Title

Benefits of a National Survey on Water Demand: Existing Data and Reporting Recommendations

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Publication Date

2024-01-04

Peer reviewed

BENEFITS OF A NATIONAL SURVEY ON WATER DEMAND

Existing Data and Reporting Recommendations

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December 2017

This work was supported by the U.S. Environmental Protection Agency, Water Infrastructure Division, Office of Wastewater Management, Office of Water, under Lawrence Berkeley National Laboratory Contract No. DW-89-92387801-3.

BENEFITS OF A NATIONAL SURVEY ON WATER DEMAND: EXISTING DATA AND REPORTING RECOMMENDATIONS

ABSTRACT

The nation faces tremendous costs required to maintain and improve its water and wastewater infrastructure. Effective management of water delivery and treatment systems would benefit from a regular national water demand data collection effort that captures consumption by economic sector as well as by end use. A water demand survey would provide the data necessary to better understand water demand trends, and ultimately to assess implications for water infrastructure needs and the U.S. economy. This report summarizes current publicly available water demand information and recommends data parameters for a national water demand survey.

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1 INTRODUCTION

The federal government has a long history of filling critical information gaps to enable effective oversight of public resources. More specifically, it has recognized the need to collect and analyze resource demand data to make informed decisions regarding policy priorities and funding allocations. For example, in the 1840s—as the country was expanding westward and new technologies enabled the move from subsistence farming to export crops production—the Census Office (moved under today's Department of Commerce and renamed the Census Bureau in 1905) was charged with conducting the first agricultural census in order to track land use and to measure trends and new developments in the nation's agricultural sector.[1] The Department of Agriculture has since assumed responsibility for this census, collecting and analyzing data on the agricultural sector, which annually contributes $992 billion to the national gross domestic product.[2] Another example can be seen in the early 1970s, when world oil prices quadrupled, shocking the stability of global economies.[3] With the volatility of oil prices and the necessity for better planning to discern how the U.S. economy uses energy resources, Congress established the Department of Energy[4] (DOE) in 1977 and charged it, in part, with the collection of energy demand data for the residential, commercial, and manufacturing sectors of the nation's economy.[5] Energy survey objectives are stated in the Federal Energy Act of 1974 as including assessment of the "adequacy of energy resources to meet demands in the immediate and longer range future for all sectors of the economy and the general public; and the collection, evaluation, assembly, and analysis of energy information on reserves, production, demand, and related economic data."[6]

The nation faces a pressing challenge of meeting water demand for a growing population in the face of aging water and wastewater infrastructure. This infrastructure requires significant improvements and expansion to reliably deliver and treat the nation's water resources, as well as to handle the resulting wastewater. Estimates of needs from the U.S. Environmental Protection Agency (EPA) range from $271 billion for wastewater infrastructure[7] to $384 billion for drinking water infrastructure[8] improvements. Although both EPA surveys are characterized as 20 year needs, they more likely reflect needs over five to seven years, consistent with capital improvement planning timeframes. Industry estimates of needed improvements to water infrastructure are estimated at $1 trillion over the next 25 years.[9] Water infrastructure affects every sector of the United States economy. Each day more than 350 billion gallons of water—

[1] Census of Agriculture Historical Archive, http://agcensus.mannlib.cornell.edu/AgCensus/homepage.do;jsessionid=AAB50E54F2460EE4041B6EBE0B74EA1E
[2] U.S. Department of Agriculture Economic Research Service, Ag and Food Sectors and the Economy, https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy.aspx
[3] U.S. Department of State, Milestones, Oil Embargo 1973-1974, https://history.state.gov/milestones/1969-1976/oil-embargo
[4] U.S. Department of Energy, A Brief History, https://energy.gov/management/office-management/operational-management/history/brief-history-department-energy
[5] 42 U.S. Code § 7135 - Energy Information Administration, https://www.law.cornell.edu/uscode/text/42/7135
[6] 15 U.S.C.764(b), https://www.law.cornell.edu/uscode/text/15/764
[7] U.S. Environmental Protection Agency (2016), EPA Survey Shows $271 Billion Needed for Nation's Wastewater Infrastructure, https://www.epa.gov/newsreleases/epa-survey-shows-271-billion-needed-nations-wastewater-infrastructure
[8] U.S. Environmental Protection Agency (2013), Drinking Water Infrastructure Needs Survey and Assessment: Fifth Report to Congress. https://www.epa.gov/drinkingwatersrf
[9] American Water Works Association (2010), Buried No More: Confronting America's Water Infrastructure Challenge. http://www.awwa.org/Portals/0/files/legreg/documents/BuriedNoLonger.pdf

almost 130 trillion gallons annually—are withdrawn from surface water and groundwater sources for use in residences, commercial and institutional buildings, manufacturing and industry, electrical energy production, agriculture, livestock, mining, and aquaculture.[10]

Despite water shortages caused by drought and these unmet and burgeoning water infrastructure needs, little is known on the national scale of water demand within each economic sector. One of the few ongoing federal government water data collection efforts is the U.S. Geological Survey (USGS) survey of water supply information and broad-stroke data on the country's water use, categorized by economic sector and conducted every five years. Another is the comprehensive Department of Agriculture's Farm and Ranch Irrigation Survey (FRIS) of irrigation water use, categorized by crop type and irrigation application method and conducted every four years (see Appendix B). In addition, the U.S. Energy Information Administration (EIA)'s Residential Energy Consumption Survey (RECS) and Commercial Buildings Energy Consumption Survey (CBECS) have recently begun collecting water consumption data, but these efforts are intermittent and narrowly focused. The utility of non-national studies, such as the Water Research Foundation's *Residential End Uses of Water*, is limited by collection frequency, sample size, and geographical coverage.[11] However, collecting and publishing national water demand data, with level of detail similar to that in the EIA surveys, would allow for the development of metrics to gauge the water use and efficiency in buildings across economic sectors in the same manner the EIA survey instruments have enabled energy metrics and analysis.

Establishing a regular national water demand data collection effort that captures consumption by economic sector as well as by end use[12] would provide the robust data necessary to assess implications for the U.S. economy from water infrastructure needs and changing water demand. Further, it would enable the innovation, efficiency, and sound policy making at local, state, regional, and national levels that will be required to meet the water-dependent economic challenges ahead. At the national level, seven federal departments and agencies fund multiple programs (summarized in Appendix A). These programs provide financial and technical assistance for developing or treating water supplies for public and industrial use, and for increasing water supply by establishing or suggesting efficiency levels for end-use equipment. These programs would be more effective and efficient with access to robust, time series water demand data.

This paper assesses currently available national, regional, and local surveys or databases that collect water demand (and related) data. Given that the data required for proper water management vary by sector, this paper is organized with a focus on three sectors: residential, commercial/institutional, and manufacturing/industrial.[13] The paper then draws upon this review

[10] U.S. Geological Survey, Total Water Use (2010), https://water.usgs.gov/watuse/wuto.html
[11] AWWA Research Foundation, Residential End Uses of Water. 1999. http://www.waterrf.org/PublicReportLibrary/RFR90781_1999_241A.pdf and Water Research Foundation, Residential End Uses of Water. 2016. https://www.waterrf.org/PublicReportLibrary/4309A.pdf
[12] "End use" is defined here as a water-using fixture or type of equipment (*e.g.*, toilet or faucet).
[13] This value is calculated from the chart at https://water.usgs.gov/watuse/wuto.html; public supply (12 percent), self-supplied domestic (1 percent), and self-supplied industrial (4 percent)—which together map to the sectors mentioned in the text—and excludes thermoelectric power, irrigation, livestock, aquaculture, and mining. While irrigation's share is around one third of withdrawals, the existing FRIS already provides appropriate data collection for this sector. This survey is summarized in

to summarize the essential data to collect in order to ensure that the data and analyses that a national survey on water consumption could enable would be useful to the variety of stakeholders likely to employ them. Ultimately, a federal survey could address the broader need to appropriately fund water infrastructure, supply, and efficiency programs on the federal, regional, state, and local levels.

2 SUMMARY OF CURRENT AND PREVIOUS SURVEYS, DATABASES, AND STUDIES

To explore possible pathways for the collection of national water consumption data, this section highlights efforts to collect data on water use and consumption across the United States by economic sector and, where available, by geographical coverage. The surveys, databases, and studies presented here vary considerably by their size, scope, objective, approach, types of data collected, and data availability. Some are long-running, large-scale national surveys, while others are more narrowly focused, one-time municipal efforts. Each has taken a varied approach to data collection and reporting of results.[14] Table 2.1 highlights the different areas of focus that each survey, database, or study contains, including the following eleven characteristics:

- General Information
  - Description: indicates study name
  - Sector: includes residential, commercial, and manufacturing/industrial
  - Geographic Range: covers the entire nation, a region, a state, multiple cities, or a single city
  - Frequency: indicates whether study is conducted on a regular basis (more than once)
- Parameters
  - Demographics: collects data on household characteristics (*e.g.*, age, number of occupants, race)
  - Building Characteristics: collects data on building characteristics (*e.g.*, age, square footage)
  - Inventory of Product Stock: quantifies/produces an inventory of water-using equipment, products, and devices
  - Characterization of Product Stock: characterizes the product stock (*e.g.*, collects data on efficiency, age, brand, make, model, etc.)
  - Characterization of Consumer Use/Interaction: characterizes consumer use/interaction of product stock (*e.g.*, number of laundry loads per week, average shower duration)
  - Measured Water Use/Consumption: evaluates measured water data (either through its own metering efforts or available billing data)

Appendix B. Thermoelectric water use is almost one half of withdrawals; a related DOE survey, Annual Electric Utility Survey, is also summarized in Appendix B.

[14] The Water Research Foundation (http://www.waterrf.org/knowledge/water-efficiency/Pages/default.aspx) has funded many of the studies mentioned in this report and has published many more useful studies that were not included here because the report or data were not publicly available. The Alliance for Water Efficiency (http://www.allianceforwaterefficiency.org/) is also a rich resource for water demand information.

- Conservation Assessment: evaluates conservation attitudes and awareness, behavior, or participation in conservation/rebate programs

In the sections below, each study is summarized briefly and then detailed more extensively in a table that highlights the eleven parameters identified in Table 2.1, as well as:

- Scope: further disaggregates the surveyed population (*e.g.*, for residential, indicates single-family residences, or homes that participated in rebate programs, etc.)
- Methodological Approach: briefly describes the methodological approach employed
- Objectives: describes the study objectives
- Information Access: details the level of public access and the format of study results and data

Most of the included studies relate to residential water use. The following sections are organized by sector: residential, commercial, and manufacturing/industrial.

Table 2.1 Summary of Reviewed Surveys, Databases and Studies

Section #	Description	Sector *R = Residential* *C = Commercial* *MI = Manufactur-ing/Industrial*			Geographic Range*	Frequency (Conducted >1)	Demographics	Building Characteristics	Inventory of Product Stock	Product Stock Characterization	Characterization of Consumer Use	Measured Water Consumption	Conservation Assessment
		R	C	MI									
2.1	U.S. Geological Survey	X	X	X	N	X			X			X	
2.2.1	Residential Energy Consumption Survey	X			N	X	X	X	X	X	X		
2.2.2	Commercial Buildings Energy Consumption Survey		X		N	X	X	X				X	
2.2.3	American Housing Survey	X			N	X	X	X	X				
2.2.4	Fannie Mae Multifamily Energy and Water Survey	X			N		X	X	X			X	
2.2.5	Residential End Uses of Water – 1999	X			M	X	X	X	X	X	X	X	X
2.2.6	Residential End Uses of Water – 2016	X			M	X	X	X	X	X	X	X	X
2.2.7	Commercial and Institutional End Uses of Water		X		M								
2.2.8	Analysis of Water Use in New Single-Family Homes	X			M		X	X	X	X	X	X	X
2.2.9	California Single-Family Water Use Efficiency Study	X			M		X	X	X	X	X	X	
2.2.10	East Bay MUD Water Conservation Market Penetration Study	X	X		M	X	X	X	X	X			X
2.2.11	Seattle PU – Study of Market Penetration of Water-Efficient Fixtures	X			C		X		X	X	X	X	
2.2.12	Seattle PU – Residential Water Conservation Benchmarking Survey	X			C		X	X	X	X		X	X
2.2.13	Albuquerque Single-Family Water Use Efficiency and Retrofit Study	X			C		X	X	X	X	X	X	X
2.2.14	North America Residential Water Usage Trends Since 1992	X			C		X	X	X	X	X		
2.2.15	Analysis of Residential Water Use for 17 Communities in Utah	X			M		X		X	X	X		
2.2.16	Outdoor Residential Water Use in Texas	X			M							X	
2.2.17	Toilet Replacement Programs	X	X		S				X	X			
2.2.18	Toilet Saturation Estimates in the U.S.	X			N				X	X			
2.2.19	Water Conservation: Customer Behavior and Effective Communication	X			N					X			X

Section #	Description	Sector *R = Residential* *C = Commercial* *MI = Manufactur-ing/Industrial*			Geographic Range*	Frequency (Conducted >1)	Demographics	Building Characteristics	Inventory of Product Stock	Product Stock Characterization	Characterization of Consumer Use	Measured Water Consumption	Conservation Assessment
		R	C	MI									
2.3.1	Manufacturing Energy Consumption Survey			X	N	X							
2.3.2	Industrial Water Survey [Canada]			X	N	X				X	X	X	X

*** N = National; S = State; M = Multiple Cities; C = City**

2.1 All Economic Sectors

The United States Geological Survey (USGS) manages the most comprehensive national water use survey, with data collected from state water agencies, which covers multiple economic sectors and aggregates state demand and supply data by water source: surface water or groundwater, fresh and saline. This data collection effort has been conducted since 1950, and is the longest-running compilation of water use data by a federal agency in the United States. The survey enables assessment of water use by source across different geographic regions and economic sectors. However, the survey does not disaggregate public supply[15] water use by building type, nor does it contain any information regarding water consumption by demand end uses (*e.g.*, product types such as irrigation devices or domestic water-using products).

Estimated Use of Water in the United States	
General	
Sponsoring Organization	USGS, Department of Interior
Sector	Residential, commercial, manufacturing/industrial
Scope	Economic sectors including public supply, self-supplied domestic, livestock, irrigation, thermoelectric power, self-supplied industrial, mining, commercial,[16] and aquaculture.
Geographic Range	United States (nationwide)
Year(s)	1950–2010[17]
Frequency	Every 5 years
Objective(s)	The series of 5-year national water-use estimates is one of the few sources of information about regional and national trends in water withdrawals. Estimates of water withdrawals enable the depiction of trends in total water use for the nation among different geographic areas, categories of use, and sources over time.
Methodological Approach	These data included site-specific well, surface-water intake, and distribution-system information on a state level. Data in the report may have been derived from reported, estimated, or calculated means using different sources and methods.
Information Access	Summary tables publicly available, https://water.usgs.gov/watuse/
Parameters	
Demographics	N/A
Building Characteristics	N/A
Inventory of Product Stock	N/A
Characterization of Product Stock	N/A

[15] USGS defines public supply as "water [delivered to] users for domestic, commercial, and industrial purposes. Part of the total is used for public services, such as public pools, parks, firefighting, water and wastewater treatment, and municipal buildings, and some is unaccounted for because of leaks, flushing, tower maintenance, and other system losses. Domestic deliveries represent the largest single component of public-supply withdrawals." (https://water.usgs.gov/watuse/wups.html). Note that most industrial water use is via self-supply (https://water.usgs.gov/edu/wuin.html).

[16] Commercial water use was listed as a category only between 1985-1995.

[17] USGS published a report on October 31, 2017 "Public Supply and Domestic Water Use in the United States, 2015." This report was published in advance of the entire data set for 2015 and report for all sectors. https://pubs.usgs.gov/of/2017/1131/ofr20171131.pdf (Last viewed on November 30, 2017)

Characterization of Consumer Use/Interaction	N/A
Measured Water Consumption	The report provides measures of water supply and withdrawals (in thousand acre-feet per year) by state and economic sector, withdrawals by source and per capita.
Conservation Assessment	N/A

2.2 Residential and Commercial Sectors

The sections below summarize studies and databases that collect water data on residential and commercial use. Efforts may be national, span multiple census regions (Northeast, Midwest, South, and West), regional, or local. It is important to note that the list provided is not all-inclusive. There may be other utility-driven or academic reviews of water use at a more regional or local level that are not captured in the section that follows. Additionally, some utilities may collect and assess data as part of their demand forecasting efforts. There is currently no mechanism to collect those efforts into a larger dataset.

2.2.1 Residential Energy Consumption Survey

The Residential Energy Consumption Survey (RECS) is a long-running, federally sponsored survey that collects data on product, housing, and household characteristics related to energy demand for a nationally representative sample of housing units. Conducted since 1978, RECS features a large sample size, wide geographic range, and considerable data on household demographics, building characteristics, and other variables that can be used in conjunction with other information to estimate product stock and energy usage. RECS primarily addresses energy consumption and energy end uses. However, data are collected for some end-use devices that also use water: dishwashers and clothes washers. These data can be used to estimate national product stock. The national product stock of other indoor water end uses can be estimated from certain housing characteristics (*e.g.*, numbers of full and half-bathrooms for numbers of toilets, faucets, and showerheads), and, for one year (RECS 2005), data were collected for outdoor irrigation devices. This data is available across a wide range of variables. However, RECS collects only limited data on water use, and does not estimate total water consumption or consumption by end use, as it does for some energy end uses.

