Residential End Uses of Water, Version 2

EXECUTIVE REPORT

Water Research Foundation℠

Contents

Introduction 3

Current Usage 4

Comparisons with the 1999 Project 7

The Future 10

About the Utilities in this Study 12

Disclaimer:

This study was jointly funded by the Water Research Foundation (WRF), City of Fort Collins Utilities, City of Scottsdale Water Department, Clayton County Water Authority, Denver Water, Portland Water Bureau, Region of Peel, Region of Waterloo, San Antonio Water System, Tacoma Public Utilities, Toho Water Authority, Tampa Bay Water, and the Alliance for Water Efficiency on behalf of Portland Water Bureau, Region of Peel, San Antonio Water System, and Tampa Bay Water (co-sponsors). WRF and the co-sponsors assume no responsibility for the content of the research study reported in this publication or for the opinions or statements of fact expressed in the report. The mention of trade names for commercial products does not represent or imply the approval or endorsement of WRF or the co-sponsors. This report is presented solely for informational purposes.

Published April 2016

Residential End Uses of Water, Version 2: Executive Report

For more information about this project, please visit **www.waterrf.org/4309**

Prepared by:

William B. DeOreo, Aquacraft, Inc. Water Engineering and Management
Peter Mayer, Water Demand Management
Benedykt Dziegielewski, University of Southern Illinois
Jack Kiefer, Hazen and Sawyer, P.C.

Jointly sponsored by:

Water Research Foundation, City of Fort Collins Utilities, City of Scottsdale Water Department, Clayton County Water Authority, Denver Water, Portland Water Bureau, Region of Peel, Region of Waterloo, San Antonio Water System, Tacoma Public Utilities, Toho Water Authority, and Tampa Bay Water. The Alliance for Water Efficiency coordinated the financial support from Portland Water Bureau, Region of Peel, San Antonio Water System, and Tampa Bay Water.

Project Technical Advisory Committee:

Doug Bennett, Southern Nevada Water Authority
David Bracciano, Tampa Bay Water
Robert Day, San Jose Water Company
Mary Ann Dickinson, Alliance for Water Efficiency
Warren Liebold, New York City Department of Environmental Protection

Published by: Water Research Foundation℠

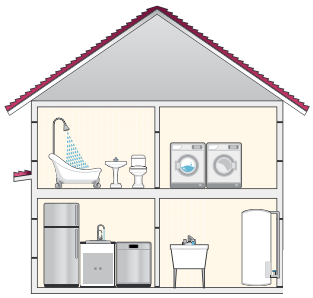
ISBN 978-1-60573-236-7

Residential End Uses of Water, Version 2: Executive Report

Single-family homes typically use the most water of any utility customer sector. The 23 utilities studied show a decline of 22 percent in average annual indoor household water use since WRF's landmark 1999 study. Water providers should consider lower household water use when making future plans.

Introduction

It is essential for water providers and the urban water supply industry to have a detailed understanding of how water is used in residential settings. While water use in homes was studied as early as the 1940s, interest intensified after the Energy Policy Act of 1992, which sought to improve energy and water efficiency. This Act established maximum flow rates for new residential toilets, showerheads, and faucets. Later federal regulations included clothes washers. Water efficiency in homes has also been encouraged by programs like EPA's WaterSense.



22%
DECREASE
1999-2016

Average annual indoor household water use

Until now, the most significant residential end use study conducted in North America was the Water Research Foundation's 1999 report, *Residential End Uses of Water* (REU1999) (Mayer et al. 1999). WRF's new report, *Residential End Uses of Water, Version 2* (REU2016) (DeOreo et al. 2016), provides an updated and expanded assessment of water use. It includes more varied study site locations, hot water usage data, more detailed landscape analysis, and additional water rate analysis.

The new study identifies variations in water use by each fixture or appliance, providing detailed information and data on changes since the REU1999 study. Looking to the future, the study's research evaluates conservation potential, and includes predictive models to forecast residential demand.

The decline in water use across the residential sector, even as populations increase, poses new challenges for water utilities. Information on single family home water consumption is significant for utility rate and revenue projections, capital planning (water supply and infrastructure needs), daily operations to provide water, water efficiency programs, and more.

