Key Findings of the Residential End Uses of Water Study Update (REUWS_2)

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This document prepared for educational purposes

There were 26 participating agencies: 9 Level 1 Water Agencies

- The Denver, Colorado Water Department
- The City of Fort Collins, Colorado, Water Department
- The City of Scottsdale, Arizona Water Department
- The San Antonio, Texas, Water System
- The Clayton County, Georgia, Water Authority
- The Toho, Florida Water Authority
- The Region of Peel, Ontario, Canada
- The Region of Waterloo, Ontario, Canada
- The City of Tacoma, Washington, Water Department

17 Level 2 Agencies

- City of Aurora Colorado Water, Department
- City of Austin, Texas
- City of Chicago, Illinois
- City of Henderson, Nevada
- City of Mountain View, California
- City of San Diego, California
- City of Santa Barbara, California
- City of Santa Fe, New Mexico
- Cobb County Water System, Georgia
- Colorado Springs Utilities, Colorado
- Town of Cary, N.C.
- EPCOR, Edmonton, Alberta, Canada
- Miami-Dade Water & Sewer, Florida
- Otay Water District, California
- Philadelphia, Pennsylvania Water Department
- Portland Water Bureau, Oregon
- Regional Water Authority, Connecticut

Objectives of Study

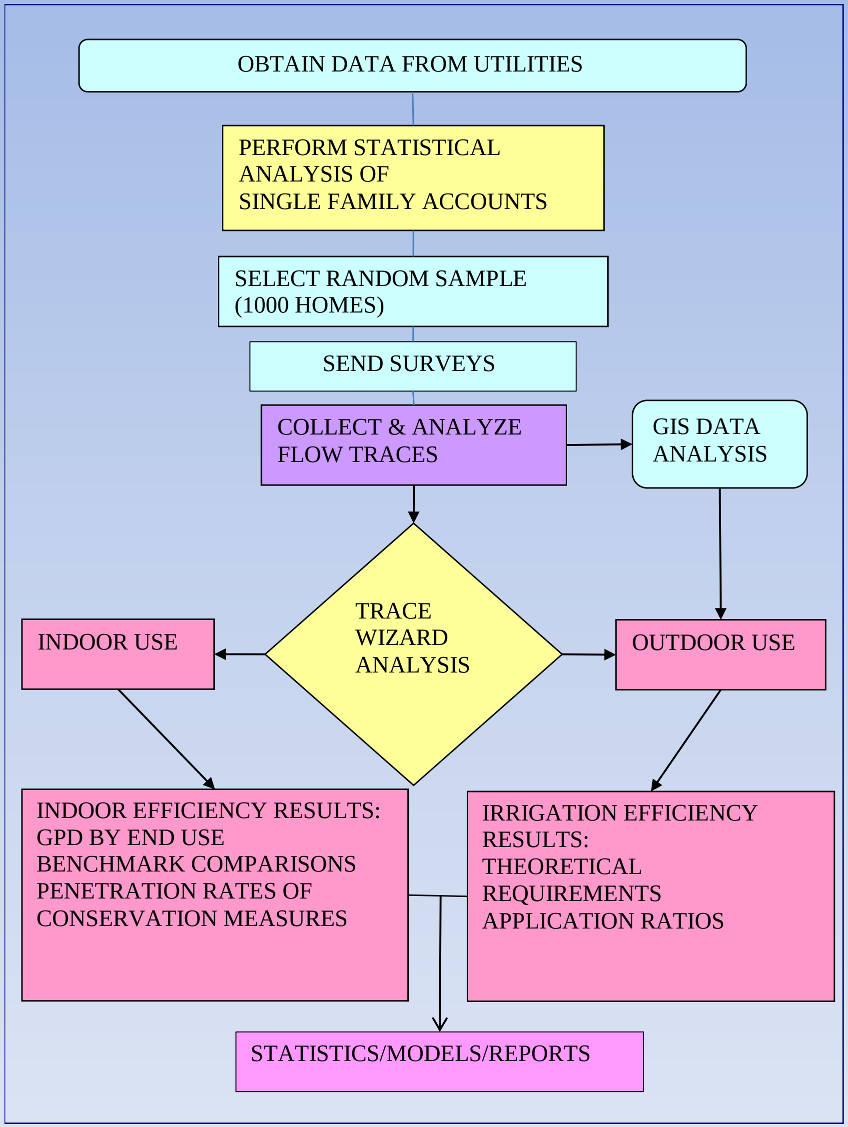
- Obtain new flow trace data on a national sample of single family homes
- Disaggregate flow trace data into end uses of water
- Compile water use data into a database
- Link water use to survey data
- Prepare statistical analyses and models
- Compare results to previous studies
- Explore conservation potential and benchmarks

