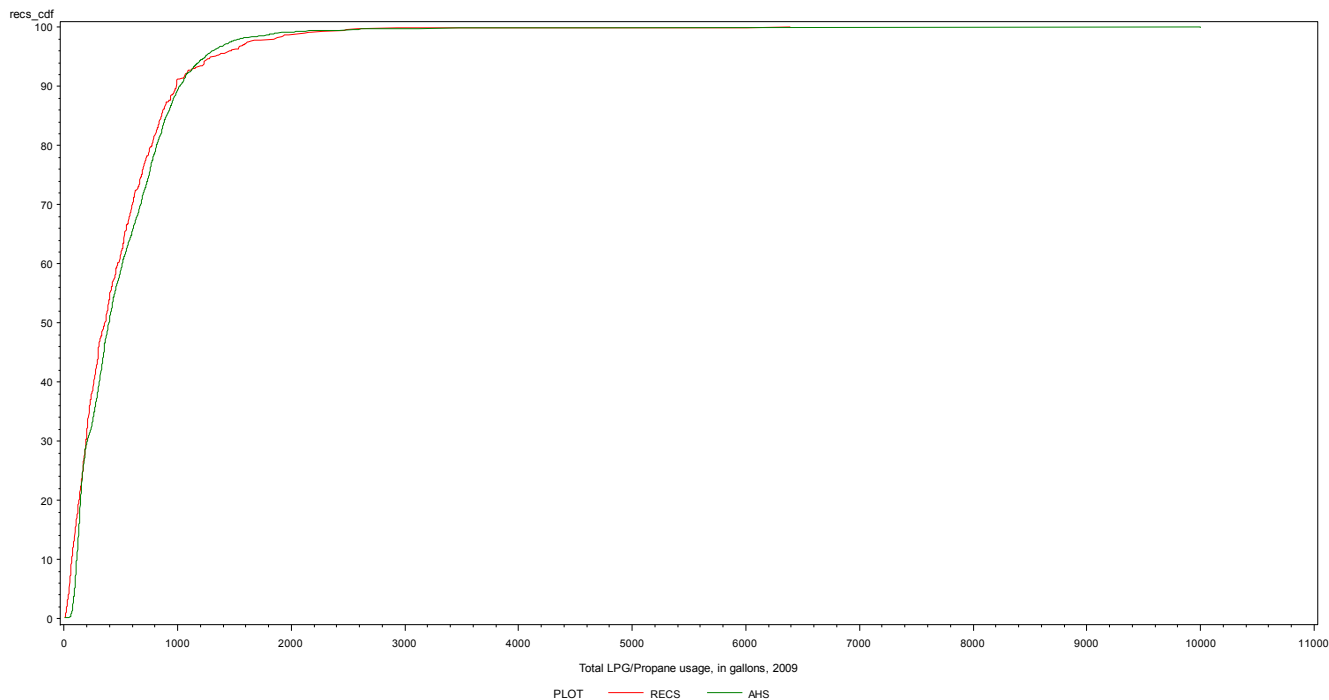
The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable cons
Classified by Variable survey

		EDF at	Deviation from Mean
survey	N	Maximum	at Maximum
RECS	9883427	0.127115	148.94200
AHSN	9472776	0.030308	-152.13612
Total	19356203	0.079739	

Maximum Deviation Occurred at Observation 600
Value of cons at Maximum = 82.0

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)
KS 0.048393 D 0.096807
KSa 212.906357 Pr > KSa <.0001

Cost

2009 ahs vs. 2009 recs electric cost cdfs

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable cons
Classified by Variable survey

survey	N	EDF at Maximum	Deviation from Mean at Maximum
RECS	107855836	0.743557	-353.04318
AHSN	106840450	0.811869	354.71684
Total	214696286	0.777551	

Maximum Deviation Occurred at Observation 30340
Value of cons at Maximum = 1715.960

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)
KS 0.034155 D 0.068312
KSa 500.463310 Pr > KSa <.0001

2009 ahs vs. 2009 recs natural gas cost cdfs

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable cons
Classified by Variable survey

survey	N	EDF at Maximum	Deviation from Mean at Maximum
RECS	60006606	0.246408	336.69502
AHSN	61244700	0.160357	-333.27441
Total	********	0.202943	

Maximum Deviation Occurred at Observation 403
Value of cons at Maximum = 450.0

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)
KS 0.043023 D 0.086051
KSa 473.746105 Pr > KSa <.0001

2009 ahs vs. 2009 recs propane cost cdfs

The NPAR1WAY Procedure

Kolmogorov-Smirnov Test for Variable cons
  Classified by Variable survey

survey	N	Maximum	EDF at Deviation from Mean at Maximum
RECS	9883356	0.118041	139.59620
AHSN	9472310	0.027307	-142.59289
Total	19355666	0.073637	

Maximum Deviation Occurred at Observation 69
  Value of cons at Maximum = 198.0

Kolmogorov-Smirnov Two-Sample Test (Asymptotic)
KS 0.045357 D 0.090735
KSa 199.549066 Pr > KSa <.0001

Appendix M. Independent Variable Cumulative Distribution Functions

Independent Variable Definitions—

- EHDEMAND = (hfuel='1')*HEATDAY
- GHDEMAND = (hfuel='2' and gaspip='1')*HEATDAY
- CENAIR = (airsys='1') * coolday
- WALL = (airsys = '2' and numair ge 1) * coolday
- EH20 = (wfuel='1')
- GH20 = (wfuel='2' and gaspip='1')
- GSTEAM = (hequip = 2) * (hfuel = '2' and gaspip = '1')
- GNOSTEAM = (hequip ne 2) * (hfuel = '2' and gaspip = '1')
- YRBUILT = BUILT
- NU1 = nunit2 in ('1','2')
- NU2 = nunit2 = '3'
- NU3 = nunit2 = '4'

- TOTROOMS = min (bedrms + kitch + living + dining + famrm + recrm + dens + othfn,25)
- BATHS = min (baths + (0.5 * halfb),7)
- MAJAPPL = (refr = '1') + (2 * (cook = '1')) + (oven = '1') + (burner = '1') + (dish = '1') + (wash = '1') + (dry = '1')
- PEOPLE = min (curper,12)
- MONEY_R = ZINC2 in Groups of $10,000
- PH20 = (wfuel = '2' and gaspip = '2')
- PCOOK= (cfuel = '2' and gaspip = '2') * min (curper,12)
- PDRY = (dfuel = '2' and gaspip = '2') * min(curper,12)
- HEATDAY = heating degree days
- COOLDAY = cooling degree days

