Measuring Efficiency in the Buildings Sector: U.S. data collection practices

测量建筑物部门的效率：美国收集数据的做法

For

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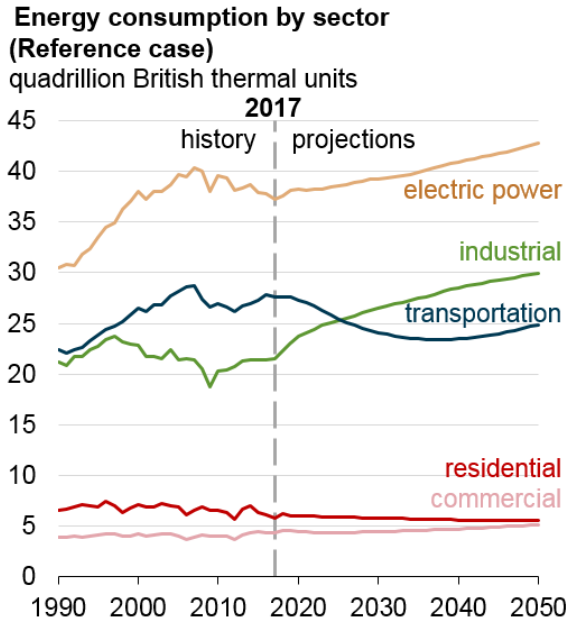
On measuring efficiency in the U.S. buildings sector, I will share--
我会分享如何测量美国建筑物部门的能源效率

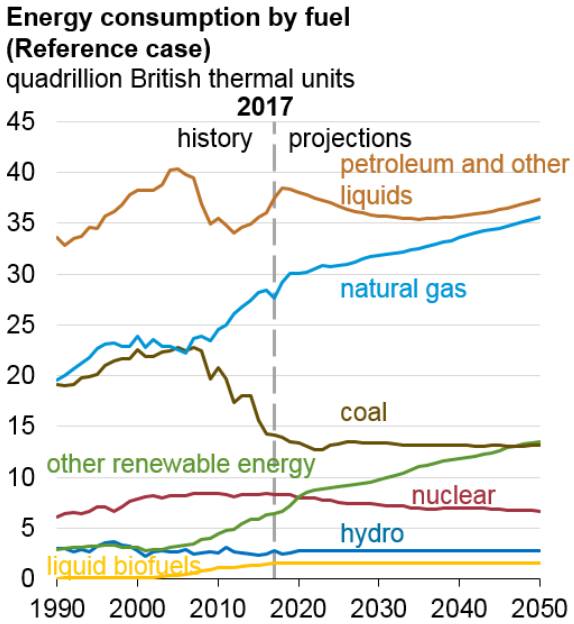
- How EIA's history helps us conduct our data program (authorities)
  依据美国能源部能源信息署的历史帮助我们权威地开展收集数据计划
- Updates to the program methods (transformation), and
  更新计划方法（ 如何转型 ），和
- Future directions for the program (innovation)
  数据计划的未来方向（ 如何创新）

Short names for major surveys in EIA's consumption data program
美国能源部能源信息署消费数据项目主要调查的简称

- "RECS" is the Residential Energy Consumption Survey
  "RECS" 是住宅能源消费调查
- "CBECS" is the Commercial Buildings Energy Consumption Survey
  "CBECS" 是商业建筑能源消费调查
- "MECS" is the Manufacturing Energy Consumption Survey
  "MECS" 是制造业能源消费调查
- "RTECS" is the Residential Transportation Energy Consumption Survey
  "RTECS" 是住宅交通能源消费调查

Energy consumption survey data are widely used
能源消费调查数据被广泛使用



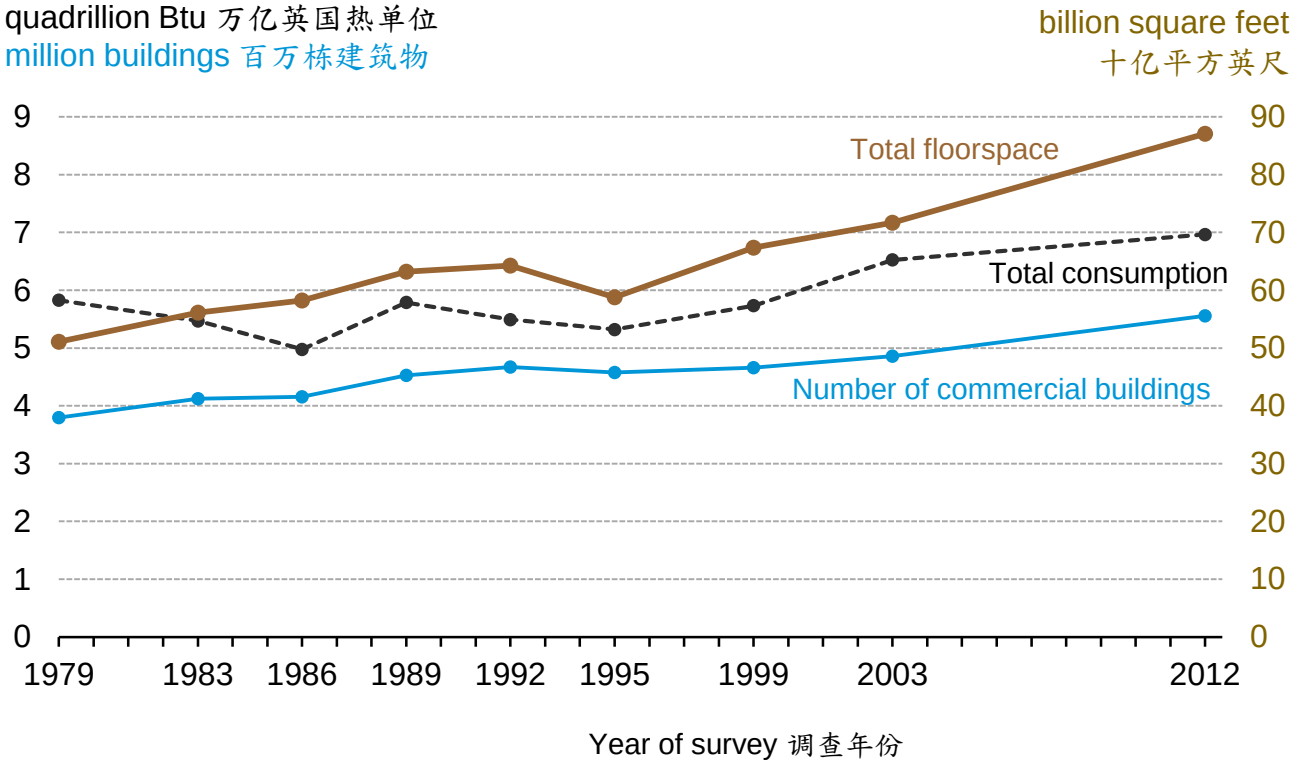


They are the basis for –
他们是以下各项的基础

- long term energy demand projections
  长期能源需求预测
- building energy performance ratings systems
  建筑节能绩效评估系统
- appliance efficiency standards, and
  家电效率标准，和
- Many other uses
  许多其他用途

Source: U.S. EIA Annual Energy Outlook 2018, https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf

Consumption is growing slower than floorspace and building counts
能源消费的增长速度低于建筑面积和建筑物数量的增长



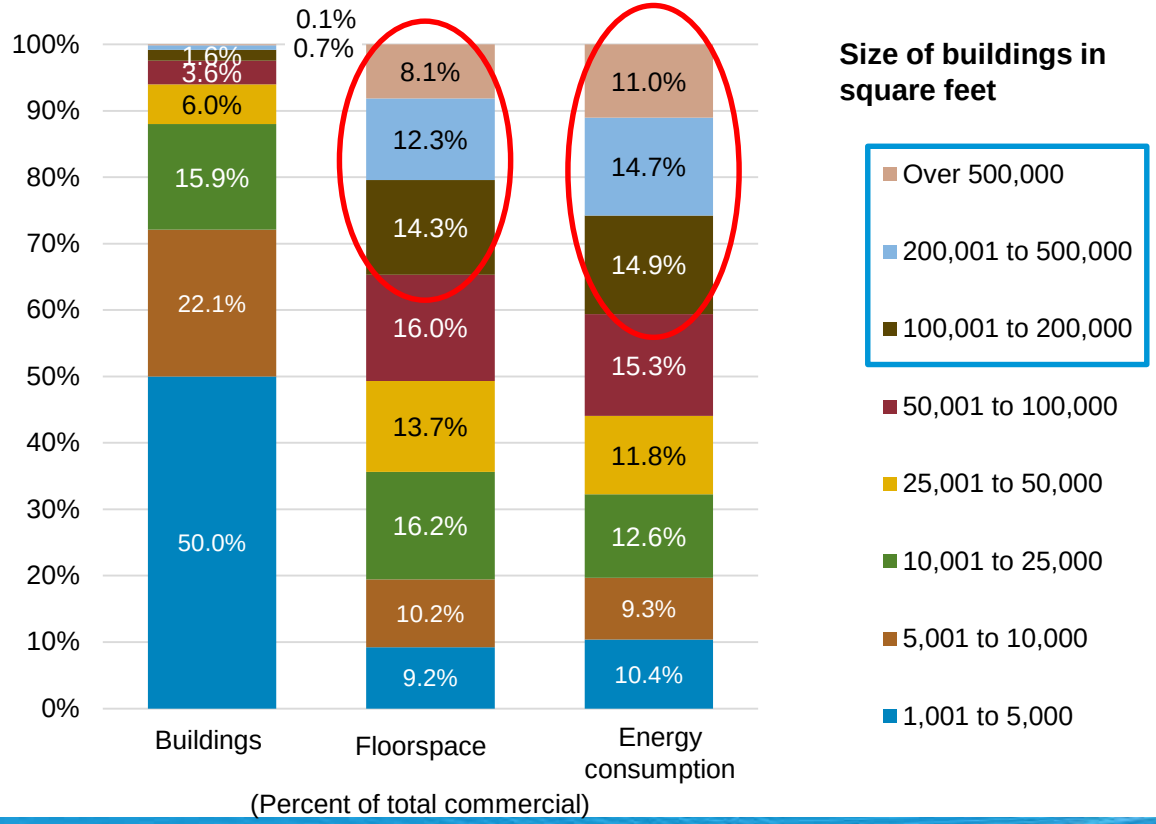
Percent change since 2003
自2003年以来增长百分比

Number of buildings
建筑物数量的增长
+14%

Floorspace
建筑面积的增长
+22%

Consumption
能源消费的增长
+7%

Large buildings use more than their population's share of energy
大型建筑物能源的消费量超过了其建筑物数量的对比份额