• Project Flowchart

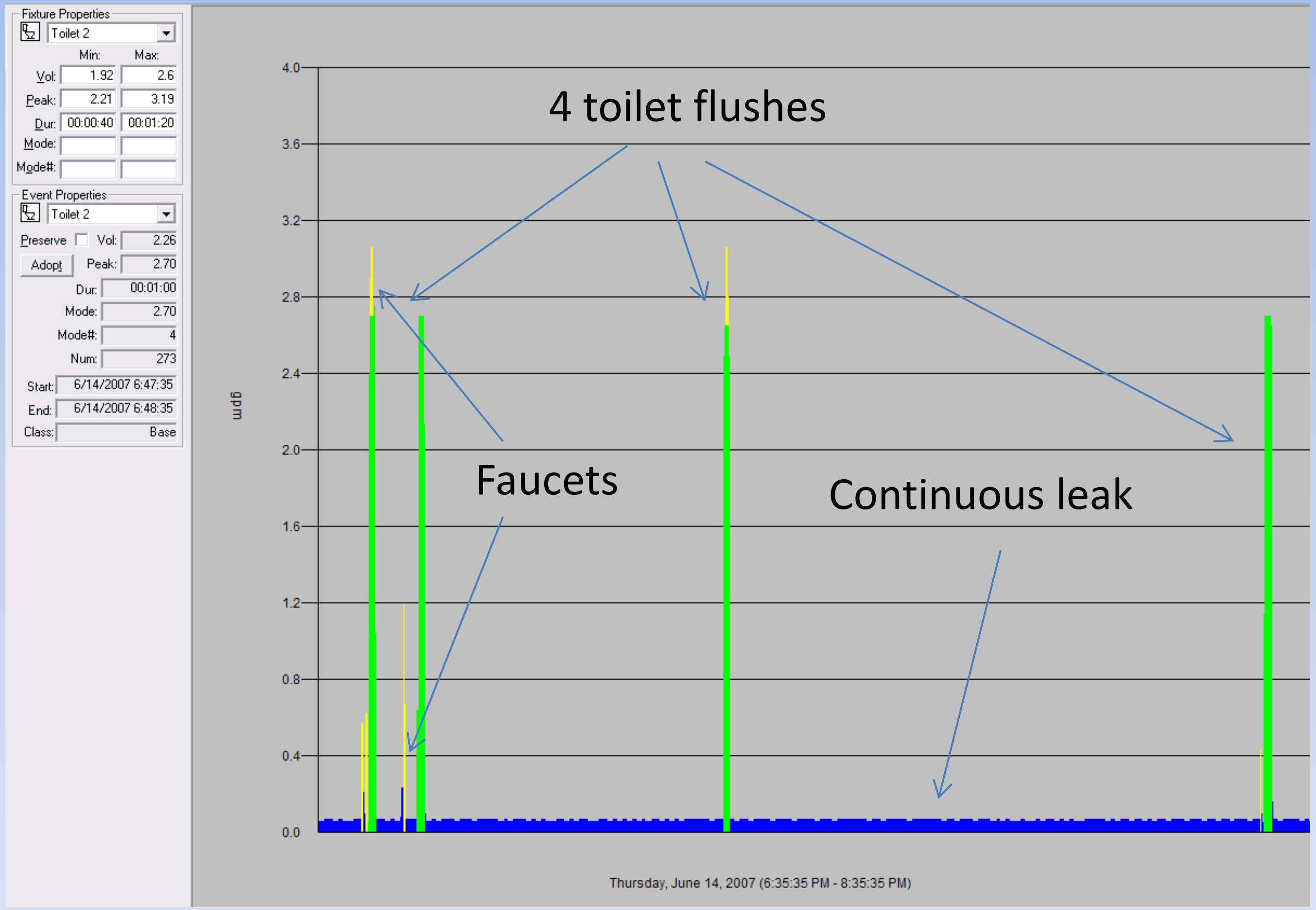
Schematic of Project

The project used a combination of data from several sources to arrive at a detailed analysis of single family household water use.