2009 ahs vs. 2009 recs ehdemand cdfs
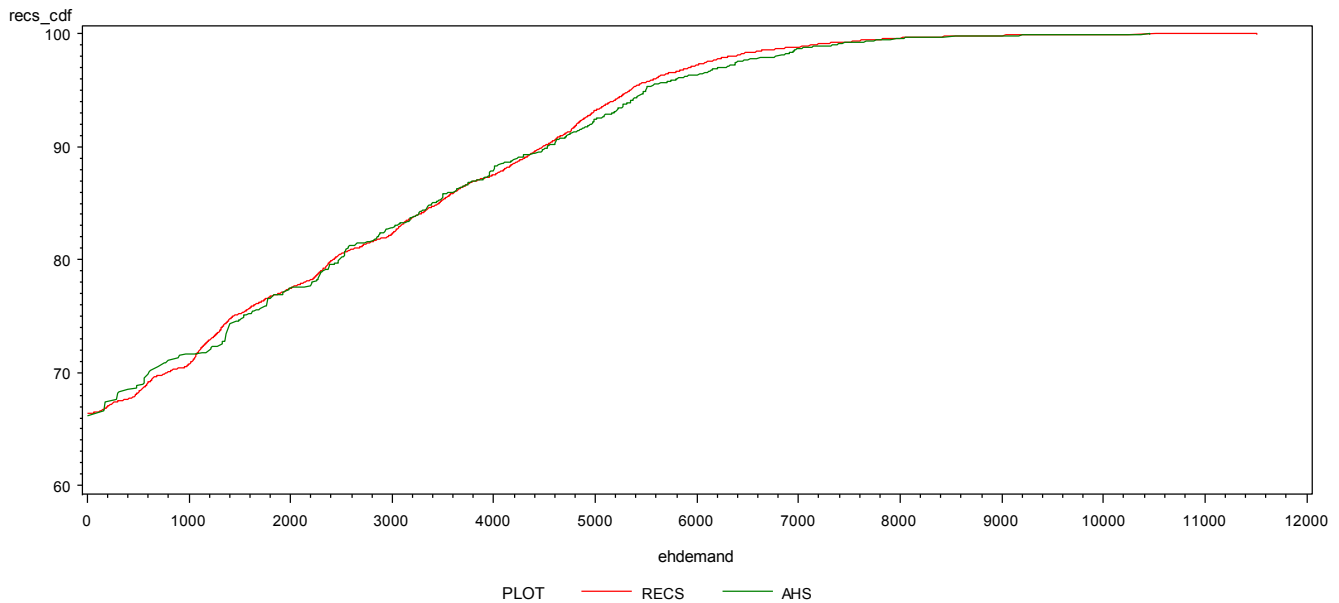
2009 ahs vs. 2009 recs ghdemand cdfs
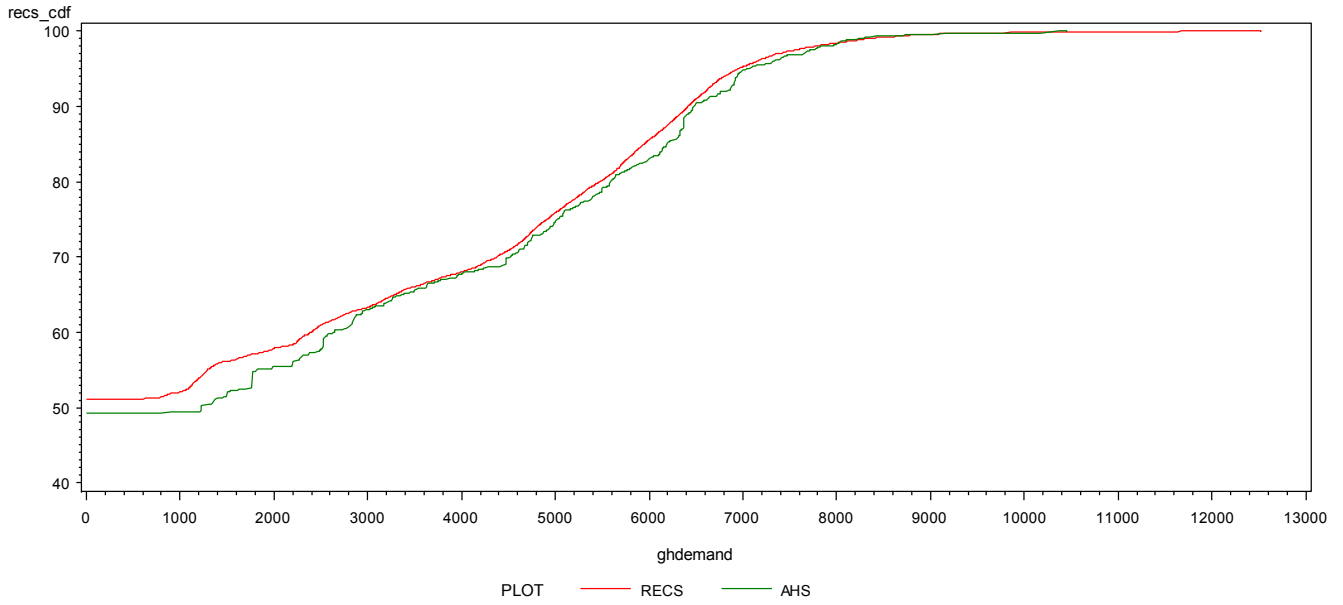
2009 ahs vs. 2009 recs cenair cdfs
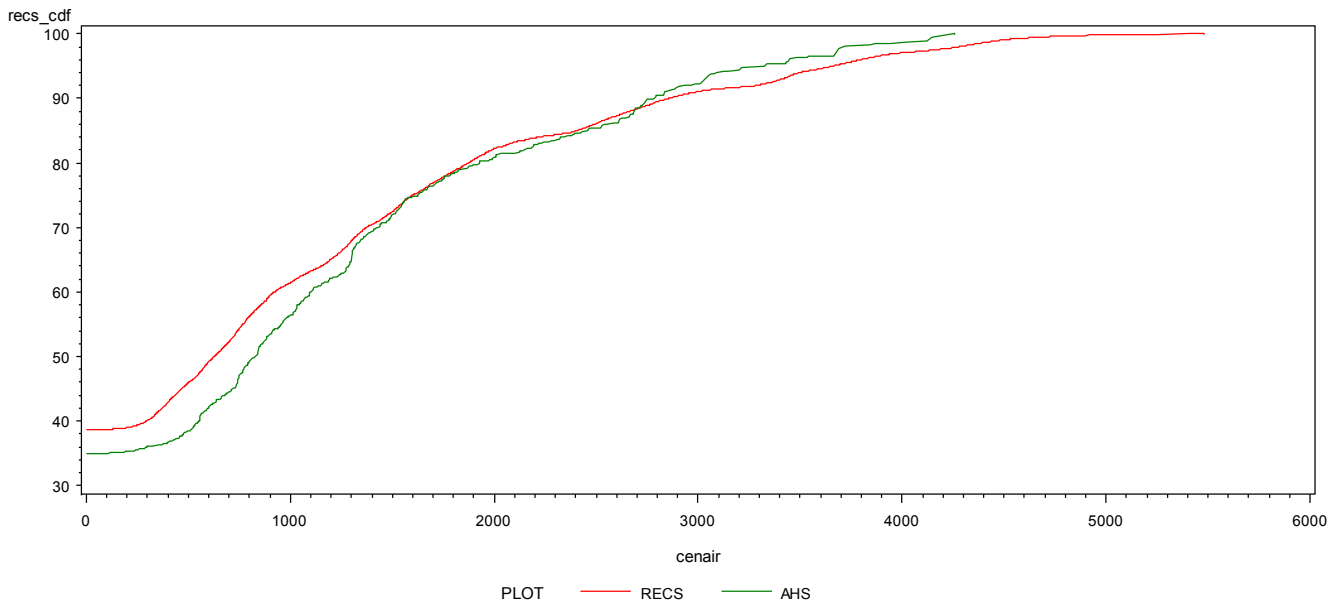
