Highlights from the 2015 RECS:
Energy consumption, expenditures, and end-use modeling

Webinar
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Agenda

- Introduction
  - Accessing RECS data on the website
- Consumption and expenditures highlights from the 2015 RECS
- Overview of end-use modeling for the 2015 RECS
- A look to the future
- Q&A

2015 RECS data products

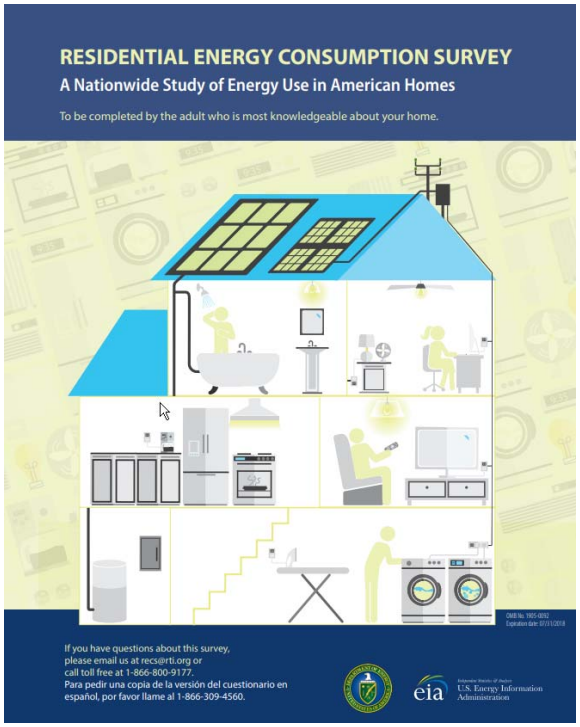
- Updated! Housing characteristics data tables
- Updated! Square footage data
- Updated! Microdata file
- Updated! Methodology documents
- New! Consumption and expenditures data

The RECS website

www.eia.gov/consumption/residential/

Consumption and expenditures highlights from the 2015 RECS

Step 1: Household Survey



- EIA's only household program
- Produces national estimates and captures subpopulation variations
- Describes the characteristics that impact household energy demand
  - Structural (housing type, age)
  - Systems (heating, cooling)
  - Devices (appliances, electronics)
  - Behavior (usage frequency, temperature set points)
  - People

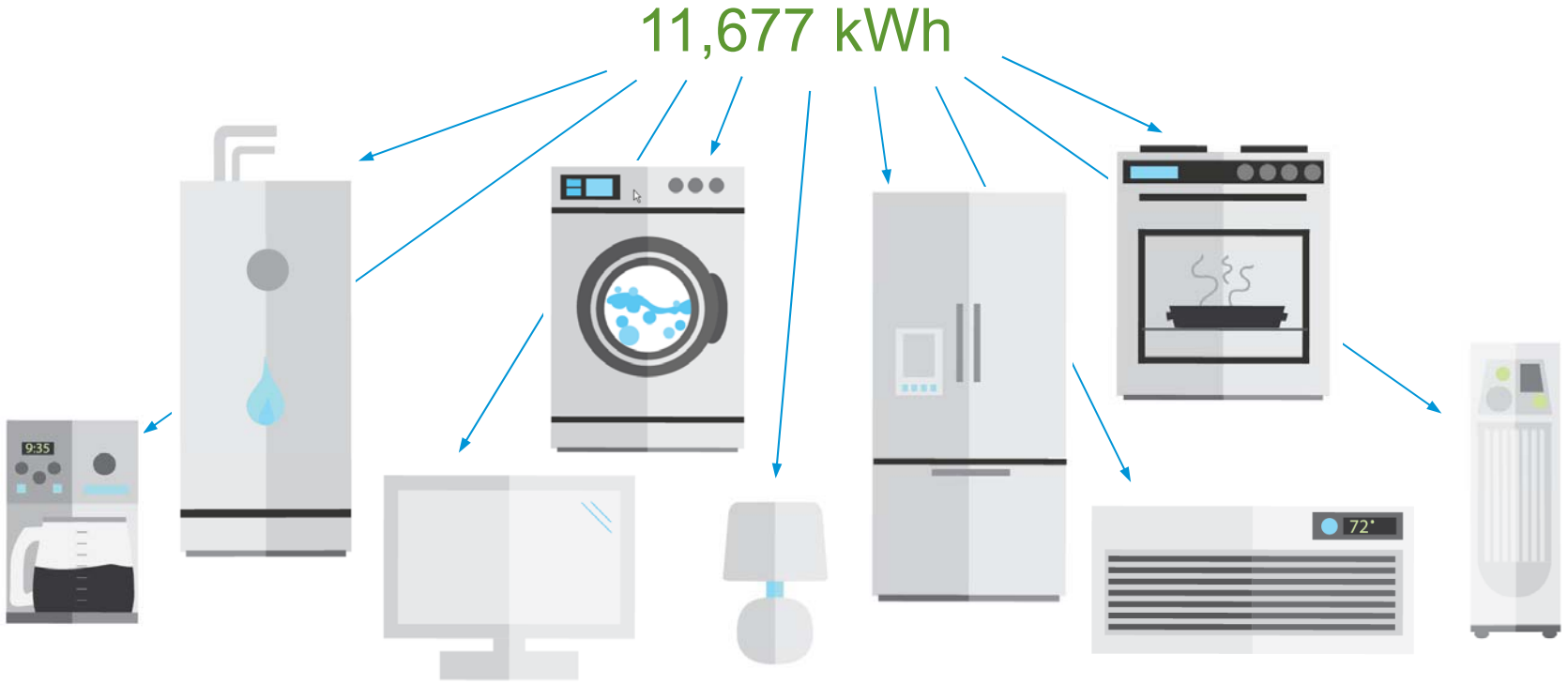
Step 2: Monthly billing data are collected from energy suppliers