- Billing Data from utilities
- Survey data obtained from customers
- Flow trace data obtained from customers' water meter (10 second intervals and ~80 pulses per gallon
- Aerial photos for landscape analysis
- Flow traces disaggregated using Trace Wizard software
- Indoor uses identified by end-use and event.
- Outdoor use based on annual use
- Statistical analysis and modelling



Example of events



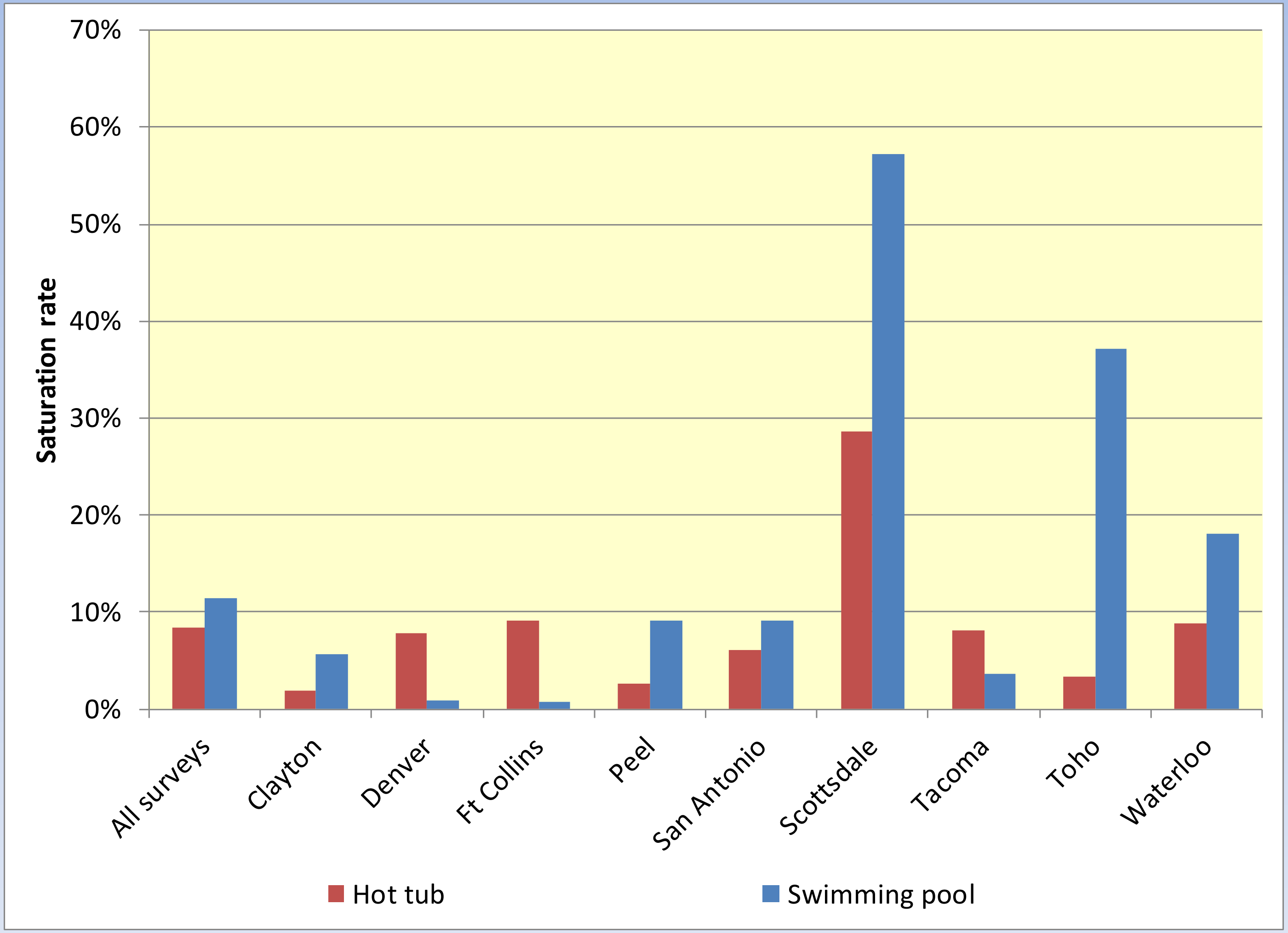
Survey Response Rates

Sample	Survey time frame	Surveys Sent	Surveys Returned	Response Rate
Clayton County	Feb / Mar 2012	1009	369	37%
Denver	Nov / Dec 2011	917	356	39%
Fort Collins	Nov / Dec 2011	999	476	48%
Peel	Apr 2012	951	231	24%
San Antonio	Mar 2012	1013	280	28%
Scottsdale	Feb / Mar 2012	1012	349	34%
Tacoma	Mar / Apr 2012	993	347	35%
Toho	Feb 2012	855	147	17%
Waterloo	Apr 2012	1000	347	35%
North American Survey	2011-2013	5000	1741	35%
Total		13,749	4643	34%