Residential Energy Consumption Survey	
General	
Sponsoring Organization	U.S. Energy Information Administration (Form-457)
Sector	Residential
Scope	Homeowners & renters, all residential unit types
Geographical Coverage	United States (nationwide)
Year(s)	1979–2015
Frequency	Every 4–6 years
Objective(s)	To provide timely information about energy consumption and expenditures of U.S. households and about energy-related characteristics of these households. RECS data is often used to meet future energy demand and improve efficiency and building design.
Methodological Approach	RECS is composed of two surveys. The Household Survey collects data on energy-related characteristics and usage patterns of a nationally representative sample of housing units. For renters that do not directly pay

	for their energy usage, a supplementary Rental Agent Survey is conducted. The Energy Supplier Surveys (ESS) collect data on how much electricity, natural gas, propane/LPG, fuel oil, and kerosene were consumed in the sampled housing unit during the reference year. It also collects data on actual dollar amounts spent on these energy sources.
Information Access	Publicly available summary tables, https://www.eia.gov/consumption/residential/
Parameters	
Demographics	• Geographic location • Age • Race • Income • Number of persons per household
Building Characteristics	Residential unit type (single-family detached, single-family attached, multi-family, or mobile home).
Inventory of Product Stock	Toilets, showerheads, and faucets can be estimated from numbers of bathrooms, RECS 2005 included data on irrigation.
Characterization of Product Stock	• Dishwasher age • Clothes washer age and type (front- or top-loading)
Characterization of Consumer Use/Interaction	• Frequency of dishwasher use • Most-used dishwasher cycle type • Clothes washer usage (number of loads per week) • Typical water temperature setting for clothes washer wash and rinse cycles
Measured Water Consumption	N/A
Conservation Assessment	For energy-using products only

2.2.2 Commercial Buildings Energy Consumption Survey

The Commercial Buildings Energy Consumption Survey (CBECS) is a long-running, federally sponsored survey designed to capture commercial building energy consumption and expenditures across the U.S. Although it has been conducted almost every four years since 1972, it only recently (in 2007) began collecting data on commercial building water consumption from water utilities. CBECS provides a bird's-eye view of how the large (>200,000 square feet) commercial buildings sector uses water. Within this sector, CBECS indicates the average water use and intensity by the building's primary activity, square footage, census region, and occupancy, along with other variables. The survey does not attempt to inventory or characterize the product stock of water-using devices, but does inquire whether the building has a select number of water-using "activities/equipment" (*e.g.*, cooling towers, commercial ice makers, laundry).

Commercial Buildings Energy Consumption Survey	
General	
Sponsoring Organization	EIA (Form-871)
Sector	Commercial
Scope	Large commercial buildings >200,000 square feet. (The reporting rate for smaller buildings [for water consumption] was too low to build a satisfactory imputation model).
Geographical Coverage	United States (nationwide)
Year(s)	First conducted in 1972. 2007, 2012 (years with water data).
Frequency	Primarily every 4 years
Objective(s)	To provide statistical information about energy consumption and expenditures in

	U.S. commercial buildings and information about energy-related characteristics of these buildings
Methodological Approach	CBECS conducts on-site surveys, and also requests billing data from corresponding water (and electric) utilities. Most survey participants are able to provide outdoor water consumption, which is subtracted from the total water consumption figure to determine indoor water consumption. Water consumption for large buildings that cannot provide data is imputed using a non-linear regression model.
Information Access	Publicly available microdata and summary tables, https://www.eia.gov/consumption/commercial/
Parameters	
Demographics	Census region/division, number of employees
Building Characteristics	CBECS collects extensive information on building characteristics but only cross-tabulates a limited number of these variables (principal building activity [*e.g.*, office, food sales], square footage, and number of employees) against the water consumption data.
Inventory of Product Stock	CBECS does not quantify water-consuming fixtures, appliances, and equipment, but does identify buildings with "special activities/equipment" contributing to water use, including: • Cooling towers • Sterilizers/autoclaves • Commercial ice makers • Hot water • Laundry • Indoor swimming pools
Characterization of Product Stock	None
Characterization of Consumer Use/Interaction	None
Measured Water Consumption	Utilities provide water consumption estimates. CBECS focuses on indoor water use. Total volume (gallons per year), whether volume is metered or estimated, if sewer flow is metered, indoor and outdoor water use, & cooler tower (and size), if applicable.
Conservation Assessment	Inquires in the 2012 survey if participants are aware of the WaterSense program.

2.2.3 American Housing Survey

The U.S. Census Bureau's American Housing Survey (AHS) is a long-running effort that conducts biennial surveys of residential buildings in the U.S. in order to provide a continuous series of data on select housing and demographic variables. AHS has been conducted since 1973 and has a large sample size of more than 70,000 respondents. The survey has extensive demographic and building data, publicly available microdata for cross-tabulation with survey statistics, and a product inventory for the select end uses it captures. AHS provides an inventory of a number of water-consuming end uses, but does not attempt to estimate water use or characterize consumer interaction with such products.

American Housing Survey	
General	
Sponsoring Organization	U.S. Census Bureau
Sector	Residential
Scope	Single-family, multi-family residences

Geographical Coverage	United States (nationwide)
Year(s)	1973–2015
Frequency	Every 2 years
Objective(s)	To provide a current and continuous series of data on selected housing and demographic characteristics
Methodological Approach	The AHS employs two separate surveys- a National Survey (for regional and national-level estimates) and a Metropolitan Survey (for specific-area estimates). In 2011, rotating topical modules were introduced into survey to cover topics of special interest.
Information Access	Publicly available microdata and summary tables, https://www.census.gov/programs-surveys/ahs.html
Parameters	
Demographics	• Owner occupied • Race • Income • Age • Age of householder • Number total persons/children per household • Education level, citizenship • Year moved into unit • Disabled household member • Monthly housing costs • Region • Metropolitan/non-metropolitan areas • First-time homeowner
Building Characteristics	• Structure type • Year built • Number of stories • Building conditions • Number of total rooms, bedrooms, and bathrooms • Unit square footage • Lot size • Primary water source • Means of sewage disposal
Inventory of Product Stock	• Kitchen sink • Dishwasher • Washing machine • Plumbing facilities (or lack thereof) • Indoor sprinkler system
Characterization of Product Stock	AHS does not gather data on specific characteristics of water-consuming products, but does inquire about various issues, including: • Toilet breakdowns • Plumbing issues • Water leakage (overflowing/backed up fixtures, leaking pipes, broken water heater, other leaks)
Characterization of Consumer Use/Interaction	None
Measured Water Consumption	None
Conservation Assessment	None

2.2.4 Fannie Mae Multi-Family Housing Energy and Water Survey

In 2012, Fannie Mae conducted the Multifamily Energy and Water Market Research Survey. The survey aimed to understand national trends in energy and water consumption and costs at multifamily properties. More than 1,000 multifamily property owners and managers participated and provided data on household and housing characteristics, including energy and water consumption and costs from January 2011 through December 2011. Of the total responses received, 672 property personnel provided both energy and water data, and an additional 64 respondents provided water data only. Fannie Mae inventories a few water-consuming end uses,

but does not attempt to estimate water use or characterize consumer interaction with such products.

Fannie Mae Multifamily Housing Energy and Water Survey		
General		
Sponsoring Organization	Fannie Mae Multifamily Mortgage Business	
Sector	Residential	
Scope	Multifamily residences	
Geographical Coverage	United States (nationwide)	
Year(s)	2011	
Frequency	Once	
Objective(s)	To understand trends in energy and water consumption and costs at multifamily properties	
Methodological Approach	Mailed questionnaire and instructions on providing energy and water data	
Information Access	Publicly available report, https://www.fanniemae.com/content/fact_sheet/energy-star-for-multifamily.pdf Publically available data, https://www.fanniemae.com/content/tool/mewmr-survey-database.xlsx	
Parameters		
Demographics	• Primary resident population (general purpose housing, military, senior/independent, student, special needs) • Rent controlled or affordable	• Total persons by number of housing units • Region • State • Cooling degree days • Heating degree days
Building Characteristics	• Unit type (rental, co-op, condo) • Building type • Year built • Green building certification • Number of bedrooms and bathrooms	• Unit square footage • Lot size • Primary water source • Total irrigated area • Pool presence and location
Inventory of Product Stock	• Dishwasher • Laundry hookups	• Plumbing facilities (or lack thereof) • Irrigation area type
Characterization of Product Stock	Fannie Mae did not collect product stock characteristics for water-using products	
Characterization of Consumer Use/Interaction	None	
Measured Water Consumption	12 months of water data	
Conservation Assessment	None	

2.2.5 Residential End Uses of Water – 1999

The AWWA Research Foundation (now the Water Research Foundation) funded the Residential End Uses of Water (REU1999) study. Composed of a survey, billing data, metering, and flow trace analysis, the study employed a comprehensive approach to assess water end uses in select residential settings across North America. The study includes an inventory of product stock based on customer paper survey responses. While the survey's assessment of product usage patterns is limited, the sample size of more than one thousand households with metered end-use data ensure a robust assessment of end-use water consumption patterns. Additionally, while the survey sample is not representative of the nation, all water use data are representative of the

areas in which they are located. REU1999 collected data mostly in the West census region, as well as Florida. Similarities of water used by toilets, washing machines, showerheads, dishwashers, faucets, and fixture leaks across twelve study sites suggest these data have significant "transfer" value across North America.

Residential End Uses of Water – 1999		
General		
Sponsoring Organization	AWWA Research Foundation and American Water Works Association	
Sector	Residential	
Scope	Single-family homes	
Geographical Coverage	12 separate North American locations (14 cities) in AZ, CA, CO, FL, ON, OR, and WA	
Year(s)	1999	
Frequency	Conducted once	
Objective(s)	• Provide specific data on the end uses of water in residential settings across North America (US & Canada); • Assemble data on disaggregated indoor and outdoor uses; • Identify variations in water used for each fixture or appliance according to multiple factors; • Develop predictive models to forecast residential water demand.	
Methodological Approach	REUS employed billing records and a survey to collect data. At each study site, historic billing records were collected from a systematic random sample of 1,000 SFR accounts (12,000 residences total). The study also gathered household-level information through mail surveys from about 6,000 households. The survey attempted to create a statistically significant representative sample of customers for each of the 12 locations. (Not statistically representative of all North America). Data logging: 2 weeks in "summer" and 2 in "winter" seasons.	
Information Access	Publicly available MS Access database with historic water billing records, survey response data, and individual end-use water data (excluding water flow data) available from Water Research Foundation website, http://www.waterrf.org/PublicReportLibrary/RFR90781_1999_241A.pdf	
Parameters		
Demographics	• Number of full-time residents (winter and summer) • Age of full-time residents • Number of resident adults employed outside the home	• Rent vs. own • Rent payment • Home value • Education of primary wage earner • Gross annual household income
Building Characteristics	• Type of residence • Separate indoor/outdoor meters • Year built • Total square feet	• Number of floors • Greenhouse, flower garden, or vegetable garden • Swimming pool
Inventory of Product Stock	• Toilets • Bathtub • Bathtub with shower • Shower • Whirlpool bathtub with jets • Bathroom sink • Kitchen faucet • Indoor utility/garage sink	• Garbage disposal • Clothes washer • Dishwasher • Free-standing hot tub • Evaporative/swamp cooler • Pressure regulator • Home water treatment system attached to water system or faucet

Characterization of Product Stock	• Clothes washer manufacture year • Clothes washer brand • Clothes washer type (top- vs. front-loading) • Dishwasher manufacture year • Dishwasher brand • Low-flow showerheads • Ultra-low-flush toilets • Sprinkling system type, soil moisture sensor/rain system
Characterization of Consumer Use/Interaction	Survey compared logged use to end-use model predictions; survey asked about: • Frequency of hand-washing dishes • Irrigation behavior (extent, frequency, additional water sources), sprinkler system operation • Frequency of car-washing at home & using hose to clean sidewalks/ driveways
Measured Water Consumption	1,188 households with detailed end-use logged data collected over a 2-week period in summer and winter. End-use volumes are collected for: • Toilets • Showers • Baths • Faucets • Water treatment systems • Clothes washers • Dishwashers • Leaks • Outdoor • Other/unknown use
Conservation Assessment	• Responsibility for water bill • Importance of conserving water on a regular basis • Whether household had taken any action to conserve water (and what types of behavior) • Asks participating utilities if there had been rebate programs for particular water-using devices

2.2.6 Residential End Uses of Water – 2016

The Water Research Foundation funded the Residential End Uses of Water (REU2016) study. REU2016 is similar to REU1999, with the addition of expanded geographical scope, hot water use by appliance and per capita, as well as more detailed landscape analysis. REU2016 gathered data on single-family residential water billing from 23 sites, nine of which hosted end use data logging. Because study sites differed between the REU 1999 and REU 2016 studies and neither REU study was designed to be representative of all North American locations, comparing outdoor water use from REU1999 to REU2016 is inadvisable, considering the influences of climate and weather. However, it is appropriate to contrast indoor water use between these two studies.

Residential End Uses of Water – 2016	
General	
Sponsoring Organization	Water Research Foundation
Sector	Residential
Scope	Single-family homes
Geographical Coverage	LEVEL 1 STUDY SITES: Clayton County, GA; Denver, CO; Fort Collins, CO; Peel, Ontario; San Antonio, TX; Scottsdale, AZ; Tacoma, WA; Toho, FL; Waterloo, Ontario LEVEL 2 STUDY SITES: Aurora, CO; Austin, TX; Cary, NC; Chicago, IL; Edmonton, Alberta; Henderson, NV; Miami, FL; Mt. View, CA; New Haven, CT; Otay, CA; Philadelphia, PA; Portland, OR; Santa Barbara, CA; Santa Fe, NM Aquacraft collected billed data from 23,749 single-family residential accounts

	(from Level 1 and Level 2). Surveys to Level 1 households: 2,902 survey responses (out of 8,749). Surveys to Level 2 households: 1,741 returned (out of 5,000).
Year(s)	2016
Frequency	Conducted once
Objective(s)	• Collect and analyze current data on indoor end uses of water in SFR settings across North America (US & Canada), as well as outdoor water use patterns and efficiency levels; • Evaluate changes in water use patterns over a 15-year period [from REU1999]; • Identify variations in water used by each appliance or fixture; • Evaluate conservation potential; determine factors influencing residential water use and evaluate their relative impact; • Create predictive models to assess and predict residential demand; • Prepare an end-use database for use by future researchers, combining results from multiple studies, including REU2016.
Methodological Approach	Similar to REU1999 (see 3.1.6 above), but expanded scope and increased depth of analysis: included more varied site locations, collection of hot water end-use data, more detailed landscape analysis, and expanded water rates analysis. The data collection effort spanned 2010-2013 (2010: billing data; 2011-2013: mail survey; data logging 02/2012–01/2013). Nine hundred (100 from each of the nine Level 1 utilities) participated in detailed flow-trace monitoring, recording flow through each customer's water meter every 10 seconds for a period of about 14 days for over 1 year. High-level flow data were successfully obtained from 762 homes.
Information Access	Publicly available MS Access database provided for subscribing utilities, academic institutions, and other researchers via inquiry at Water Research Foundation. Database includes all end-use water events recorded during REU2016 study, along with survey response data, historic billing data, and other data obtained for each study site (excluding water flow data). http://www.waterrf.org/Pages/Projects.aspx?PID=4309 Database also includes summary results from other studies conducted by Aquacraft (and reviewed in this paper): Analysis of Water Use in New Single-Family Homes (www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=6020), California Single-Family Water Use Efficiency Study (http://www.aquacraft.com/2015/07/28/california-single-family-water-use-efficiency-study/), and Albuquerque Single-Family Water Use Efficiency and Retrofit Study. http://www.aquacraft.com/wp-content/uploads/2016/07/Albuquerque-Report-Exec-Summary.pdf
Parameters	
Demographics	• Number of full-time residents • Number of adult residents usually at home during the day on a weekday (i.e., not working outside home or full-time student) • Rent vs. own • Highest level of education in household • Annual household income
Building Characteristics	• Year built • Year current residents moved in • Number of bedrooms • Swimming pool
Inventory of Product Stock	• Toilets • Bathtub • Bathtub with shower • Shower • Whirlpool bathtub with jets • Garbage disposal • Clothes washer • Dishwasher • Free-stranding hot tub • Evaporative/swamp cooler

	• Bathroom sink • Kitchen faucet • Indoor utility/garage sink • Pressure regulator • Home water treatment system attached to water system or faucet
Characterization of Product Stock	• Low-flush, ultra-low-flush, dual-flush toilets • Number of showerheads/rain panels/body spray panels in shower • Whether toilets/showerheads/clothes washer/dishwasher have been replaced in past 10 years • Sprinkler system characteristics (automatic timer, WBIC, master valve, back-flow preventer, drip irrigation, SMS, rain sensor) • Swimming pool/spa characteristics (fill level, filling system type, cover type)
Characterization of Consumer Use/Interaction	Compared logged use to end-use model predictions; survey asked about: • Frequency of hand-washing dishes • Use of garbage disposal/clothes washer/dishwasher less frequently or use fuller loads • Waiting for hot water to reach fixtures (and associated time) • Irrigation behavior (frequency, manner, responsibility, additional water sources) • Sprinkler system operation • Water lawn/shrubs less often • Avoid watering mid-day • Low-water-use landscaping • Shorter runtimes on sprinklers • Monitor irrigation system for leaks/blown heads • Cycle irrigate lawns • Use graywater or rain barrel/cistern • Frequency of car-washing at home • Frequency of using hose to clean sidewalks/driveways
Measured Water Consumption	Similar to REU1999, with the addition of hot water use by appliance and per capita. End-use volumes were collected for: • Toilets • Showers • Baths • Faucets • Water treatment systems • Dishwashers • Clothes washers • Leaks • Outdoor • Hot water use • Other/unknown use
Conservation Assessment	• Importance of conserving water on a regular basis • Whether household had taken any action to conserve water (and what types of behavior) • Asked participating utilities about rebate programs for water-using devices • Water bill responsibility (household or landlord/HOA), including landscape irrigation responsibility • See “Characterization of Consumer Use/Interaction”, which characterizes use and efficiency efforts

2.2.7 Commercial and Institutional End Uses of Water – 2000

The AWWA Research Foundation and American Water Works Association funded the Commercial and Institutional End Uses of Water study. This report summarizes three general categories for water use in five commercial/institutional types. The three categories include indoor, cooling, and irrigation for schools, hotel/motel, offices, restaurants, and

supermarkets/food stores. A model enables water use estimates based on different parameters including number of employees and establishment square footage.