Large buildings over 100,000 square feet are –

超过10万平方英尺的大型建筑物 –

- just 2% of the building stock
  只占所有建筑物数量的2%
- 35% of the total floorspace,
  占所有建筑面积的35%
- and 41% of consumption
  占能源消费量的41%

The role of EIA's history in the consumption data program
能源信息署的历史在能源消费数据计划中的角色

EIA's authorities strengthen how consumption surveys are conducted
能源信息署的法定权力加强了能源消费调查的进行

- As a result of being formed during the 1970s energy crisis, EIAs authorities are stronger and more independent than other U.S. statistical agencies
  在1970年代能源危机期间成立的能源信息署，其法定权力比其他美国联邦统计机构更强大和更独立
- EIA conducts the household and buildings surveys on a voluntary basis, but energy utilities are required to provide energy records for sampled buildings
  能源信息署进行家庭和建筑物自愿调查，但能源公用事业部门需要为抽样的建筑物提供能源消费记录
- Strong privacy laws for statistical collections are important to our survey respondents and help us access, use, and protect non-EIA sources of data used for statistical purposes
  强大的统计数据收集隐私法对我们的调查受访者非常重要，并帮助我们存取，使用，并保护非能源信息署数据仅能用于统计目的

A few key dates in EIA's history
历史上的几个能源信息署关键日期

1973-74 Arab Oil Embargo 阿拉伯石油禁运

1974 The *Federal Energy Administration* (FEA) begins gathering energy production and supply data from other government agencies

联邦能源管理局（FEA）开始收集其他政府机构的能源生产和供应数据

1976 The U.S. Congress passes the *Energy Conservation and Production Act* that establishes the FEA Office of Energy Information and Analysis

美国国会通过了节能与生产法案，该法案建立了能源信息与分析办公室

Apr 18, 1977 President Carter gives his "Moral Equivalent of War" speech on the energy crisis

卡特总统就能源危机发表了他的"Moral Equivalent of War"演讲

Aug 4, 1977 President signs the *Department of Energy Organization Act*, which establishes EIA as the federal authority on energy statistics and analysis

总统签署能源部组织法案，该法案规定能源信息署为联邦能源统计和分析部门

The DOE law includes strong provisions for independence
美国能源部法律包含强有力的独立条款

"The Administrator shall not be required to obtain the approval of any other officer or employee of the Department in connection with the collection or analysis of any information; nor shall the Administrator be required, prior to publication, to obtain the approval of any other officer or employee of the United States with respect to the substance of any statistical or forecasting technical reports which he has prepared in accordance with law."[2]

[1]Department of Energy Organization Act, Public Law 95-91, August 4, 1977; Sec. 205(a)(2).

Hogan, 1978

Strong U.S. statistical privacy laws protect respondents, data, and access
强大的美国统计隐私法保护受访者，数据和存取

The “Confidential Information Protection and Statistical Efficiency Act” lets us--
“机密信息保护和统计效率法案”让我们--

- Be directly involved in all stages of the study design
  直接参与研究设计的所有阶段
- Make finer data linkages to energy use, for example, link the best, nearest daily weather data to sampled buildings
  将最佳的每日天气数据与采样建筑物相链接，从而实现更精细的数据链接
- Have access to monthly energy bills so we can be full stewards of quality from sample design, collection, editing, estimation to modeling
  可以获得每月的能源消费账单，因此我们可以成为样本设计，收集，审核，估算和建模的全面质量负责人
- Engage in data sharing through strict confidentiality agreements
  通过严格的保密协议参与数据共享

Read more about “CIPSEA” here: https://www.eia.gov/cipsea/cipsea.pdf

Updates to EIA's consumption data program
能源信息署消费数据计划的更新

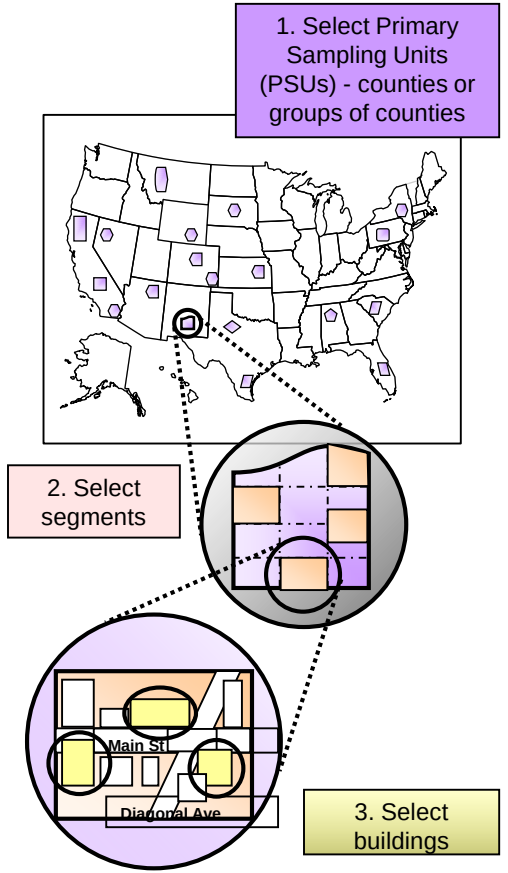
Recent updates to the consumption data program include the following:
能源消费数据的计划最新更新包括以下内容：

- How we sample, design, collect, and estimate building energy characteristics and consumption
  我们如何抽样，设计，收集和估算建筑物能源特性和能源消耗
- How we model demand for energy end uses and by fuels, and
  我们如何模拟对能源最终用途和燃料的需求，以及
- How we contract, manage, and monitor large, complex data projects
  我们如何签约，管理和监控大型复杂的数据项目

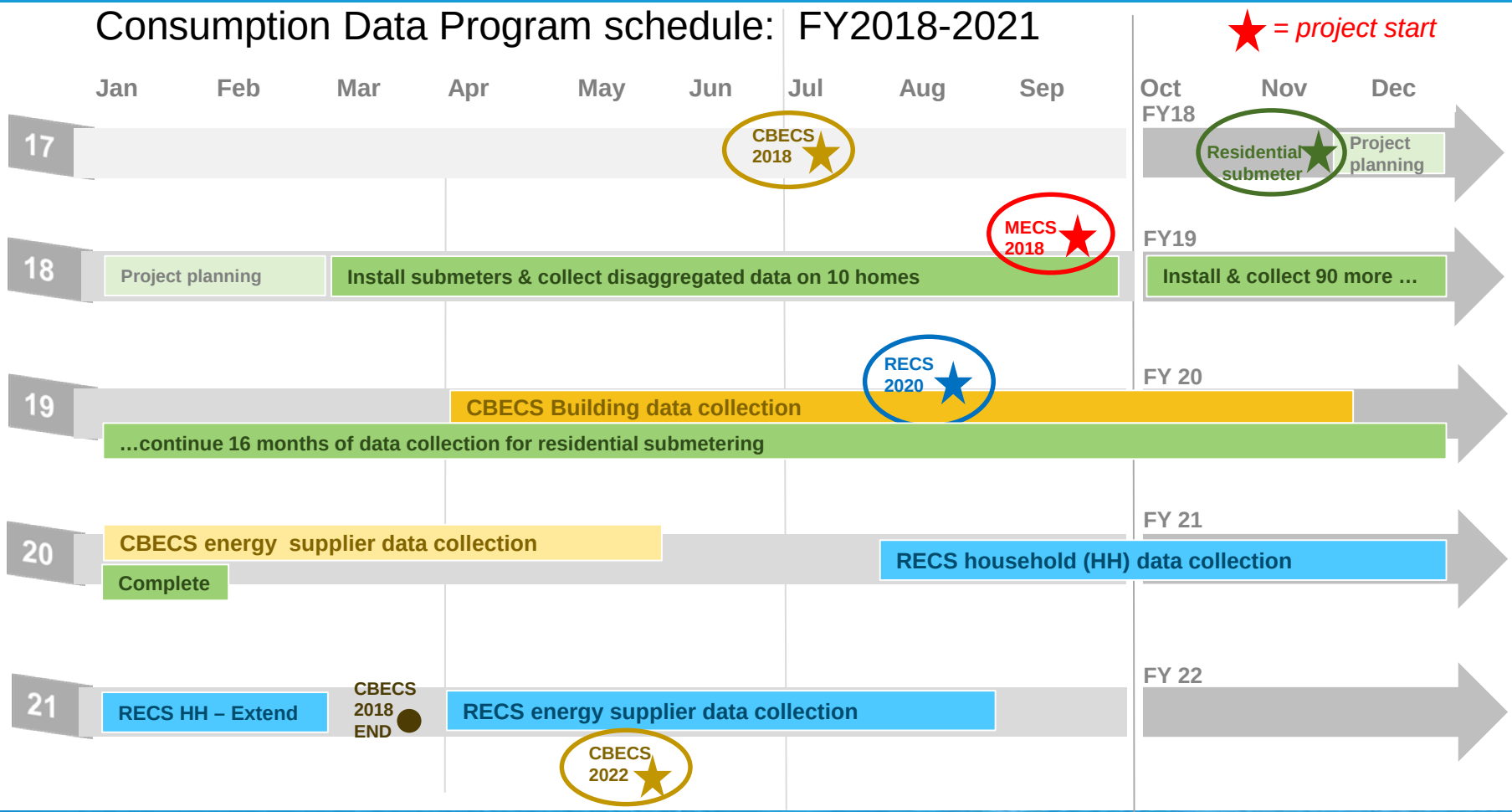
Sampling requires “complex” methods
采样需要”复杂”的方法