Current Residential Water Use: the REU2016 Study

The homes studied in REU2016 showed an average annual use of 88,000 gallons per household per year (gphy).[1]

Annual Use

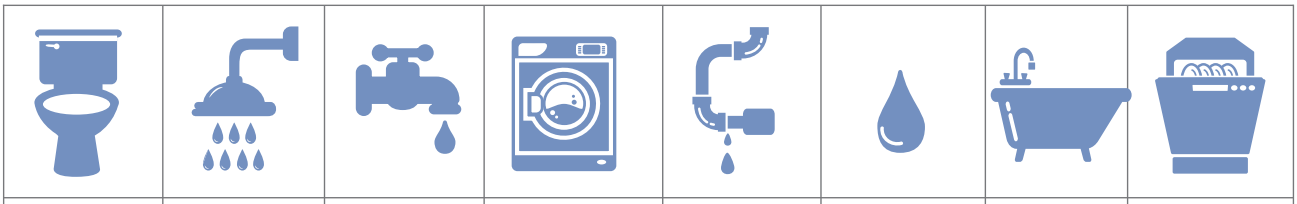
In REU2016, approximately 1,000 single-family residential accounts were randomly selected from each of 23 study sites (see Figure 8). Billing records showed average annual per household water use ranging from 44,000 to 175,000 gphy.

The large range in use reflects the strong influence of climate and weather patterns. Agencies participating in the study come from across the United States and Canada and encompass a tremendous geographic and climactic diversity. Outdoor use is more variable than indoor use, and homes in warmer climates have higher outdoor use, continuing to irrigate in winter.

A fundamental goal of REU2016 was to quantify how much water is used both indoors and outdoors, as well as per capita and household. Such metrics are valuable for understanding water use patterns, establishing efficiency levels, and developing predictive models of future demand.

[1]This REU2016 statistic is based on 23,749 homes (23 study sites, mostly 2010 billing data) with a standard deviation of 32,000 gphy. The median annual water use was 83,000 gphy.

Figure 1. Indoor household use by fixture



Toilet	Shower	Faucet	Clothes washer	Leak	Other*	Bath	Dishwasher
24%	20%	19%	17%	12%	4%	3%	1%
33.1 gphd	**28.1 gphd**	**26.3 gphd**	**22.7 gphd**	**17.0 gphd**	**5.3 gphd**	**3.6 gphd**	**1.6 gphd**

* The "Other" category includes evaporative cooling, humidification, water softening, and other uncategorized indoor uses.

Indoor Use

Toilet flushing is the largest indoor use of water in single-family homes, followed by faucets, showers, clothes washers, leaks, bathtubs, other/miscellaneous, and dishwashers (see Figure 1).

Mandated reductions in toilet flush and clothes washer volumes and shower and faucet flow rates have contributed to the declines in residential water use. REU2016 showed indoor water use at 138 gallons per household per day (gphd). A sample of new homes built according to EPA's WaterSense New Home Specification Version 1.0 had an average daily per household water use of 110 gphd (DeOreo et al. 2011[2]).

Hot Water

In a sub-sample of 94 homes, the average household hot water use was 45.5 gphd, which accounted for 33.2% of total indoor water use. Showers and faucets each consumed substantially more hot water than all the other end uses combined. For showers, the average daily household hot water use was 17.8 gallons, and for faucets, 15.4 gallons.

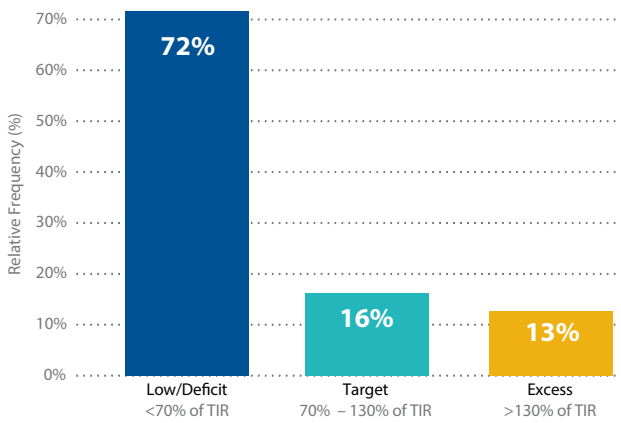
Table 1. Average daily hot water use per household

Shower	39.1%	**17.8 gphd**
Faucet	33.8%	**15.4 gphd**
Clothes washer	9.7%	**4.4 gphd**
Bath	5.7%	**2.6 gphd**
Dishwasher	4.8%	**2.2 gphd**
Leak	4.6%	**2.1 gphd**
Other	2.0%	**0.9 gphd**
Toilet	0%	**0.0 gphd**
Total		**45.5 gphd**

[2]Nearly 100 percent of the 25 new homes studied in DeOreo et al. 2011 met the following efficiency criteria: clothes washers with capacities of ≤ 30 gallons per load (gpl), shower flow rates ≤ 2.5 gallons per minute (gpm), and toilet flushes ≤ 2.0 gallons per flush (gpf).