Monthly billing data from electric utility

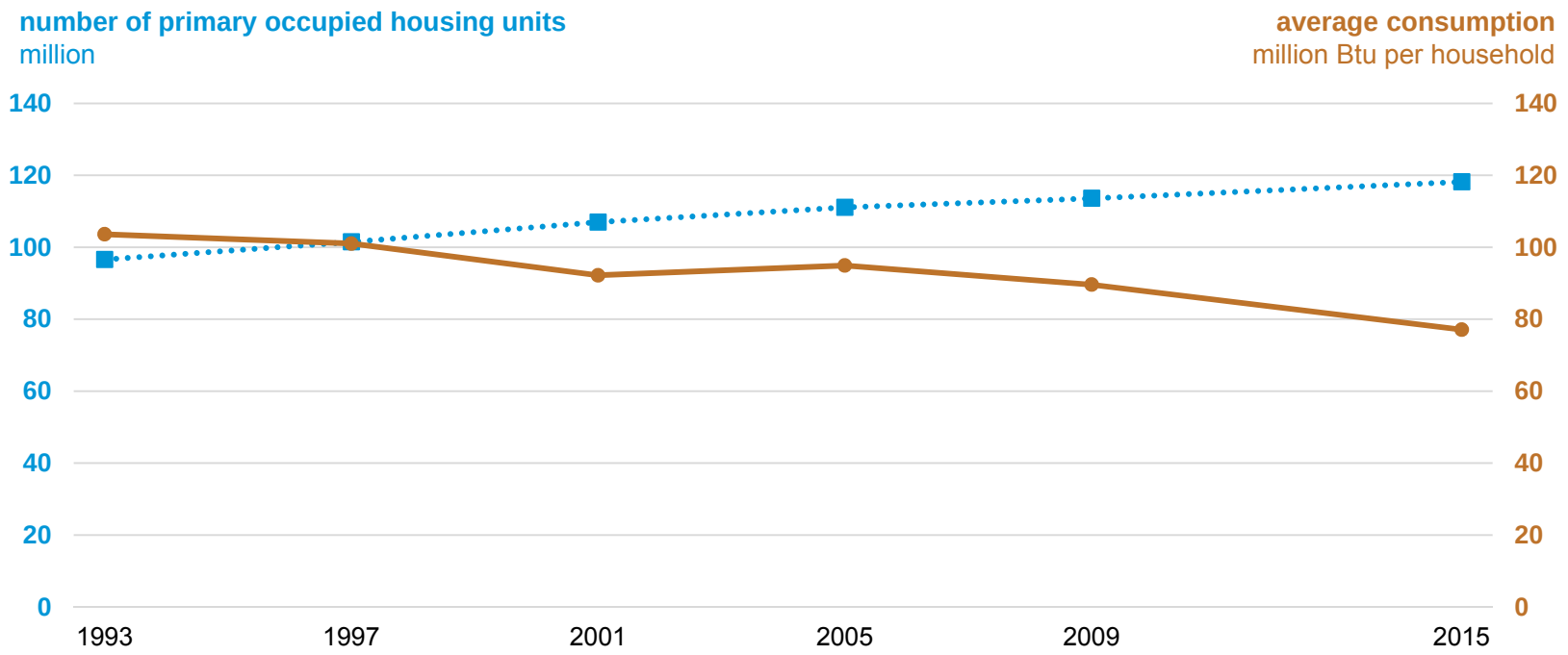
Billing Date	kWh	Cost
1/7/2015	813	$194.44
2/5/2015	627	$133.11
3/9/2015	615	$122.90
4/7/2015	758	$143.89
5/7/2015	689	$149.44
6/8/2015	703	$148.03
7/8/2015	965	$228.99
8/6/2015	1302	$335.73
9/4/2015	1467	$386.86
10/6/2015	1584	$387.18
11/5/2015	1191	$300.21
12/8/2015	963	$223.40
Total	**11,677 kWh**	**$2,754**