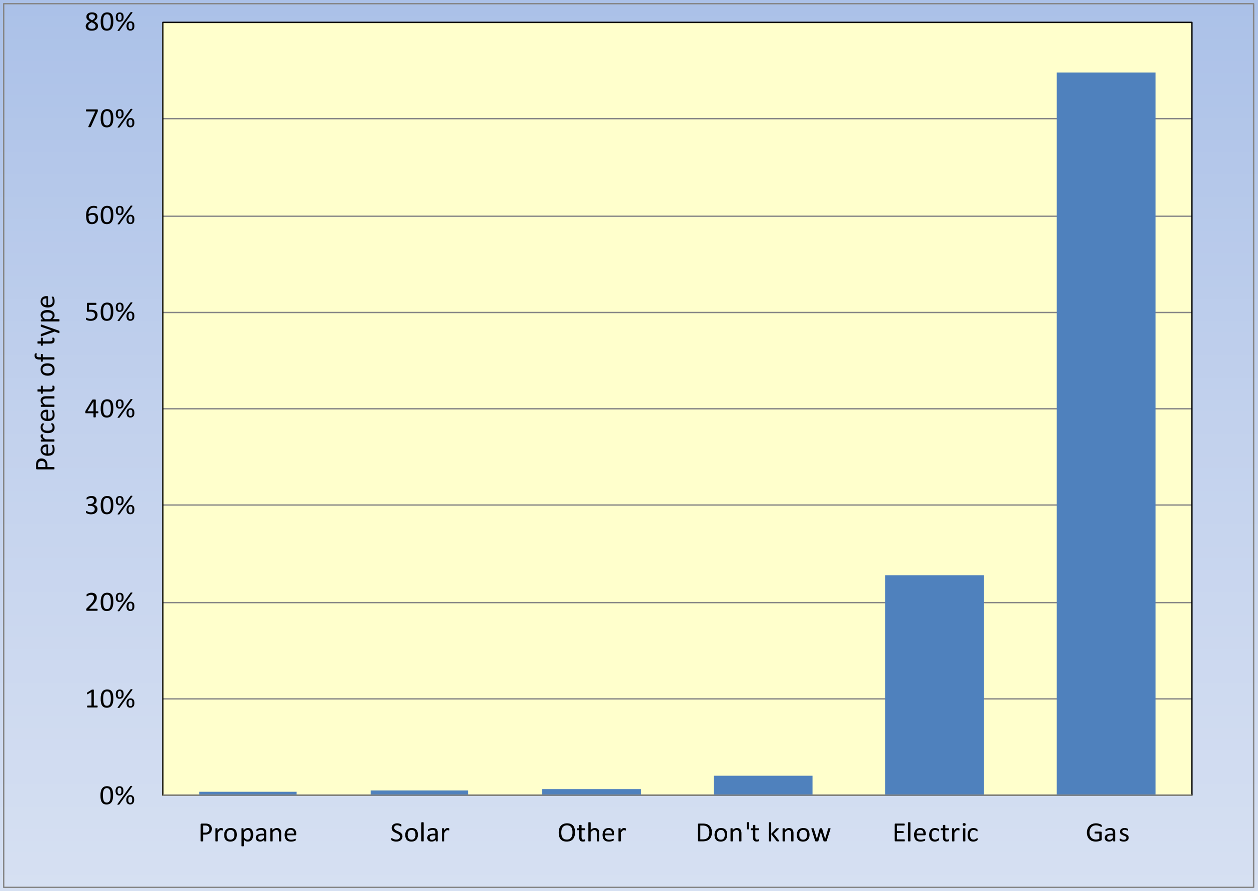
Household Occupancy Rates

	Average	Standard Deviation	Number of responses
Persons per home	2.6	1.4	2,790
Adults	2.1	0.9	2790
Teens	0.2	0.5	482
Children	0.3	0.7	730
Infants/toddlers	0.1	0.3	173

Pools & Hot tubs: found in all sites



Gas: main energy for water heating



Some Key Findings

- Reduction in Domestic Use has occurred in all categorires
- Big improvements in toilets and clothes washers
  - Categories which show the best statistically significant reductions.
- Skewed Uses need special attention
  - Leakage (still number 5 category, just below CW)
  - Irrigation (small number of big users raise the mean)
- At least 20% potential for indoor conservation remains.
- Landscape use is quite varied, but follows similar patterns among groups.