Outdoor Use

Figure 2. Percent of the Theoretical Irrigation Requirement (TIR) applied to landscape.



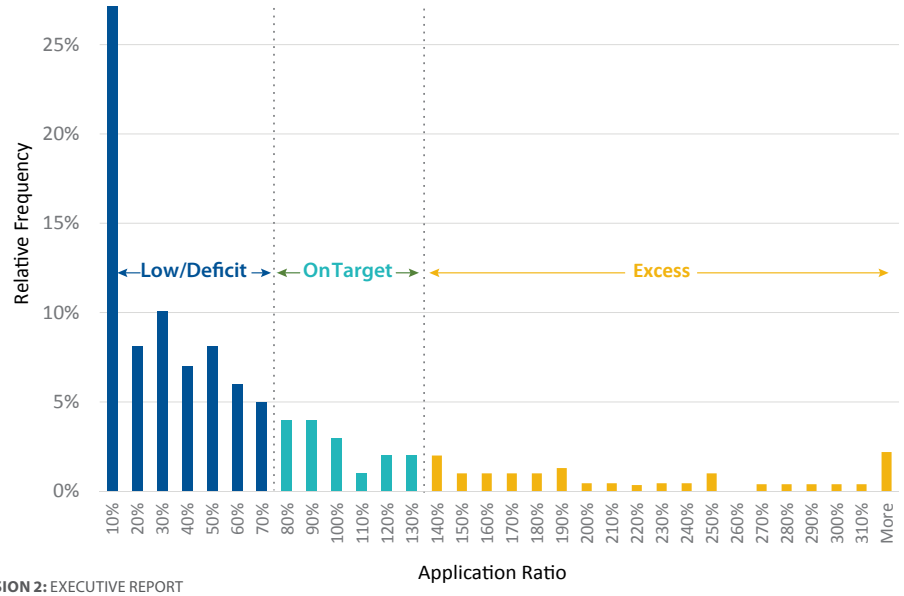
Outdoor water use was studied more extensively in REU2016 than REU1999, specifically, the efficiency of landscape irrigation. The Landscape Group was comprised of a sample of 838 homes selected as a representative subset from participating water utilities. Local weather conditions, irrigated area, water cost, and type of plant material are major drivers of outdoor use. The outdoor water use category is comprised of water uses like landscape irrigation, water used through hose bibs, water for filling and backwashing swimming pools, water for washing pavement and cars, and so forth.

While the average annual use for all sites (23,749 homes) was 88,000 gphy, the Landscape Group's annual use averaged 101,000 gphy, of which outdoor use constituted 50 percent, or 50,500 gphy.

To analyze outdoor water use, the estimated actual use was compared to the theoretical irrigation requirement—an estimation of water needs for residential and park landscapes. The theoretical irrigation requirement is considered the amount of irrigation that is theoretically required, although many landscapes can thrive on a lesser amount. The theoretical irrigation requirement was customized for each lot in the Landscape Group, considering irrigation area, groundcover type, and other local factors.

The majority of study participants—72 percent—applied considerably less water than was theoretically required and were termed "low/deficit irrigators." Sixteen percent of study participants were considered "target" irrigators, because they applied close to the theoretical irrigation requirement. A small group of over-irrigators applied gross excess water compared to the estimated theoretical requirement. This 13 percent accounts for the bulk of excess irrigation for the whole group.

Figure 3. Distribution of application ratios, Landscape Group (n=838)



Comparison with the 1999 *Residential End Uses of Water* Study

Reductions in household water use are largely due to more efficient fixtures and appliances and are not the result of either occupancy or behavior.