Annualized total

Step 3: Annualized totals are disaggregated into energy end-use estimates



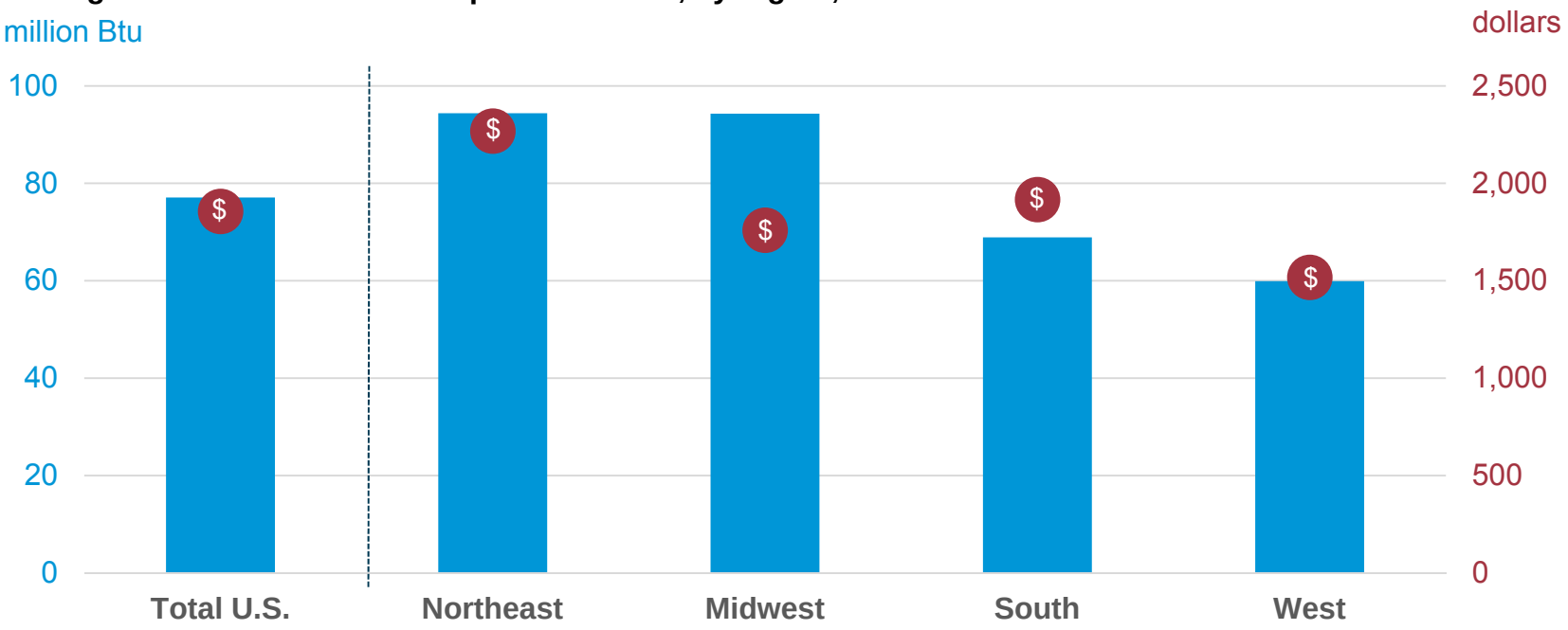
Nation's 118 million households consumed 77 million Btu on average in 2015



Source: EIA, 2015 Residential Energy Consumption Survey

Average site consumption was highest in Northeast and Midwest, but Midwest costs were lower than national average

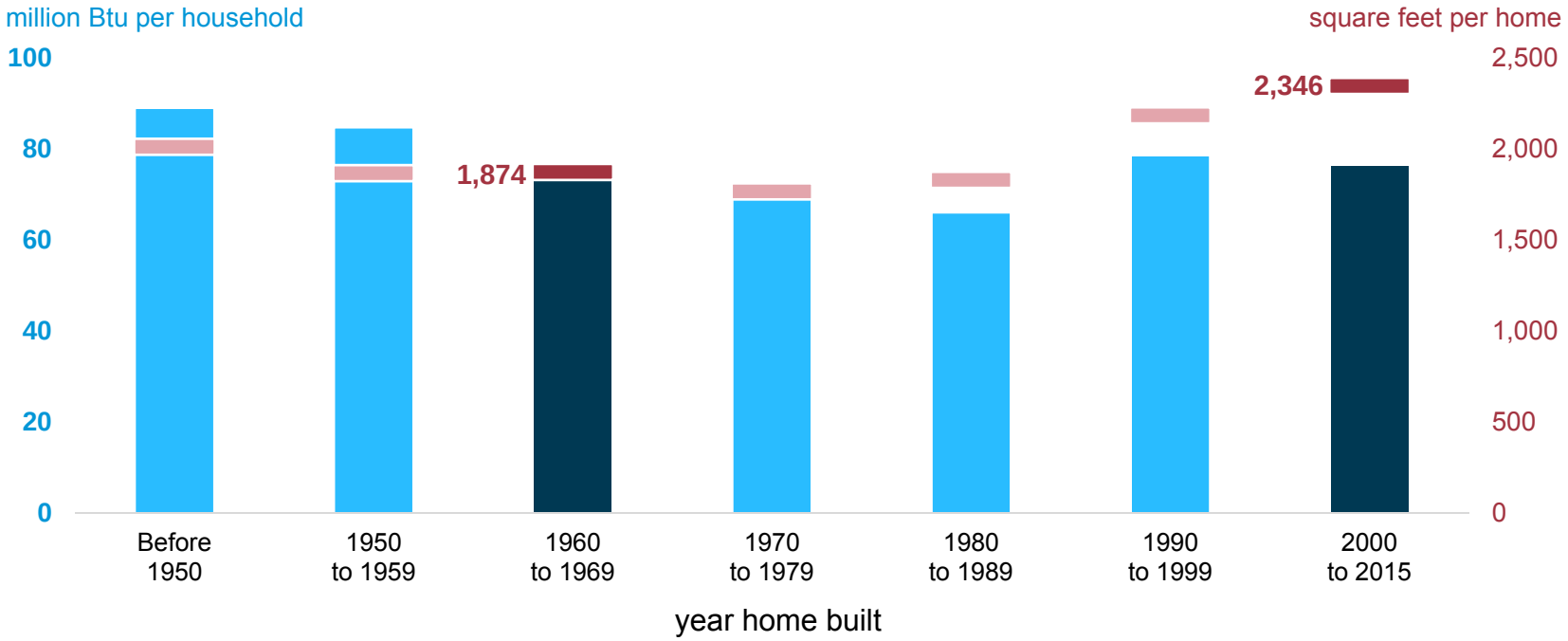
Average household site consumption and cost, by region, 2015