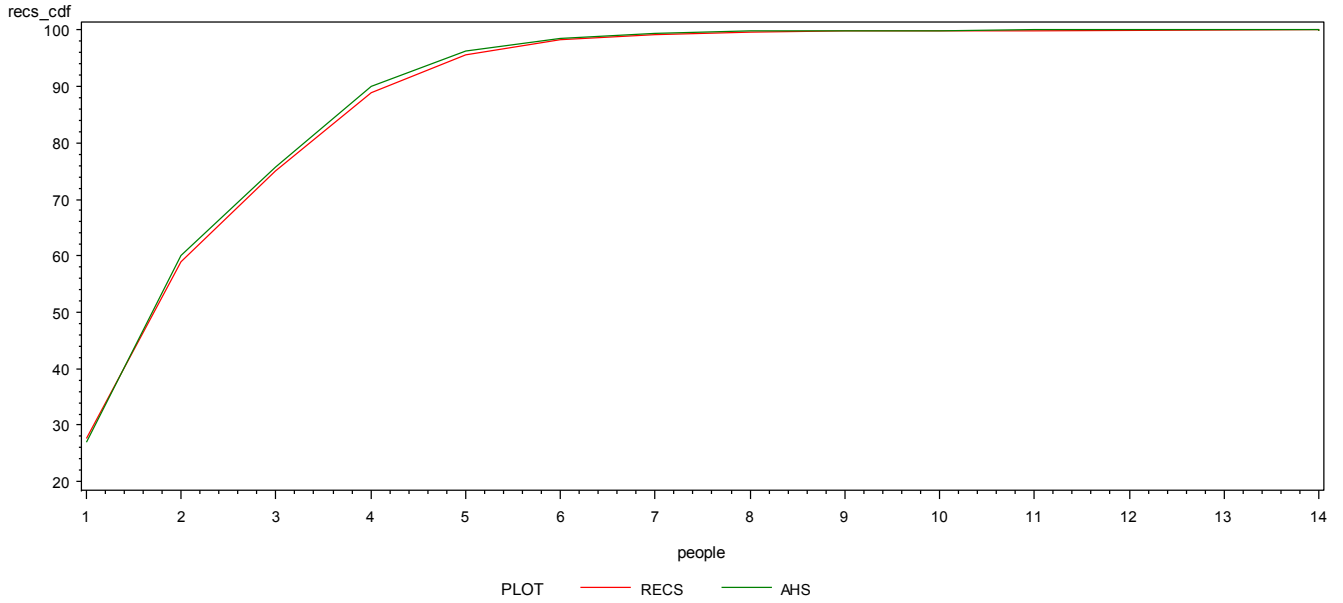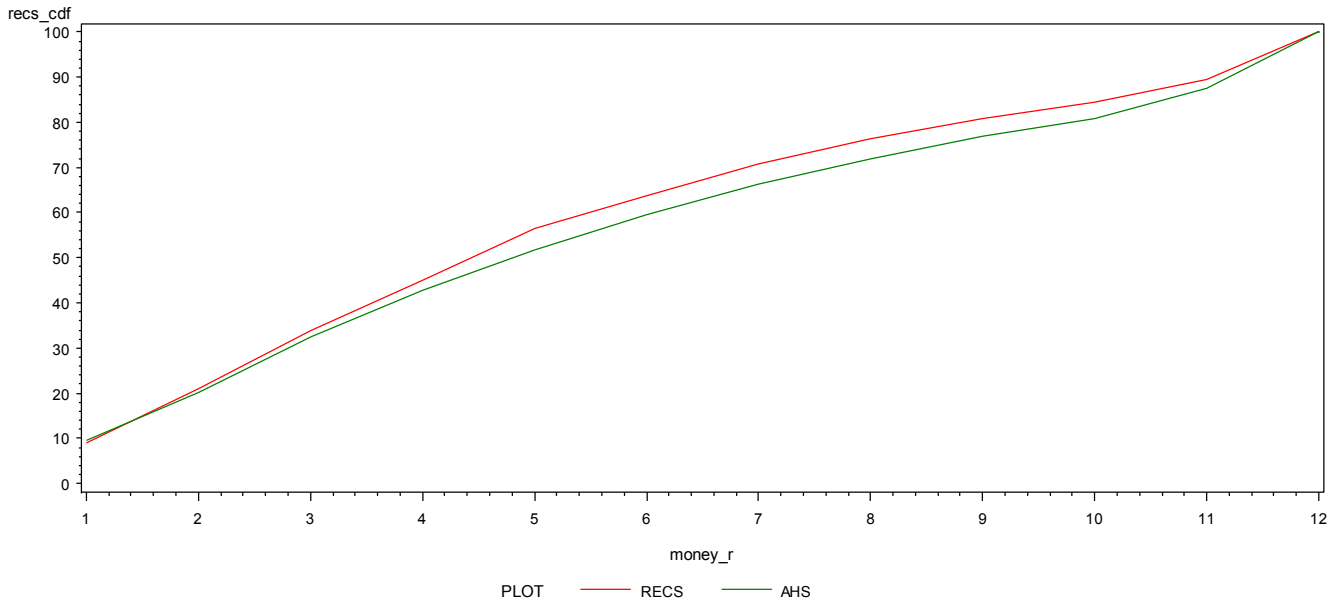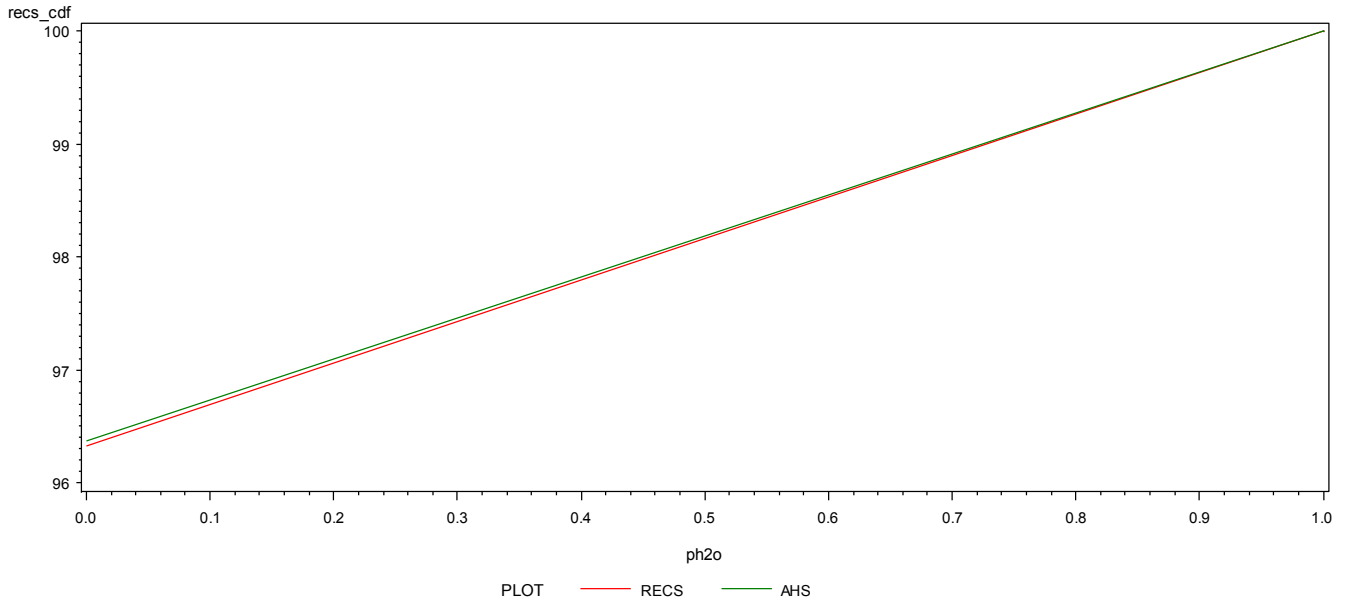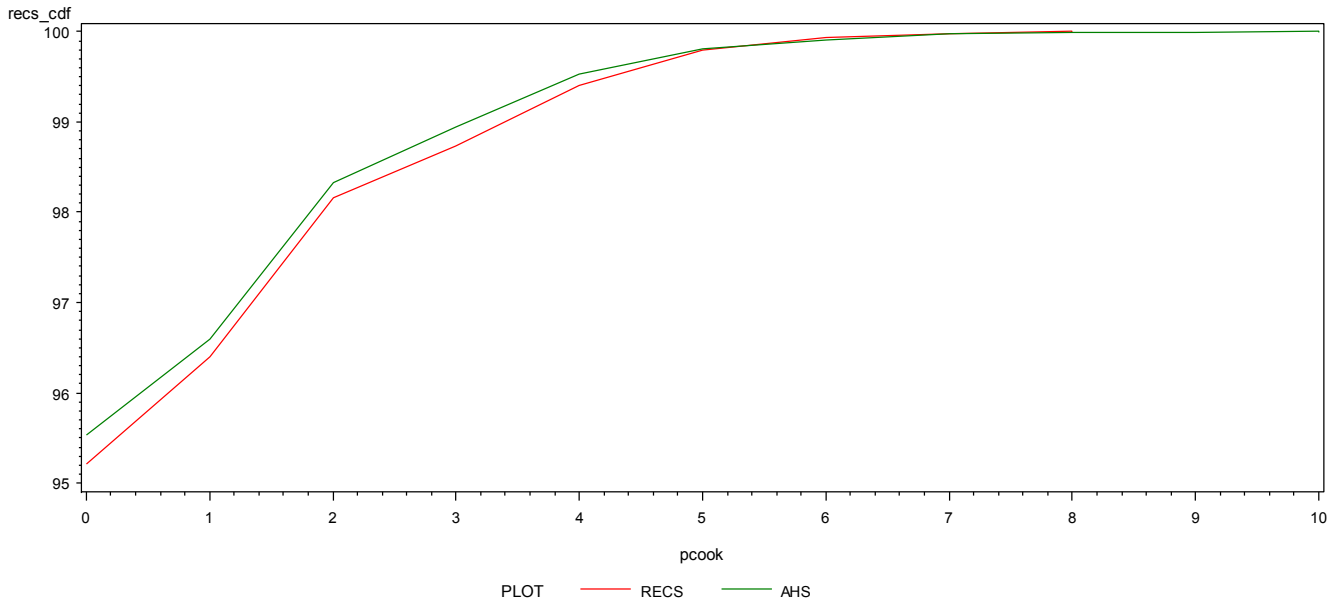## 2009 ahs vs. 2009 recs wall cdfs