Annual Use

While it is tempting to compare annual use from REU1999 (146,100 gphy) to REU2016 (88,000 gphy), it is inappropriate to do so, since the participating utilities differed between the two studies. Neither of these studies was designed to be representative of all North American locations. This limits the statistical inferences and generalizations that can be drawn from the data.

REU1999 had 12 participating utilities, with 12,055 households in the sample group. Ten of the 12 participating utilities were located in the western and southwestern United States.

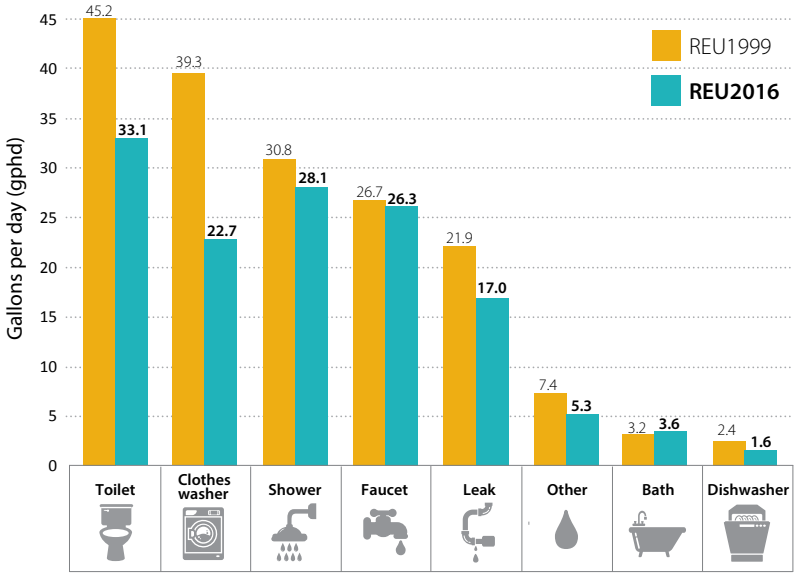
REU2016 had 23 participating utilities, with 23,749 homes in the sample group. The REU2016 participating utilities are spread more diversely throughout the United States, with many more eastern sites.

For both REU1999 and REU2016, the sites show extreme variation in climate and weather, and therefore it can be supposed that households will vary greatly in outdoor water use. It is more useful and appropriate to compare indoor water use between the two studies.

Indoor Daily Per Household and Per Capita Use

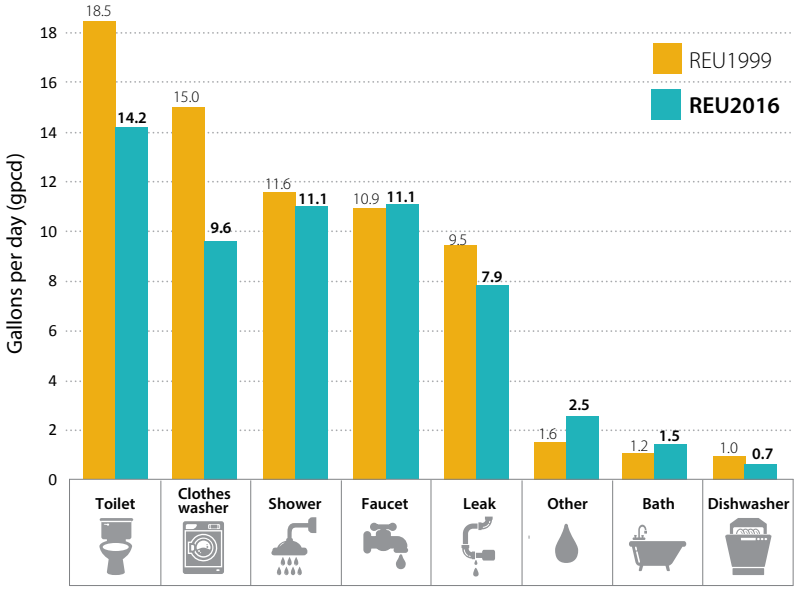
Residential indoor water use in single-family homes has decreased. The average per household daily water use has decreased 22 percent, from 177 gphd (REU1999) to 138 gphd (REU2016). Per capita average water use has decreased 15 percent, from 69.3 gpcd (REU1999) to 58.6 gpcd (REU2016). In REU1999, a household averaged 2.77 people and in REU2016, a household averaged 2.65 people. The improved water efficiency of clothes washers and toilets accounts for most of the decreases in indoor use.