- RECS and CBECS use “area frame” sampling methods to control costs and stratification to improve precision
  RECS 和 CBECS 使用”区域总体”采样方法来控制成本和分层以提高精确度
- CBECS requires multiple frames: area-based (typical buildings) and list-based (large unique buildings)
  CBECS 需要多个采样总体：基于面积（典型建筑物）和基于列表（大型独特建筑物）
- RECS uses a “postal frame” for most of its sample now
  RECS 现在大部分样本都使用 “邮政总体”

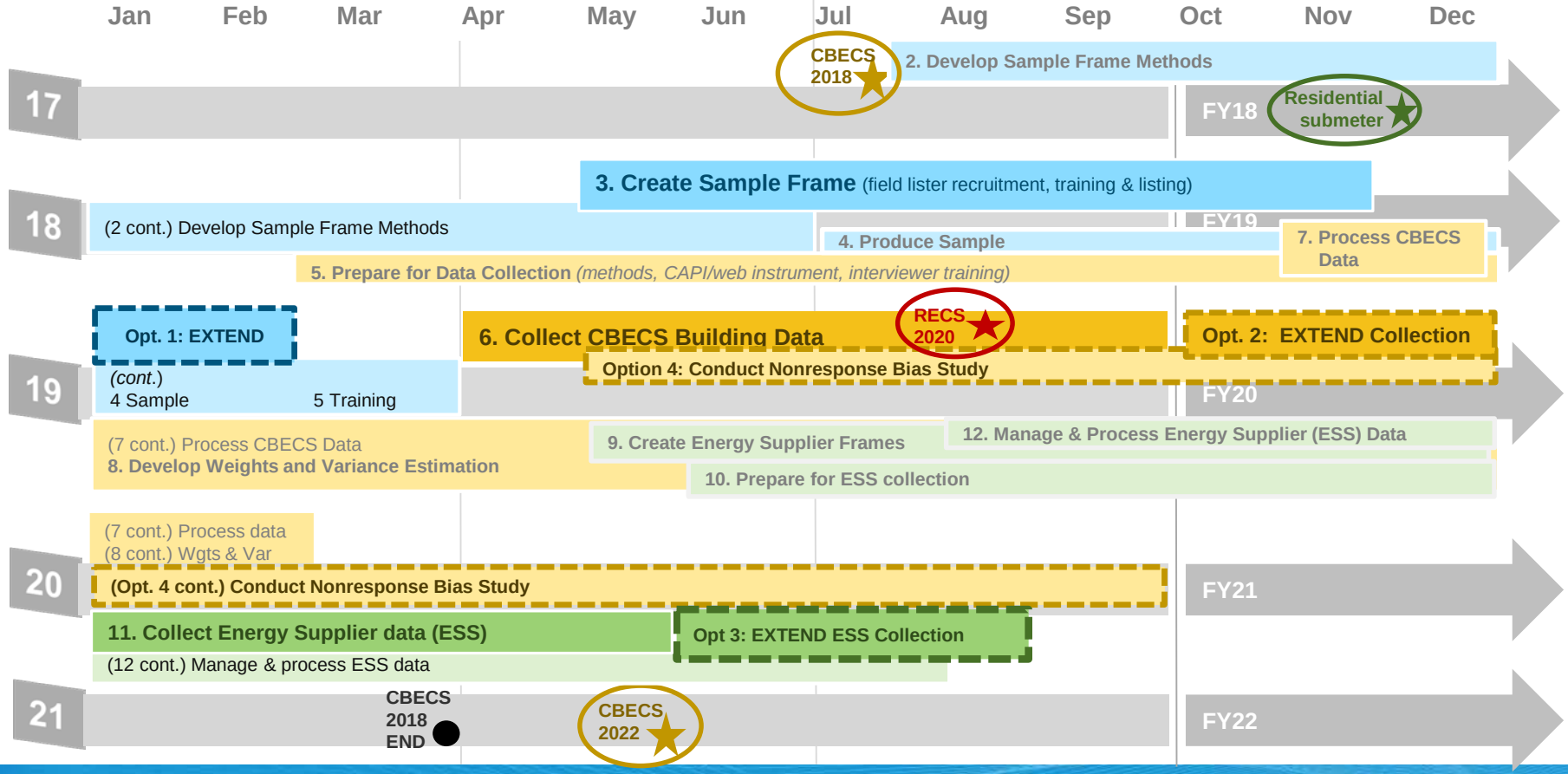
EIA sampling methods are evolving; some are ahead of the field
能源信息署抽样方法正在演变;有些领先于该领域



Consumption Data Program schedule: FY2018-2021



Task Order Schedule for the CBECS only

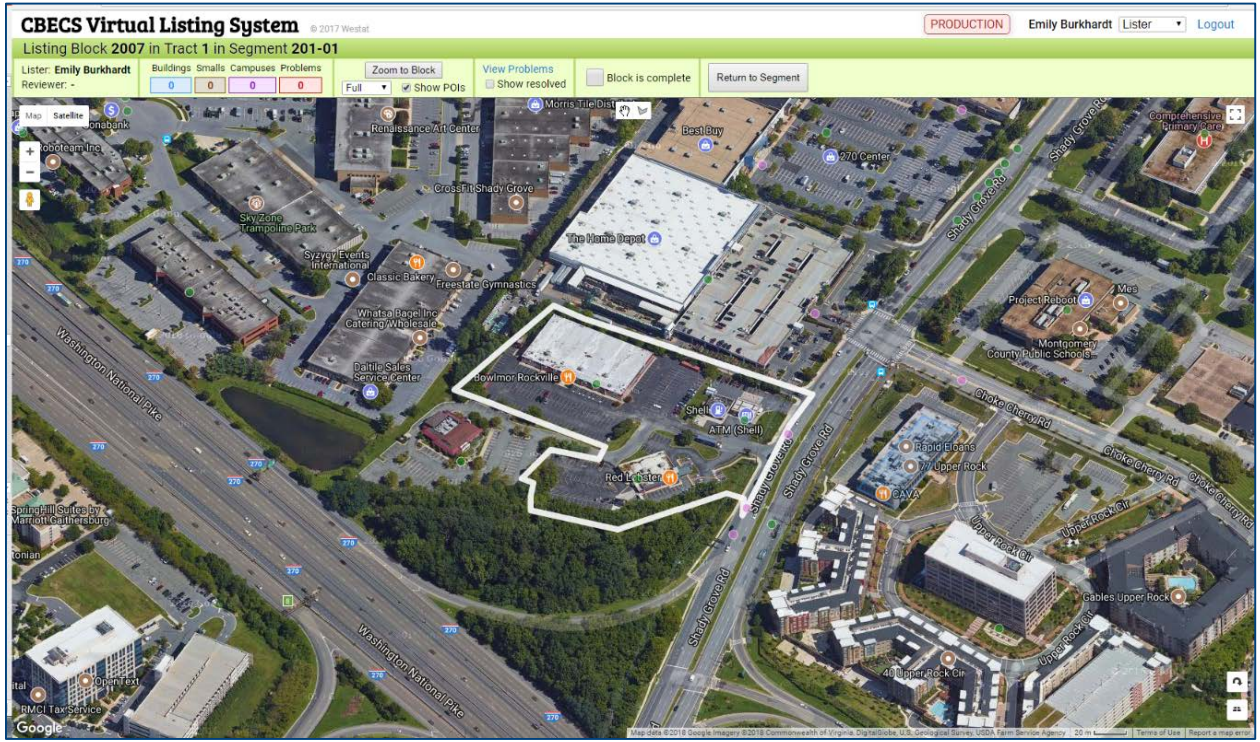


Recent updates have cut labor hours and costs; neutral on quality
最近的更新已经减少了劳动时间和成本;保持质量

Sector	Unit of analysis	Sample frame, new methods	Mode of data collection	End use methods
Residential	Primary home	Since 2005, only field-list units in area segments with 'bad' coverage on U.S. postal address frame. Use augmented postal list for most of sample frame.	Since 1997, CAPI/CATI. In 2015, mix of modes: CAPI, mail, and web.	With 2015 RECS, engineering-based models were used to calibrate energy bills to end uses
Commercial	Buildings	PLANNED 2018: only field-list area segments with poor coverage relative to traditional, field-list methods: use GIS methods for most of frame.	Since 1995, CAPI and/or CATI. In 2018, will allow self-completion by secure web form.	Since the 2003 CBECS, engineering-based models calibrated to annualized energy bills.
Industry	Manufacturing establishments	Business registry of the U.S. Census Bureau	Since 2006, majority by web.	Direct response or derived form.