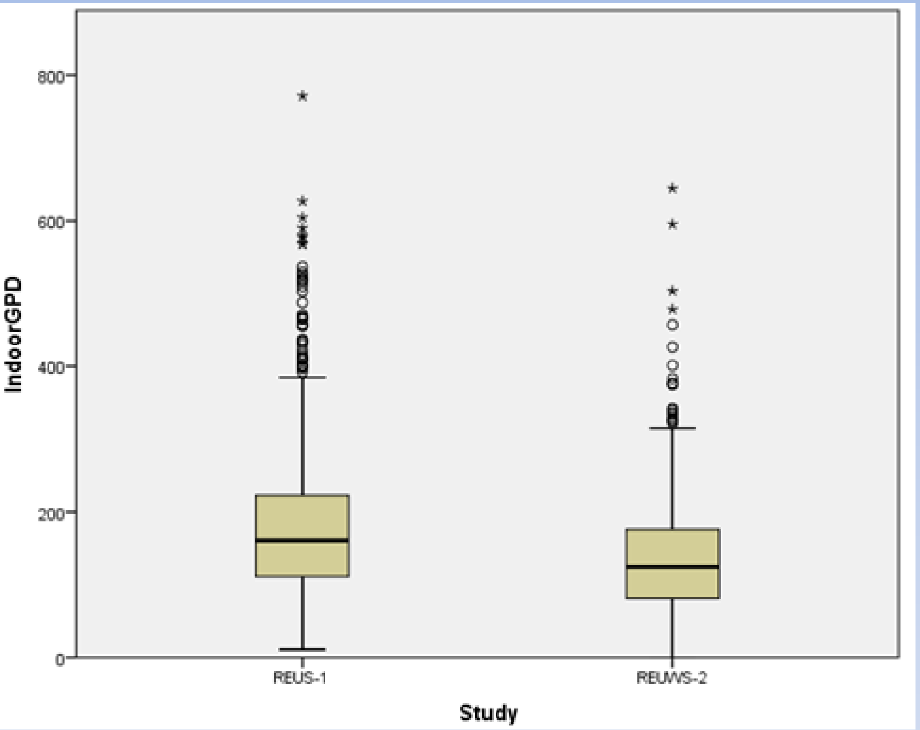
Drop in Domestic Use
Box Plot of Indoor GPD

Median Use levels have dropped from 160 gpd in REUWS1 to 125 gpd in REUWS2

That is a 21% reduction in indoor use

The number of persons per home has not changed significantly

These reductions are due mainly to use of better efficiency toilets and clothes washers



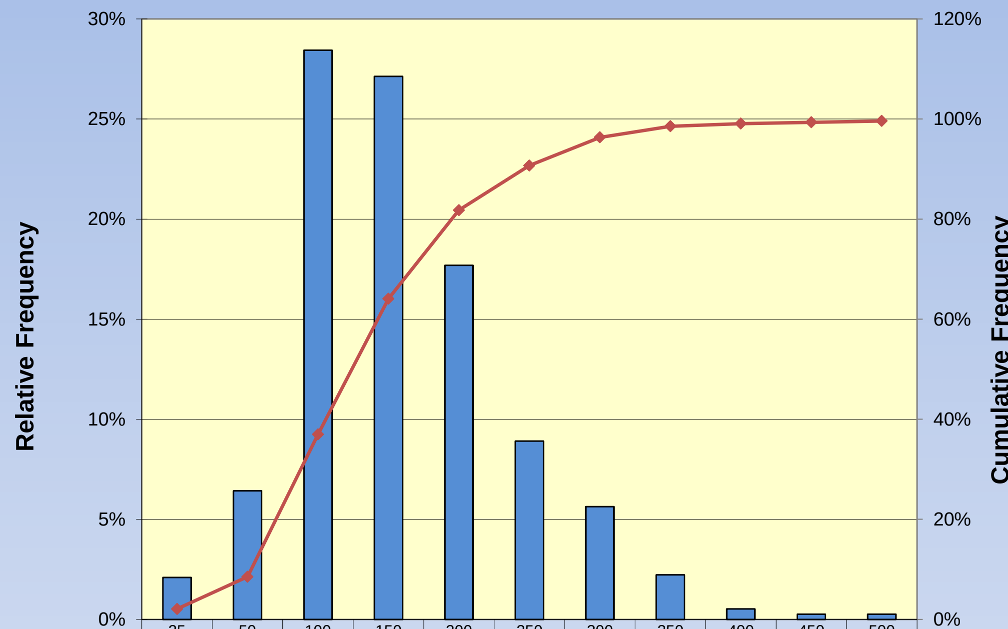
Distribution of Indoor Water Use

Most households use between 50 and 200 gphd for indoor purposes.