Source: EIA, 2015 Residential Energy Consumption Survey

A home built since 2000 consumed the same amount of energy as one built in the 1960s

Average household site consumption by year built, 2015

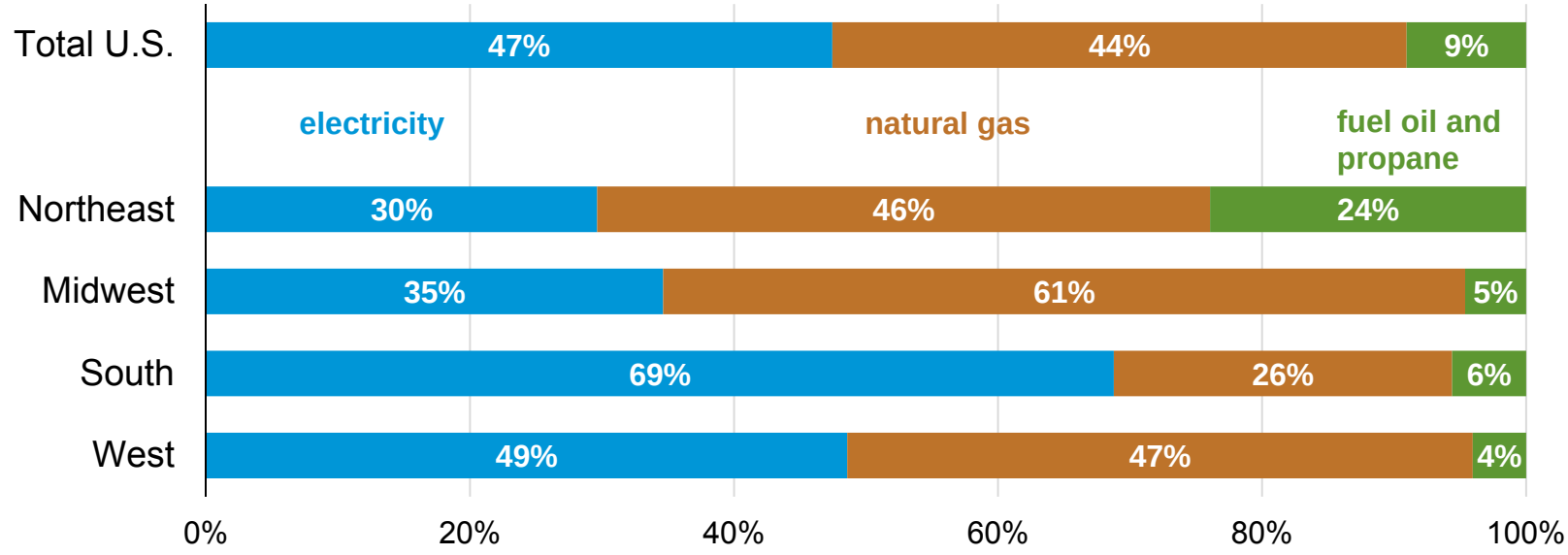


Source: EIA, 2015 Residential Energy Consumption Survey

Electricity was the most consumed energy source across all U.S. households; in coldest areas natural gas was most-consumed

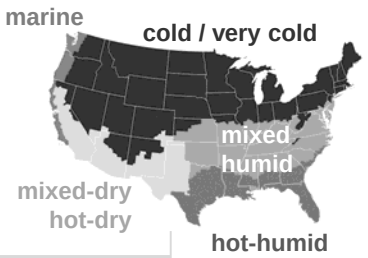
Household site energy consumption by Census region, 2015

