Energy consumption surveys and end uses estimation in the U.S. EIA



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By

Eileen M. O'Brien, Team Lead, Buildings Surveys Statistics Team



U.S. Energy Information Administration

Independent Statistics & Analysis | www.eia.gov

Overview

- Governance of energy consumption data in the U.S.
- The Energy Consumption and Efficiency Statistics Program: "RECS" as an example
- New directions going forward



Mission of the U.S. Energy Information Administration

"The U.S. Energy Information Administration (EIA) collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment."

- EIA's independence is defined in its originating legislation
- EIA is required by law to conduct the consumption surveys
- EIA data are widely used; visits to <u>www.eia.gov</u> exceed 2 million per month



Basic design features of RECS & CBECS drive the cost and quality

- Both use multi-stage area probability sample designs from sample frames constructed by EIA
 - CBECS' frame is made up of multiple <u>frames</u>—a deduplicated, hybrid list of buildings listed in sampled areas (the area frame) complemented with special lists of large, complex buildings (e.g., airports, hospitals, etc.).
- Both begin with in-person, voluntary computer assisted personal interviews (CAPI)
 - RECS is experimenting with different modes of collection, principally web and mail
 - CBECS has used telephone collection entirely (1999) and as an opt-in cost mitigation (about 20% in 2012)
- · Field efforts to reduce sampling error are important
 - CBECS administers a special screener to every sampled building; RECS has also surveyed Rental Agents of apartment units for key survey items that household respondents answer poorly (e.g., type, fuel for heating)
- Both include a follow-on of energy suppliers; by law, suppliers must participate

Residential Energy Consumption Survey (RECS)

- RECS is the <u>only</u> representative, nationwide source of energy related characteristics, consumption, expenditures and end uses for U.S. homes
- RECS began as an annual survey, but rising costs and budget constraints changed the periodicity. U.S. law now mandates a quadrennial cycle.
- The 2013 cycle was delayed two years for budget and planning purposes





RECS begins with drawing a multistage area-probability sample from a complex frame of eligible housing units

- Primary sampling units (PSUs) vary in size but cover about the same amount of people
- Secondary sampling units (segments) are groups of Census blocks within PSUs
- Most of the residential sample frame is made up of addresses in the U.S. Postal Service Delivery Sequence File (DSF)
- Unit of analysis: housing units that are occupied as a primary residence





"RECS" is more than a survey. Its data are derived from a series of surveys, processes, and models.





Three types of data are available from the RECS program

1. Household characteristics, including:

- Structural characteristics of the housing unit (levels, rooms, windows, square footage*): type, number, size
- Energy systems (heating, cooling and ventilation): types, fuel, age, and usage
- Water heating: number, type, fuel, age, usage
- Major appliances (refrigerators, cooking, laundry and other): number, type, age, usage
- Electronics (TVs, TV peripherals, computers, other): number, type, characteristics
- Household demographics: number, sex, race/ethnicity*, education, income, ages
- "Big data": census geographies, weather and climate data from NOAA

RECS collects both interviewer-measured and self-reported square footage. ** Race/ethnicity is only collected for the householder.

RECS data types (cont.)

2. Annualized energy consumption & expenditures and modeled end uses for these fuels

- Electricity Fuel oil
- Natural gas Kerosene
- Propane Wood

3. Public Use Microdata

After ensuring that no individual households can be identified from the data, EIA releases raw data for researchers to perform their own analyses



How are RECS program data produced? Household surveys Energy supplier surveys Annualize billing data Model end uses

- 1. Housing characteristics data are collected from respondents on a voluntary basis
- 2. Consumption and expenditures are reported by energy suppliers, via web forms and standardized spreadsheets submitted through a secure server
- 3. EIA annualizes billing data to create totals by fuel for the survey reference year, e.g., total electricity consumed
- 4. End-use consumption and expenditures are the result of complex statistical models now supplemented with engineering parameters