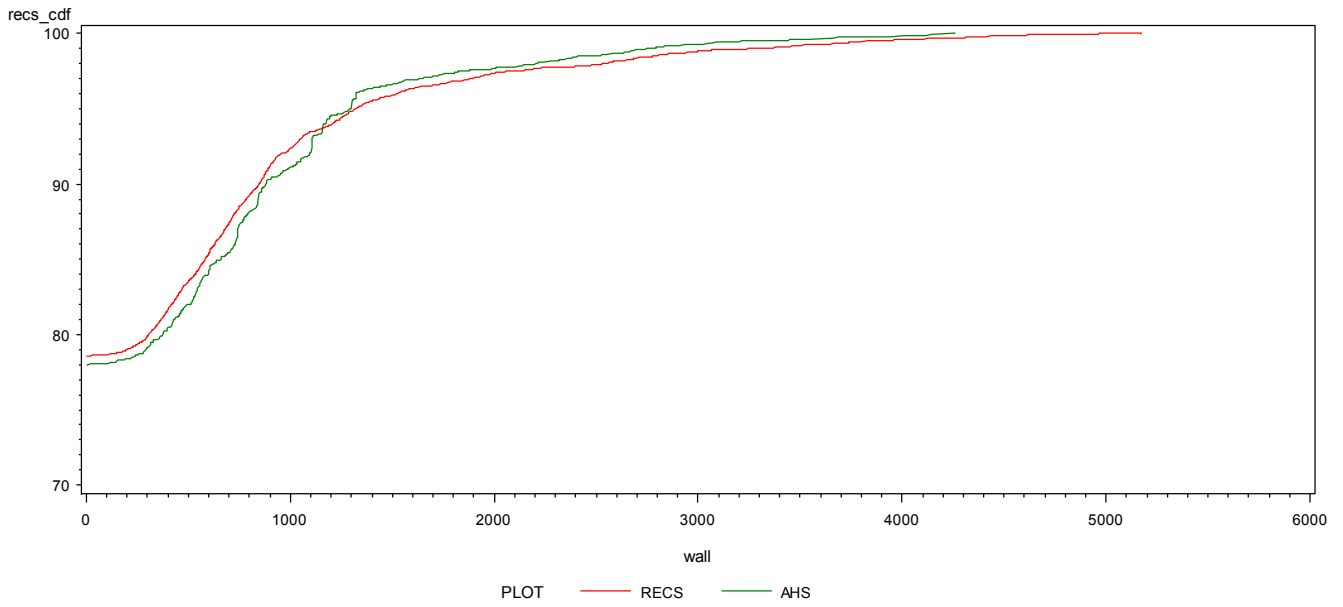
2009 ahs vs. 2009 recs eh2o cdfs
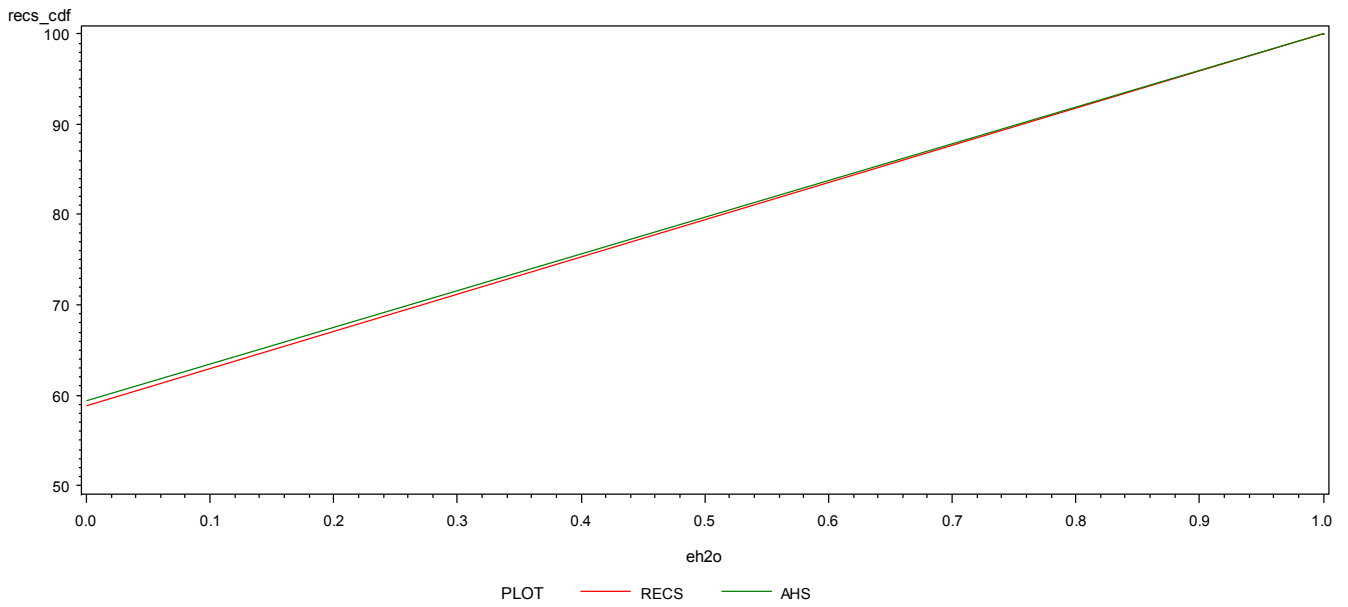
2009 ahs vs. 2009 recs gh2o cdfs
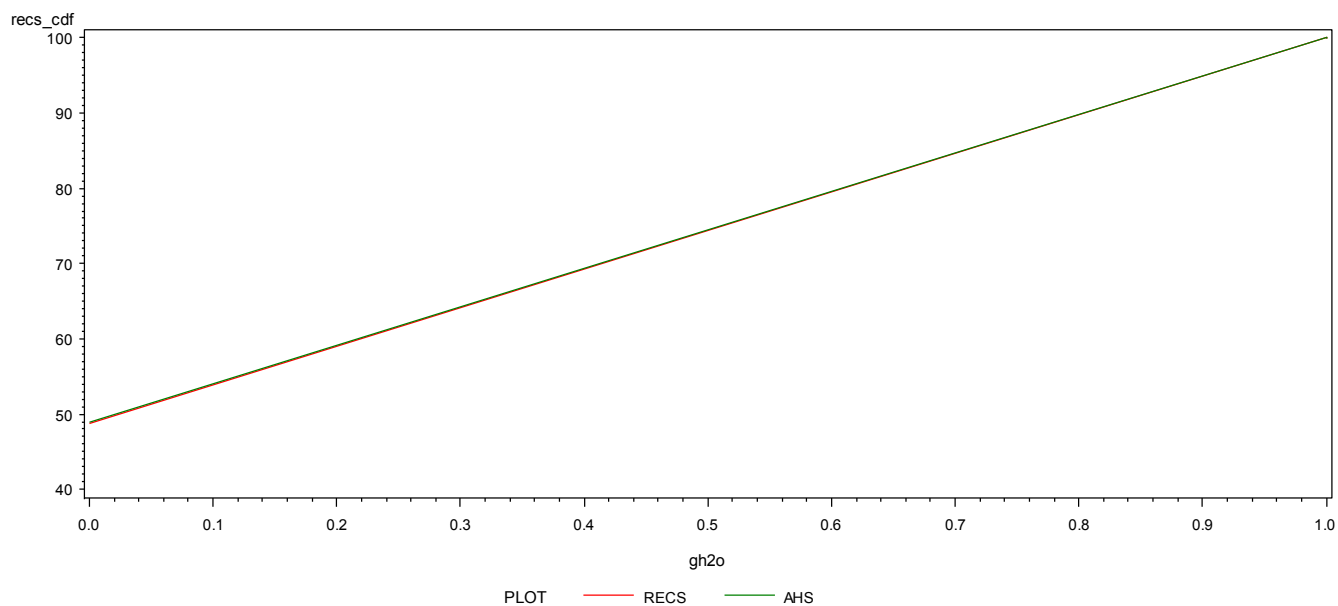
2009 ahs vs. 2009 recs gsteam cdfs