percentage of total site consumption by fuel

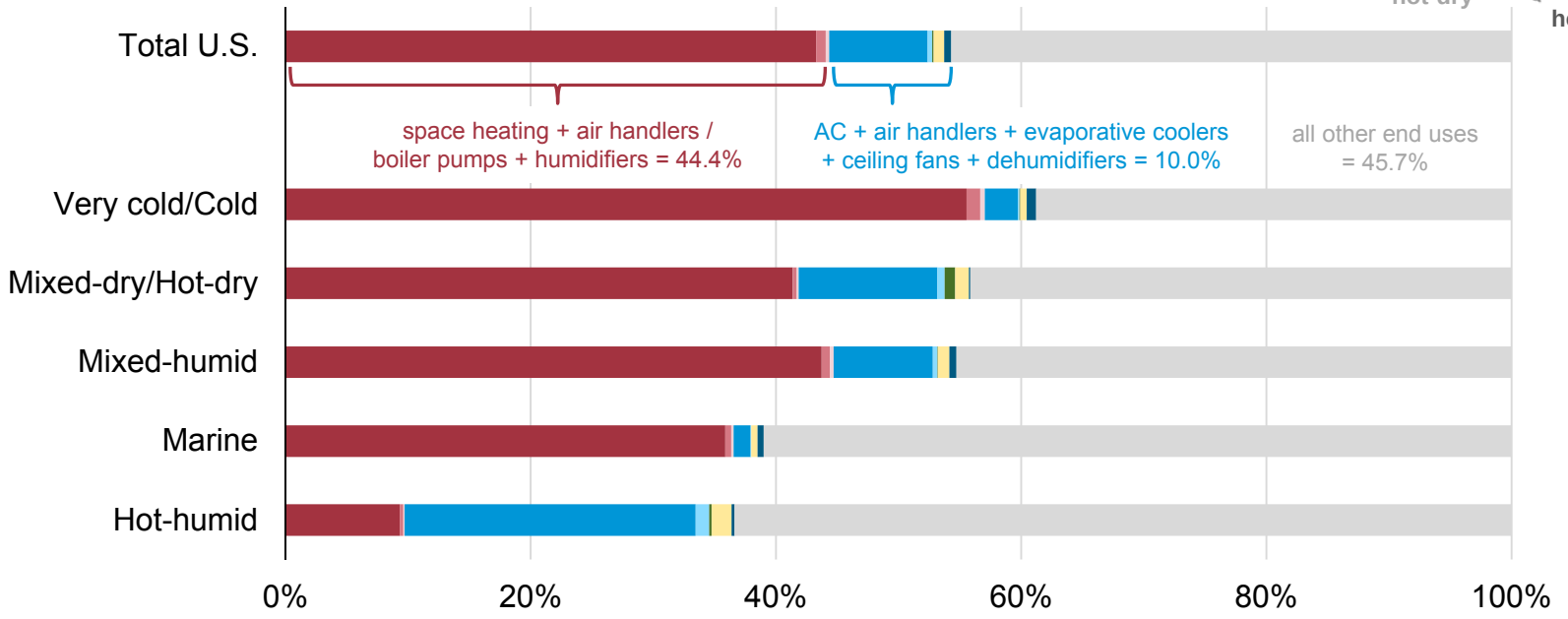


Source: EIA, 2015 Residential Energy Consumption Survey

Heating, cooling, and ventilation accounted for about half of home energy use, but the share varies by climate region