CAPI = computer assisted personal interview; CATI=Computer Assisted Telephone Interview; and web is a standardized online version of the survey questionnaire offered to a respondent via a mail or in-person invitation

“Virtual listing” methods are being tested for CBECS 2018
CBECS 2018正在进行测试”虚拟列表”方法



More information about CBECS sampling methods can be found here:
更多关于CBECS 抽样方法的信息可以在这里找到：
https://www.eia.gov/consumption/commercial/2012-cbecs-building-sampling.php

RECS tested web & mail against traditional in-person collection
针对传统的面对面, RECS测试了网页和邮件方式收集数据

Sample and Survey Design

Household collection

Processing

Collect Billing Records

Consumption, Expenditures & End Uses

2015 RECS benchmark in person
以2015年住宅能源消费调查为个人基准

2014 2015 2016 2017

National Pretest*

"Cities" Pilot

"Bills"

Research pilots in web & paper
使用网页和纸张做研究试点

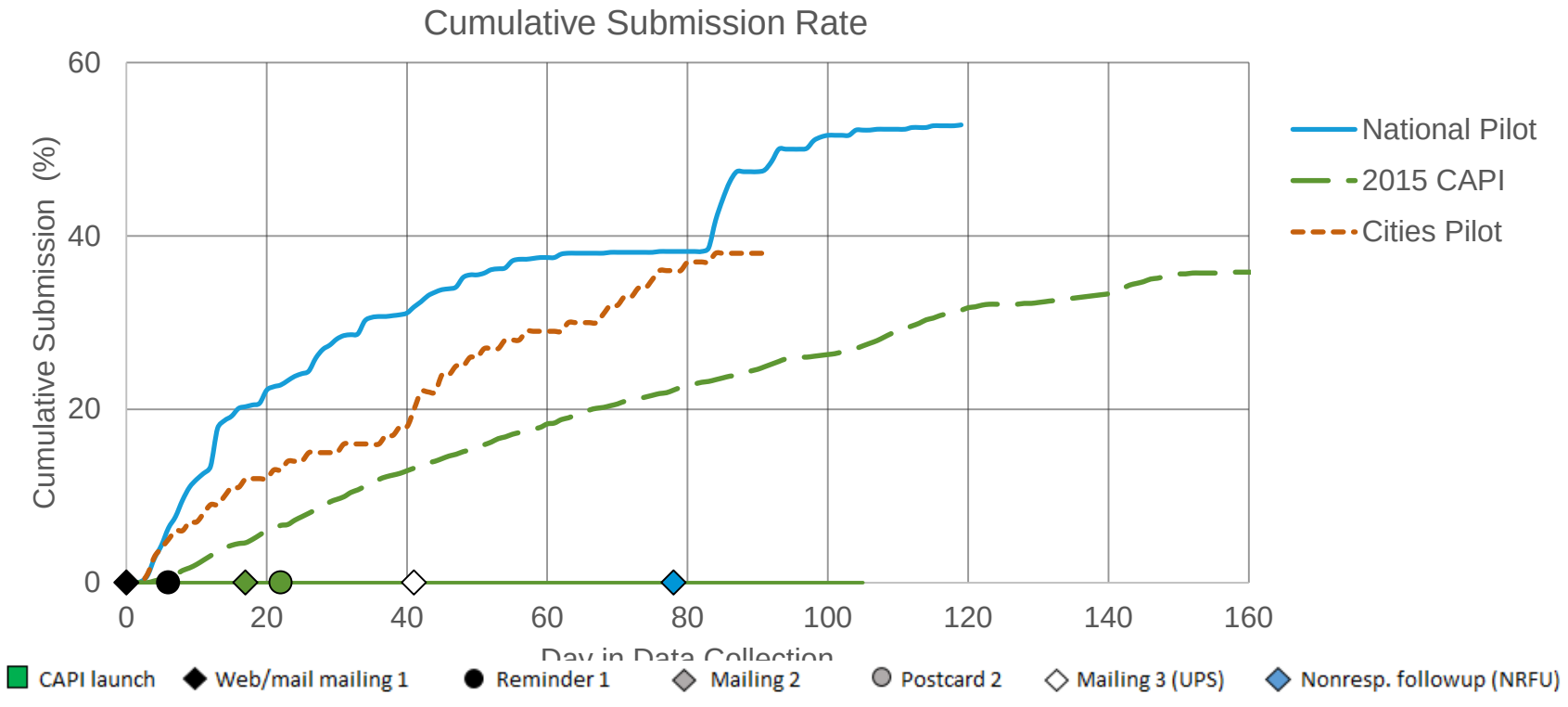
National Pilot

Collect Bills

Consumption, Expenditures & End Uses

= *results*

Web and mail collection was timelier, cheaper, and of equal quality.
网络和邮件收集数据时间更长，更便宜，质量也更好.



What's new for the 2018 CBECS?
2018商业建筑能源消费调查的新方向

- Modernization of survey processes 现代化的调查处理
  - Listing, screening, case management 建筑物名单, 筛选, 案件管理
- Option for web completion (self-administered) of the building questionnaire
  访者可以使用联网完成调查问卷（自我管理）

模式	1979	1983	1986	1989	1992	1995	1999	2003	2007	2012	2018
Paper and pencil (PAPI) 纸张形式	X	X	X	X	X						
Telephone (CATI) 电话形式							X			X	X
In-person (CAPI) 面对面形式						X		X	X	X	X
Web 联网形式											X

RECS End-use modeling methods now begin with engineering components
新的家电终端消费模型由工程模型而不是概率模型组成(住宅能源消费调查)

Stage 1: Household respondents report housing characteristics and usage behavior (voluntary)

阶段1:家庭受访者报告住房特征和使用行为（自愿）

Stage 2: Energy Suppliers provide consumption data for sampled units (response is mandatory)

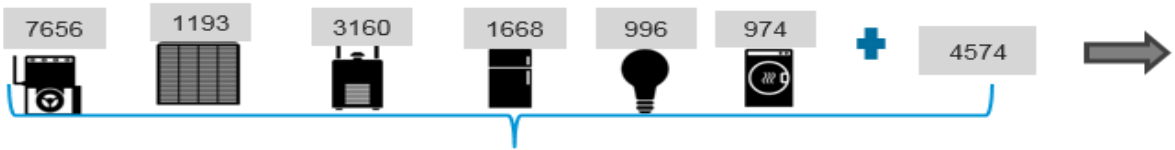
阶段2:能源供应商提供受访单位的能源消费数据（回复是强制性的）

Stage 3: Produce individual end-use estimates using engineering-based models

阶段3:使用工程的模型来推算家电终端消费

Stage 4: To obtain the final end-use estimates for each housing unit, calibrate the engineering result to agree with the annualized energy supplier amount

阶段4:使用年度能源供应商数据来校准工程模型估计,去推算最后家电终端消费



Total Engineering Estimate
家庭工程模型电消费总量
Y_{eng} = 20221 kWh

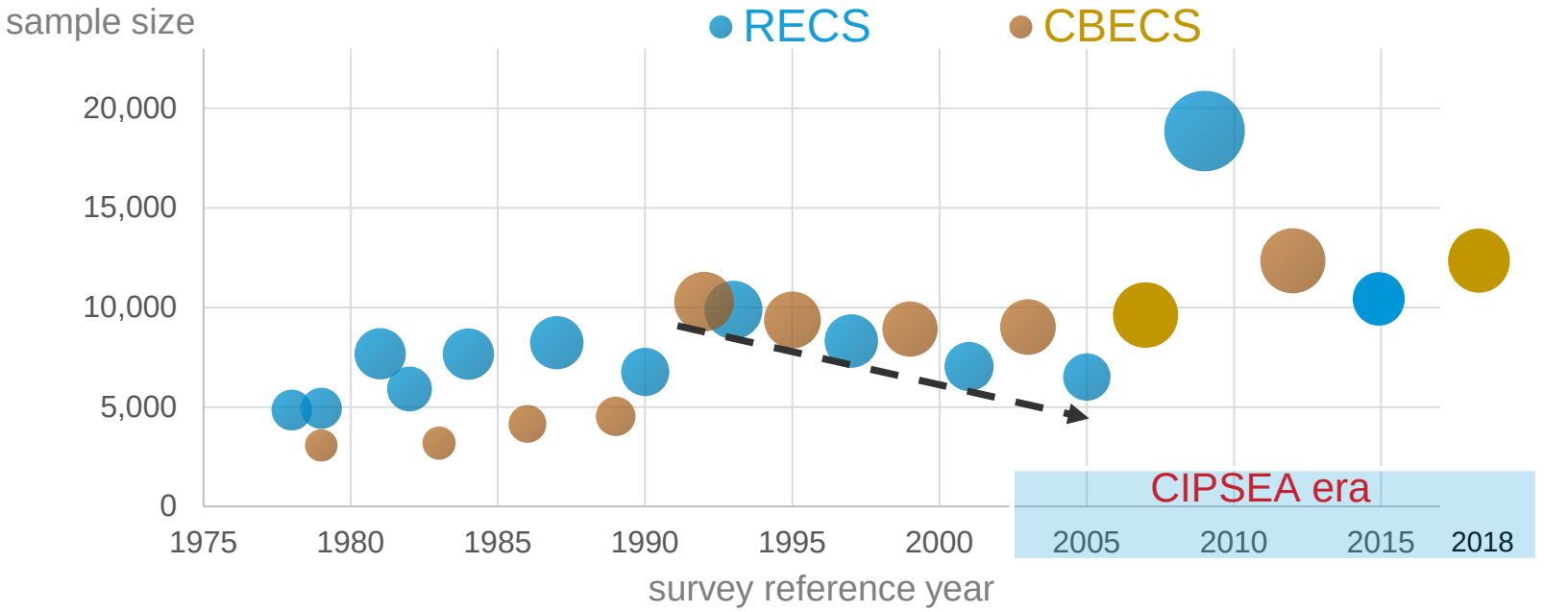
Billing Data Total
供应商帐单数据电消费总量
Y_{truth} = 27084 kWh