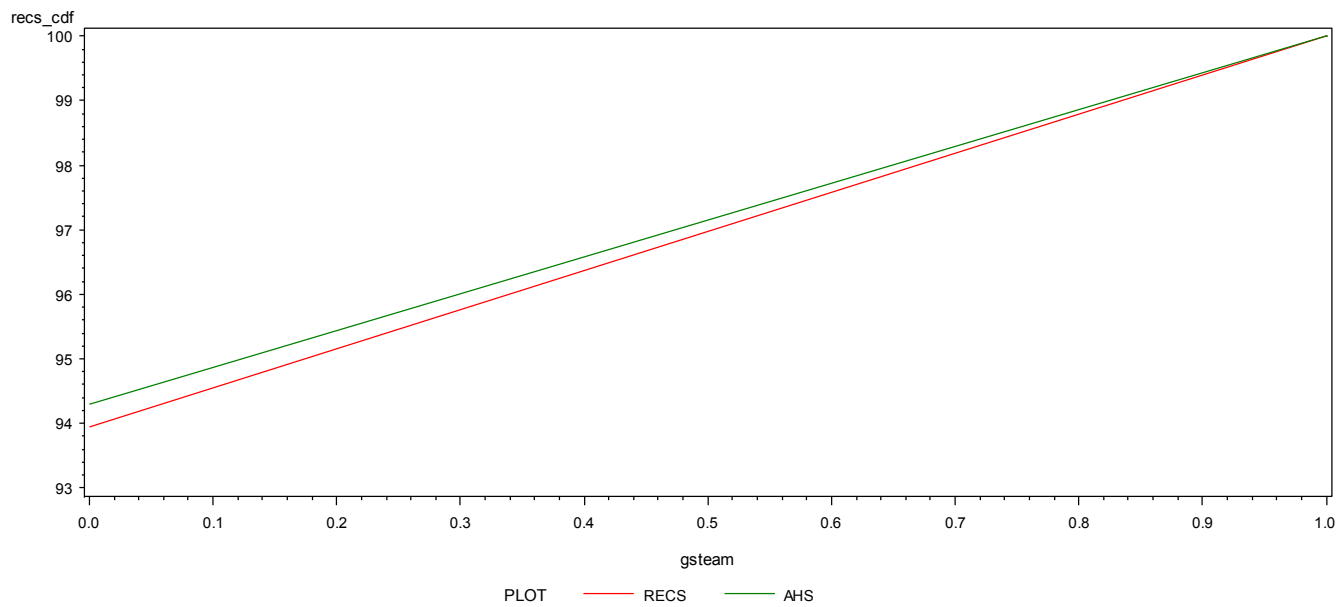
2009 ahs vs. 2009 recs gnosteam cdfs
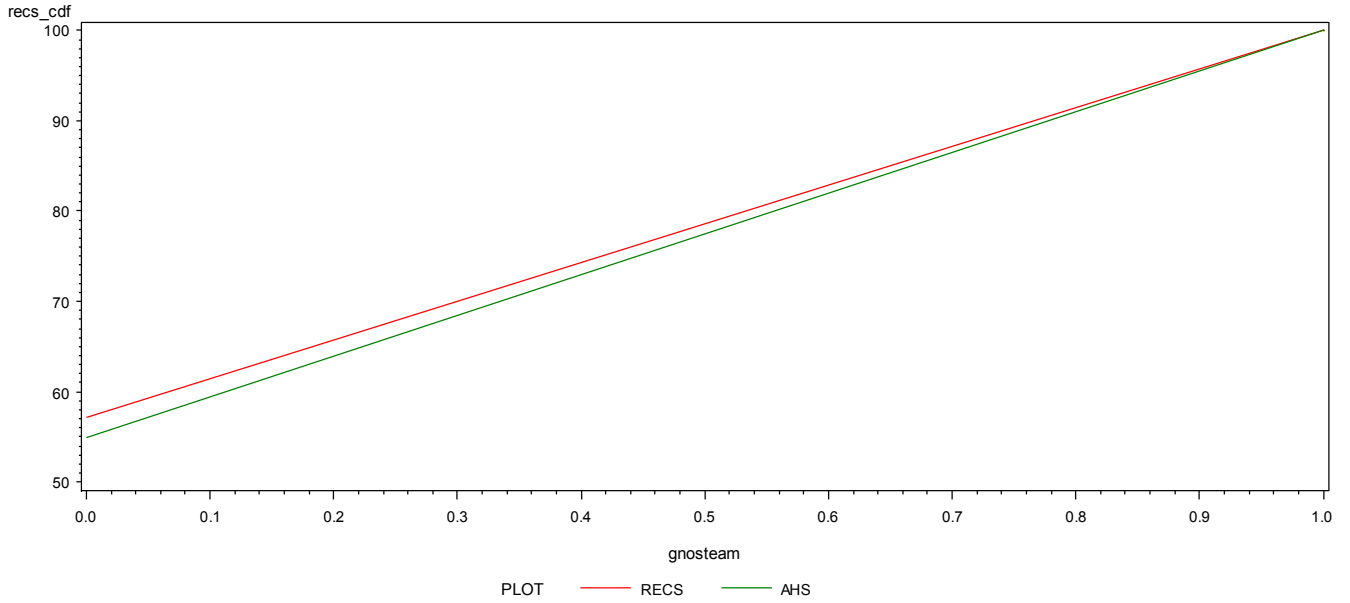
2009 ahs vs. 2009 recs yrbuilt cdfs
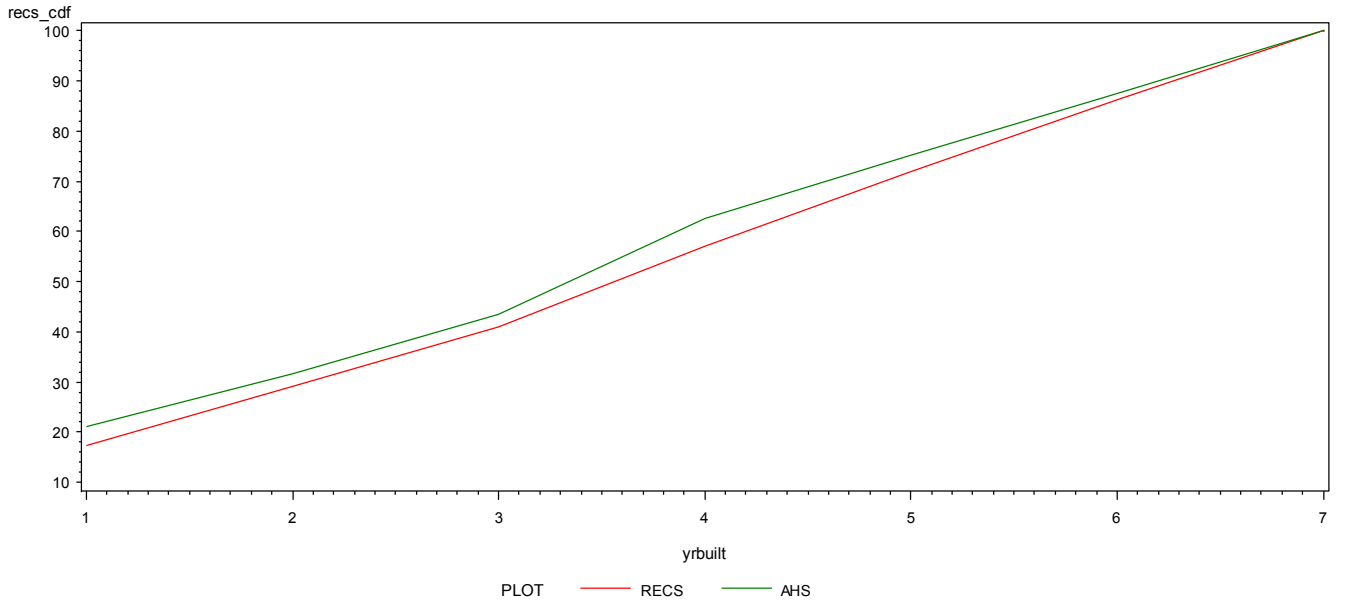
2009 ahs vs. 2009 recs nu1 cdfs