Figure 4. Average daily indoor per household water use REU1999 and REU2016



22%
DECREASE PER HOUSEHOLD
DAILY WATER USE
1999 TO 2016

Figure 5. Average daily indoor per capita water use REU1999 and REU2016



15%
DECREASE PER CAPITA
DAILY WATER USE
1999 TO 2016

Clothes Washers

The biggest reduction in per capita water use between the two studies was measured in the clothes washer category. Starting in the mid-1990s, efficiency improvements dramatically reduced water usage, from an average volume of 41 gallons per load (REU1999) to 31 gpl (REU2016). Per capita use decreased 36 percent, from 15.0 gpcd (REU1999) to 9.6 gpcd (REU2016).

36%
DECREASE (gpcd)

Toilets

The flush volume of toilets has decreased 29 percent, from 3.65 gallons per flush (REU1999) to 2.6 gpf (REU2016). Toilet flushing frequency has remained the same—5.0 flushes per person per day. In REU1999, just 8.5 percent of homes had average toilet flushes less than 2.0 gpf. In REU2016, 37 percent of homes had average toilet flushes less than 2.0 gpf.

29%
DECREASE (gal/flush)

Dishwashers

An automatic dishwasher was present in 84 percent of the end use study homes in REU2016. The average water volume per dishwasher load decreased 39 percent, from 10.0 gallons per load (REU1999) to 6.1 gpl (REU2016). A comparison of households showed that if a house lacked a dishwasher, faucet use did not increase, which would normally be supposed. Regardless of the presence of a dishwasher, faucet use averaged 26 gphd.

39%
DECREASE (gal/load)

Leaks

The average daily per capita leakage decreased 17 percent, from 9.5 gallons per capita daily (REU1999) to 7.9 gpcd (REU2016). Thirty-two percent of homes had higher leakage rates, as high as 600 gallons per household per day.

17%
DECREASE (gpcd)

Showers, Faucets and Bathtubs Showed Minimal Change

REU2016 shows minimal change in showering patterns. The average duration held steady at 7.8 minutes per shower. The flow rate decreased just 0.1 gallon per minute. The average faucet use per household and per capita did not change at a statistically significant level from REU1999 to REU2016. Bathtubs showed a small increase, from 1.2 gpcd (REU1999) to 1.5 gpcd (REU2016). The presence of children (aged 12 and under) increased bathtub use.