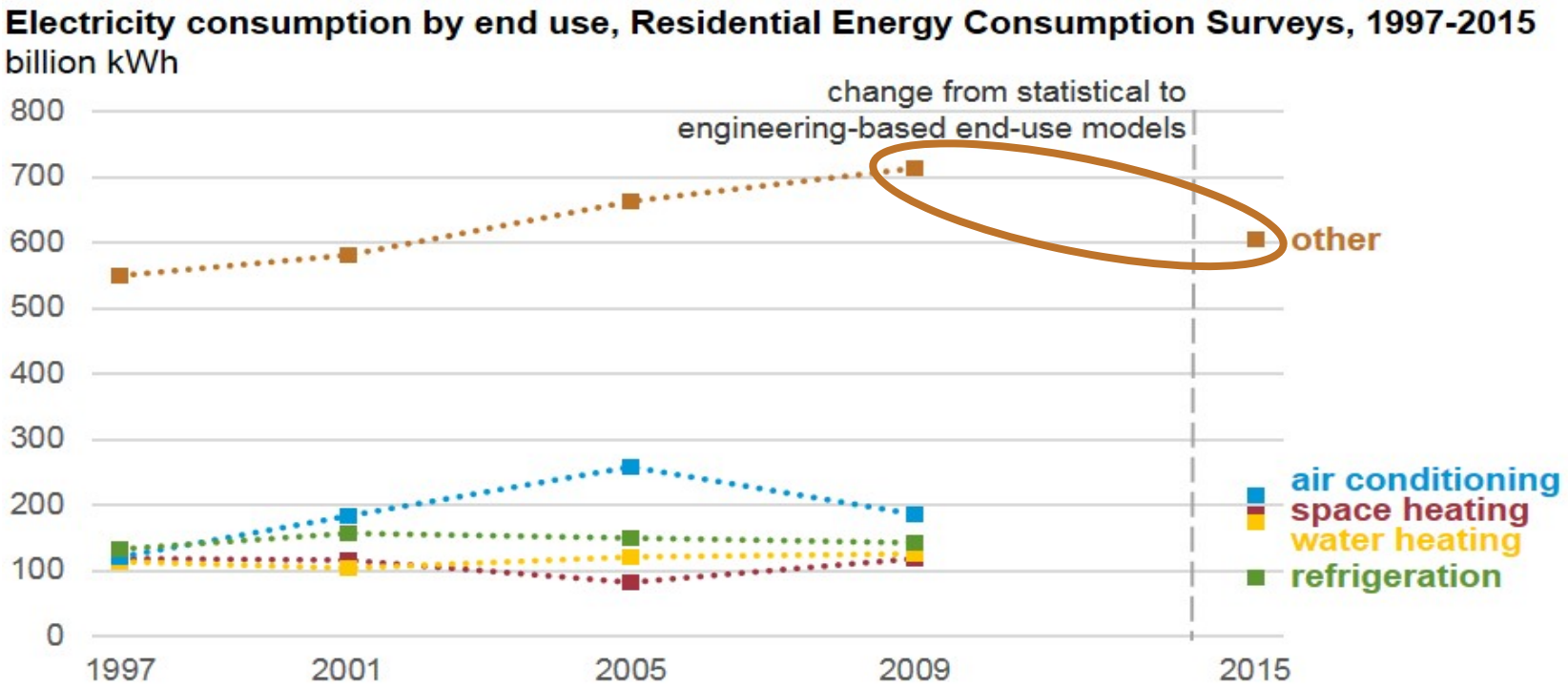


Share of home energy use, 2015

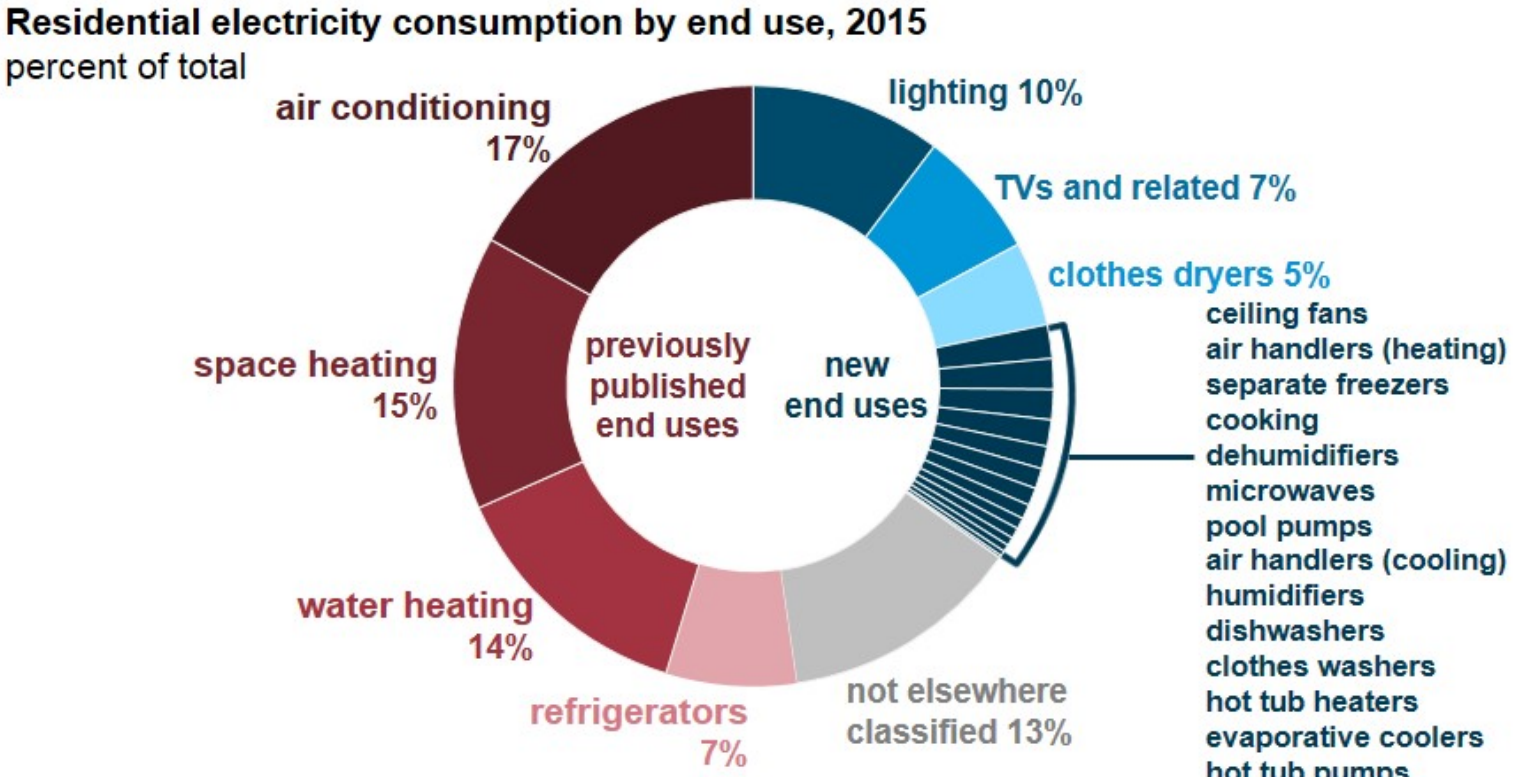


Source: EIA, 2015 Residential Energy Consumption Survey

Electric *Space Heating* increased, *Other* decreased relative to 2009 RECS and prior rounds



2015 RECS reports 26 electricity end-use estimates, up from 5 in previous rounds



Source: EIA, 2015 Residential Energy Consumption Survey

End-use modeling methodology from the 2015 RECS

What information is available for estimating national end-use consumption?