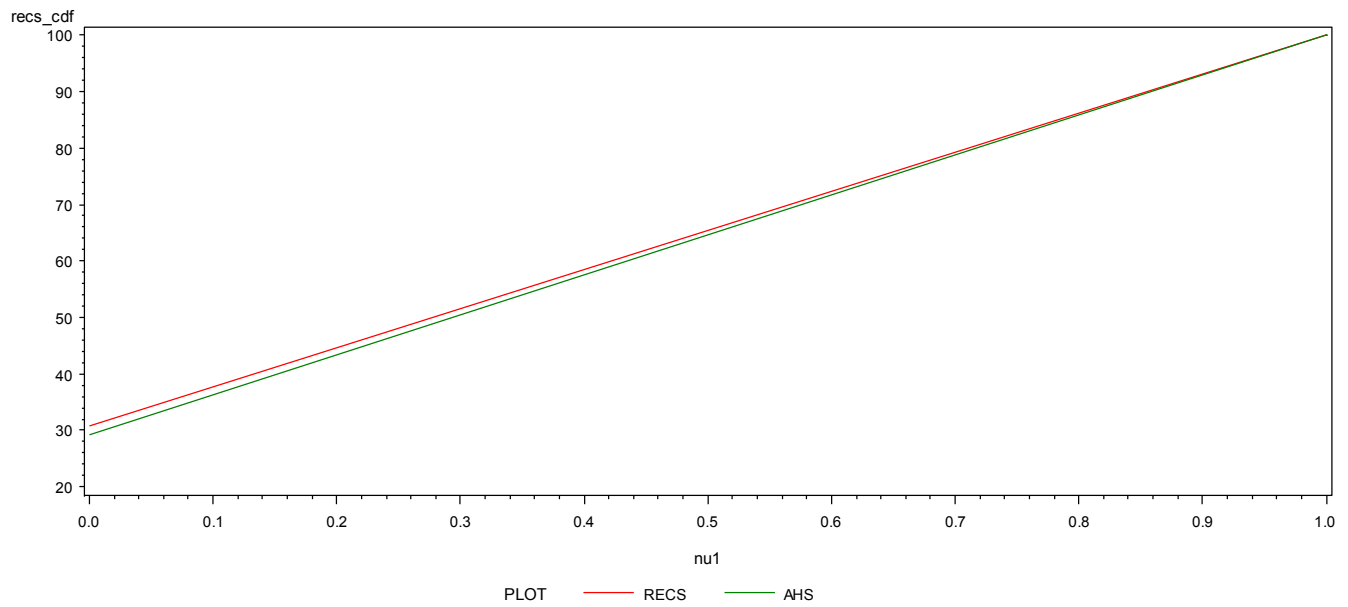
2009 ahs vs. 2009 recs nu2 cdfs
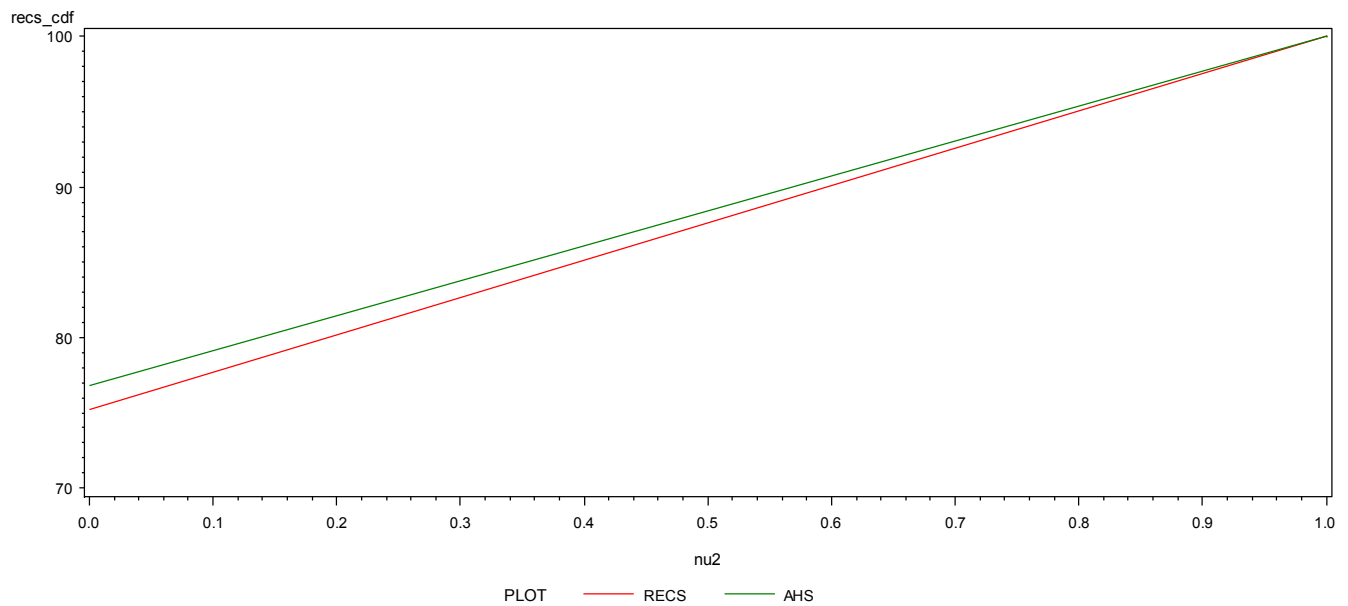
2009 ahs vs. 2009 recs nu3 cdfs
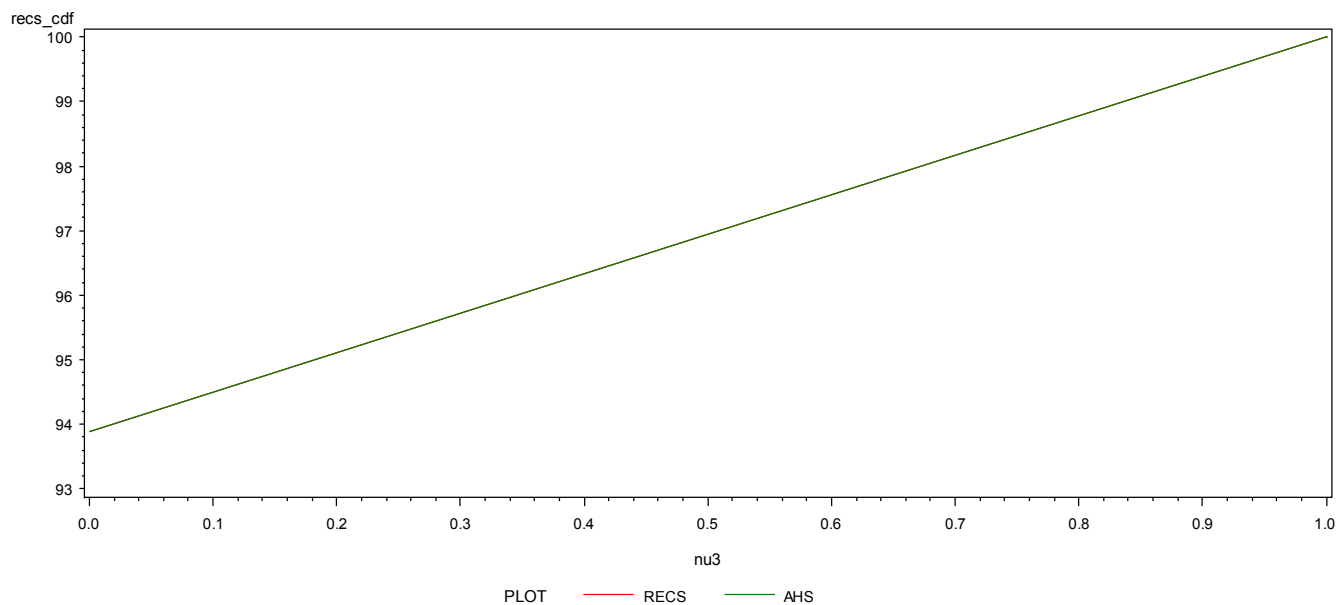
2009 ahs vs. 2009 recs totrooms cdfs