0%
DECREASE

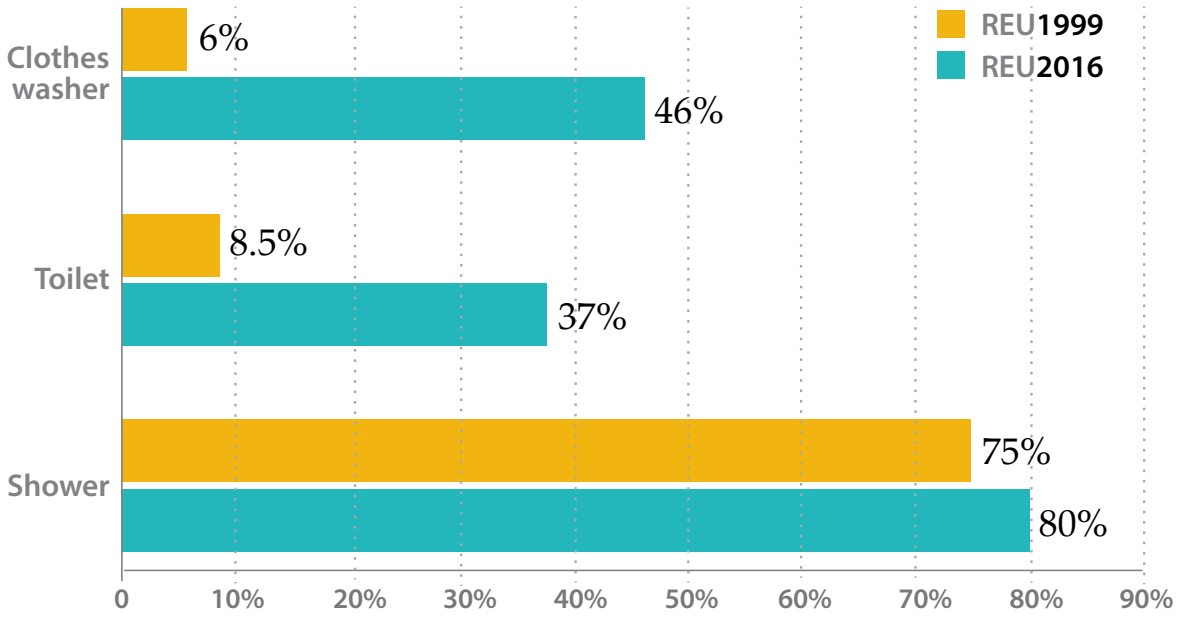
The Future: Conservation Potential

Substantial indoor and outdoor conservation potential exists in the single-family sector. With 100 percent occurrence of higher efficiency devices, indoor household water use could drop 35 percent or more, to below 40 gallons per capita per day. Aggressive outdoor water conservation could reduce outdoor use even further.

More efficient appliances and fixtures have contributed to significant reductions in residential indoor water use, but there remains much potential for additional savings. In REU2016, more than half of residences did not meet the study's efficiency criteria for clothes washers and toilets, and 20 percent did not meet those standards for showers (see Figure 6). In addition, households that currently over-irrigate could change their habits and substantially reduce their outdoor use.

Figure 6. Percent of homes meeting efficiency criteria, REU1999 and REU2016

Efficiency criteria include: clothes washers <30 gal/load, toilets <2.0 gal/flush, showers <2.5 gal/minute.

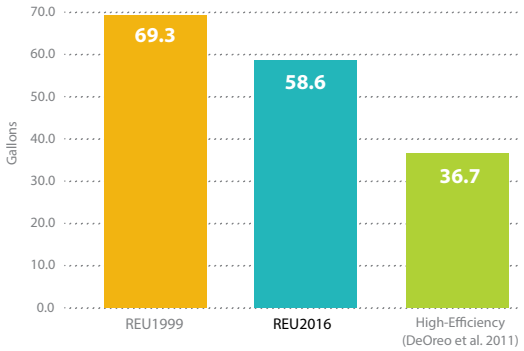


Indoor Conservation Potential

Even without a concerted effort on the part of homeowners to switch to more efficient appliances and fixtures, reductions are anticipated as old toilets and clothes washers wear out and are replaced. The current average daily indoor per household use of 138 gphd is expected to reduce to 110 gphd. Per capita use of 58.6 gpcd is expected to reduce to 36.7 gpcd in the coming years.

Further reductions are anticipated as customer side leakage is reduced (through automated metering and leak alert programs) and through on-site reuse. There are many variables that contribute to indoor water use patterns, such as the age of the fixtures and appliances, the age of housing stock, and the frequency of remodeling. Utilities should determine appropriate efficiency targets for their own service area based on local factors.

Figure 7. Indoor average gallons per capita per day, REU1999, REU2016, High Efficiency Studies



Outdoor Conservation Potential

There are a number of common strategies to maximize outdoor efficiency. Utilities should target water efficiency programs at excess irrigators. Deficit irrigators (those using less than the theoretical irrigation requirement) should be prevented from increasing their irrigation in the future. Pricing programs and reduction in planting areas may achieve outdoor demand reductions beyond efficiency measures. For example, water reductions of 20-50% are estimated when using mild to aggressive landscape conservation programs.

If excess irrigation could be eliminated in the Landscape Group, the average outdoor use would drop by 8.2 kgal per house, or 16 percent.

About the Utilities in this Study

The 23 utilities studied in this report represent a time and place snapshot of how water is used in single-family homes in North America, based on a statistically representative sample of customers from these locations.

Research Approach

Random samples of representative single-family customers were the center of the research. The study collected highly detailed information from 2010 to 2013 on water use, demographics, and the homes' landscapes.

REU2016 followed the same basic research approach as REU1999, with some notable additions. The new study included more varied site locations, collection of hot water data, and more detailed landscape analysis.

Study Participants

Utilities from across the United States and Canada were invited to participate as study sites. Ultimately, 23 utilities joined the study as full participants. Each selected a sample of approximately 1,000 single-family homes from their active customer accounts. From that database, billed consumption data were collected from 23,749 homes. An extensive survey was mailed to a total of 13,749 selected households and a total of 4,643 usable surveys were returned. The 23 utilities also provided information on metered consumption, water conservation programs, drought and conservation plans, budgets, staffing levels, and water and wastewater rates.