Calibrate the engineering model estimates so that the final total is equal to the billing total (27084 kWh)

需要校准工程模型估计，使最后总和等于供应商帐单总量（27084）

Future directions for data collection
数据收集的未来方向

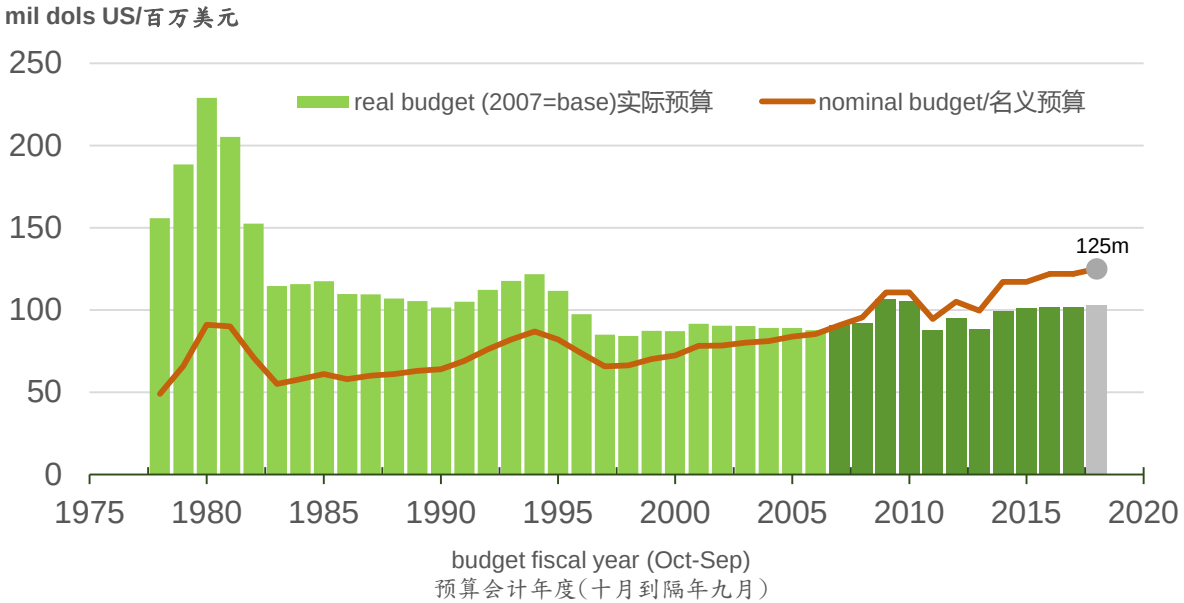
EIA has conducted 13 RECS and 10 CBECS
美国能源部能源信息署完成了13次住宅能源消费调查和10次商业建筑能源消费调查



11 surveys/11次 | *8 surveys/8次* | *5-6 surveys/5-6次*

Consumption surveys are also complex and expensive, and they run against a relatively flat budget profile.
能源消费调查很复杂且昂贵，但是预算相对平稳.

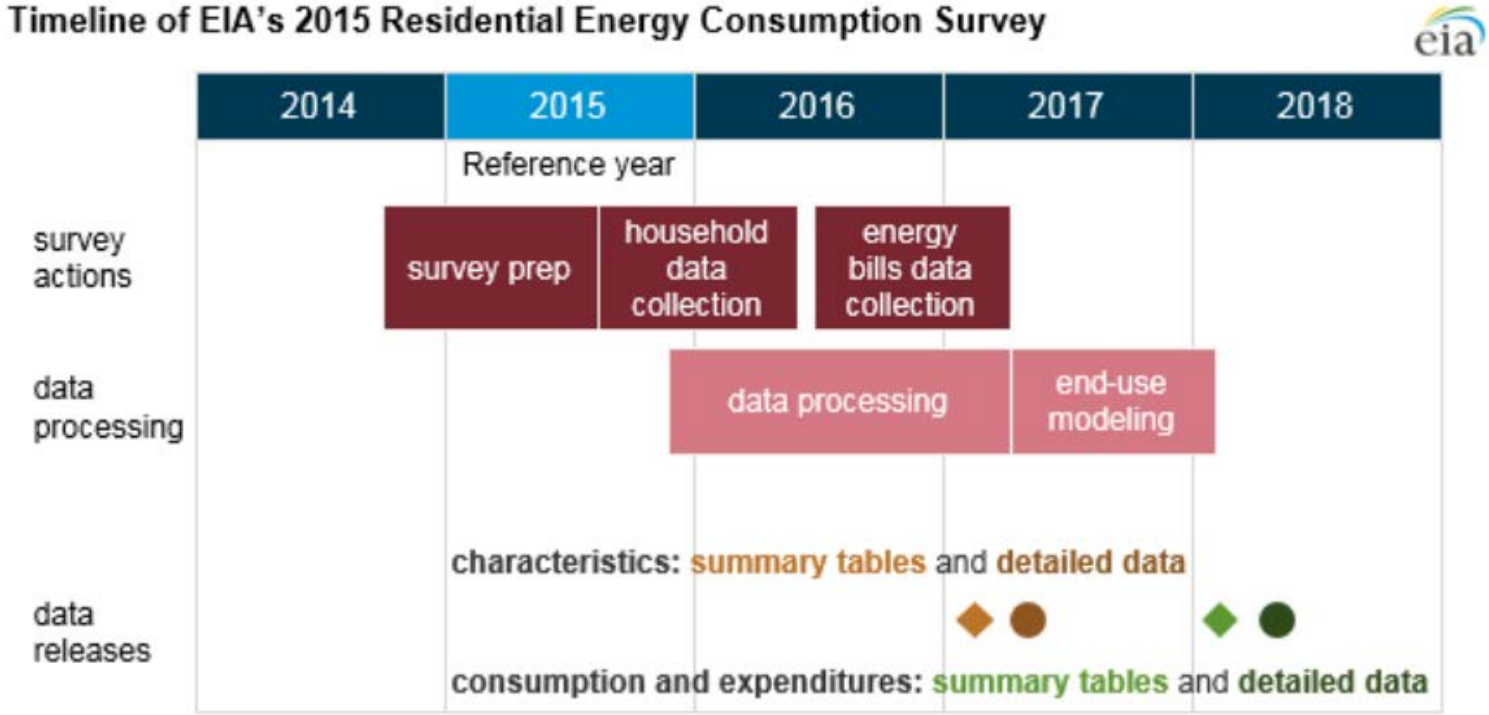
Budget of the US EIA (美国能源信息署预算)



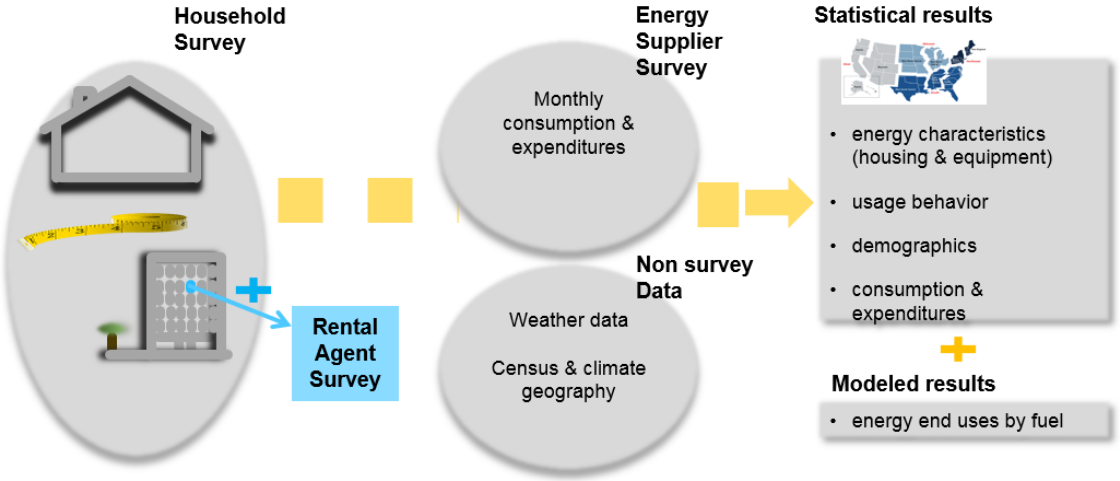
- Costs have risen to achieve the same or less success
  成本已经上升，达到相同或较小的成功
- Survey costs are rising faster than agency budgets
  调查成本上涨速度快于机构预算
- Budgets are flat in *real* economic terms
  预算在实际经济上是平稳的

Source/资料来源:OMB, Statistical Programs of the United States Government 美国政府管理和预算局，政府统计方案