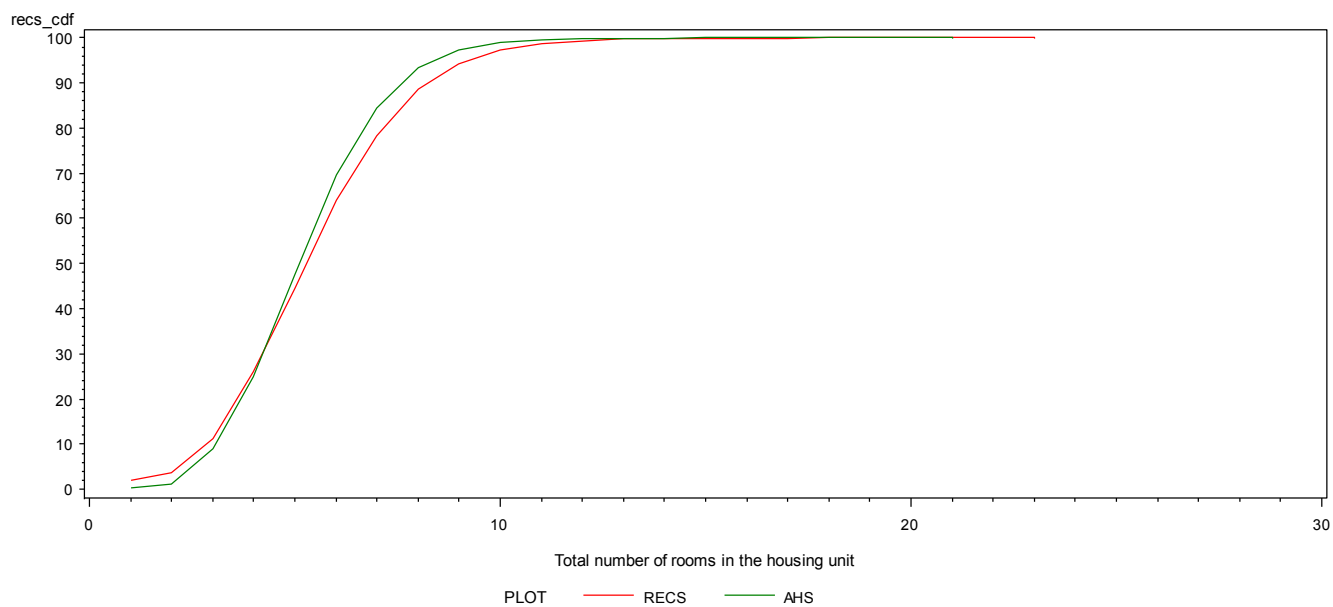
2009 ahs vs. 2009 recs baths cdfs
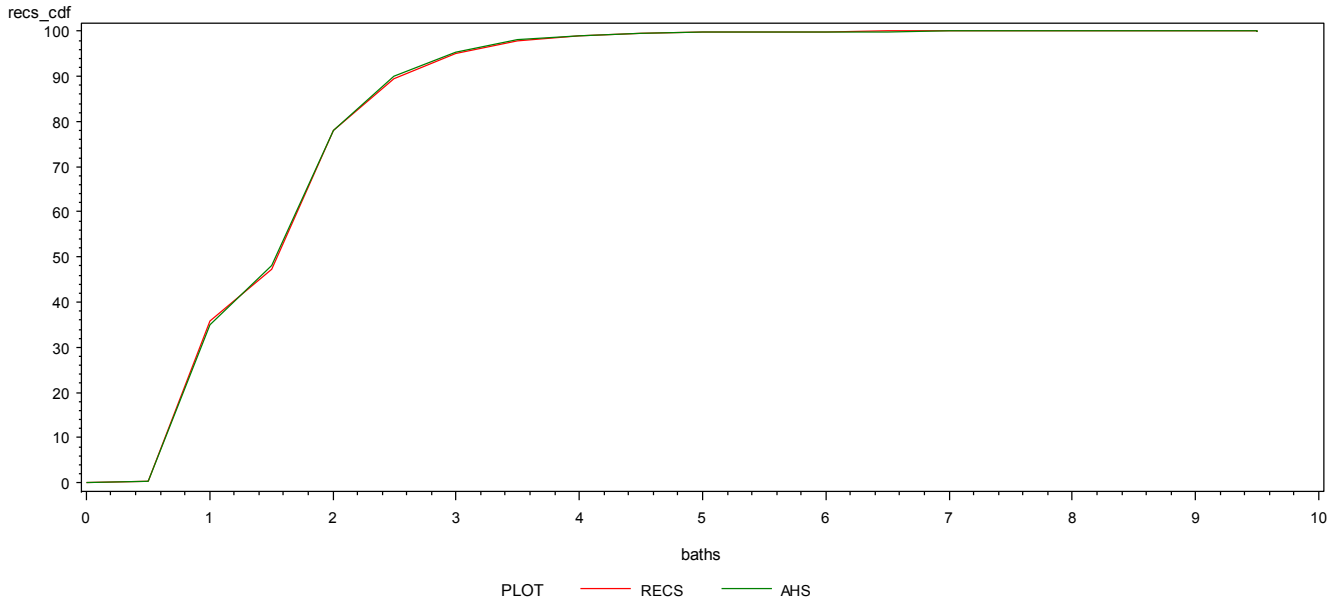
2009 ahs vs. 2009 recs majappl cdfs
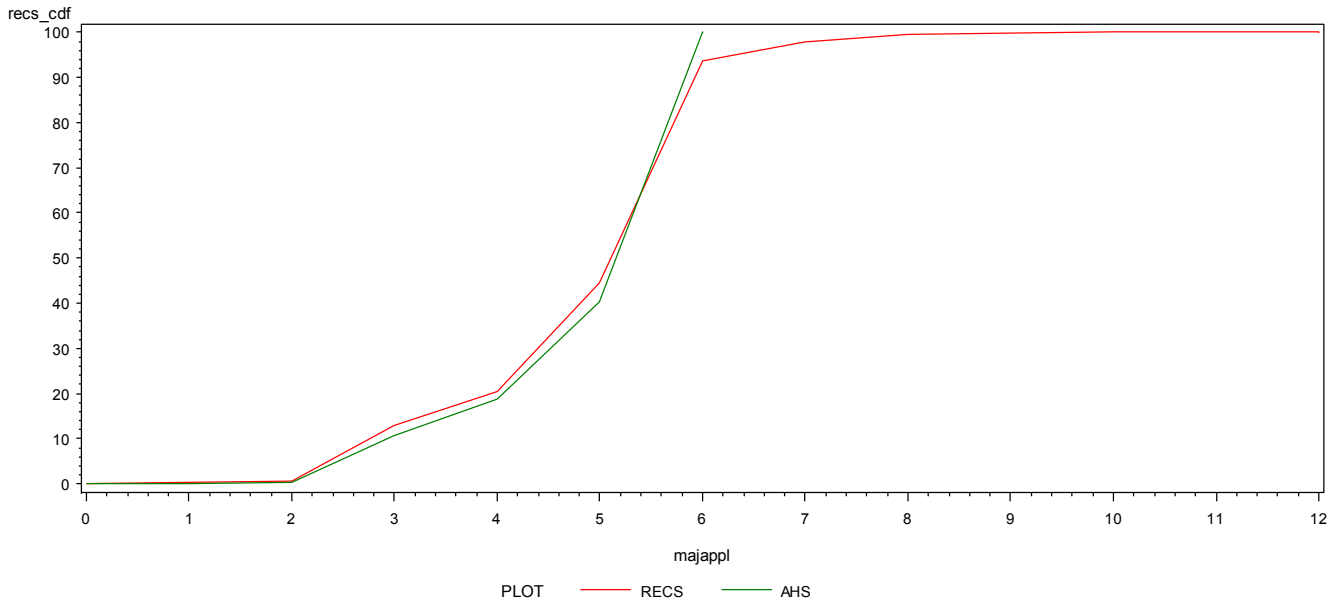
2009 ahs vs. 2009 recs people cdfs