- Sadly, no submetering data across a representative, national sample
- Hence, end-use consumption must be ***Estimated*** from available information:
  - **RECS Housing Characteristics Survey data**
  - **RECS Annualized Billing data**
  - **Administrative data**
  - **Wider Community Knowledge!**

The basics of end-use estimation

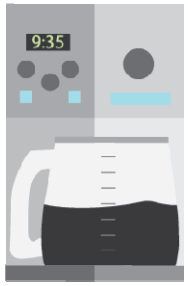
- Housing Characteristics data + Weather data give ***Expectations*** of consumption from individual end uses
  - Expectations are quantified by use of ***Models***
- Annualized Billing data are essentially ***Measurements*** of the total consumption across all end uses, for a particular fuel
- Combine Expectations and Measurements through ***Calibration***

Estimates = Calibration(Expectations, Measurements)

End-use energy expectations set by modeling

- Example: the end-use model for coffee makers has no usage information

```
if COFFEE = 1
     Coffee_Consumption = P_coffee
else
     Coffee_Consumption = 0
end
```

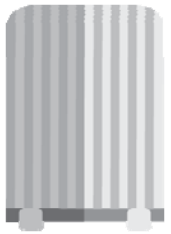


- Prior to the 2015 RECS, modeling was ***Statistical***:
  P_coffee looks like a UEC value, but it is merely part of a set of many unknown parameters that are sensitive to the specifications of all models

- The 2015 RECS used ***Engineering Models***:
  P_coffee was specified based on published values for the UEC of coffee makers (e.g., “wider expectations”)

End-use energy expectations can get complicated

- A model for space conditioning clearly depends on many inputs, like building size, materials, and location, as well as weather and occupant behavior



- Prior to the 2015 RECS, analysts supposed functional forms and inserted unknown parameters:

  "*Does space heating consumption depend on the* square-root *of HDDs?*"

- In the 2015 RECS, analysts followed engineering principles and tables to calculate an underlying "Heating Load" or "Cooling Load," and then considered the efficiency of the fuel and equipment used to meet the load
  - U-A calculations for heat conduction
  - Normalized Leakage for air infiltration
  - e.g., a Natural Gas furnace that is 10 to 14 years old

Calibration is capable of using more information, if one can provide it

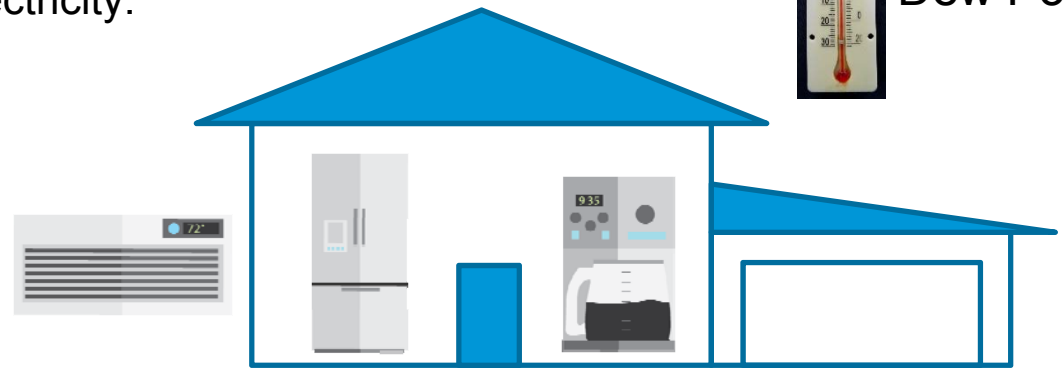
- Prior to the 2015 RECS, the Calibration method was ***Simple Normalization***, where all residuals from regression were prorated across all end uses
  - Treats all modeled end uses as equally certain/valid

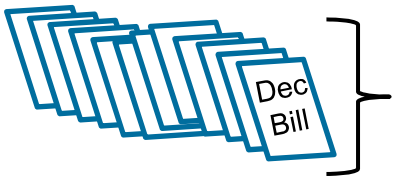
- In the 2015 RECS, the Calibration method follows a ***Minimum Variance Estimation*** approach
  - Does not treat all modeled end uses as equally certain/valid
  - Requires specifying the uncertainties of and correlations between end uses
  - Execution is a constrained minimization problem

A Simple Example: the available information

- Consider a hypothetical RECS Housing Unit
  - **Housing Characteristics Survey**
    Only **3** end uses for Electricity:
    - AC
    - Refrigerator
    - Coffee Maker
  - **Administrative Data**
    Weather data, etc.
  - **Energy Supply Survey**
    Annualized billing total of **2,000 kWh**

Temperature,
Dew Point

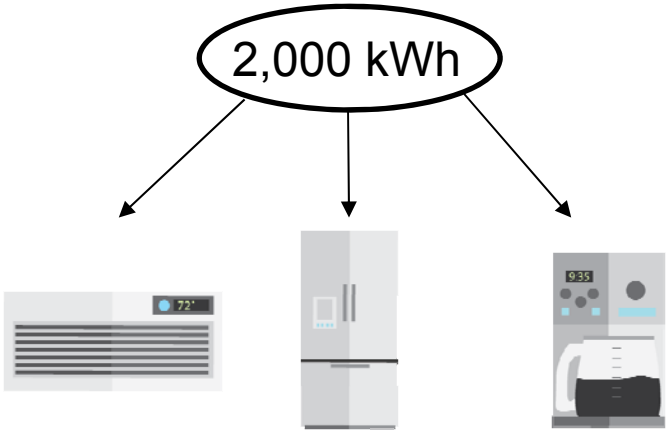




Σ = 2,000 kWh

A Simple Example: possible disaggregations

- What are the end-use estimates of consumption?