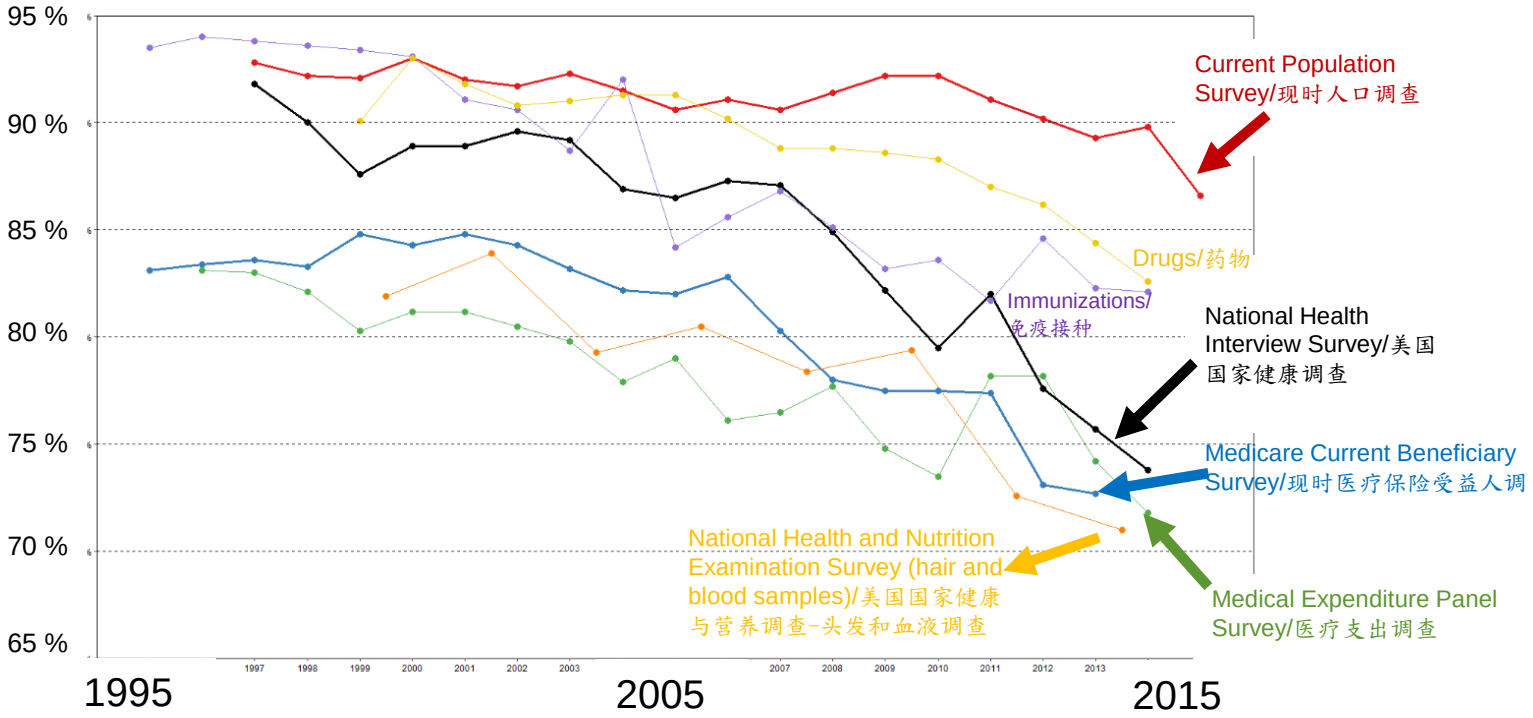
The typical consumption survey cycle is about 4 years
通常住宅能源消费调查周期约为4年



(another view)
通常住宅能源消费调查周期约为4年



Response rates in voluntary federal surveys are trending down
自愿性质的联邦调查问卷回应率正在下降



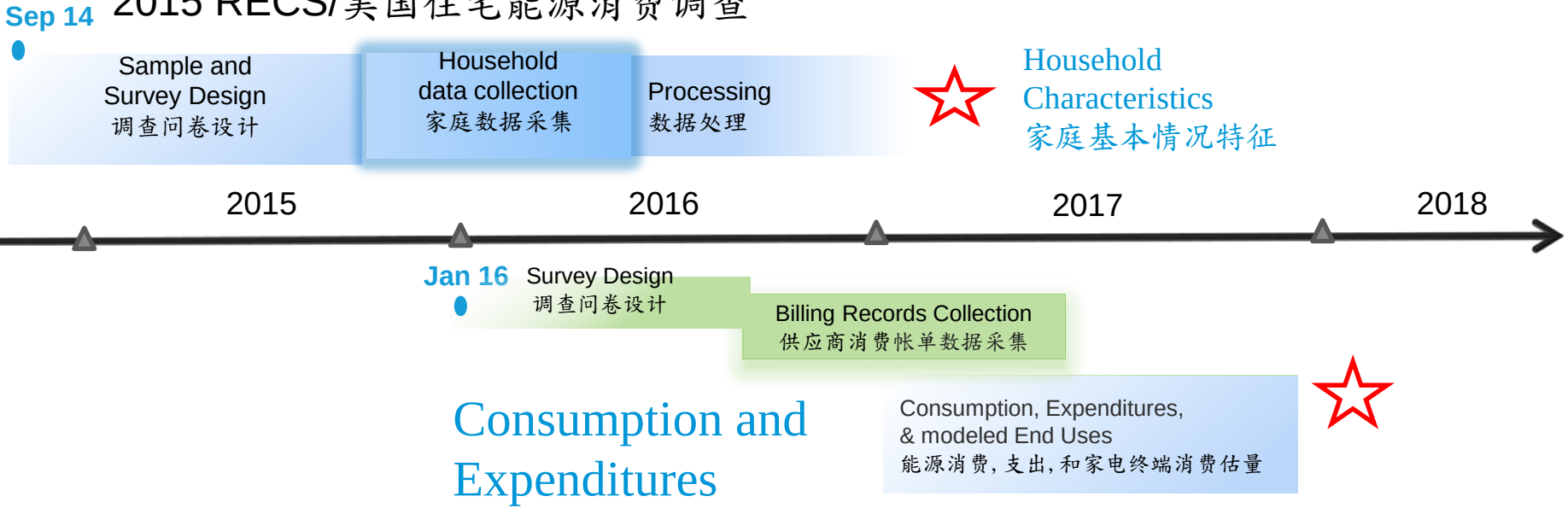
Czajka, J., & Beyler, A. (2016, July 15). Declining Response Rates in Federal Surveys: Trends and Implications (Working paper)

联邦调查问卷回应率的下降：趋势和影响（未发表的论文）

The principal threats to complex, periodic studies are timeliness and relevance. We don't produce useful results fast enough.

定期性复杂的调查研究主要的威胁是结论的及时性和相关性. 因为处理调查数据的时间比较长, 所以发布结果相对比较慢.

2015 RECS/美国住宅能源消费调查



We're testing passive measurement technologies for end uses
我们正在测试家电终端消费的测量技术

- So-called "NILMs" (Non-Intrusive Load Monitoring) are being evaluated for –
  正在评估非侵入负荷监测量技术–
  - Energy Efficiency, Demand Response, Measurement & Verification, Energy Audits, Appliance Diagnostics, Cost of Service, etc.
    能源效率，需求响应，测量和验证，能源审计，设备诊断，服务成本等。
- Research is being run by consultants, non-profits, academics, and a few utilities
  研究由咨询公司，非营利组织，学者和一些能源公用事业部门运作
  - Almost all extant work has been circuit-level metering, and not NILM methods
    几乎所有以前的研究都是电路级监视，而非侵入负荷监测量技术
  - Whole-Premise monitoring considered to be NILM by some but still requires home visit as well as a disaggregation algorithm
    虽然非侵入负荷监测量技术被认为是整体预测，但仍需要现场参观以及分解算法.
- *Residential sub-metering can be challenging* logistically
  *住宅分计量*在后勤方面可能具有挑战性
  - Complex stages: Planning, Design, Recruitment, Installation, Data Collection
    复杂的阶段：规划，设计，招聘，安装，数据收集
  - Expensive– costs thousands per housing unit, but more, timelier data is possible
    昂贵 – 每个房屋单位需要花费数千美元;但更多,更及时的数据是有可能的

EIA's has three goals for this pilot study of energy end uses
美国能源信息署对能源最终用途试点研究有三个目标

- Compare usage patterns between NILM device and respondent's self report, (e.g., number of clothes washer cycles
  比较非侵入负荷监测量技术与问卷受访者的自我报告的使用数据（例如，洗衣机周期的数量）
- Compare usage characteristics (e.g., self-reported versus observed water temperature for a clothes washer or heated drying for a dishwasher)
  比较使用特征（例如，洗衣机水温的自报测量或洗碗机的干烘选项）
- Compare actual consumption by end use to the RECS 2015 model results
  将家电终端实际消耗量与2015年模型结果进行比较

We'll prioritize the research in three tiers in preparation for the 2020 RECS
我们将会在三个优先研究结果上为2020年的家庭能源消费调查做准备工作

Priority	Products
Tier 1	Refrigerators, Dishwashers, Clothes Washers, Dryers, Cooking, Air Conditioning, Space Heating, Water Heating
Tier 2	Computers, Televisions, Home Entertainment
Tier 3	Lighting, Rare End Uses, Residual

Some lessons learned over 40 years of consumption studies
在40年的能源消费研究中获得的一些经验教训

- Start with good sample frames; tradeoff the value of covering the ‘whole’ population; define subpopulations sensibly—taxonomies matter.
  以良好的样本总体开始；权衡覆盖“整个”总体的价值；明智地定义亚群 – 分类学很重要。
- Innovate strategically—run pilots, measure and adjust strategies.
  创新战略运行试点，衡量和调整战略。
- Use surveys where respondents report well; augment, impute, and model elsewhere.
  使用受访者报告良好的调查;在其他地方扩充,推广和建模。
- Engage stakeholders before, during, and after data collection
  在数据收集之前,之中和之后与利益相关者讨论.