Based on average occupancy of 2.6 this equates to between 20 and 77 gpcd

A few households use as little as 25 gphd and a few use as much as 500 gphd. These are not typical

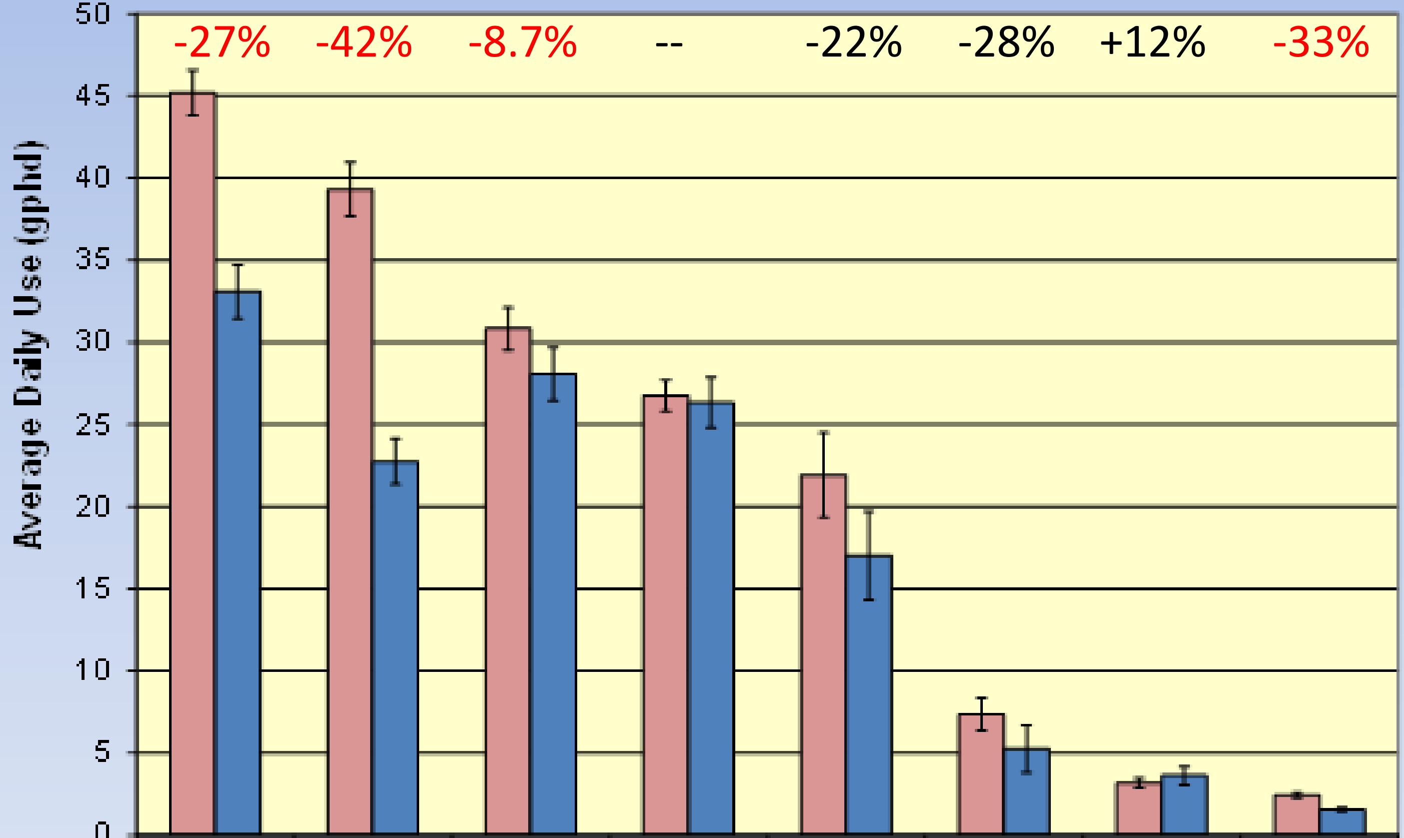
There are many factors that affect indoor water use.