Nine of the utilities, called Level 1 study sites, participated more extensively. Nine hundred homes were selected for additional end use sampling. Of these, 762 analyzed flow traces, 110 were selected for hot water flow monitoring, and 838 homes participated in a Landscape Analysis Group. (The other 14 locations are called Level 2 study sites.)

The 23 utilities participating in REU2016 come from across North America and encompass a tremendous climatic, geographic, and demographic diversity.

Survey data collection

23,749
Billed consumption data

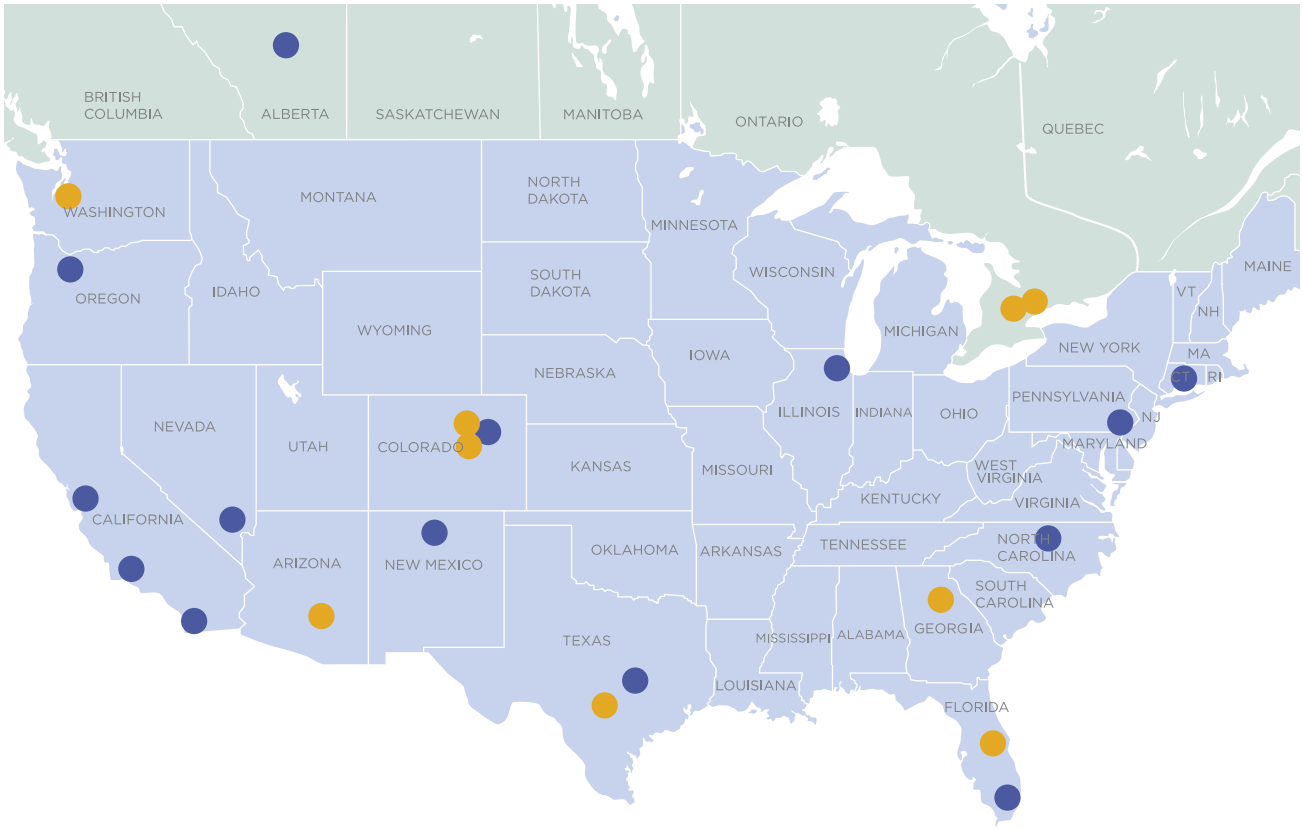
4,643
Extensive surveys

838
Landscape analysis group

762
End use monitoring samples

94
Hot water end use flow monitoring

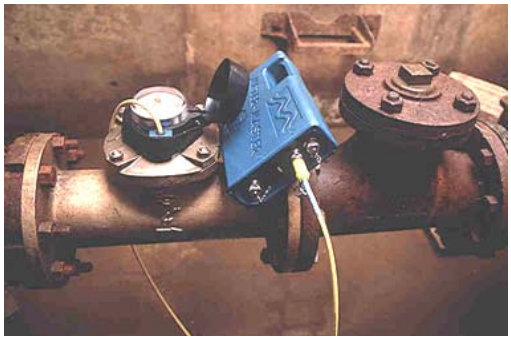
Figure 8. Diversity of the Level 1 and Level 2 study site locations