Commercial and Institutional End Uses of Water – 2000	
General	
Sponsoring Organization	AWWA Research Foundation and American Water Works Association
Sector	Commercial
Scope	Schools, hotel/motels, office buildings, restaurants, and food stores
Geographical Coverage	Irvine Ranch Water District (CA) Santa Monica Water Department (CA) Los Angeles Department of Water and Power (CA) San Diego Water Department (CA) Phoenix Water Department (AZ)
Year(s)	2000 (summary of data collected from other studies in 1980s and 1990s)
Frequency	Conducted once
Objective(s)	• Create database of existing CI water use information • Develop econometric end-use model • Develop water efficiency profile/benchmark for five CI customer categories
Methodological Approach	Two years of billing data and customer classification data for non-residential customers from participating utilities. A conditional demand analysis was used to model CI water demand and modified depending on data availability and independent variable specification. Field studies collected information about 5 selected CI categories (restaurants, hotel/motel, food stores, schools, office buildings) from surveys, water billing data, and flow-trace measurements.
Information Access	Report available: http://www.waterrf.org/PublicReportLibrary/RFR90806_2000_241B.pdf
Parameters	
Demographics	Number of employees in all categories Number of rooms in hotel/motel category Number of students/staff in school category Number of customers in restaurant and food store category
Building Characteristics	Primary building use categories • Schools and colleges • Hotels or motels • Office buildings • Restaurants • Supermarkets or food stores
Inventory of Product Stock	• Indoor use Bathtub Clothes washer Dishwasher Faucets Ice Machine Spray valve Shower Toilet Urinal Wash station • Cooling use Display fountain
Characterization of Product Stock	None
Characterization of Consumer Use/Interaction	Estimates of gallons per person per day given for indoor use by building type
Measured Water Consumption	Water volume totals were collected by building area for indoor water use, irrigation use, and cooling.
Conservation Assessment	• Conservation technology possibilities listed by end use, but no inventory of

	current implementation in study sites provided • Reasons provided for lack of implementation of conservation measures

2.2.8 Analysis of Water Use in New Single-Family Homes

The Salt Lake City Corporation and the U.S. EPA supported this study in 2011 to evaluate the changes in baseline water use in older homes, newer homes, and new "high-efficiency" homes. Specifically, the study sought to determine whether household water consumption has been reduced over the years via the use of high-efficiency devices. Generally speaking, the study provides insight into individual end uses and their characteristics, as well as water consumption profiles and distributions (including per capita consumption). The summary data also provide a comparison of disaggregated water use and water use efficiency rates between standard new homes and high-efficiency new homes, and can be contrasted to the REU studies (REU1999 and REU2016). While most of the study benefitted from surveying homes across several states in the U.S. with varied characteristics (*e.g.*, climate, average home size, etc.), the sample size for high-efficiency new homes was very small (22, vs. a planned sample size of 150 to 180 new homes) and limited to only two sites: Eugene, OR and Roseville, CA.

Analysis of Water Use in New Single-Family Homes		
General		
Sponsoring Organization	The Salt Lake City Corporation and U.S. EPA	
Sector	Residential	
Scope	Single-family homes	
Geographical Coverage	9 separate locations in the U.S. in AZ, CA, CO, FL, OR, and NV	
Year(s)	2011	
Frequency	Conducted once	
Objective(s)	• Measure baseline water use in "standard" new homes built after 1/1/2001 and in "high-efficiency" new homes built using WaterSense New Home specification or better, and compare to REU1999. • Determine whether household water use has declined over time through the use of high-efficiency devices/appliances. Assess major domestic end uses, both indoor and outdoor.	
Methodological Approach	Historic billing data was obtained from each participating water agency for 2 random samples of approximately 1,000 SFR accounts built before and after 1/1/2001 (over 17,000 homes total). A mail survey of all these customers was conducted (over 6,000 homes total). A sample of 50 standard new homes at each site was selected to participate in end-use measurement; study goal was to obtain data from 40 homes at each site. High-efficiency new homes selected via criteria that aligned closely with draft WaterSense New Home specifications. Agencies attempted to find about 20 high-efficiency new homes.	
Information Access	Summary data in REU2016 Access database available via inquiry at Water Research Foundation, www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=6020	
Parameters		
Demographics	• Number of full-time residents • Age of full-time residents • Number of adult residents employed full-time outside the home • Rent vs. own	• Rent payment • Market value of home • Highest level of education of primary wage earner • Annual household income
Building Characteristics	• Decade/year built • Year current residents moved in	• Attached/detached garage • Swimming pool

	• Number of bedrooms	• Septic system
Inventory of Product Stock	• Toilet • Bathroom sink • Shower without tub • Tub without shower • Whirlpool tub with jets, • Dishwasher	• Kitchen faucet • Indoor utility sink • Pressure regulator on main house service line • Hot tub • Water feature (*e.g.*, pond, fountain)
Characterization of Product Stock	• Ultra-low-flush toilets • Low-flow showerheads • Presence of handheld sprayer in shower • Clothes washer type (front-loading vs. top-loading) • Sprinkler system characteristics (broken heads, automatic timer, SMS/rain sensor, WBIC) • Swimming pool/spa characteristics (fill level, filling system type, cover type/months of use) • Energy source of water heater	
Characterization of Consumer Use/Interaction	• Wait for hot water to reach fixtures (and associated time) • Whether residents have installed remedy to eliminate/reduce hot water wait • Whether wait time bothers respondents • Landscape breakdown between turf, garden, other landscape plants • Irrigation behavior (frequency during summer vs. winter months dep. on landscape type, manner, responsibility, additional water sources) • Sprinkler system operation • Whether plumbing, bathroom fixtures, or kitchen fixtures had been renovated/replaced since 1995 • Leaks	
Measured Water Consumption	Continuous flow data collected for 2 weeks and analyzed using Aquacraft's flow trace software. Data loggers were installed on 40 standard new homes in each of 9 participating sites (450 total), as well as 22 high-efficiency new homes for indoor data logging (in Eugene, OR and Roseville, CA).End-use volumes collected included: • Toilet • Clothes washer • Shower • Faucet	• Leak • Other indoor • Bathtub • Dishwasher
Conservation Assessment	Survey covered conservation awareness and attitudes including: • How respondent felt about local water waste ordinances • Whether respondent knew amount of typical water bill • How much water household used, whether cost of water was important for quantity of indoor or outdoor use • Whether water conservation was done for environmental reasons • Whether respondent wastewater charges were included on water service bill, and if so if respondent considers cost of wastewater • Whether household or a landlord/HOA paid water bill	

2.2.9 California Single-Family Water Use Efficiency Study

The 2011 California Single-Family Water Use Efficiency Study characterized the water consumption habits in over 780 residential single-family homes serviced by 10 different water agencies across the state. The study conducted both water agency and customer surveys, and deployed data loggers to meter water consumption attributable to various water-consuming end

uses. A particular focus was given to evaluating indoor and outdoor water end uses based on detailed measurements, with the goal of better understanding the distribution of water use in single-family homes across California. The study also provides insight into where and how much water is used in California residential settings, and into the potential water savings that might yet be achieved from various conservation measures. To better understand and predict demand, the study produced predictive models to help utilities and agencies describe the relationship between water end uses and water consumption, as well as, household socioeconomic and demographic data. While no microdata are available, there are numerous relevant summary tables with descriptive data (*i.e.*, means, medians, and ranges for various parameters).

California Single-Family Water Use Efficiency Study	
General	
Sponsoring Organization	Aquacraft, the Pacific Institute, California Department of Water Resources, & Irvine Ranch Water District
Sector	Residential
Scope	Municipal: 10 different water agencies & 735 single-family homes within these agencies
Geographical Coverage	California (Sonoma County, Calabasas, Redwood City, San Francisco, Davis, East Bay, Los Angeles, Irvine, San Diego County, and parts of Costa Mesa, Lake Forest, Newport Beach, Orange, Tustin, Orange County).
Year(s)	2011
Frequency	Conducted once
Objective(s)	• Estimate water use efficiency by single-family customers • Develop baseline to be used to estimate remaining conservation potential • Collect information on rate of adoption and market penetration of high-efficiency fixtures/appliances • Develop baseline demand data for future studies • Collect information that can be used by water agencies to update urban water management plans and target resources for conservation effectively
Methodological Approach	Uses a 2-stage survey approach: • Customer Survey: Conducted to obtain information to use in the modelling of factors that affect residential water use. • Agency Survey: Conducted to determine what types of water conservation programs were in place for each utility during the study period, and whether there is an observable impact on water use. The survey collected data on an agency's climate & ET information (to determine irrigation requirements), customer base description/statistics, water supply & demand characteristics, historical consumption data (for estimation of indoor and outdoor demands), rate structure and water/sewer commodity charges and service fees, conservation program information. • Data loggers deployed to collect flow trace data, and flow trace analysis for different water-consuming end uses was conducted. • Using regression analysis, models were built for total indoor water use (gphd) and outdoor water use (kgal/year), and individual models were also built for the important end uses because variables that might not show up as significant for whole-house indoor use may be significant for individual end uses. • Predictive models developed using multiple regression techniques to examine the impact of a range of likely independent variables.
Information Access	The data outcomes as outlined above are typically presented in the form of tables with averages, ranges, medians, etc. or distribution plots. Microdata are

	not provided. http://water.cityofdavis.org/Media/PublicWorks/Documents/PDF/PW/Water/Documents/California-Single-Family-Home-Water-Use-Efficiency-Study-20110420.pdf	
Parameters		
Demographics	• Age • Number of children • Annual household income • Education • Percent of families below poverty level	• Housing value • Mortgage/rent • Employment • Percent of owner-occupied housing units • Number of persons per household • Number of bedrooms
Building Characteristics	• Construction year • Number of bedrooms • Garage	• Amount of turf in yard (%) • Septic system • Swimming pool
Inventory of Product Stock	• Toilets • Shower/bath tub • Jet tub • Indoor spa • Indoor garage/utility sink	• Garbage disposal • Washing machine type(top- vs. front-loading) • Dishwasher • Indoor water features • Irrigation system
Characterization of Product Stock	• Low-flow/flush toilets & showers • Age of end uses • Hot water wait time • Clothes washer type (front- vs. top-loading) • Bathtub description • Presence of handheld shower	• Multiple showerheads • Broken sprinkler heads • Automatic timer for irrigation system • Override shut-off device or SMS/rain sensor for irrigation system • Swimming pool filling system • Swimming pool cover
	While the survey did not inquire about rated product efficiency, the study developed efficiency criteria for clothes washers, showers, and toilets, and evaluated the % of products meeting that criteria based on their flow rate information gathered from data loggers.	
Characterization of Consumer Use/Interaction	• Consumer use of indoor water-consuming devices largely evaluated through metered data loggers • Frequency of watering turf/garden/landscape plants by season • Percent of landscape manually watered • Use of landscape contractor • Months of year swimming pool use	
Measured Water Consumption	Detailed flow trace data was obtained from portable data loggers which were attached to the water meters of each of the study homes. These flow traces provided readings at ten-second intervals, making it possible to identify individual water use events. The flow trace data indicated total gallons consumed per day as well as gallons per day for individual end uses such as toilet flushing, clothes washing, dishwashers, showers, irrigation, faucets and leaks.	
Conservation Assessment	• Opinions on water waste ordinances • Whether water cost or environmental reasons influenced household water use • Responsibility for water bill (household/landlord).	

2.2.10 East Bay MUD Water Conservation Market Penetration Study

In the mid-1980s, northern California's East Bay Municipal Utility District (EBMUD) set out to collect data that would provide clarity regarding customer conservation attitudes and behavior, the saturation of water-conserving hardware, and conservation potential. This study comprehensively characterizes both indoor and outdoor water conservation behaviors and expands the ability to make inferences about the market penetration of water-conserving hardware, the rate of hardware replacement, and customer behavior and attitudes. Summary tables are available for nearly all of the measures indicated in the "Parameters" section of the table below. Site studies were conducted to measure the flow rates of certain devices, but did not measure total consumption, nor report consumption by end use.

East Bay MUD Water Conservation Market Penetration Study	
General	
Sponsoring Organization	East Bay Municipal Utility District (EBMUD)
Sector	Residential & non-residential
Scope	Nine market sectors within EBMUD's service area: three residential (single-family, multi-family two-to-four units, and multi-family five or more units) and six non-residential (warehouses, retail, trade, food sales, fast food places, restaurants, and offices)
Geographical Coverage	California (cities and towns of Alameda, Albany, Berkeley, Danville, El Cerrito, Emeryville, part of Hayward, Hercules, Lafayette, Moraga, Oakland, Orinda, Piedmont, Pinole, part of Pleasant Hill, Richmond, San Leandro, San Pablo, San Ramon, part of Walnut Creek and the unincorporated communities of Alamo, Ashland, Blackhawk, Castro Valley, Cherryland, Crockett, Diablo, El Sobrante, Fairview, Kensington, North Richmond, Oleum, Rodeo, San Lorenzo and Selby)
Year(s)	1995, 1998, & 2001
Frequency	Conducted 3 times
Objective(s)	• Collect current data on water conservation attitudes and behavior • Determine the types and saturation of water-conserving hardware • Assess water conservation potential for identified market sectors • Relate the study findings to those of the previous studies.
Methodological Approach	The study conducted two types of surveys: Attitudes Survey: Telephone survey to assess water conservation attitudes and behavior (763 total). Site Surveys: Conducted for the single-family, multi-family, and non-residential sites (747 residential sites total, 536 non-residential sites total) in order to determine the types and saturation of water-conserving hardware, as well as consumer interaction with these products. The study also evaluated water conservation potential and fixture replacement rates. They were determined as outlined below: • Water conservation potential within the market sectors analyzed in the study was assessed from collected data and other sources. • Replacement rates: Survey data and studies on volume and frequency of fixture use were used to estimate the annual rates of total replacement and natural replacement of common water-using hardware with low-water use and high-efficiency hardware. Replacement rates were calculated by comparing the number of non-conserving fixtures in a base year (1991 for toilets, 1994 for other fixtures) with the number of the same fixtures at a later point in time.
Information Access	Extensive summary tables, but no microdata for custom analysis/cross-

	tabulation, http://www.ebmud.com/index.php/download_file/force/1464/1365/?market_penetration_study_0.pdf	
Parameters		
Demographics	• Number of persons per household • Occupant(s) age	• Tenancy/ownership • Annual income
Building Characteristics	• Year built • Number of floors • Square footage of landscapable areas, lawn, and irrigated areas in front or back of house • Graywater system • Well water	• Swimming pool • Average occupancy rate • Average occupancy rate by season • Building square footage • Building square footage attributable to living quarters/retail establishment/food service/ government offices/other
Inventory of Product Stock	• Toilets/urinals • Showerheads • Bathtubs • Dishwashers • Clothes washers • Faucets • Refrigerators • Water softener • Water purification units • Point of source water heater • Evaporative coolers • Water pressure regulators • Irrigation system • Spas/Jacuzzis • Fountains • Ponds • Showers • Cooling towers • Evaporative coolers	• Air washers • Humidifiers • Boilers • Air conditioners • Air compressors • Commercial washers • Coin-operated washers • Dry cleaning • Garbage compactors • Ice-making machines (water-cooled/air-cooled) • Landscape/decorative uses • Facility washdown • Vehicle washdown • Water filters • Reverse osmosis units • Deionization/ion exchange. • Recirculating hot water, commercially delivered bottled water • Drinking fountains
Characterization of Product Stock	• Toilet type (gravity flush/pressure-assisted, flushometer valve) • Toilets make/model • Toilet year manufactured/installed • Toilet tank volume/flush volume • Toilet conservation devices (if any), leaks • Urinal location (private/common area) • Urinal type (siphon, washdown, waterless) • Urinal leaks • Showerhead gallons per minute • Showerhead type (atomizing or steam/spray, fixed/handheld) • Showerhead shut-off button • Showerhead leaks	• Clothes washer efficiency (standard vs. high efficiency) • Clothes washer water saving/load size selection feature • Refrigerator built-in water dispenser or ice maker • Water softener make/model • Water softener tank volume • Water purification units • Swimming pool indoor/outdoor • Swimming pool dimensions, • Swimming pool cover • Spa dimensions • Spa cover • Irrigation system type (hose, hose & sprinkler, in-ground system with controller, drip irrigation),