	25	50	100	150	200	250	300	350	400	450	500
% of homes	2%	6%	28%	27%	18%	9%	6%	2%	1%	0%	0%
Cum %	2%	9%	37%	64%	82%	91%	96%	99%	99%	99%	100%

Changes in Water Use

(Those in red are statistically significant.)

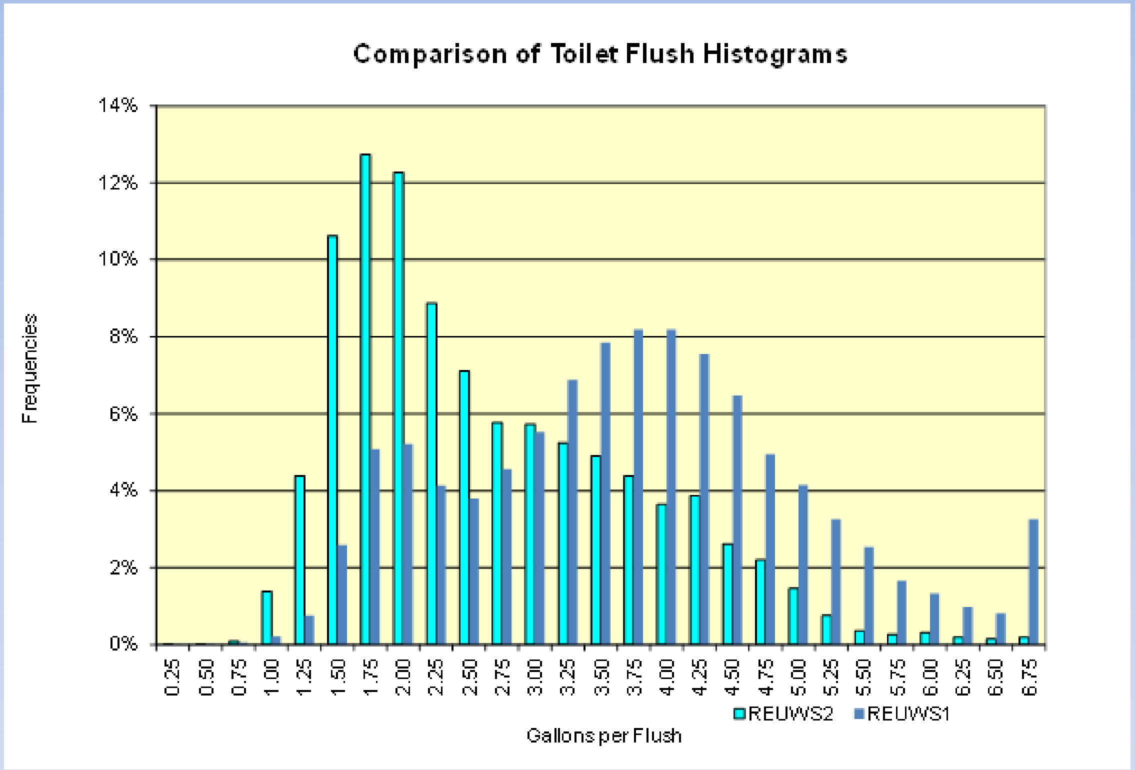


	Toilet	Clothes washer	Shower	Faucet	Leak	Other	Bathtub	Dishwasher
REUWS1	45.2	39.3	30.8	26.7	21.9	7.4	3.2	2.4
REUWS2	33.1	22.7	28.1	26.3	17.0	5.3	3.6	1.6

• Comparison of flush distributions 2012-1995

Shift in flush volumes

- This graph shows distributions of individual toilet flushes logged during REUWS1 and REUWS2
- 1999 Data are in dark blue; show bulk of flush volumes around 4.5 gallon, with a second peak at 1.75 gallon.
- 2013 Data are in light blue, show major peak at 1.75 gallon and greatly diminished percentages at the 4 gallon level.
- In 10 years the flushes will probably be normally distributed around the 1.75 gallon bin.