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

Flow Trace Monitoring



Meter-Master flow recorder installed on a magnetic drive water meter.
(Photo courtesy of the F. S. Brainard Company)

After the surveys were tabulated, 900 homes (100 from each of the nine Level 1 utilities) agreed to participate in detailed flow trace monitoring, which involved recording flow through each customer's water meter every 10 seconds for a period of about two weeks. The flow trace monitoring portion of the study took more than a year to complete, as the research team installed the equipment, collected the data, and moved the equipment from city to city. High-level flow data were successfully obtained from 762 homes.

Hot Water Flow Trace Analysis

A subset of the end use sample group was selected for hot water flow trace analysis. Accurate and usable hot water data were obtained from 94 homes that had been monitored for hot water use for approximately two weeks. This represents one of the largest efforts to date to collect and analyze hot water end use data in North America.

Outdoor Use Investigation

The Landscape Group was comprised of a sample of 838 households. The primary aim was to explore the efficiency of irrigation practices through a comparison of the volume of irrigation water applied to the theoretical irrigation requirements of each residential lot. Annual outdoor water use was estimated for each house using historical billing records, flow trace monitoring, and pre-existing high-resolution aerial photographs of each home's landscape.

Improved Understanding of Residential Water Use

The information provided by utilities in this study is significant because single-family homes typically use the most water of any customer sector. These data are essential for understanding demand patterns and establishing end-use benchmarks. Indoor water use will continue to decline in the future, which will impact utility water sales. REU2016 provides current data, evaluates conservation potential, and develops predictive models to assess and forecast residential demand.

Works Cited

DeOreo, W.B., P.W. Mayer, L. Martien, M. Hayden, R. Davis, et. al. 2011. *Analysis of Water Use in New Single Family Homes*. Aquacraft, Inc. Water Engineering and Management. Boulder, CO.

DeOreo, W.B., P.W. Mayer, B. Dziegielwski, J.C. Kiefer, 2016. *Residential Uses of Water 2016*. Water Research Foundation. Denver, CO.

Energy Policy Act of 1992, Pub. L. No. 102–486, 106 Stat. 2776 (1992).

Mayer, P.W., W.B. DeOreo, E.M. Optiz, J.C. Kiefer, W.Y. Davis, B. Dziegielewski, J.O. Nelson. 1999. *Residential End Uses of Water*. Denver, Colo.: AwwaRF.

Participating Utilities

Level 1 Study Sites

City of Fort Collins Utilities, Fort Collins, CO
City of Scottsdale Water Department, Scottsdale, AZ
Clayton County Water Authority, Morrow, GA
Denver Water Department, Denver, CO
Region of Peel Public Works, Brampton, ON, Canada
Region of Waterloo, Kitchener, ON, Canada
San Antonio Water System, San Antonio, TX
Tacoma Water, Tacoma, WA
Toho Water Authority, Kissimmee, FL

Level 2 Study Sites

Austin Water Utility, Austin, TX
City of Aurora Water Department, Aurora, CO
City of Chicago Water Management, Chicago, IL
City of Henderson, Henderson, NV
City of Portland Water Bureau, Portland, OR
City of Santa Barbara Public Works Department, Santa Barbara, CA
City of Santa Fe, Santa Fe, NM
EPCOR Water Services, Inc., Edmonton, AL, Canada
Miami-Dade Water and Sewer Department, Miami, FL
Mountain View City Water Division, Mountain View, CA
Otay Water District, Spring Valley, CA
Philadelphia Water Department, Philadelphia, PA
S. Central Connecticut Water Authority, New Haven, CT
Town of Cary Water Department, Cary, NC

Other Utility Participants

City of San Diego, San Diego, CA
Cobb County Water System, Marietta, GA
Colorado Springs Utilities, Colorado Springs, CO