Technical references 技术资料参考

Recent modeling efforts

- Comparisons of Calibration Methods for the RECS Engineering End-Use Estimates — Shaofen Grace Deng, U.S. Energy Information Administration ; Greg Lawson , U.S. Energy Information Administration ; Chrishelle Lawrence, U.S. Energy Information Administration. Presented at the Joint Statistical Meetings, Baltimore (2017, July 31).

- Deriving Estimates for the Energy Consumption of U.S. Residential Space Conditioning Using Seasonal Datasets —William Lawson, U.S. Energy Information Administration (EIA). Presented at the Joint Statistical Meetings, Baltimore (2017, Aug 3).

Related technical documentation for CBECS and RECS

- Residential Energy Consumption Survey (RECS) 2015 Technical Documentation Summary, U.S. EIA, May 2017.

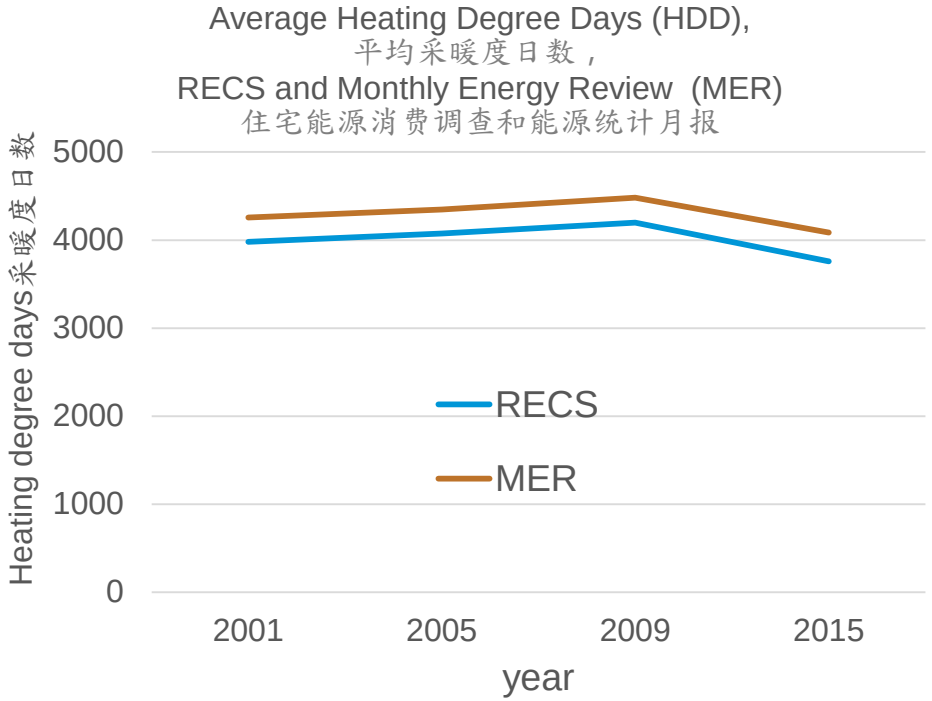
- 2015 RECS Square Footage Documentation Summary, U.S. EIA, October 2017.

- 2012 CBECS Methodology

- Lewis, Katie, “Exploratory Research on the Use of Google Earth to Create a Sampling Frame of Buildings,” U.S. Energy Information Administration, 2013 Federal Committee on Statistical Methodology (FCSM) Research Conference, Washington D.C. November 4-6, 2013.

Coming soon—RECS 2015 results!
2015住宅能源消费调查结果即将发布！

Analysis of the 2015 RECS shows the sample is representative. Good!
2015住宅能源消费调查分析显示该样本具有正确的代表性.



- Characteristics that correlate with energy consumption are representative (Example: Heating Degree Days)

  与能源消耗相关且具有代表性的特征（例如：采暖度日数）

- The process that annualized consumption was verified multiple times

  已多次验证年度能源消费总量

Improved models = more end uses from the 2015 RECS
改进的模型=2015年住宅能源消费调查的更多最终使用

- 2015 RECS results will include many more end uses, mostly for electricity, some for other fuels.

  2015住宅能源消费调查的结果将包括更多的最终使用，主要是使用电力，和使用其他燃料.

- End uses are still the result of modeled not measured results, however…

  最终使用仍然是建模的结果，不是测量的结果，但是...

The 2015 models include two major improvements:

2015的模型包括两项重大改进：

1) The models are now engineering-based. We use data from energy studies that had objective measures of end uses to inform engineering parameters

   这些模型现在是以工程为基础的模型. 我们使用来自能源研究的数据，这些数据以最终使用的客观测量来计算工程参数

2) Models use more energy characteristics information from the RECS Household Survey

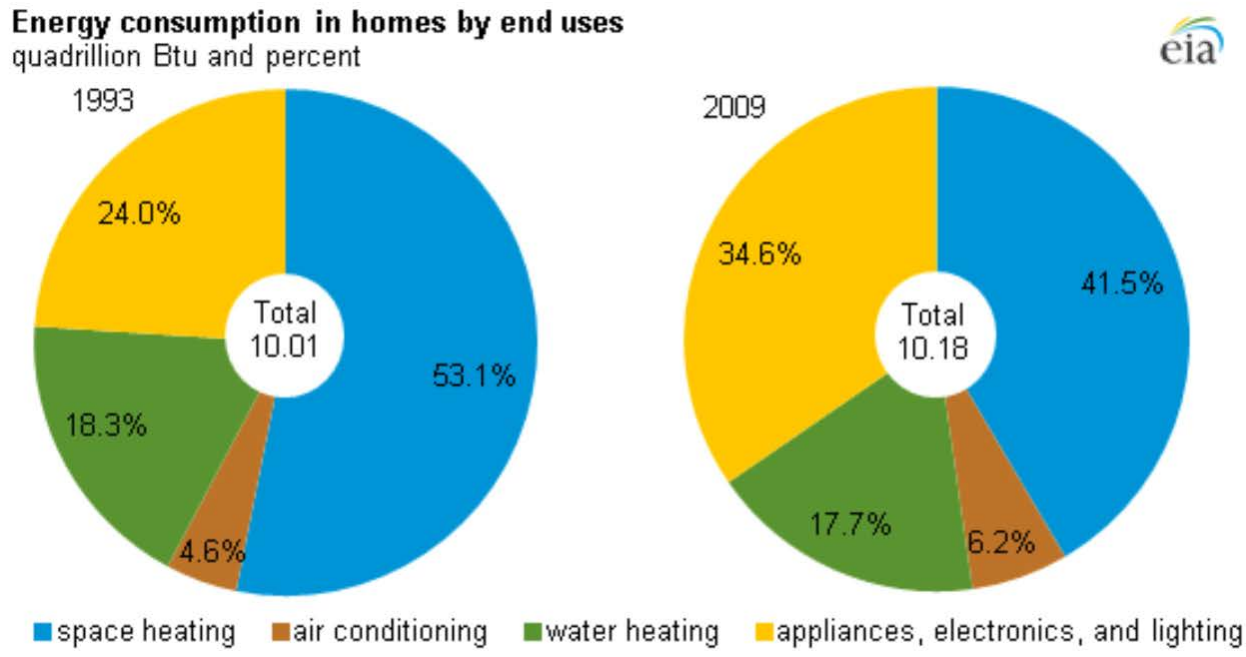
   模型使用住宅能源消费调查家庭调查中更多的能源特征信息

End-use estimation methodology improvements
终端用途估算方法的改进

	2009	2015
Modeling 模型	*Nonlinear Regression 非线性回归* Statistical models rely on including unknown parameters and finding their least square values 统计模型凭借着包含未知参数和他们的最小二乘回归值 → Models depend on billing data totals 模型取决于帐单数据的总计	*Engineering Models 工程模型* Engineering models rely on approaches and parameter values as can be found in published studies 工程模型凭借着在已发表的研究中找到途径和参数值 → No reliance on billing data totals 不需依赖帐单数据的总计
Calibration 校准	*Simple Normalization 简单的标准化* Modeled sums of end uses are calibrated to meet billing data totals by proration 最终使用的模拟总和是按比例分配以帐单数据总计来校准 → Every estimate is multiplied by the same value 每个估计值乘以相同的数值	*Minimum Variance Estimation 最小方差估计* Modeled end uses are accompanied by estimates of their uncertainties and correlations with other end uses 最终使用的模拟是以他们的不确定性并与其他最终使用相关性来估计 → The most uncertain estimates tend to get the largest corrections 最不确定的估计值将得到最大的修正

More information on submetering research
有关分表计量研究的更多报告

Residential end use shares, 1993 and 2009



Source: Today in Energy, March 7, 2013

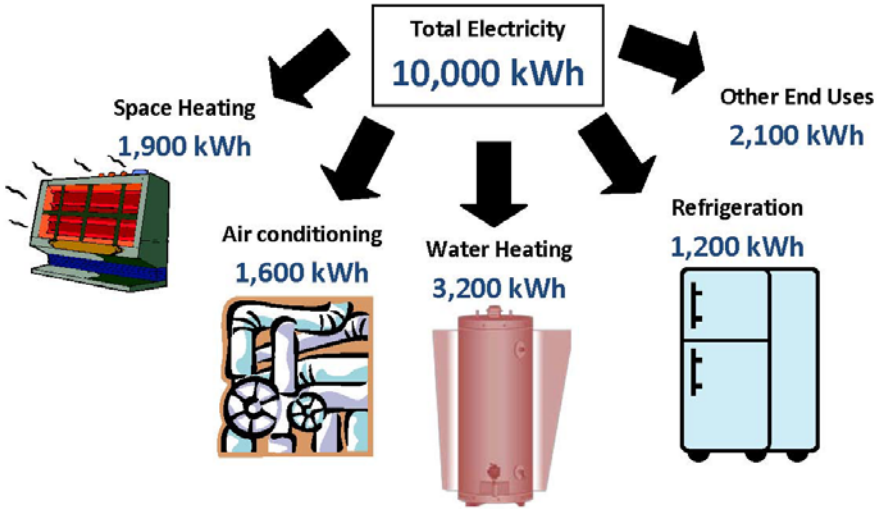
Goals of EIA Submetering Project
能源信息署评估分表计划项目的目标

- Simultaneous collection of characteristics and consumption data through use of whole home submetering technology
  通过使用全屋分表技术同时收集特性和能源消耗数据
- Validation of current RECS end-use models
  验证当前住宅能源消费调查的最终使用模型
- Collect data on more and smaller end uses (“miscellaneous” end uses)
  收集更多和更小的最终使用的数据（“杂项”的最终用途）
- Evaluate potential for submetering collection on a national basis
  评估在全国范围内进行分表测量收集的可能性
- Collect data on new, emerging energy-using products in the home in “real time”
  “即时”收集家中新兴的耗能产品数据
- Develop capacity to collect, process, and store large amounts of “real time” data
  开发收集，处理和存储大量“即时”数据的潜能

Traditionally, EIA had produced statistical **estimates** of end-uses
传统上, 能源信息署已经对最终用途进行了统计估计

- Knowing the *annual* total energy consumption for a specific fuel, decompose the number into the end uses that use that fuel, for example, space heating, air conditioning, water heating, and so on.