To estimate the end uses, characteristics and energy supplier data feed into disaggregated end-use consumption and expenditure models

Total fuel consump- tion	Space Heating	A/C	Water Heating	Refrig- erators	Appl/ Elec/ Light
FUEL MODEL	Space Heating	A/C	Water Heating	Refrig-erators	Appliances/ Electronics/ Lighting
Electricity	Х	Х	Х	Х	Х
Natural gas	Х		Х		Х
Propane	Х		Х		Х
Fuel oil	Х		Х		
Kerosene	Х				

More info: http://www.eia.gov/consumption/residential/methodology/2009/pdf/faqs-enduse-models022013.pdf



Home energy consumption over the past 30 years is a story of competing trends

- Total energy consumption in homes has stayed relatively constant, but electricity now makes up a larger share
- Efficiency gains have offset increases in the number of appliances (ex: more than one refrigerator) and electronic "plug loads"
- Energy performance standards to improve A/C efficiency have been offset by the growing share and size of homes using it
- Newer homes are built with more efficient features, but this efficiency is in part offset by trends in larger homes



Shares of energy end uses have changed significantly





Number of homes with 2 or more refrigerators is approaching 30% in the Midwest

Homes with 2+ refrigerators, selected survey years Percent of homes





Newer homes are much more likely to have efficient features, such as double or triple-pane windows...



Source: U.S. Energy Information Administration, 2009 Residential Energy Consumption Survey

Eileen O'Brien, InterEnerStat, Paris



Homes built in last two decades are much larger than homes built in earlier decades

3,500 3,000 2,500 2,000 1970s 1,500 1980s 1,000 500 1990s Northeast Midwest South 0 2000s S Nest

Average total square footage, 2009



Commercial Buildings Energy Consumption Survey (CBECS)

- CBECS is the <u>only</u> national-level data source for *characteristics* and *energy use* of commercial buildings
- Mandated by Congress, it has been conducted every 3 to 5 years since 1979
- CBECS data are an essential input to EIA's demand projections, and energy performance standards for buildings, building energy systems and other end uses





CBECS is also a multi-year, multi-phase project

2012	2013	2014	2015	2016
Construct frame & select sample	Design survey & collect building data	Design forms & collect energy supplier data	Process energy data & model end uses	Complete data dissemination
Releases spa	n several vears	*		

Releases span several years Characteristics summary tables
Characteristics microdata
Characteristics microdata
Characteristics



Many aspects of CBECS are similar to but more complex than the RECS

- The <u>unit of analysis</u> is a building not a business, which complicates many aspects of design and collection
- CBECS requires more effort to develop its complex frame. This ensures we can make statistical inferences from a relatively small sample to the population of buildings
- CBECS is <u>the</u> benchmark, so we must be cautious in testing and implementing new methods.



The 2012 CBECS showed the average size of new commercial buildings has increased relative to vintage buildings

average commercial building size thousand square feet



Percent of total commercial building stock



Health care and lodging lead the growth in average building size average building size (thousand square feet)



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Large buildings (over 100,000 square feet) are just 2% of the building stock but about 35% of the total floorspace and 41% of consumption





EIA Secretary of Energy Brown Bag Briefing, 2012 CBECS Results, June 16, 2016

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With the latest CBECS (2012), we see that <u>total</u> electricity consumption in commercial buildings has almost doubled since 1979 quadrillion Btu



Year of survey

While electricity <u>share</u> is up 23 percentage points from 1979; natural gas share is down 12 percentage points.



Energy usage per square foot is down significantly from 2003 (-12%)



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Lighting and space heating contributed the most to reductions in energy intensities

total consumption quadrillion Btu



Decrease in total energy intensity driven by office and education buildings





New directions in the consumption program



Presenter name, Presentation location, Presentation date

EIA runs two complex periodic surveys of energy consumers against this agency budget profile



Budget of the US Energy Information Administration

- It costs more to achieve the same or less success
- Survey costs are rising faster than budgets
- Budgets are declining in real terms

Source: OMB, Statistical Programs of the United States Government





Complexity and challenges are motiving changes in how we will conduct the consumption data program in the future.