	• Bathtub dimensions • Bathtub type (Jacuzzi or regular) • Faucet gallons per minute • Faucet aerator attached • Faucet leaks • Dishwasher manufacturer/make/model • Dishwasher water efficiency setting • Clothes washer manufacturer/make/model mechanical/digital • Irrigation system location (front/back) • Irrigation system manufacturer/make/model • Irrigation number of stations served • Irrigation multiple start capabilities • Irrigation type of calendar clock Irrigation moisture/rain sensors
Characterization of Consumer Use/Interaction	The study did not make an attempt to characterize frequency or duration of use of water-consuming fixtures, products, and equipment. The following data was collected: • Months evaporative coolers commonly used • Frequency of water softener unit recharged • Frequency of watering turf/garden/landscape plants by season • Percent of landscape manually watered • Use of landscape contractor • Months of year swimming pool used • Domestic/sanitary: employee or customer use
Measured Water Consumption	None. While site visits collected data on measurements of flow rates (faucets and showerheads) landscaped areas, and toilet flush volumes, actual measurements of end uses were not taken.
Conservation Assessment	• Reasons for conserving or not conserving water • Perceptions regarding water-conserving fixtures/ appliances • Estimation of household water use, months of use for certain items • Willingness to conserve • Types of conservation actions taken (shorter showers, running dishwasher/clothes washer less often or with full loads, restricting car washing, restricting landscape watering, watering landscaping in morning/evening, drought resistant landscaping, limiting pool/spa use) • Installation of water conserving devices (low-flow showerheads, low-flow toilets, displacement devices in toilets) • Knowledge of District conservation programs • Desire to change water use habits and/or install efficient devices • Effect of rebate on decision to install low flush toilets, purchase high-efficiency clothes washers, or change landscaping(change plant materials or reduce lawn area)/improve irrigation system

2.2.11 Seattle Public Utilities – Study of Market Penetration of Water-Efficient Fixtures

Seattle Public Utilities (SPU) conducted the Study of Market Penetration of Water-Efficient Fixtures to assess the success of their water conservation programs and observe the extent to which customers had reduced water use through behavioral changes and switching to more efficient fixtures. The 2003–2004 study captures the penetration of water-consuming devices, particularly the split between high-efficiency and "standard" products. The study provides distribution profiles of average daily water consumption for a range of end uses, as well as its results on the penetration of water-efficient appliances. The report produces results summary tables of its results, but data are not available in any other format. Both the narrow geographic

scope of this study (limited to the Seattle area) and the lack of available enumerated survey response data limit its utility.

Study of Market Penetration of Water-Efficient Fixtures		
General		
Sponsoring Organization	Seattle Public Utilities (SPU), Aquacraft	
Sector	Residential	
Scope	Households, both SPU customers (within Seattle city limits) and wholesale customers (in metro area)	
Geographical Coverage	Seattle city limits & metro area	
Year(s)	2003–2004	
Frequency	Conducted once	
Objective(s)	Enable SPU to assess effectiveness of water conservation programs and extent to which customers have reduced water use through behavioral changes and conversion to efficient fixtures	
Methodological Approach	SPU provided historical billing data and address information; Aquacraft generated a random sample of 1,500 regional customers. Mail surveys sent to 1,000 Seattle customers and 500 wholesale customers. Selected group for in-home data logging (flow-trace analysis) was random sample of 125 homes from survey respondent group. Continuous high-resolution flow traces were collected for at least 10 days' duration. The study results were compared to other study results to place the study on a line between no retrofits and complete retrofits to see where this sample of 100 homes lies, and how far Seattle must go to capture all water savings available.	
Information Access	N/A – lack of data availability beyond report. Survey response analysis (starting pg. 28) summarizes responses. http://www.aquacraft.com/wp-content/uploads/2015/10/Conservation-Potential-Water-Use-Assessment.pdf.	
Parameters		
Demographics	• Number of year-round residents • Age of year-round residents • Own vs. rent	
Building Characteristics	• Swimming pool	
Inventory of Product Stock	• Toilet • Bathroom sink • Shower without tub/tub without shower • Whirlpool tub with jets • Dishwasher	• Kitchen faucet • Indoor utility sink • Pressure regulator on main house service line • Hot tub • Water feature (*e.g.*, pond, fountain)
Characterization of Product Stock	• Toilet age, whether toilet has been replaced since 1993. • Toilet brand/model number • Clothes washer age	• Clothes washer type (top- vs. front-loading) • Low-flow shower head • Faucet aerator
Characterization of Consumer Use/Interaction	• Reductions in shower time • Keeps water displacement device in toilet • Repairs faucet and toilet leaks • Flushes toilet less often • Runs fuller dishwasher loads • Avoids pre-rinsing dishes • Uses garbage disposal less often	• Removes thatched lawn • Aerates lawn • Uses water timer to turn off hose/soaker hose • Checks moisture levels of soil below surface before watering • Amends soil with compost • Puts in plants that require little

	• Leaks that need repair • Runs fuller loads in washing machine • Washes car less often/uses shut-off nozzle for duration • Maintains mulch layer on planting beds
Measured Water Consumption	Used data logger for flow-trace analysis for a subset of the sample for at least a 10-day period.
Conservation Assessment	• Participation in utility rebate program • See "Characterization of Consumer Use/Interaction for more conservation behavior.

2.2.12 Seattle Public Utilities – Residential Water Conservation Benchmarking Survey and Attribution/Consumption Analysis

SPU conducted a study to explore conservation awareness, attitudes, and behavior among its customers—and the implications a range of variables have for water conservation. The 2006 study produced an inventory for a limited number of water-consuming devices. It tracked household upgrades regarding more efficient devices and water conservation practices, as well as the underlying motivations driving these changes. This study examined these drivers as they relate to water billing and utility conservation programs. Results for the distribution of survey respondents for each variable or subset of variables are presented in summary tables. More than others, this SPU study assessed how potential water bill savings influence use.

Residential Water Conservation Benchmarking Survey and Attribution/Consumption Analysis	
General	
Sponsoring Organization	Seattle Public Utilities (SPU)
Sector	Residential
Scope	Households, both SPU customers (within Seattle city limits) and wholesale customers (in metro area)
Geographical Coverage	Seattle city limits & metro area
Year(s)	2006
Frequency	Conducted once
Objective(s)	• Track trends over time by comparing these 2006 data to similar data collected in 1999 and 2001 • Create baseline measures for new topics of concern • Provide feedback on awareness and satisfaction with conservation services • Help guide future conservation efforts • Explore the relation of Saving Water Partnership's conservation efforts to changes in awareness, attitudes, and behaviors • Explore relation of survey variables to water consumption, especially the effects of conservation program efforts on consumption
Methodological Approach	Telephone interviews lasting 20-25 minutes were conducted in late fall of 2006. Respondents confirmed address; SPU staff matched these addresses with account numbers and 2006 consumption data, as well as selected household data from King County Assessor. Consumption and assessor data were appended to household survey data and evaluated for attribution/consumption analysis.
Information Access	N/A - lack of data availability outside report. Survey responses are summarized in pages 6-14. http://www.savingwater.org/cs/groups/public/@spu/@swp/documents/webcontent/04_009144.pdf.

Parameters		
Demographics	• Own vs. rent • Race • Age • Gender • Number of residents during most of year	• Whether respondent accesses Internet/email from home PC • Whether people have added or left household in last 5 years • Time lived in home • Household income +/- $50K
Building Characteristics	• Period built (before 1994, 1994–2000, after 2000) • Whether bathrooms remodeled, code to later date	
Inventory of Product Stock	• Toilets • Showerheads	• Clothes washers • Outdoor
Characterization of Product Stock	(Only via telephone survey) • High-water-using toilets • At least one low-flow toilet • High-water-using showerheads • At least one low-flow showerhead	• "Spa" bathrooms with multiple showerheads and sprays • Clothes washer type (front- vs. top-loading clothes washer) • Drip irrigation systems • Irrigation timers, rain sensors.
Characterization of Consumer Use/Interaction	• Frequency of lawn watering • Sprinkler system behavior • How often various outdoor areas are watered	
Measured Water Consumption	None	
Conservation Assessment	• Whether bill reading/comparison influenced water consumption • Rationale for replacing toilet/shower with low-flow option • What might motivate such a replacement in future • Whether respondent checks for leaks • Whether a top-loading clothes washer had been replaced with a front-loading one, as well as rationale/motivation for past/future replacement • Respondent satisfaction with low-flow toilets and showerheads • Whether in last five years respondent had reduced lawn size, reduced amount of water applied to lawn, added mulch to garden beds, checked soil for moisture level before watering, added plants that use less water once established, grouped plants together according to water needs, added soaker hoses/drip irrigation system, added time to an outdoor faucet (excluding automatic systems), used tuna can test to see how much water sprinkler puts out, and rationale for all this outdoor behavior • Interest in yard care programs and services potentially offered by water utility	

2.2.13 Albuquerque Single-Family Water Use Efficiency and Retrofit Study

The Albuquerque Bernalillo County Water Utility Authority conducted the Single-Family Water Use Efficiency and Retrofit study in an effort to examine water use patterns and estimate potential water savings from high-efficiency upgrades. The 2011 study employed a three-pronged approach, consisting of a survey assessing water-consuming devices and conservation attitudes, a metered sub-sample, and analysis of billing data. Results include household indoor water use for rebate and non-rebate homes disaggregated by end use, as well as per capita patterns for indoor use.

Albuquerque Single-Family Water Use Efficiency and Retrofit Study		
General		
Sponsoring Organization	Albuquerque Bernalillo County Water Utility Authority	
Sector	Residential	
Scope	Single-family residences of three types: • Baseline households who did not receive any rebates from Water Authority • Baseline households who received indoor, outdoor, or both rebates from the Water Authority, • Subset of baseline households then retrofitted with high-efficiency toilets, clothes washers, faucets (w/ quick shut-off devices), and showerheads.	
Geographical Coverage	Albuquerque, NM	
Year(s)	2011	
Frequency	Conducted once	
Objective(s)	To conduct a detailed investigation of current water use patterns of a representative sample of single-family water utility customers to determine potential water savings. Another component was a retrofit study on a group of 29 homes from the baseline group, where water-using fixtures were upgraded to high-efficiency devices, and water use measured post-installation to determine water use savings from these retrofits.	
Methodological Approach	Historic billing data obtained from Water Authority for 3,000 households (1,500 for those with no rebates, 1,500 for those who had received any rebate from the utility). Mail survey conducted of these households (476 responses). Random sample of households who returned surveys selected for data logging (209 participants). Flow trace data were collected from main water meters every 10 seconds for a two-week period following household survey responses; for retrofit group (31 households total), these data were collected for another two weeks following appliance retrofits.	
Information Access	Summary data in REU2016 Access database via request at Water Research Foundation, http://www.aquacraft.com/wp-content/uploads/2016/07/Albuquerque-Report-Exec-Summary.pdf	
Parameters		
Demographics	• Number and age of full-time residents • Number of adult residents not employed or students outside the home	• Rent vs. own • Gross annual household income
Building Characteristics	• Decade/half-decade built • Year current residents moved in	• Number of bedrooms • Swimming pool
Inventory of Product Stock	• Toilets • Shower/bath type (bathtub w/ shower, standard bathtub only whirlpool tub w/ jets, shower stall only) • Indoor utility/garage sink • Garbage disposal • Washing machine • Dishwasher	• Indoor spa/hot tub • Evaporative/swamp cooler • Water feature (*e.g.*, pond) • Water softener • In-ground irrigation system, • Spa/hot tub
Characterization of Product Stock	• Clothes washer type (front- or top-loading) Clothes washer replaced since 1995 Toilet efficiency	Multiple showerhead Showerhead replaced since 1995 Water heater type (gas, electric, propane, solar, other, don't know)

	Toilet ultra-low flush/dual flush Toilet replaced since 1995 Toilet leaks Low-flow showerhead	Irrigation timer Pool cover • Pool refilling system type (automatic or manual)
Characterization of Consumer Use/Interaction	• Responsibility for landscape irrigation • Percent watered manually • Frequency of adjustments to irrigation timer	• Timer over-ride or shut-off device • Weather based irrigation controller/smart controller
Measured Water Consumption	A subset of 209 homes was metered in the fall/winter of 2010. Metered end uses include toilet, clothes washer, shower, faucet, leak, other indoor, bathtub, dishwasher. A figure also compares pre- and post-retrofit water use by indoor appliance for the subset of homes that participated.	
Conservation Assessment	• Responsibility for water bill • Attitudes on water meters, cost, and conservation • Whether resident knew their water source • Penalties for overuse	• Awareness of rebates • Why respondents conserved water • Whether residents had installed remedy to eliminate/reduce hot water wait

2.2.14 North America Residential Water Usage Trends Since 1992

The Louisville Water Company (LWC) in Kentucky conducted a study of residential water use trends in North America. The study had three components: to understand changing water use on a national level, a regional level and a local level. For the local level, representative homes in the LWC service area had electronic data loggers installed to capture flow signatures. The results from the data loggers were able to accurately differentiate among various types of water use. Additionally, socioeconomic characteristics were collected by survey from participating households, as well as an inventory of indoor and outdoor water-using fixtures. The details in the table below focuses on the local level study.

North America Residential Water Usage Trends Since 1992	
General	
Sponsoring Organization	Louisville Water Company
Sector	Residential
Scope	• National trends analyzed from historical data from 43 representative utilities • Regional trends analyzed from 11 utilities • Local trends analyzed from Louisville area homes
Geographical Coverage	Louisville, KY
Year(s)	2007
Frequency	Once
Objective(s)	• Understand residential water-usage behavior patterns and trends • Assess the impact of those patterns on water utility operations • Produce data that can be correlated with future trends for planning purposes
Methodological Approach	For the local trend, surveys were sent to a stratified random sample of 1,002 LWC households for a response rate of 30.2 percent. The surveys gather household and product characteristics. Data loggers were installed in 65 respondent households for 14 days, recording water flows at 10-second intervals. Collected data combined with publicly available information from census tracts and tax records.

Information Access	Report available: http://www.waterrf.org/PublicReportLibrary/4031.pdf	
Parameters		
Demographics	• Number of persons per household • Household member age • Own or rent	• Education amount • Water bill payment responsibility
Building Characteristics	• Number of bedrooms • House vintage	• House square footage
Inventory of Product Stock	• Toilet • Bathtub with shower • Bathtub only • Shower only • Bathtub with jets • Indoor spa or hot tub	• Garbage disposal • Clothes washer, top-loading • Clothes washer, front-loading • Dishwasher • Utility garage sink • Indoor/outdoor water feature • Swimming pool
Characterization of Product Stock	• Ultra-low-flush toilet • Low-flow showerhead • Hand-held shower sprayer • Multiple showerheads in one shower	• Size of irrigated area • Type of landscaping
Characterization of Consumer Use/Interaction	• Outdoor watering practices	
Measured Water Consumption	Flow trace meters identified flows for: • Toilet • Clothes washer • Shower • Faucet	• Leak • Other • Bath • Dishwasher
Conservation Assessment	• Leaking toilet • Dripping faucet	• Pool system leak • Irrigation system leak

2.2.15 Residential Water Use: Survey Results and Analysis of Residential Water Use for Seventeen Communities in Utah

The Utah Department of Natural Resources and Division of Water Resources conducted this 2009 study in a joint effort to evaluate the water consumption split between indoor and outdoor end uses, as well as assess awareness and action instigated by a local conservation campaign. The study characterized product stock on a limited scale and reports results regarding conservation campaign awareness, implemented conservation practices, and outdoor water use. The results are available in summary tables only.

Residential Water Use: Survey Results and Analysis of Residential Water Use for Seventeen Communities in Utah	
General	
Sponsoring Organization (s)	Utah Department of Natural Resources, Division of Water Resources
Sector	Residential
Scope	Residential housing unit type not specified
Geographical Coverage	Utah (17 different communities)
Year(s)	2001, 2009
Frequency	Conducted twice
Objective(s)	To duplicate the approach used in the 2001 DWR study to determine residential indoor use versus persons per household and residential outdoor use. Additionally, the study sought to relate outdoor water use to irrigation

	practices, analyze outdoor water use to household income, look into water use habits of residents who have knowledge of Utah's "Slow the Flow" media campaign, and introduce a remote-sensing-based approach to estimate watering of residential landscaped areas for a sample of Salt Lake City residents.
Methodological Approach	Mailed survey and at least 3 years of water bills of randomly selected houses.
Information Access	Summary tables (but no microdata) available, https://water.utah.gov/OtherReports/RWU_Study.pdf
Parameters	
Demographics	• Number of persons per household • Income
Building Characteristics	• Year built • Lot size • Livable floor space
Inventory of Product Stock	• Clothes washer • Toilets • Showerheads • Faucet aerators • Dishwashers • Irrigation system
Characterization of Product Stock	Irrigation type (hose system, manual sprinkler system, automatic sprinkler system, SMS/ET controller)
Characterization of Consumer Use/Interaction	• Evaporative cooler use • Leaks/repairs
Measured Water Consumption	None, metered water use billing data analyzed. Inquired about secondary water availability.
Conservation Assessment	• Knowledge of "Slow the Flow" conservation media campaign. • Installation of water-efficient washing machines • Installation of ultra-low-flow toilets • Installation of low-flow showerheads • Installation of aerator faucets • Installation of water-efficient dishwashers

2.2.16 The Grass is Always Greener…Outdoor Residential Water Use in Texas

The Texas Water Development Board (TWDB) conducted this study in 2008 and 2011 to expand awareness of indoor and outdoor water consumption patterns in single-family homes, with the TWDB's Annual Water Use Survey providing the data. The study did not attempt to collect any information on water-consuming product stock or characterize such end uses. The study presented its results in summary tables, including the breakdown between indoor and outdoor water use by city.