2009 ahs vs. 2009 recs money_r cdfs

2009 ahs vs. 2009 recs ph2o cdfs
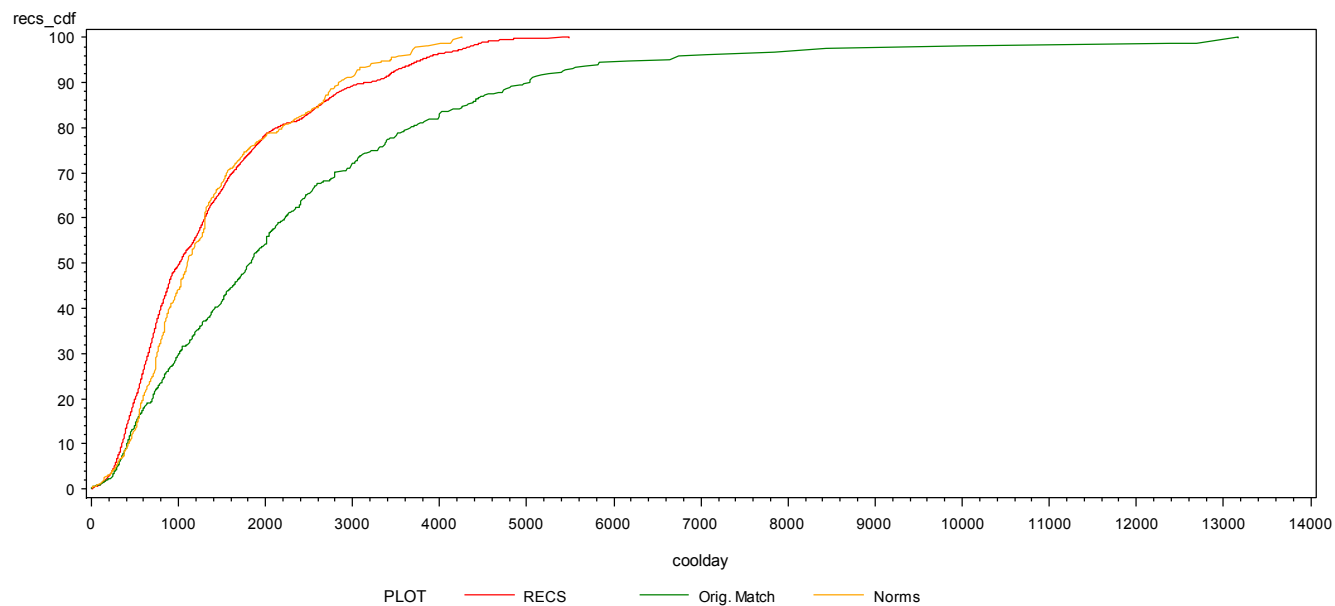

2009 ahs vs. 2009 recs pcook cdfs

2009 ahs vs. 2009 recs pdry cdfs
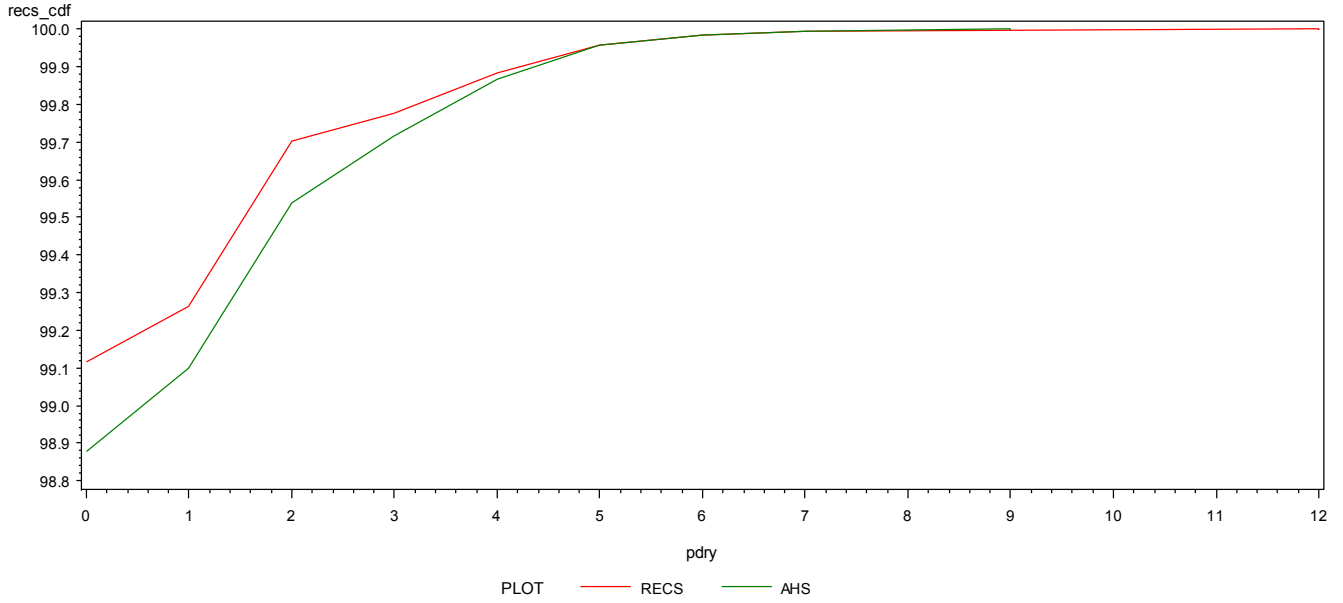
2009 recs vs. 2009 match vs. 2009 norms heatday cdfs
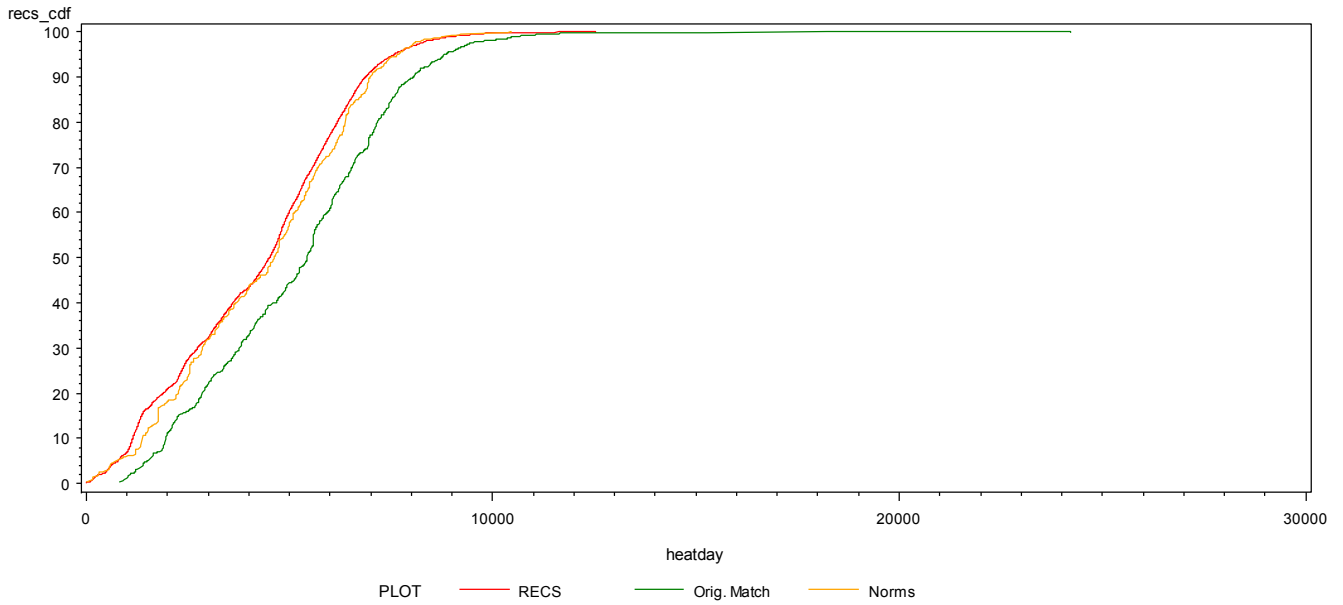
2009 recs vs. 2009 match vs. 2009 norms coolday cdfs

Appendix N. Imputation Rates in Different RECS Models

Table N1. 2009 RECS Electric-Only Model Input Variables, Imputation Rates

Variable Name	Imputation Rate (%)
FUELHEAT	0.82
FUELH20	3.76
YEARMADERANGE	2.45
ZNHSLDMEM	0.16
COOLTYPE	0.18
MONEYPY	10.24
STOVEN	0.02
STOVE	0.00
OVEN	0.00
NUMFRIG	0.02
DISHWASH	0.00
CWASHER	0.00
DRYER	0.00
NCOMBATH	0.10
NHAFBATH	0.09

RECS = Residential Energy Consumption Survey.

Table N2. RECS Electric-Gas Mixed Model Input Variables, Imputation Rates

Variable Name	Imputation Rate (%)
FUELHEAT	1.47
FUELH20	7.49
YEARMADERANGE	2.88
ZNHSLDMEM	0.44
COOLTYPE	0.09
MONEYPY	14.16
STOVEN	0.00
STOVE	0.00
OVEN	0.00
NUMFRIG	0.00
DISHWASH	0.00
CWASHER	0.00
DRYER	0.00
NCOMBATH	0.01
NHAFBATH	0.01

RECS = Residential Energy Consumption Survey.

Table N3. 2009 RECS Natural Gas Model Input Variables, Imputation Rates

Variable Name	Imputation Rate (%)
FUELHEAT	0.76
FUELH20	5.06
YEARMADERANGE	2.72
ZNHSLDMEM	0.45
COOLTYPE	0.10
MONEYPY	13.92
STOVEN	0.00
STOVE	0.00
OVEN	0.00
NUMFRIG	0.00
DISHWASH	0.00
CWASHER	0.00
DRYER	0.00
NCOMBATH	0.01
NHAFBATH	0.01

RECS = Residential Energy Consumption Survey.

Table N4. 2009 RECS Propane Model Input Variables, Imputation Rates

Variable Name	Imputation Rate (%)
FUELHEAT	1.05
FUELH20	2.70
DRYERFUEL	0.51
FUELFOOD	0.37
KOWNRENT	0.72
YEARMADERANGE	0.88
ZNHSLDMEM	0.07
MONEYPY	10.19

RECS = Residential Energy Consumption Survey.

Appendix O. Utility Price Data

Electric

1. Navigate to http://www.eia.gov/electricity/monthly.

2. Locate tables 5.4.A (Retail Sales of Electricity to Ultimate Customers by End-Use Sector) and 5.6.A (Average Retail Price of Electricity to Ultimate Customers by End-Use Sector) for the months of May 2014 through April 2015.

   • Note that the reports are 2 months behind the reporting month; for example, the June 2014 report contains the data applicable for April 2014.

3. Obtain the residential sales and average price from each month for each state.

Natural Gas

1. Navigate to http://www.eia.gov/naturalgas/monthly.

2. Locate tables 2 (Natural Gas Consumption by End Use) and 3 (Natural Gas Price).

3. Obtain the monthly residential consumption and price for each state for the months of May 2014 through April 2015.

   • If a value is missing, use the previous year's value for that month. Consumption and price overall are fairly cyclical.

Propane

We calculated an average price from the Residential Energy Consumption Survey cost and consumption data using the propane universe we defined with the cases in RECS2009_PUBLIC_V3.sas7bdat.

For 2015 American Housing Survey production, we used the following.

1. Navigate to http://www.eia.gov/dnav/pet/pet_pri_wfr_a_EPLLPA_PRS_dpgal_w.htm.

2. Obtain each state's weekly propane residential price data from October 13, 2014, through March 30, 2015.

   • Note that price data are collected only through the winter months.

3. Calculate the division's average price with the price data.

   • Use the available states, even if the division is incomplete.

4. If a division has no states, navigate to http://www.eia.gov/forecasts/aeo/data.cfm#enprisec.

5. Locate the appropriate census division in table 3.

6. Locate the 2015 projection for propane, in 2013 $/million British thermal units (BTUs).

7. Divide this number by 10.948945, which is the conversion factor to convert BTUs to gallons.

   • Refer to http://www.eia.gov/Energyexplained/?page=about_energy_units for more details.

8. Inflation-adjust the 2013 dollars to 2015 dollars.

9. Use the calculator in http://data.bls.gov/cgi-bin/cpicalc.pl.