- Timeliness
- Cost
- Quality
- · Project resilience and oversight



RECS 2015 example: At week 10 (Nov 3), effort, contacts and output varied widely across RECS sample areas.



RECS ATD Report, Nov 3, 2015



Eileen O'Brien, InterEnerStat, Paris December 13, 2016

Weekly Production Rates – RECS 2015 in CAPI

Completes by Week



RECS 2015 ATD Report – Jan 25 2016



Eileen O'Brien, InterEnerStat, Paris December 13, 2016

Multi-mode studies are going to be more common and also more important to design and monitor well

- "Mode differences" differences in response patterns within questionnaires (e.g., conflicting responses), item missing rates, nature and amount of 'write in' responses, and quality of responses
- Different response distributions across respondents, possibly resulting from varying interpretations, but also instrument differences by mode, e.g., use of 'screener' questions
- Weighting the sample and imputation is more complex
- Differences in survey questions and quality may affect how data items may be published (e.g., we did not collect comparable detail on *secondary* heating equipment in web/mail)



New directions in the end uses estimation

- End use estimation has moved away from statistical-only based models to a hybrid approach
- In 2003, engineering models were incorporated into the CBECS. CBECS 2012, RECS 2015 and future rounds will include such parameters.
- We expect future rounds will experiment with more objective measurement of end uses.



Algorithm: Imputation, Engineering, and Calibration Models, 2003

	Purpose Estimate end-uses for buildings v	data from:	Model is applied to:
Imputation Model	known totals and extrapolate to those with unknown consumption (statistical model)	Buildings n with <u>good</u> consumption	Buildings with <u>missing</u> consumption
Engineering Model	Calculate consumption for end u using deterministic formulas (algebraic model)	ises N/A	All buildings
Calibration Model	Make the total consumption from engineering model as close as possible to actual total (statistical model)	n Buildings with "good" consumption	All buildings



Algorithm: Engineering, Calibration, and Imputation Models, 2012 Model is fit





For more information

Residential Energy Consumption Survey | <u>http://www.eia.gov/consumption/residential/</u>

Commercial Buildings Energy Consumption Survey | http://www.eia.gov/consumption/commercial/

Manufacturing Energy Consumption Survey | http://www.eia.gov/consumption/manufacturing/

U.S. Energy Information Administration home page | www.eia.gov

Energy Projections Annual | <u>www.eia.gov/aeo</u>, Short-Term | <u>www.eia.gov/steo</u>, International | <u>www.eia.gov/ieo</u>

Monthly Energy Review | www.eia.gov/mer

Today in Energy | <u>www.eia.gov/todayinenergy</u>

State Energy Profiles | www.eia.gov/state



Resources

Executive Office of the President, Office of Management and Budget. (2013). Statistical programs of the U.S. government: Fiscal year 2014. <u>http://www.whitehouse.gov/sites/default/files/omb/assets/information_and_regulatory_affairs/statistical-programs-2014.pdf</u>

Federal Committee on Statistical Methodology, Methodology Reports. http://www.fcsm.gov/reports/

Journal of Official Statistics, Statistics Sweden: http://www.degruyter.com/view/j/jos

Meetings and Events of the American Statistical Association, International Conference on Establishment Surveys, Conference Proceedings: <u>http://www.amstat.org/meetings/ices.cfm</u>

Principals and Practices of a Federal Statistical Agency by the National Academy Press: https://download.nap.edu/login.php?record_id=18318&page=%2Fdownload.php%3Frecord_id%3D18318

Statistical Programs and Standards of the United States http://www.whitehouse.gov/omb/inforeg_statpolicy

Summer Institute of Survey Research Techniques at the University of Michigan, Ann Arbor, MI http://si.isr.umich.edu/