The Grass is Always Greener…Outdoor Residential Water Use in Texas	
General	
Sponsoring Organization	Texas Water Development Board (TWDB)
Sector	Residential
Scope	Single-Family homes
Geographical Coverage	Texas (259 Texas cities from 2004- 2008 and 17 Texas cities from 2004 -2011).
Year(s)	2008, 2011
Frequency	Conducted twice
Objective(s)	To further the understanding of how single-family residences in Texas distribute their water use between indoor and outdoor purposes. Gaining a sense of the variability and scale of this division would allow for more effective planning and targeted conservation efforts as Texas prepares for the future.
Methodological Approach	Texas Water Development Board Water Use Survey: annual assessment of municipal and industrial users of ground and surface water: volumes of water used, sources of water, water sales, etc. All data in the survey were self-reported and individual utilities are responsible for their accuracy and

	completeness.
Information Access	Summary tables with study results; no microdata available. Enumerated responses for all utilities. No microdata. See https://www.researchgate.net/publication/264003923_The_Grass_Is_Always_Greener_Outdoor_Residential_Water_Use_in_Texas.
Parameters	
Demographics	None
Building Characteristics	None
Inventory of Product Stock	None
Characterization of Product Stock	None
Characterization of Consumer Use/Interaction	None
Measured Water Consumption	Individual utilities provided consumption data.
Conservation Assessment	None

2.2.17 Toilet Replacement Programs in the U.S.

Koeller and Company conducted the "Toilet Replacement Programs in the U.S." study in 2008 for the Alliance for Water Efficiency (AWE) to consider advantages, disadvantages, and salient characteristics of four typical types of programs for toilet replacement: rebate, voucher, distribution, and direct installation programs. Estimates of product stock and efficiencies are presented for select cities. The study also presents examples of water use reductions and infrastructure impacts achieved through toilet replacement programs in New York City, Los Angeles, Redwood City (CA), and Seattle.

Toilet Replacement Programs in the U.S.	
General	
Sponsoring Organization	Alliance for Water Efficiency
Sector	Residential and commercial
Scope	Households and businesses
Geographical Coverage	National in terms of surveying maximal flush volume for toilets, but more details in California (statewide, and specifically Los Angeles and Redwood City), New York City, and Seattle
Year(s)	2008
Frequency	Conducted once
Objective(s)	To further the understanding of national standards and specific local initiatives for toilet flush volumes.
Methodological Approach	Literature review and personal communication with municipalities.
Information Access	Paper at http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=1252
Parameters	
Demographics	None
Building Characteristics	None
Inventory of Product Stock	Toilets in individual cities
Characterization of Product Stock	Toilet efficiency (flush volume, flush type [*e.g.*, dual])
Characterization of Consumer Use/Interaction	Type of toilet replacement program: rebate, voucher, distribution, or direct installation

Measured Water Consumption	Not directly measured by study; municipalities reported average daily water use reductions as result of toilet replacement programs, or declining per capita water use projections
Conservation Assessment	None

2.2.18 Toilet Saturation Estimates in the U.S.

Koeller and Company conducted the "Saturation Study of Non-Efficient Water Closets in Key States" study for the AWE and Plumbing Manufacturers International in 2017 to quantify the savings potential from replacing inefficient toilets with toilets meeting the federal standard. The study estimates that about one fifth of toilets in the five states reviewed flush at volumes of greater than 1.6 gpf. With a natural replacement rate of 4 percent a year from toilet failure, half the possible savings could be reached over 17 years. The study also found that tremendous water savings could be attained from early replacement of high-flush volume toilets, but that the costs of replacement programs could offset utility savings.

Saturation Study of Non-Efficient Water Closets in Key States	
General	
Sponsoring Organization	Alliance for Water Efficiency and Plumbing Manufacturers International
Sector	Residential
Scope	Households
Geographical Coverage	Arizona, California, Colorado, Georgia and Texas
Year(s)	2017
Frequency	Conducted once
Objective(s)	To estimate the numbers of inefficient toilets in households and quantify savings potential by replacement with efficient units.
Methodological Approach	Estimates from American Housing Survey and existing literature
Information Access	Paper at www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=10002
Parameters	
Demographics	None
Building Characteristics	None
Inventory of Product Stock	Toilets in five states
Characterization of Product Stock	Characterized by toilet flush efficiency
Characterization of Consumer Use/Interaction	None
Measured Water Consumption	Estimated flush volumes and flush rates
Conservation Assessment	90 billion and 170 billion gallons of potable drinking water could be saved per year in these five states (or 250 to 465 million gallons per day)

2.2.19 Water Conservation: Customer Behavior & Effective Communication

The EPA and Water Research Foundation commissioned this 2010 study to evaluate the relationships between the water conservation of residential customers and the communication approaches that seek to influence that behavior. The study collected an account of the distribution of water-consuming product stock, conservation attitudes and the effectiveness of various messaging channels, as well as detailed conservation behavior and the motivations underlying this behavior. Also, the study focused primarily on detached single-family homeowners and includes a statistical analysis of key factors that drive water consumption

(including the type of residence, number of bathrooms, household size, and household income). The study gathered billing data for a geographically diverse range of cities in the United States; however, no microdata are available.

Water Conservation: Customer Behavior & Effective Communication	
General	
Sponsoring Organization	Water Research Foundation (WRF), EPA
Sector	Residential
Scope	Customers from 7 different utilities, 93% were owners of detached single-family residences
Geographical Coverage	Various U.S. cities, including: Durham, North Carolina; Jacksonville, Florida; Orange County, Florida; Phoenix, Arizona; Seattle, Washington; Tempe, Arizona
Year(s)	2010
Frequency	Conducted once
Objective(s)	To evaluate the relationships between the water conservation behavior of residential customers and the communication approaches that seek to influence that behavior
Methodological Approach	Distributed survey to utility customers about their conservation practices and attitudes. Obtained billing information for surveyed customers, along with additional billing records. A multiple regression model was used to examine the factors found to influence water use at a 95% confidence interval.
Information Access	Summary tables publicly available in report, see http://www.waterrf.org/PublicReportLibrary/4012.pdf
Parameters	
Demographics	• Rent vs. own • Length of time at residence • Number of people in household • Education • Income
Building Characteristics	• Type of residence • Year built • Number of bathrooms
Inventory of Product Stock	• Clothes washer • Shower • Dishwasher • Irrigation system • Toilet
Characterization of Product Stock	• "Water wise" gardening techniques/technology • Water-efficient dishwashers • Water-efficient faucets • Water-efficient clothes washer • Water-saving shower heads
Characterization of Consumer Use/Interaction	See “Conservation Assessment”
Measured Water Consumption	Billing records for corresponding survey households evaluated
Conservation Assessment	• Watering after rain • Monitoring outdoor use • Managing runoff and potential leaks • Changing water schedule, use of water wise plants • Running the dishwasher when full • Scraping off food before entering in dishwasher • Conserving water during cooking • Only running clothes washer when full • Checking for plumbing leaks • Shorter showers • Motivation for activity (monetary savings, water restrictions, water availability, etc.). 93 percent of respondents were homeowners and indicated that monetary savings on

	• Turning off water during teeth brushing	their water bill was the leading reason for conservation.

2.3 Manufacturing/Industrial Sector

The sections below include national surveys on U.S. manufacturing energy use and Canadian industrial water use. The latter survey is included here given the scarcity of U.S. data on manufacturing water use, as well as the similarities between the U.S. and Canadian industrial sectors. The value added for manufacturing as a share of the gross domestic product is comparable: 12 percent in the U.S. and 11 percent in Canada, while both countries experience parallel declines in manufacturing employment. Both are highly industrialized democracies belonging to the Group of 7 (G7), and both use the North American Industry Classification System (NAICS) for business statistics. U.S. manufacturing productivity, in terms of output per labor hours, outpaces Canada, which may be partially because the U.S. manufactures more high-value goods such as electronics. Rao *et al.* (2017) established these parallels and correlated the Canadian data to U.S. manufacturing characteristics to make estimates about water use in the U.S. manufacturing sector. [18]

2.3.1 Manufacturing Energy Consumption Survey

The Manufacturing Energy Consumption Survey (MECS) has been conducted since 1985 and is federally mandated to collect energy demand data for multiple categories of industries as defined by the North American Industry Classification System (NAICS). In addition to energy demand details, data on manufacturing/industrial hot water, steam components (from local utility or other source), and water heating are collected as used by the NAICS code for subsector and industry. Data are reported in million BTUs; water volumes are not included.

Manufacturing Energy Consumption Survey	
General	
Sponsoring Organization	EIA (Form-846)
Sector	Manufacturing/industrial
Scope	Manufacturing industries, specifically 21 3-digit industry subsectors, and 50 industry groups and industries as defined by NAICS.
Geographical Coverage	United States (nationwide)
Year(s)	1985–2014
Frequency	Quadrennial (approximately)
Objective(s)	To publish aggregate statistics on the consumption of energy for fuel and nonfuel purposes, as well as certain energy-related issues such as energy prices, on-site electricity generation, purchases of electricity from utilities and non-utilities, and, occasionally, the capability to switch fuels.
Methodological Approach	The basic unit of data collection for MECS is the manufacturing/industrial establishment. The 2010 MECS sample size of approximately 15,500 establishments was drawn from a nationally representative sample frame

[18] Rao, Prakash, *et al*. Estimating U.S. Manufacturing Water Use. 2017. ACEEE Proceedings. http://aceee.org/files/proceedings/2017/data/polopoly_fs/1.3687919.1501159097!/fileserver/file/790285/filename/00036_0053_000025.pdf

	representing 97-98% of the manufacturing/industrial payroll. The survey combines steam and industrial hot water is combined into an "other" category that also includes net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power or as feedstock/raw material inputs. Steam and hot water used are measured in Btu/pound. (A pound is considered to be 7.84 pounds/gallon).
Information Access	Summary tables publicly available, https://www.eia.gov/consumption/manufacturing/
Parameters	
Demographics	None
Building Characteristics	Number of buildings and establishment square footage
Inventory of Product Stock	Types of technologies used within facility not relevant to water
Characterization of Product Stock	Steam and industrial hot water used as energy source. Details of onsite generation data not included in publicly available data.
Characterization of Consumer Use/Interaction	None
Measured Water Consumption	Data on manufacturing/industrial hot water, steam components (from local utility or other source), and water heating.
Conservation Assessment	N/A

2.3.2 Industrial Water Survey [Canada]

Statistics Canada has conducted the Industrial Water Survey every two years since 2005. The survey collects data on the sources, intake (including both self-supplied and municipal sources), recirculation, treatment, discharge, and costs of water used for the Canadian manufacturing sector at the 3-digit NAICS level, as well as mining and thermal-electric power production. The Industrial Water Survey also breaks down each subsector by purpose of use (*e.g.*, process water, water for condensing, steam, and cooling, sanitary service). Results are publicly accessible as summary and detailed tables.

Industrial Water Survey [Canada]	
General	
Sponsoring Organization	Statistics Canada
Sector	Manufacturing/industrial
Scope	Thermoelectric power generation (NAICS 221112 and 221113), mining (NAICS 2121, 2122, and 21233 excluding 21232), and manufacturing industries, specifically 17 NAICS 3-digit manufacturing subsectors (31-33): food; beverage and tobacco product; textile mills; textile product mills; wood product; paper; petroleum and coal product; chemical; plastics and rubber products; non-metallic mineral product; primary metal; fabricated metal product; machinery; computer and electronic product; electrical equipment, appliance, and component; transportation equipment. Another subsector, other manufacturing industries, combines the NAICS subsectors of clothing; leather and allied product; furniture and related product manufacturing; and printing and related support activities.
Geographical Coverage	Canada (nationwide)
Year(s)	2005–2017
Frequency	Biennial
Objective(s)	To provide Canadians with detailed national and regional indicators related to the use of water in the manufacturing, mining, and electrical power generating industries by collecting information on who uses water, how much, where, and at

	what cost.
Methodological Approach	The basic unit of data collection for IWS is the manufacturing location, defined as a production unit located at a single geographic location at or from which economic activity is conducted and for which a minimum of employment data are available. The 2013 IWS sample size included 128 units for thermal-electric power generation, 378 units for mining, and 5,037 units for manufacturing (NAICS 31-33). Three separate questionnaires were designed, one for manufacturing, one for mineral extraction, and one for power generation. Questionnaires solicit data on volume of water brought into the facility (including information on source, purpose, treatment, and possible recirculation), volumes of water discharged, treatment of this water, and cost information on intake and discharge of water.
Information Access	Summary and detailed CANSIM (Statistics Canada's key socioeconomic database) tables publicly available, http://www23.statcan.gc.ca/imdb-bmdi/pub/5120-eng.htm
Parameters	
Demographics	None
Building Characteristics	None
Inventory of Product Stock	None
Characterization of Product Stock	Only in terms of purpose: process water; cooling, condensing, or steam; sanitary service/domestic use, and other
Characterization of Consumer Use/Interaction	Volume of intake water treated prior to initial use, by method. Water intake and recirculation/reuse by purpose: process water, cooling/condensing/steam, sanitary service/domestic use, and other. Volume of treated and discharged water by treatment process, discharge sink, and whether final effluent is monitored for various characteristics (*e.g.*, suspended solids, phenols, temperature). Annual capital expenditures on water intake, discharge, or treatment facilities.
Measured Water Consumption	Data on monthly and annual total water intake and discharge volumes, as well as annual volume per year by source and kind
Conservation Assessment	Volumes recirculated/reused by purpose

3 BENEFITS OF AND OPTIONS FOR COLLECTING NATIONAL WATER DEMAND DATA

A national water survey effort requires careful consideration of the data to be collected. The review of existing studies in the previous section provides high-level insight into their strengths and challenges. This section reviews the benefits of existing national survey efforts. Further, it describes the added value that a regular, consistent, detailed national survey could provide and highlights the benefits to each of the relevant sectors (residential, commercial, and manufacturing/ industrial), as well as from each of the categories of parameters assessed (*e.g.*, demographics, building characteristics).

This section concludes with the consideration of whether water demand data should be added to existing national surveys or efforts, or whether gathering these data warrants the development of a stand-alone water demand survey.

3.1 Value of DOE and USDA National Demand Data

DOE's Energy Information Administration surveys and the USDA Farm and Ranch Irrigation Survey (FRIS) are now used within the federal government by numerous departments and agencies, as well as outside the federal government by other stakeholders. This section demonstrates the utility of existing federally collected resource demand data and underscores the potential analogous benefits of national water demand data to federal projects and programs focused on water supply and demand concerns, as listed in Appendix A.

In particular, multiple organizations now depend upon the demand data collected by RECS and CBECS, as evidenced by Office of Management and Budget (OMB) supporting statements.[19,20,21] A partial list of stakeholders is shown below; descriptions are based on the referenced Office of Management and Budget (OMB) supporting statements. The full supporting material can be found in Appendix C.

- RECS and CBECS data used by Commerce, DOE (EIA/Energy Efficiency and Renewable Energy [EERE]), EPA, Health and Human Services, Labor for:
    - Investigating consumption-based measures of poverty and determining funding levels for energy assistance programs;
    - Adjusting electricity and gas costs in American Housing Survey;
    - Inputs to EIA Short Term Energy Outlook;
    - Characterizing the U.S. residential sector in the National Energy Modeling System;
    - Estimating energy savings from energy efficiency investments;
    - Verifying programmatic savings and identifying new products for the ENERGY STAR label;
    - Imputing utility costs for renters whose utility costs are included in their rent for consideration in the Consumer Price Index.

- RECS and CBECS data used by DOE, private for-profit entities, non-profits and stakeholders for:
    - Recommending efficiency levels for appliances and equipment;
    - Determining economic impacts of product and equipment energy standards due to technology changes;
    - Evaluating existing and developing new standards and codes for buildings;
    - Determining where new energy efficiency improvements would be most effective;

[19] Office of Management and Budget, Paperwork Reduction Act for RECS 2015, Supporting Statement A, 2015 RECS SS Part A Cover and TOC_050715.docx. https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201504-1905-002

[20] Office of Management and Budget, Paperwork Reduction Act for CBECS 2012, Supporting Statement A, 2012 CBECS Supporting_Statement_Part_A.docx. https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201209-1905-001

[21] Office of Management and Budget, Paperwork Reduction Act for FRIS 2013, Support Statement A, 0234-fris-2013-SSA - Rev.docx, https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201306-0535-001

    - Establishing baseline energy use to measure energy improvements for determining rents and purchase prices;
    - Inputs for research, marketing, and product development.