  了解特定燃料的年度能源消费总计, 将该数量分解为使用该燃料的最终使用;例如空间加热, 空调, 水加热等。



Published end uses by fuel are comprised of many subcomponents
公布的燃料最终使用由许多子部分组成

Fuel 燃料	2009 Modeled 2009 模拟数	2009 Published 2009公布数	2015 Modeled 2015 模拟数	2015 Published 2015 公布数
Electricity 电力	52	5	85	?
Natural Gas 天然气	13	3	18	?
Propane 丙烷	12	3	16	?
Fuel Oil 燃油	6	3	7	?

Submetering Technology Landscape – Established Technologies
分表技术景观 – 成熟的技术

- Plug-load Outlet Monitor:
  插入式插座监视器：

- Appliances plug into small monitor. The monitor plugs into wall outlet.
  电器插入小型显示器. 显示器插入墙上插座.
- End use is measured and recorded as electricity passes through the monitoring device.
  在电力通过监控设备时, 测量并记录最终用途的能源消费。

- Circuit-level Monitor:
  电路层级监视器

- Monitor is mounted near or inside a breaker panel.
  监视器安装在断路器面板附近或内部。
- This technology uses current transformers and line voltage to measure power and energy use for multiple electrical circuits.
  该技术使用电流互感器和线路电压来测量多个电路的功率和能源使用。

Submetering Technology Landscape – Innovative Technology
分表技术的特点 – 创新技术

- Whole-house Monitor with Load Disaggregation Algorithms:
  全屋监控的负载分解算法：

- Monitor is mounted near or within a breaker panel, and uses current transformers and measured line voltage to determine power and energy consumption at the electrical mains.
  监视器安装在断路器面板附近或内部，并使用电流互感器和测量线路电压来确定电力干线的功率和能量消耗。

- Electrical pattern detection algorithms are used to identify electrical signatures of specific appliances and other loads.
  电气模式检测算法用于识别特定电器和其他负载的电气特征。

Proposed Timeline – residential submetering
建议的时间表 – 住宅分表计算

- Oct 2017 – April 2018 – EIA partners with US Energy Department's Pacific National Lab, selects technology, recruits households
  能源信息署与美国能源部太平洋国家实验室合作，选择技术，招募家庭
- Apr 2018 – Begin installation on 8 homes *(Small Pilot)*
  开始安装8个家庭（小试点）
- Sept 2018 – Begin installation on additional 80 homes *(Large Pilot)*
  开始安装额外的80个家庭（大型试点）
- Nov 2018 – Begin evaluation of "*Tier One" end uses*
  开始评估"第一层次"的最终使用能源
- May 2019 – Complete one full year of submeter data collection
  完成一次分表计算数据收集
- Jan 2020 – Update *household questionnaire* for RECS 2020
  更新 2020 住宅能源消费调查的家庭问卷
- Sept 2020 – Potentially include submeter data collection in RECS 2020
  可能包括 2020 住宅能源消费调查中的分表计算数据收集
- Jan 2021 – Apply results to RECS 2020 *end use models*
  将结果应用于 2020 住宅能源消费调查最终使用模型

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Quadrennial RECS + rotating panel of submetered homes. Add 500 submetered homes each year; keep in panel 5 years.

Submetering Cohort year	RECS 2020	2021	2022	2023	RECS 2024	2025	2026	2027	RECS 2028	2029
2020 *(2028)*	500	500	500	500	**500**				**500**	500
2021 *(2029)*		500	500	500	**500**	500				500
2022 (…)			500	500	**500**	500	500			
2023				500	**500**	500	500	500		
2024					**500**	500	500	500	**500**	
2025						500	500	500	**500**	500
2026							500	500	**500**	500
2027								500	**500**	500
Total	500	1,000	1,500	2,500	**2,500**	2,500	2,500	2,500	**2,500**	2,500
					+					
RECS (50 states)	**25,000**				**25,000**				**25,000**	

Transformation of “RTECS”

residential transportation energy consumption survey

Measurement goal

- To reinstate a residential transportation data program to inform transportation programs and policy at a National and Regional Level

Data to collect

- **Transportation data –** vehicle miles traveled, vehicle type, miles per gallon (rural, interstate, on road, in-use), count of vehicle(s) on the road, number of vehicles sold, and the number of alternative fuel vehicles.
- **Energy related data –** type of fuel consumed, type of fuel sold, price of fuel, inventory of fuel, alternative fuel locations, and energy consumed by Kw/h (AFV)
- **Household or demographic data –** population of the capture area, employment makeup (number of employed and unemployed), income, household size, how many children, age, sex and location (zip code) of participants of the study.

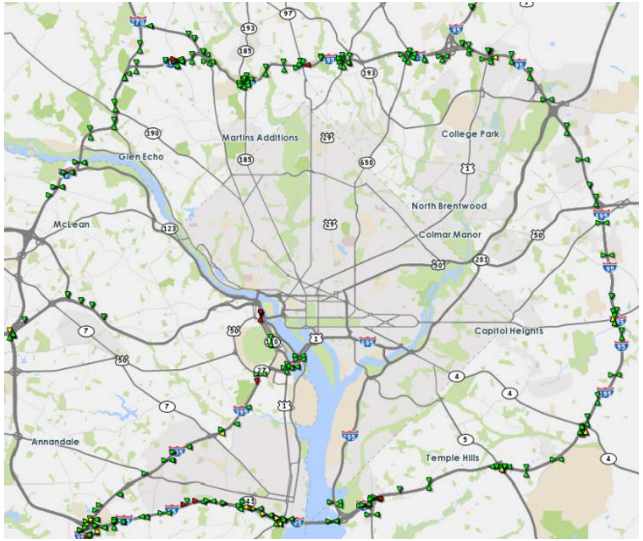
Consideration of using “data loggers” to passively collect data

- Methodology – new data collection method, but commercially available
- Cost – high relative to basic survey methods
- Data velocity, volume, - Could be as frequent as we want
- Positive – Minimal burden to household respondents
- Negative– Household acceptance, concerns about privacy or being “tracked”
- Value – High. “Big data” could offer high volume, timely data to make regular even real-time updates to transportation models

Tracking travel – what is this?

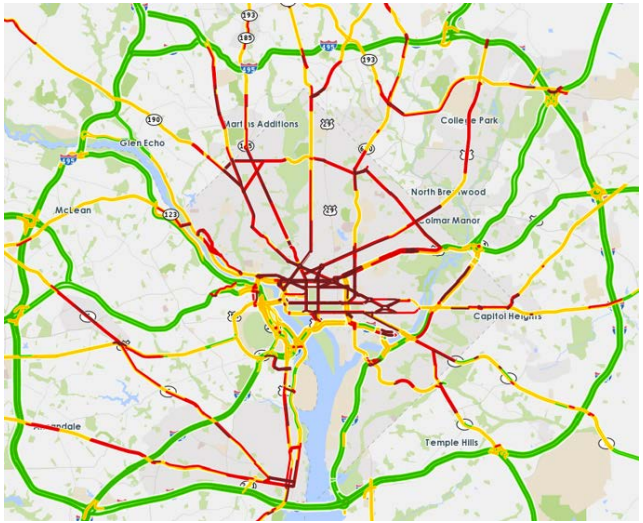
Sensor Data Availability

- To the right, is a network of sensors within the I-495 Beltway for Washington D.C.
- These sensors capture everything from speed to volume on the corridor in which they are located.
- For our purposes, we want to capture speed for an area, here “The Beltway”.
- From the speed collected, we want to make a network model of what a typical scenario would look like (Rush Hour, 15 Minute time Period, Holiday, etc)



Visualization of Sensor Data into Speed Data

- Develop a ‘speed model’ within an area
- Apply other data sets to estimate daily commuter and vacationer share within area
- For given time frames, combine key metrics such as vehicle miles traveled, speed, congestion, fuel pricing, other data to derive consumption and expenditures
- Goal: develop a “real time” data dashboard of typical travel for a local area, with modeled estimates of energy consumption and expenditures



Speed: Current speed of the segment in MPH

Green: Speed is above 50MPH

Yellow: Speed is between 25MPH and 50MPH

Red: Speed is between 15MPH and 25MPH

Dark Red: Speed is below 15MPH