1,900	+	50	+	50	=	2,000	
667	+	667	+	666	=	2,000	
			…				
1,300	+	600	+	100	=	2,000	???

A Simple Example: end-use energy expectations

- Plausible, hypothetical model estimates for the end uses:
  - AC = **1,000 kWh**
  - Refrig = **500 kWh**
  - Coffee = **60 kWh**
- Sum of model estimates is **1,560 kWh**

This is **440 kWh** less than the annualized billing total of **2,000 kWh**

- How to correct the model estimates so that they add to 2,000 kWh?

A Simple Example: calibration prior to the 2015 RECS

- Previous Calibration: Simple Normalization (Proration)
  - AC_norm = 1,000 kWh · (2,000 / 1,560) = **1,282 kWh**
  - Refrig_norm = 500 kWh · (2,000 / 1,560) = **641 kWh**
  - Coffee_norm = 60 kWh · (2,000 / 1,560) = **77 kWh**

  } Σ = 2,000 kWh

- These add to 2,000 kWh, but does it make sense to treat all estimates as if they are all equally valid? No!
  - Refrigerators are relatively easy to model
  - AC is difficult to model
  - Coffee Makers cannot be modeled beyond presence in housing unit

A Simple Example: specify uncertainties and correlations

- In the 2015 RECS: include uncertainties and correlations in the Calibration
- Plausible, hypothetical estimates for the uncertainties and correlations:
  - AC has 50% relative uncertainty :: **1,000 ± 500 kWh**
  - Refrig has 20% relative uncertainty :: **500 ± 100 kWh**
  - Coffee has 100% relative uncertainty :: **60 ± 60 kWh**
  - All 3 are uncorrelated ::

    Corr(AC, Refrig) = Corr(AC, Coffee) = Corr(Refrig, Coffee) = 0

  - Uncertainty Propagation :: Sum = AC + Refrig + Coffee = **1,560 ± 513 kWh**

A Simple Example: improved calibration in the 2015 RECS

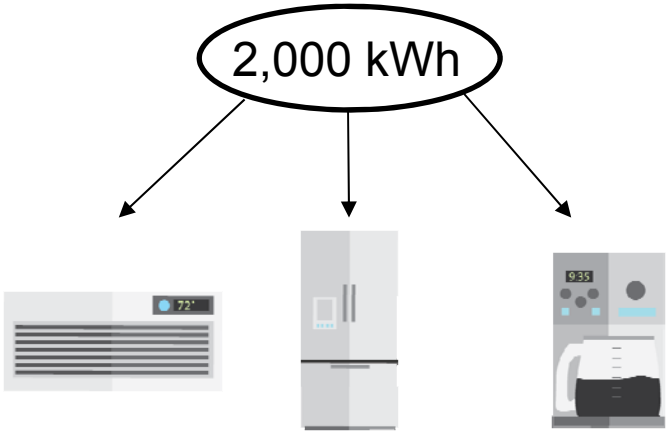
- Uncertainties and correlations lead naturally to *Minimum Variance Estimation*
  - Weight model estimates by inverse variance-covariance matrix
  - Optimization problem
  - Assume the billing total has no uncertainty
  - Apply constraints to ensure no negative consumption

- Final estimates in this hypothetical problem:
  - AC_cal = 1,000 kWh + (250,000 / 263,600) · 440 kWh = **1,417 kWh**
  - Refrig_cal = 500 kWh + (10,000 / 263,600) · 440 kWh = **517 kWh**
  - Coffee_cal = 60 kWh + (3,600 / 263,600) · 440 kWh = **66 kWh**

  } Σ = 2,000 kWh

A Simple Example: two calibration solutions

- The Minimum Variance Estimation and Simple Normalization solutions:



Minimum Variance:	1,417	+	517	+	66	= 2,000
Simple Normalization:	1,282	+	641	+	77	= 2,000

A Simple Example: comparing results

- Bringing the estimates together

	Modeled	Previous Calibration	Relative Uncertainty	Absolute Uncertainty	Minimum Variance Estimate
AC	1,000	1,282	±50%	±500	1,417
Refrig	500	641	±20%	±100	517
Coffee	60	77	±100%	±60	66
Total	1,560	2,000			2,000

Most of the +440 kWh correction has been given to AC, the end use with the largest absolute uncertainty

A look ahead…

Innovations and improvements for 2015 RECS present opportunities for future studies

Flexibility to:

- Draw larger samples to cover 50 states and lower RSEs for key subpopulations
- Conduct more frequent and timely data collections
- Study special populations in more depth
- Measure end-use consumption using load disaggregation devices

Planning is underway for the 2020 RECS

Questions?

(Please submit them through the Chat box)

Contact us!

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