- FRIS data used by USDA (Economic Research Service/ Natural Resource Conservation Service), Interior (USGS/Bureau of Reclamation), federal and state legislatures for:
    - Analyzing the impact of alternative farm policies on the irrigated sector;
    - Appraising the status and condition of water and water-use trends on non-federal lands;
    - Preparing national water summaries;
    - Conducting feasibility studies of irrigation projects;
    - Formulating and assessing natural resource legislation.

- FRIS data used by other stakeholders for:
    - Informing investments in irrigation equipment, facilities, and land improvements;
    - Estimating yields of irrigated versus non-irrigated crops.

3.2 Value of National Water Data by Sector

As indicated above, resource demand data collected at regular intervals support legislation and program evaluation at the federal and state levels, manufacturer investigations of their markets, and stakeholder feasibility assessments for planning and purchasing decisions. Water demand data could be used similarly: to assess federal[22], state, and local programs; evaluate national or regional economic impacts from resource shortages; and set conservation or efficiency levels to assist resource planning. This section summarizes some of the benefits of national water demand data to three economic sectors.

Residential: Efforts to characterize and quantify water demand habits in households across the United States are not new. While existing water demand studies indeed make useful contributions to the literature, their results are inherently limited by geographic scope and sample size, among other considerations.[23] The number of studies that examine water use in the residential sector points to how valuable an enhanced understanding of water demand is in stakeholders' eyes. Collecting water data in the residential sector could enable forecasting of residential water consumption[24] as well as historical projections of water-consuming product stock, and also improve understanding of the savings opportunities available through retrofitting with water-efficient fixtures.

Commercial: Commercial buildings (office buildings, schools, restaurants, hotels, etc.) use a significant amount of water. Their water demand is generally greater and more varied, however,

[22] See Appendix A for a partial list of federal water supply and water efficiency programs and projects.
[23] The federal energy survey RECS has sufficient geographic scope and sample size, but limited water data.
[24] Diringer *et al*. (2018) suggest ways water planners and managers can improve long-term water demand forecasts by more precisely accounting for building codes and requirements, changes in existing and new product and equipment water efficiency standards, and third-party certification programs. Publication of report pending by Water Resource Foundation.

than the residential sector, with some building activities using notably more water than others (*e.g.*, a law office uses water very differently than a hospital or hotel). Because of their potential larger scale, individual commercial buildings typically present larger water and financial savings opportunities than those in the residential sector. As mentioned in section 2, the EIA's CBECS collected water consumption data in its 2007 and 2012 surveys.[25] The results, however, are fairly high-level, and do not allow for cross-tabulation of water consumption data across many variables beyond building activity and square footage. A more detailed assessment of the types of commercial buildings that consume water, itemization of water-consuming product stock, and data on descriptive characteristics of this product stock (*e.g.*, product type and efficiency) would better explain commercial building water use. It would also reveal savings opportunities to commercial building owners and operators by benchmarking their water consumption against that of similar buildings, and would inform targeted conservation efforts and commercial rebate programs.

A source for addressing water end-use data collection that includes the commercial, institutional, and industrial sectors can be found in Kiefer *et al*. (2015), who address the complexities of data collection.[26] As mentioned in this previous section and further described in Appendix C, a vision for the use of commercial water demand data can be found in the ENERGY STAR program's use of CBECS energy data for the benchmarking models used by building owners or managers. Benchmarking model results allow building owners and managers to compare their energy usage with similar buildings, inform efforts they may undertake to improve their building's efficiency and value, and potentially qualify them for the ENERGY STAR label or a Leadership in Energy and Environmental Design (LEED) designation.

Manufacturing/Industry: The mandate for collecting manufacturing/industrial energy data can be found in section 13(b) of the Federal Energy Administration Act, 15 U.S.C. 772(b).[27] A similar mandate for collecting manufacturing/industrial information on water demand and use type would produce a threefold benefit by: (1) estimating water demand correlated with related manufacturing/industrial characteristics and behaviors; (2) providing industry, policymakers, and the public with unbiased and accurate data; and (3) evaluating manufacturing/industrial demands in the face of increased infrastructure needs and rising water prices. Robust analyses require accurate and sufficiently detailed data from two sources: the manufacturing/industrial entity and the water utility. This data could include water end-use types, efficiencies, and volume event usage; building characteristics; participation in water management programs; and wastewater pre-treatment. Data collected from water utilities could include general water use and

[25] EIA does not plan to collect water data in its 2018 CBECS.

[26] Kiefer *et al.* (2015) *Methodology for Evaluating Water Use in the Commercial, Institutional, and Industrial Sectors* The authors defined a methodology to estimate end-uses of water specific to commercial, institutional, and industrial buildings and developed analytical elements for characterizing water use in the CII sector. http://www.waterrf.org/PublicReportLibrary/4375.pdf

[27] "All persons owning or operating facilities or business premises who are engaged in any phase of energy supply or major energy consumption shall make available to the [Secretary] such information and periodic reports, records, documents, and other data, relating to the purposes of this Act, including full identification of all data and projections as to source, time, and methodology of development, as the [Secretary] may prescribe by regulation or order as necessary or appropriate for the proper exercise of functions under this Act."

expenditures, tap size for building type, and energy use for water treatment. Water use units and year of expenditure would need to be included.

3.3 Value of National Water Data by Assessed Parameters

Demographic Information: The inclusion of demographic information in a national survey is critical to understanding how water consumption and conservation behavior vary across populations. Demographic data enable assessment of the characteristics of high (and low) water users, the type and quantity of water-consuming products certain populations have in their homes or businesses, the populations that should be targeted in conservation efforts, and the barriers some populations may face with respect to these efforts. These data could enable local utilities, cities, states, and the nation as a whole to evaluate water demand types and urgent infrastructure repair.

Additionally, nearly all large nationally conducted residential surveys (*e.g.*, the U.S. Census, AHS, RECS) collect robust information on demographic characteristics. Amassing similar data on demographics for water demand would enable multiple resource datasets to be examined in conjunction with one another. While demographic information would likely be most useful for the residential sector, other sectors have also included it in survey efforts. The CBECS, for example, collects data on the number of employees in a building.

Building/Site Characteristics: The inclusion of building and site characteristics data can paint a more accurate picture of which types of homes, businesses, and manufacturing/industrial enterprises consume more water than others. This could enable analysts, policymakers, and water resource managers to assess which building characteristics influence water consumption. For example, one might expect that in the residential sector, water consumption is a function of home size, lawn size, presence of swimming pools, climate zone, etc. In the commercial sector, hospitality and healthcare establishments are likely to see more water use per occupant than a standard office building. Data on general building and/or site characteristics is particularly useful for cross-tabulation across other data parameters. For example, analyzing the stock and characteristics of water-consuming products by building age would allow one to assess whether the number and efficiency of water-consuming devices are increasing in newer construction.

Product Stock Inventory and Characterization: Having an accurate assessment of the water-consuming product stock saturation in all sectors across the United States is essential. A national water survey should itemize and characterize water-consuming product stock. Without this information, a survey would only be able to inform how much water is used where—but not why or how. Long-running data on water-consuming product stock and certain characteristics across different sectors would, among other things, enable stock and consumption projections (including evaluating changing purchase trends), which in turn would help utilities plan water resources more effectively.

Consumer/User Interaction: Data on occupant behavior and interaction with water-consuming end uses can help disaggregate consumption data into specific end uses, develop daily water demand profiles, and provide a more robust understanding of how people interact with water-

consuming end uses across various sectors. This could provide insight into which household habits and behaviors present the largest water savings opportunities.

Conservation Assessment: Knowledge of participation in water efficiency rebate programs, as well as conservation behavior and attitudes across all sectors, is important in order to understand future opportunities and obstacles to achieving efficiency. Data on past and future conservation efforts, as well as on what motivated a household, commercial enterprise, manufacturing/ industrial plant, or thermoelectric power generator to take such actions would be critical for informing resource management and conservation campaigns. Assessment could be modeled on the Consortium for Energy Efficiency consumer surveys done for ENERGY STAR.[28]

Water Use/Cost: Collecting data on water consumption and cost is perhaps the most important component of a national survey effort. The data described above in section 3.2 and above would be significantly less valuable if trends and patterns observed across these other parameters could not be evaluated in conjunction with actual consumption data. The most desirable approach is metering individual water-consuming fixtures, as it produces individual water consumption trends for specific end uses. This methodology, however, is resource-intensive, and is often only employed in studies with relatively small sample sizes or for smaller sub-samples within a study. Electronically connected technologies, especially water meters, could facilitate data gathering in the future and could be brought to use sooner with federal incentives.

Additionally or alternatively, billing information for the accounts participating in the survey should be sought. This would provide data on responsibility for the water bill, water rates, monthly/quarterly water bills, and total consumption. In addition to providing data on water rates[29] and billing, this would also deliver total water consumption figures. Water reporting units and year of expenditure should also be included. Metering individual end uses is not always feasible (at least for the entire surveyed population). In those scenarios, consumption data available from water bills would provide significant value. Moreover, some analytical approaches allow for the disaggregation of water consumption by end use once the product stock and total consumption is known.

3.4 Data Considerations for a National Water Demand Survey

Table 3.1 provides examples to serve as a guide for content development of a national water demand survey, showing seven data parameters. Two parameters in the table, including demographics and building characteristics, duplicate AHS and EIA national survey questions (as described in sections 2.2.1 through 2.2.3, and section 2.3.1). Two other parameters, the characterizations of product stock and consumer use, mirror the regional Residential End Use surveys (as described in sections 2.2.4 and 2.2.5), which provide more detail than the 2005 RECS and 2012 CBECS. While characterization of product stock can be difficult to obtain, many

[28] CEE queries households regarding their assessment of the ENERGY STAR® label. Results contribute to ENERGY STAR program support. https://www.cee1.org/content/national-awareness-energy-star-surveys

[29] Every other year since 2002, American Water Works Association and Raftelis Financial Consultants have been publishing surveys of selected utility water and wastewater charges. While they include several hundred utilities, the surveys are not statistically representative at the national level.

existing regional surveys have been successful at obtaining this information through on-site visits. Both national and regional surveys gather information to quantify product stock, and the CEE surveys[30] on ENERGY STAR can be used to assess consumer conservation awareness. However, no publically available statistical survey exists that reports national water use and costs.

[30] CEE is a member organization of gas and electric efficiency program administrators dedicated to promoting energy efficient products and services. Their surveys on ENERGY STAR products can be found at their website. https://www.cee1.org/content/national-awareness-energy-star-surveys

Table 3.4.1 Recommended for Data Requirements for a Federal Water Demand Survey[31]

PARAMETER	SECTOR		
	RESIDENTIAL	**COMMERCIAL**	**MANUFACTURING/INDUSTRIAL**
Demographics			
General	# of occupants; renters vs. owners	# of workers; visitors in a day; rent vs. own	Work force size, # of workers per machine or operation
Other	Age; income; race; gender; highest level of education	Age; income; race; gender; highest level of education	Age; income; race; gender; highest level of education
Building Characteristics			
Site/Building Type	Multifamily or single-family	Storefront, skyscraper, etc.	N/A
General	# of bedrooms and bathrooms; year built	Building activity type: education, food sales, healthcare, lodging, retail, office, etc.; cooling method type	NAICS activity code
Location	State; climate zone	State; climate zone	State; climate zone
Size	House square footage	Building square footage	Building square footage
Outdoor Characteristics	Lawn and garden square footage; lawn ground cover distribution and type (*e.g.,* % lawn, % planted); presence and number of hot tubs, pools, ponds, fountains, "water features", presence of irrigation/smart controllers		
Inventory of Product Stock			
Itemization of Product Stock	Presence and number of dishwashers, clothes washers, faucets, toilets, etc.	Presence and number of toilets, urinals, ice makers, drinking fountains, kitchen appliances, cooling tower(s)	Quantify range of water-using machinery for production; presence and number of toilets, urinals, ice makers, drinking fountains, kitchen appliances
Product Stock Type	Clothes washer: front- or top-loading; sprinkler system: automatic or manual	Sprinkler system: automatic or manual; clothes washer: front- or top-loading (hotels, hospitals)	N/A
Characterization of Product Stock			
Efficiency of Product Stock	Rated efficiency; WaterSense label; low-flow toilets, showerheads	Rated efficiency; WaterSense label; low-flow toilets, urinals, showerheads	Rated efficiency of water-using machinery or method of production
Product Stock Details	Age, brand, and model #	Age, brand, and model #	Age, brand, and model #

[31] This table is intended as a guide to parameters that should be collected; it is by no means an exhaustive list.

Characterization of Consumer Use/Interaction			
Occupancy	Average hours home per day for all occupants (excluding sleeping hours)	# of employees; operating hours; hours occupied out of 24; % of building occupied on average	# of employees; operating hours; hours occupied out of 24; % of building occupied on average
Frequency/Duration of Use of Water-Consuming Devices	# of laundry loads per week; # of dishwasher loads per week; # of showers/baths per week; duration of shower; lawn watering frequency and duration	Plumbing (toilet, urinal) usage, kitchen appliance usage); outdoor irrigation frequency and duration	N/A
Conservation Behavior	Shorter showers; turning off water during tooth brushing; pre-rinse dishes before running dishwasher; whether dishwasher and clothes washer loads are full; landscape plant types; outdoor irrigation practices	Landscape plant types; outdoor irrigation practices; (for a restaurant) turning off faucet during dish pre-washing; filling or refilling customer water glasses only when requested; (for a hotel) placing placards for towel and linen re-use by guests; ISO 14001 (Environmental management) or similar certification	Regular water audits; efficiency training programs; sustainability policies or commitments; water efficient labeled products; ISO 14001 (Environmental management) or similar certification
Water Use & Cost			
Metered[32]	Total consumption metered; individual end uses metered using flow trace loggers	Total consumption metered; individual end uses metered using flow trace loggers	Total consumption metered; individual end uses metered using flow trace loggers
Billing[33]	Responsibility for water bill; historical billing data for residences from water utility (including water reporting units and year of expenditure)	Responsibility for water bill; historical billing data for buildings from water utility (including water reporting units and year of expenditure)	Responsibility for water bill; historical billing data for buildings from water utility (including water reporting units & expenditure year), tap size for entity, and water treatment costs
Conservation Assessment			
Participation in Rebate or Management Programs	Awareness & participation in residential rebate programs	Awareness & participation in commercial rebate programs; building sustainability programs/plans; ISO 140001 Environmental Management certification	ISO 14001 Environmental Management certification

[32] Metering individual end uses would allow greater precision in estimations of indoor and outdoor water use volumes.

[33] When collecting billing information, initial efforts should be undertaken to ensure that reporting across utility billing is consistent and uniform. Kiefer and Krentz (2016) provide a guide to improving the amount and quality of billing information. (http://www.waterrf.org/ExecutiveSummaryLibrary/4527_ProjectSummary.pdf)

Attitudes on Conservation	Motivation and willingness to conserve water and take efficiency actions

3.5 Implementing a National Water Demand Survey

A national water demand survey could be implemented as a stand-alone survey, or as an addition to existing surveys. This section reviews the implementation and cost of existing national surveys, and discusses the benefits and drawbacks of potential implementation approaches for a national water demand survey.

Of note, for any federal agency to gather identical information from more than nine respondents, the agency must obtain approval from the Office of Management and Budget (OMB) under the Paperwork Reduction Act (PRA) of 1980, and as amended in 1995. This approval requirement includes information collected under a contract or other agreement, and any activities related to development or testing of data collection plans.[34]

3.5.1 USGS Water Use in the United States

For its report "Water Use in the United States," the USGS gathers information from an array of sources[35] relying primarily on approximately 20 state water agency site-specific databases.[36] Where state data are not available, USGS relies on national datasets (EPA's Safe Drinking Water Information System, U.S. Census Bureau population estimates, USDA's FRIS, USDA Census of Agriculture, USDA crop and livestock estimates, DOE thermoelectric power), individual contacts, and individual questionnaires.

The 2010 water use report cost the federal government an estimated $182,000 annually for USGS staff time. Note that this cost is exclusive of the cost incurred by federal and state agencies[37] to collect the data that is compiled into the USGS report. Three USGS staff are dedicated to reviewing state water agency proposals for water data collection, research and analysis. Staff responsibilities include: (1) developing the program announcement, (2) organizing the proposals, (3) completing all logistics for the peer panel meetings to review proposals, (4) notifying recipients of awards, (5) preparing requisitions, (6) making awards, and (7) requesting and reviewing required reports.

3.5.2 American Housing Survey

For the 2015 AHS, the Policy Development and Research group within the Department of Housing and Urban Development prepared four forms for survey respondents. Two additional documents provided supporting information addressing the (1) justification of the survey and (2) information collection employing statistical methods.[38] Every other year, AHS interviewers visit

[34] For a full list of documents, visit OMB website (https://obamawhitehouse.archives.gov/omb/inforeg_statpolicy)
[35] USGS, "Estimated Use of Water in the United States in 2010." https://pubs.usgs.gov/circ/1405/pdf/circ1405.pdf
[36] USGS used the same method in its 2010 report that it did in 2005 for collecting state water agency data. "Guidelines for Preparation of State Water-Use Estimates for 2005." https://pubs.usgs.gov/tm/2007/tm4e1/pdf/tm4-e1.pdf
[37] State water agencies may apply to USGS for funding to support water use-related research, but that funding is not reported here. The funding can assist with state information that will go to national water use estimates and also support other state work. https://pubs.usgs.gov/circ/1405/pdf/circ1405.pdf
[38] OMB Packet for 2015 AHS. OMB AHS15 Supporting Statement PART A.docx, https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201501-2528-003

or telephone each household in the sample. The sample size for each survey year is about 50,011 housing units.[39]

The 2015 AHS cost the federal government an estimated $60 million[40] over a two-year period. Details of the budget were not available.

3.5.3 EIA CBECS and RECS

For 2012 CBECS, EIA prepared twelve individual forms. Ten forms were to be viewed and completed by respondents.[41] Two additional supporting statements provided (1) justification for the survey, including legal authority, needs and uses of the data, method of dissemination, statement of uniqueness, burden reduction on small businesses, changes from any previous survey, and statements of support from stakeholders;[42] and (2) the sampling methodology and estimation procedures. Every 4–5 years, CBECS interviewers collect data using computer-assisted interviewing techniques, both in-person and by telephone. Almost 7000 buildings were surveyed in the 2012 CBECS sample.[43]

The 2012 CBECS cost the federal government an estimated $19.3 million (annualized costs are $4.8 million).[44] Almost 85 percent of the funding is paid to data collection contracts[45] and the remaining funds are allocated to staff time for survey preparation and data analysis. Staff costs include: (1) interfacing with data users; (2) specifying the survey design; (3) programming and testing the questionnaires; (4) directing and monitoring the survey contractor on sample design, data collection and non-response follow-up procedures; (5) editing the data; (6) developing the non-response adjustments (imputations); (7) analyzing the data; (8) preparing the data reports for dissemination; and (9) preparing public use data for release on the internet. Twenty-two full-time equivalent staff are employed to work on CBECS.

For 2015 RECS, EIA prepared six individual forms: four forms were to be viewed and completed by respondents [46] and, similarly to CBECS, two supporting statements provided (1)

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[39] American Housing Survey Methodology. 2015 https://www.census.gov/programs-surveys/ahs/about/methodology.html

[40] OMB Packet for 2015 AHS. OMB AHS15 Supporting Statement PART A.docx, https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201501-2528-003

[41] Building Questionnaire, Authorization Form, Natural Gas Usage, District Heating Usage, Electricity Usage, Fuel Oil Usage, Worksheet 1 (Building Version), Worksheet 2 (Establishment Version), Mall Building Questionnaire, Mall Establishment Questionnaire).

[42] For a full list of information included in the statement, see https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201209-1905-001

[43] The 2012 CBECS and the 2018 CBECS will be collected by Leidos. https://insights.leidos.com/news-releases/department-of-energy-awards-leidos-prime-energy-information-administration-contract
How Was the 2012 CBECS Buildings Survey Conducted?
https://www.eia.gov/consumption/commercial/reports/2012/methodology/conducted.php

[44] OMB packet for CBECS 2012. Supporting Statement A, https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201209-1905-001

[45] Contracts include: (1) preparing the sample; (2) administering a pre-test; (3) training the interviewers; (4) collecting the data; (5) processing the data, including variance estimation; and (6) documenting the survey procedures

[46] Household Questionnaire, Rental Agent Questionnaire, Energy Supplier Survey, Authorization Form.

the justification for the survey; and (2) the sampling methodology and estimation procedures. Every 4–6 years, RECS interviewers collect data in-person. Almost 6000 homes were visited in the 2015 RECS sample.[47]

Total government staff and contractor costs[48] for the 2015 RECS are estimated at just under $9.4 million (annualized costs are $2.3 million).[49] These costs include: (1) necessary revisions and redesign of the questionnaire; (2) sample update and selection, (3) data collection, (4) data processing, non-response adjustments, weighting and variance estimation, (5) data analysis; (6) preparing data reports; (7) preparing public use data files; (8) updating dissemination websites (9) and survey documentation. [50] Sixteen full-time equivalent staff are employed to work on RECS.

3.5.4 Augmenting Existing National Surveys vs. Conducting a Stand-Alone Survey

As seen in the section above, effort and cost can be significant for survey preparation, implementation, and results analysis and dissemination. When compared with unmet water infrastructure needs or benefits to federal programs to increase their effectiveness, the survey effort and costs are low; however, it is prudent to explore whether it is efficacious to add questions to existing surveys or whether a stand-alone water demand survey is warranted. Gathering national water demand data as part of an existing national survey would almost certainly cost less than implementing a stand-alone survey, but would also permit less independence of survey design and less tailoring to meet water agency needs. The EIA energy surveys, the AHS survey, or the USGS *Water Use in the United States* effort are potential candidates to consider augmenting. An additional consideration includes whether the sponsoring entity of these surveys is an appropriate party to carry out such a data collection activity. A brief discussion of these options is below.

One option is to add water demand questions to EIA energy surveys. The EIA already addresses energy demand at a structural (household, building, industrial facility) level. While they collect data regarding energy-using products, housing/building characteristics and household/building occupants, existing EIA surveys (with the exception of 2005 RECS and 2012 CBECS) do not gather data regarding (1) similar counts or characterizations of indoor and outdoor water-using products, types and durations of water-consuming events, or sizes of irrigated areas; and (2) monthly water and wastewater utility costs and consumption for consumers. Adding questions to the EIA surveys is an option worth considering, as was done by EPA in 2005 RECS and 2012 CBECS. However, without an act of Congress, the questions cannot be repeated without additional funding for each survey year, nor are utilities obligated to provide water consumption and cost information.

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[47] *Overview and History of RECS* https://www.eia.gov/consumption/residential/reports/2015/methodology/index.php
[48] 2015 RECS was conducted by RTI, https://www.eia.gov/consumption/residential/reports/2015/home-selected.php
[49] OMB packet for RECS 2015. *Supporting Statement A*, https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201504-1905-002
[50] For the complete statement, see https://www.reginfo.gov/public/do/PRAViewICR?ref_nbr=201504-1905-002

A second option is to add water demand questions to the AHS. The primary mission of the HUD surveys is to use housing condition information in the *Worst Case Needs* reports[51] to Congress to justify appropriate policy responses. The AHS collects extensive demographic and residential housing information, and makes limited characterizations of residential products (*e.g.*, types of heating and cooling systems, type of plumbing, water source). As with the EIA surveys, it may be possible to expand the AHS to include water demand details. The surveys, however, are restricted to the residential sector and no companion surveys report commercial building or manufacturing plant conditions. Also, the surveys do not currently gather and report resource use so the agency would need to establish relationships with resource utilities.

A third option is to expand the USGS effort. The USGS collects water use information from state water agencies regarding supply distribution to different sectors of the economy. While useful for evaluating water use volume at a broad scale, water demand by product or service at the building or industry level is currently not possible, given that state water agencies are not collecting detailed information to provide to the USGS. For state water agencies to begin collecting detailed water demand data, funding and effort would need to be considered, as well as uniform data collection efforts to enable data aggregation and comparability. To compel state water agencies to collect data for a federal agency would require an act of Congress and compliance with the Paperwork Reduction Act.[52]

A stand-alone water demand survey is a fourth option that offers an opportunity to develop a survey instrument (or instruments) sufficiently comprehensive to be useful to existing federal programs, described in part in Appendix A, and meet expected need from other federal entities and stakeholders similar to the breadth of users of energy demand data described in section 3.1 and Appendix C. It allows the survey to be tailored to water data rather than energy or housing data, making it most likely that all of the desired parameters in Table 3.1 could be collected. Aside from the effort and cost of initiating and maintaining a regular water demand survey, one significant hurdle for a stand-alone survey is determining which agency would be responsible for the collection and maintenance of the data.

While this paper stops short of providing a formal recommendation on the best option to pursue, the information provided within can inform further stakeholder engagement and dialogue to determine the merits of a national collection of water use data and how this effort would best be achieved.

4 CONCLUSION

The lack of consistent and cohesive data collection regarding where, how, and how much water is used and/or consumed in the United States inhibits informed and effective decision making across many organizational entities and within all economic sectors. As seen in Section 2, surveys, databases, and studies about water demand already exist for numerous economic

[51] https://www.huduser.gov/portal/publications/Worst-Case-Housing-Needs.html
[52] Information Collection and Paperwork Reduction Act (PRA) Overview. https://www.usability.gov/how-to-and-tools/guidance/pra-overview.html

sectors, from the local to the national level. However, significant factors preclude the use of this existing information to inform water resource management and infrastructure investment. Broadly, these data issues relate to consistency: frequency of collection, sample size, sector representation, units of use, building or site descriptions, characteristics of water-consuming end uses, and user characteristics. Without consistency within and across data sets, demand over any time period cannot be adequately characterized.

More frequent and comprehensive collection and dissemination of water end-use data would allow regional, state, and local water managers to make better decisions regarding water use, foster efficient practices, bolster the development of new technologies, enable government and university researchers to analyze emerging issues, and help safeguard the sustainability of the nation's water resources. Further, water and wastewater infrastructure in particular stand to benefit from a national survey effort. The critical infrastructure treating and carrying water to citizens in homes, businesses, and places of industry has fallen into such disrepair that it requires hundreds of billions of dollars for maintenance, replacement, and expansion over the next two decades. Needed wastewater infrastructure investment is on the order of $271 billion over a shorter time frame. These investments require local and state resources (*e.g.*, water rates and surcharges, municipal bonds, and capital spending) in addition to federal investment funds (*e.g.*, the Clean Water State Revolving Fund, Drinking Water State Revolving Fund, and USDA Rural Development Water and Environmental Program).

Better water data would also facilitate data-driven decision making around aging federal water infrastructure investments such as those in the Colorado River basin, the Central Valley Project, the Tennessee Valley Authority, and the Army Corps of Engineers reservoir system. Fundamentally, understanding the myriad ways in which water is used would assist decision makers at all levels in determining how to allocate funds that could ultimately negate infrastructure expansion needs and delay capital investment costs via better-informed water resources planning and more efficient water use. Moreover, a national survey on water consumption would provide manifold direct benefits to existing federal and state water and wastewater supply programs mentioned in Appendix A, by equipping federal departments and agencies with a rich dataset to make sound policy decisions and thereby ensure the effective stewardship of public resources and tax dollars.

The federal government is uniquely positioned with the authority and capacity to develop and conduct a large-scale national water use survey. A national effort is crucial to regularly collect and analyze water demand data in a similar way to the data already collected for energy demand or irrigation water demand—and to enable direct comparison to these other valuable resource datasets. The success of its energy surveys (RECS, CBECS, MECS) and irrigation survey (FRIS) attest to the federal government's prime candidacy to conduct a national water survey that will underpin and benefit water-related decision making at the federal, state, regional, and local levels for decades to come.

5 APPENDIX A: Federal Water and Wastewater Supply and Efficiency Projects and Programs

The following summaries detail current federal water and wastewater supply projects and programs that span seven departments and agencies, as well as federal efficiency programs (since water made available through efficiency can be considered a source of water supply). Within each broader category, the summaries are organized alphabetically by department, and the purposes are paraphrased from a recent Congressional Research Service report.[53]

Infrastructure and Supply Programs

Department/Agency: Agriculture / Rural Development
Program/Project Category: Water and Waste Disposal Programs
Purpose: Provide basic human amenities, alleviate health hazards, and promote the orderly growth of the nation's rural areas by meeting the need for new and improved rural water and waste disposal facilities. Projects can include drinking water facilities, sanitary sewers, and storm water drainage and disposal facilities. The programs enable contracting for problem solving, operation, and maintenance of existing water and waste disposal facilities in rural areas. The program is analogous to the Health and Human Services' Low Income Home Energy Assistance Program (LIHEAP), which distributes energy assistance to more than eight million low-income households per year to assist in meeting the costs of home heating and cooling.

Department/Agency: Commerce
Program/Project Category: Economic Development Administration
Purpose: Provide investments to facilitate distressed communities in becoming more competitive through development of key infrastructure, including water supply and wastewater treatment, by investing in infrastructure directly tied to job creation.

Department/Agency: Defense / Army Corps of Engineers
Program/Project Category: Civil Works Program
Purpose: Provide water storage for municipal and industrial purposes only when and if additional storage is available in its multi-purpose reservoirs.

Department/Agency: Defense / Army Corps of Engineers
Program/Project Category: Environmental Infrastructure Assistance
Purpose: Provide rural and small communities with design and construction assistance for drinking water and wastewater infrastructure (including treatment and distribution/collection facilities) and source water protection and development.

Department/Agency: Environmental Protection Agency
Program/Project Category: Clean Water State Revolving Fund Loan Program

[53] Copeland, Claudia, et al. *Federally Supported Water Supply and Wastewater Treatment Programs*. 2016. Congressional Research Service 7-5700, RL 30478.

Purpose: Provide assistance in constructing publicly owned municipal wastewater treatment plants, implementing nonpoint pollution management programs, and developing and implementing management plans under the National Estuary Program.

Department/Agency: Environmental Protection Agency
Program/Project Category: Drinking Water State Revolving Fund Loan Program
Purpose: Provide assistance for infrastructure projects and other expenditures that facilitate compliance with federal drinking water regulations or that promote public health protection.

Department/Agency: Environmental Protection Agency
Program/Project Category: Water Infrastructure Finance and Innovation Act (WIFIA) Program
Purpose: Provide long-term, low-cost supplemental credit assistance under customized terms to creditworthy water and wastewater projects of national and regional significance.

Department/Agency: Interior / Bureau of Reclamation
Program/Project Category: "Traditional" Multi-purpose Reclamation Projects
Purpose: Support projects built for irrigation water supply, flood control, and hydroelectric power purposes, or projects included in the Rural Water Supply or Title XVI water reuse programs.

Department/Agency: Interior / Bureau of Reclamation
Program/Project Category: Rural Water Supply Projects
Purpose: Primarily support Pick-Sloan Missouri Basin Program irrigation projects. Many projects are linked to Native water settlements or provide benefit to Native populations.

Department/Agency: Interior / Bureau of Reclamation
Program/Project Category: Title XVI Projects
Purpose: Provide supplemental water supplies by recycling/reusing agricultural drainage water, wastewater, brackish surface and groundwater, and other sources of contaminated water. Projects may be either permanent or for demonstration purposes.

Efficiency Programs

Department/Agency: Energy / Energy Efficiency and Renewable Energy
Program/Project Category: Appliance and Equipment Standards Program
Purpose: Reduce water consumption of toilets, urinals, faucets, showerheads, dishwashers, and pre-rinse spray valves by setting standards on flow rate or maximum amount of water used per event.

Department/Agency: Energy / Federal Energy Management Program
Program/Project Category: Water Efficiency in Federal Buildings and Campuses
Purpose: Provide guidance and direction to governmental agencies on ways to increase water efficiency and reduce water use in federal buildings and campuses.

Department/Agency: Environmental Protection Agency
Program/Project Category: ENERGY STAR

Purpose: Promote energy efficiency in the United States through the use of a special voluntary label on consumer products for use in residential and commercial economic sectors. Promote efficiency in commercial buildings and industrial facilities through the use of benchmarking.

Department/Agency: Environmental Protection Agency
Program/Project Category: WaterSense
Purpose: Promote water efficiency in the United States through the use of a special voluntary label on consumer products for use in residential and commercial economic sectors.

Department/Agency: Housing and Urban Development
Program/Project Category: Community Development Block Grants
Purpose: Provide decent housing, a suitable living environment, and expanding economic opportunities, principally for low- and moderate-income persons. Water availability and quality, as well as wastewater treatment, are correlated with economic opportunity.

Department/Agency: Interior / Bureau of Reclamation
Program/Project Category: WaterSMART Water and Energy Efficiency Grants
Purpose: Provide cost-shared funding for projects for five functions: save water; increase energy efficiency and the use of renewable energy in water management; support environmental benefits; mitigate conflict risk in areas at a high risk of future water conflict; and accomplish other benefits that contribute to water supply sustainability in the western U.S.

6 APPENDIX B: Agricultural/Irrigation Sector and Electric Utility Sector

The Farm and Ranch Irrigation Survey (FRIS), mandated by federal law,[54] provides data relating to on-farm irrigation activities. It is conducted in conjunction with the quinquennial Census of Agriculture, with its target population being all farms and ranches in 50 states reporting irrigated land in the previous year's Census of Agriculture. The Department of Agriculture uses it to inform its activities related to water use. FRIS provides data that are complete, consistent, and accurate enough to be used for benchmarking on-farm irrigation measures over time.

Farm and Ranch Irrigation Survey	
General	
Sponsoring Organization	US Department of Agriculture
Sector	Agricultural
Scope	Irrigated acres by land use categories, acres and yields of irrigated crops, quantity of water applied and method of application to selected crops, acres irrigated and quantity of water used by source, acres irrigated by type of water distribution system, and number of irrigation wells and pumps
Geographical Coverage	United States (nationwide)
Year(s)	Limited data collected since 1890; dedicated irrigation data collected since 1979. 1979-2013
Frequency	Every five years in the year following the Census of Agriculture
Objective(s)	To provide detailed profile of irrigation in the U.S. for water application methods comparison, improved technology development, federal program development, water use trend tracking, congressional legislation impact assessment
Methodological Approach	A sample of farms reporting irrigated acres is systematically selected covering about 35 percent of the total acres irrigated. A stratified sample design is employed, which allows larger farms to be more heavily sampled. Data are collected by mail out/mail back with a telephone follow-up of farms not responding. In some special cases, personal visits are made to maximize response. Sample weights of the reporting farms are adjusted to account for non-response.
Information Access	Aggregated data publicly available, https://www.agcensus.usda.gov/
Parameters	
Demographics	• Ownership type • Race • Gender
Building/Land Characteristics	Crop type, open or protected growing area
Inventory of Product Stock	Irrigation type, water source
Characterization of Product Stock	• Crop type (corn for silage or greenchop; sorghum for grain or seed, wheat for grain or seed, soybeans for beans, beans (dry, edible), rice, other small grains, alfalfa and alfalfa mixtures, other hay, peanuts, cotton, vegetables, sweet corn, tomatoes, lettuce and romaine, potatoes (excluding sweet), orchards, vineyards, nut trees, berries, all other crops, pastureland) • Irrigation type (hand watered, gravity irrigation, sprinkler, drip, trickle, or low-flow micro irrigation, sub-irrigation) • Water source (groundwater well, surface water on farm, surface water

[54] U.S. Code: Title 7 – Agriculture, Section 2204g, https://www.law.cornell.edu/uscode/text/7

	external to farm)
Characterization of Consumer Use/Interaction	Water management practices including conservation techniques for water delivery system acres by state and water resource region
Measured Water Consumption	The following parameters are reported by number of farms and by total irrigated acres for states and water resource regions: • precipitation rates; • acres of irrigation land; • irrigation acres by irrigation type, water pressure, and delivery system; • quantity of water delivered; • crop yields by irrigation and non-irrigated acres; • irrigated open and horticultural operation acres.
Conservation Assessment	Assistance for improvements (technical or financial) received 9 options given for barriers to implementing improvements to reduce energy use or conserve water in irrigation system • Not a priority • Risk of reduced yield or poorer quality of crop • Field or crop limits improvement • Not cost-effective • Unable to finance • Owner will not share costs • Water availability uncertainty • Short-term operation prevents justification for improvements • Increased management time or cost

The Annual Electric Utility Survey (AEUS) has been conducted since 1970 and is federally mandated[55] to collect energy demand data for power generation (NAICS code 22). The survey collects data on the water withdrawal from a water body for cooling (for eleven different cooling system types), water discharge back to the water body, diversion of water within the system, consumption due to evaporative losses, water temperature during withdrawal, and water temperature during discharge.

Annual Electric Utility Survey	
General	
Sponsoring Organization	EIA (Form-923 and Form-861, previous form EIA-906/902)
Sector	Power Generation, NAICS Code 22
Scope	Manufacturing
Geographical Coverage	United States (nationwide)
Year(s)	Data for utility plants are available from 1970, and for nonutility plants from 1999. Beginning with January 2004 data collection, the EIA-920 was used to collect data from the combined heat and power plant (cogeneration) segment of the nonutility sector; also as of 2004, non-utilities filed the annual data for nonutility source and disposition of electricity. Beginning in 2008, the EIA-923 superseded the EIA-906, EIA-920, FERC 423, and the EIA-423.
Frequency	Monthly, Annual
Objective(s)	To produce generation and fuel consumption time series data
Methodological Approach	The AEUS uses an online survey form to collect data.

[55] U.S. Code, Title 15, Chapter 16B, Subchapter I, § 761: https://www.law.cornell.edu/uscode/text/15/761

Information Access	Publically available Excel worksheets, https://www.eia.gov/electricity/data/eia923/index.html
Parameters	
Demographics	None
Building Characteristics	None
Inventory of Product Stock	None
Characterization of Product Stock	Cooling system types include: • Dry (air) cooling system • Hybrid: recirculating cooling pond(s) or canal(s) with dry cooling • Hybrid: recirculating with forced draft cooling tower(s) with dry cooling • Hybrid: recirculating with induced draft cooling tower(s) with dry cooling • Helper tower • Once through with cooling ponds • Once through without cooling pond(s) or canal(s) • Recirculating with cooling ponds • Recirculating with forced draft cooling tower • Recirculating with induced draft cooling tower • Recirculating with natural draft cooling tower
Characterization of Consumer Use/Interaction	None
Measured Water Consumption	Method of measurement of cooling water rate includes: • Streamflow gage or weir • Cumulative or continuous flow meter • Instantaneous flowmeter and pump running time • Stated pump capacity and pump running time • Estimated from measured withdrawals • Calculated difference between withdrawal and discharge flows • Estimated from withdrawal amount and a loss coefficient • Estimated based on power generation • Estimated based on design characteristics The survey also collects electric power data on electricity generation, fuel consumption, non-utility source and disposition of electricity, fossil fuel stocks, environmental data, and fuel receipts and costs at the power plant and prime mover level.
Conservation Assessment	None

7 APPENDIX C: Stakeholders Benefitting from Existing Federal Surveys (CBECS, RECS, FRIS, and AEUS)

This section summarizes supporting documents provided by DOE and USDA to the OMB for survey approval under the Paperwork Reduction Act. It demonstrates a wide breadth of users for national resource demand and end-use data. For full supporting statements, refer to the websites listed below.

Department/ Survey	Document	Website
DOE / CBECS	2012 CBECS Supporting Statement Part A.docx	https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201209-1905-001
DOE / RECS	2015 RECS_SS Part A Cover and TOC_050715.docx	https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201504-1905-002
USDA / FRIS	0234-fris-2013-SSA - Rev.docx	https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201306-0535-001
DOE / AEUS	Elec 2011 Supporting Statement Part A.pdf	https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201007-1905-001

Federal Agencies using CBECS and RECS data

- US Commerce Department, U.S. Census Bureau: EIA has provided extensive analysis of RECS data to the Census Bureau as part of an investigation into the use of consumption-based measures of poverty, using expenditures and other indicators of material well-being. The U.S. Census Bureau also uses the RECS data to adjust the reporting of electricity and gas costs by American Housing Survey respondents.

- US DOE, EIA, Office of Energy Analysis, Short Term Energy Outlook: RECS consumption and cost data are used as benchmark input estimates for near-term energy demand forecasts within EIA. This includes the annual Winter Fuels Outlook, which forecasts heating fuel prices and expected household energy costs for October to March each year.

- US DOE, EIA, Office of Energy Analysis, National Energy Modeling System: The NEMS, EIA's modeling system, meets a broad spectrum of Departmental needs. It is used frequently to assess policy questions posed by the Administration and the Congress. RECS and CBECS data are tailored to meet the needs of this model and are used to characterize the U.S. commercial sector in the NEMS. The residential and commercial modules of the NEMS provide the 30-year energy forecasts for the residential and commercial sectors that appear in a congressionally mandated publication reporting forecast data, the Annual Energy Outlook.

- DOE, Economic Analysis: The Office of Policy extensively uses the RECS data in a variety of analytical studies. These studies have used RECS data to arrive at national estimates of energy savings for various energy program investments and evaluations within DOE; to assess the amount of energy used by heating and cooling equipment when

setting efficiency standards; and to assess the potential for fuel switching and cogeneration.

- DOE, Office of Energy Efficiency and Renewable Energy Programs:
  - EERE's Appliances and Commercial Equipment Standards Program develops test procedures and minimum efficiency standards for residential appliances and commercial equipment. As an example, the program uses the annual RECS end-use consumption estimates to determine whether efficiency improvements have a suitable payback time for consumers.

  - EERE's Residential Buildings Program developed the Building America Research Benchmark in consultation with the Building America industry teams. The RECS data are used to analyze relationships between various household characteristics and energy consumption.

  - RECS data supports the development of building codes. DOE works with other government agencies, state and local jurisdictions, national code organizations, and industry to promote stronger building energy codes and help states adopt, implement, and enforce those codes.

  - The Weatherization and Intergovernmental Program uses RECS consumption data to track the efficiencies of newly constructed housing units, and other weatherization data track longitudinal changes in conservation measures as well as the energy burden for low-income households.

- U.S. EPA, ENERGY STAR: EPA uses RECS data to support their programs and identify new products that have the potential as ENERGY STAR products.

- U.S. EPA, Benchmark for ENERGY STAR Buildings: CBECS data are used to create benchmarking models by EPA that allow building owners or managers to assess and then rank their buildings' energy efficiency in order to apply for the ENERGY STAR label. The models relate building energy consumption to statistically relevant drivers of energy consumption. Using the CBECS data, the EPA has developed an innovative energy management tool called Portfolio Manager that helps building owners, managers and operators evaluate energy use and document performance. Building owners and management companies use Portfolio Manager results to apply for the ENERGY STAR efficiency label, satisfy Leadership in Energy and Environmental Design (LEED) requirements, support real estate transactions, and as a basis for establishing rents in long term leasing contracts.

- Energy Independence and Security Act, Benchmark for Energy Reduction Targets for Federal Buildings: The EISA of 2007 cited the 2003 CBECS as the benchmark for energy reduction for federal buildings, as well as for energy performance targets and standards for new federal buildings and buildings undergoing major renovations.

- U.S. Department of Health and Human Services, Administration for Children and Families, Low-Income Home Energy Assistance Program: LIHEAP distributes energy assistance to more than 8 million low-income households per year to assist in meeting the costs of home heating and cooling. Since 1981, HHS/ACF has supported the RECS by funding a set of questions added to the household interview. These and other RECS data are used for analysis included in the LIHEAP Home Energy Notebook and Annual Report to Congress.

- U.S. Department of Housing and Urban Development: HUDs Office of Community Planning and Development uses RECS data to evaluate its energy efficiency portfolio—from energy efficiency mortgages, to weatherization and retrofits, to utility incentive programs.

- U.S. Department of Labor, U.S. Bureau of Labor Statistics, Consumer Price Index: The BLS uses RECS data in the preparation of the Consumer Price Index. BLS uses the RECS microdata file to develop equations for imputing utility costs for renters whose utility costs are included in their rent. BLS has automated this imputation process for approximately one fifth of the renter sample used for the CPI. As a result of this process, BLS is not required to field an additional survey to collect these important data.

Other Countries using CBECS data

- Natural Resources Canada, Canadian Commercial Buildings Energy Use Surveys: CBECS was used as the model for the 2000 Commercial Institutional Building Energy Use Survey conducted by the Natural Resources Canada and the Statistics Canada. The CBECS design and methodology were used to develop the CIBEUS. Both building characteristics and energy consumption data were collected in a sample of Canadian commercial buildings. EIA was also consulted by Natural Resources Canada as they were developing the 2008 Commercial & Institutional Consumption of Energy Survey.

Stakeholder Organizations using RECS data

- Alliance to Save Energy: ASE uses RECS data to set recommendations for energy efficient appliance and equipment standards. RECS data are also used to determine the economic impacts of specific projects, for example, a campaign to increase cold water laundry.

- American Council for an Energy-Efficient Economy: ACEEE uses RECS data to help develop recommended appliance and other product standards for their recommendations to DOE. RECS data show the market saturation and age of various products and are used to develop the estimated savings from any new standard. ACEEE also uses RECS data to influence recommendations for work on national and state building codes. ACEEE has also developed a cities scorecard which includes some inputs from RECS.

- American Society of Heating, Refrigerating and Air-Conditioning Engineers, Standardization and Codes for New Building Design: CBECS data are used by ASHRAE

as input to evaluate existing and develop new standards and codes for buildings. CBECS data are also used in the development of ASHRAE's Building Energy Quotient building energy labeling program.

- Joint Center for Housing Studies and National Multifamily Housing Council: Both organizations use RECS data to help develop a profile of rental housing. RECS is used to characterize the landscape of energy efficiency in apartments and to determine where energy efficiency improvements would be most effective.

- National Association of State Energy Officials: NASEO uses RECS data to influence residential appliance standard recommendations. NASEO also uses RECS data for specific state initiatives where the data allow. They have also used RECS data for specific energy research topics, such as the availability of liquid fuels.

Other Stakeholders using CBECS data

- Architects, New Building Design: CBECS is used to benchmark energy demand during the design phase of new and retrofit buildings and to meet targets for the 2030 Challenge. The 2030 Challenge asks the global architecture and building communities to design all new buildings and major renovations to meet energy consumption performance standard of 60% below the regional (or country) average for the specific building type, as reported by the CBECS.

- Building Owners and Property Managers, Benchmark for Building Operations: CBECS benchmarks are used to help building owners and property managers drive down fixed operating costs related to energy use in buildings. By establishing a baseline, building owners and managers can identify areas for improvement and measure their success. The energy performance of buildings is becoming a more widely accepted criterion for determining rents and purchase prices.

- Manufacturers, Technology and Energy Service Companies, Definition of Market Potential: From national diversified technology companies to small start-ups, many companies use the CBECS data for research, marketing, and product development.

For the USDA's Farm and Ranch Irrigation Survey (FRIS), numerous government agencies, research organizations, irrigation industries, land-grant universities, and many farm operators and managers use the data FRIS provides.[56] Some of the data users include those shown below.

Federal Agencies using FRIS data

- USDA, Economic Research Service: The ERS relies on FRIS data to assist policy makers and to provide essential data for economic models which are used to analyze the impact of alternative farm policies on the irrigated sector.

[56] Office of Management and Budget, Paperwork Reduction Act for FRIS 2013, Supporting Statement A. 0234-fris-2013-SSA-Rev.docx. https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201306-0535-001

- USDA, Natural Resource Conservation Service: The NRCS uses these data (in addition to that of the Census of Agriculture) in appraising the status and condition of water and water-use trends on non-federal lands. Also, NRCS uses these data to plan and evaluate a national water-conservation program.

- US Department of the Interior, USGS: The USGS uses these data for preparing national water summaries used by the Environmental Protection Agency, the Army Corps of Engineers, and other agencies for developing water-related programs.

- US Department of the Interior, Bureau of Reclamation: The Bureau relies on these data for conducting feasibility studies of irrigation projects.

- US Congress and state legislatures: Both the United States Congress and state legislative bodies use the data for formulating and assessing natural resource legislation.

State Agencies using FRIS data

- State Water Resource Agencies: State water resource agencies use the survey results to develop programs and prepare descriptive information.

Other Stakeholders using FRIS data

- Farmers and ranchers: These stakeholders use the economic cost-and-return data which is collected in FRIS to determine the feasibility of investing in irrigation systems. Examples of use cases of these data include investing in irrigation equipment, facilities, and land improvements; figuring maintenance and repair expenditures of irrigation equipment and facilities; and estimating yields of irrigated versus non-irrigated crops.

- Irrigation system manufacturers and related businesses: These stakeholders all use these data to monitor trends in equipment use, irrigation expansion, and other market production related activities.

- Land grant universities and other research organizations: These stakeholders use these data to study irrigation technology development and adopt them to agricultural productivity.

- Planning agencies: These stakeholders use FRIS information regarding water supplies and water use by state and water resource area to evaluate ground water withdrawals, especially the depletion of ground water reserves in the major irrigation areas.

DOE's Annual Electric Utility Survey (AEUS) statement to OMB shows uses of the survey data to support federal and state programs. Publications are listed as well.

Federal and State Agencies Using AEUS Data:

- U.S. DOE, EIA, Office of Energy Analysis, National Energy Modeling System: The NEMS uses sales data to project long-term electricity demand, sales for resale and

purchases are used to validate the wholesale model results; other data applications include:
    - The development and maintenance of time series data showing average wholesale electric power volumes and average prices by NERC region;
    - Verification of information provided to state and other federal agencies in other forums;
    - Assessment of the degree of market concentration in market-based applications;
    - Evaluation of unbundled retail electricity rates;
    - Monitoring and analysis of the economic and operational impacts of industry restructuring;
    - Monitor sales and prices of electricity for use by the Public Utility Commissions when reviewing rate cases;
- U.S. DOE: The data are used to accurately maintain the electric power frame and to be a source from which samples are drawn for other electric power surveys (*e.g.*, Form EIA-826);
- U.S. DOE, EIA: The survey results provide input into the following reports issued by EIA:
    - *Electric Power Monthly*
    - *Electric Power Annual*
    - *Annual Energy Review*
    - *Renewable Energy Annual*
    - *State Electricity Profiles*
    - *Electric Sales and Revenue*
    - *Monthly Energy Review*
    - *Annual Energy Outlook*
- Congress, other federal and state agencies, the electric power industry, and the general public: General queries pertain to:
    - Time series data showing distributed and dispersed generation resources;
    - Development of net metering and green pricing programs;
    - Annual and incremental effects of DSM programs and their costs;
    - Changes in electricity prices in the various states and sectors of the economy;
    - Effect of price changes on the demand for electricity;
    - Progress of energy service providers as they expand in the states with retail competition;

Other data users include electricity-related trade associations; independent system operators; electric utility companies; nonutility companies; energy service providers; wholesale electricity traders; electrical equipment companies; numerous local, state, and federal government agencies; environmental associations; consumer groups; financial analysts; data aggregators; modelers; independent research groups; academia; consultants; and the news media.

8 ACKNOWLEDGEMENTS

The authors would like to thank the following individuals for their helpful comments: Jonah Schein and Veronica Blette of the U.S. Environmental Protection Agency, Eileen O'Brien of the U.S. Department of Energy, Maureen Hodgins of the Water Research Foundation, and Alison Williams, Louis Desroches, and Katie Coughlin of Lawrence Berkeley National Laboratory.

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