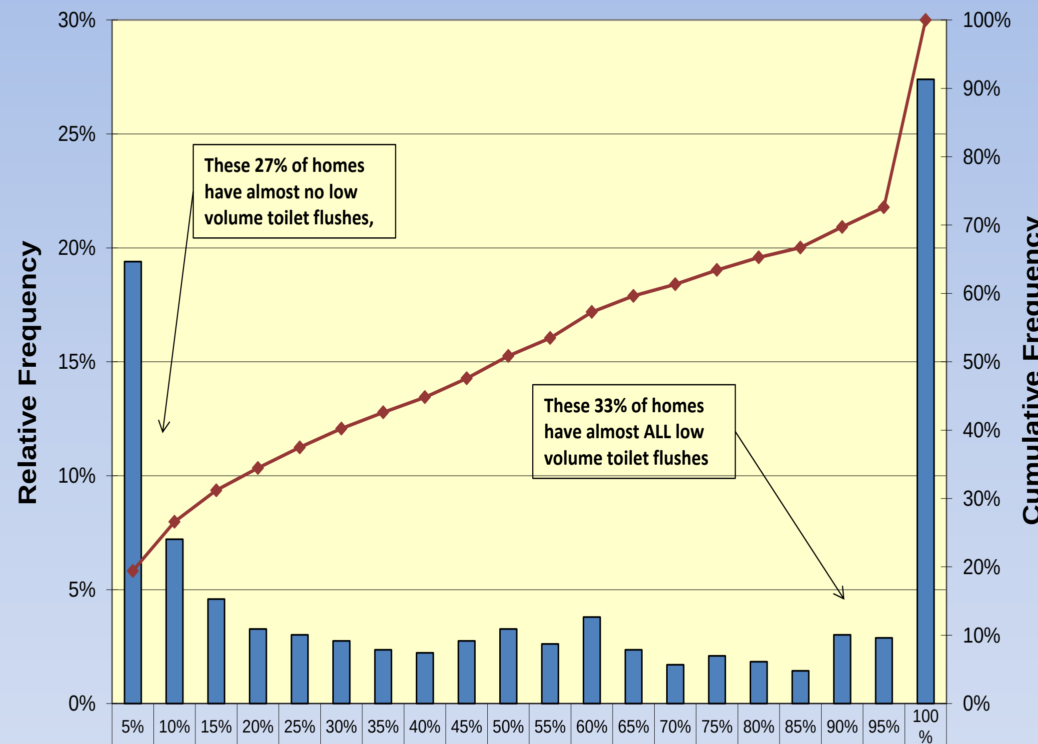
Toilet Use Statistics

	REUWS2	REUWS1
Number of houses logged	762	1187
Total number of flushes recorded	124,611flushes	348,345 flushes
Total number of days logged	9659 days	28013
Average number of residents per home	2.6	2.7
Average flushes/household per day	13 flushes/household/day	12.4 flushes/household/day
Average flushes per person per day	5.0	4.6
Average flush volume	2.6 ± .01 gal	3.65 ± .06 gal
Average daily use for toilet flushing	33.1 ± 2 gpd	45.2 gpd
Median daily use for toilet flushing	29 gpd	43 gpd
% of Flushes < 2.2 gal	51%	16%

• Toilet Mixtures

Fewer Homes with mixtures of toilets

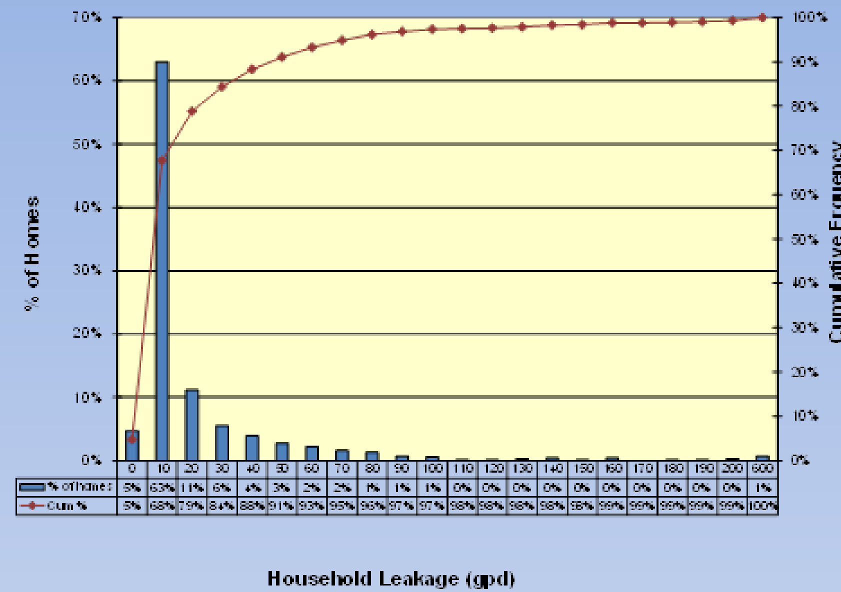
- More homes are showing higher percentages of low volume flushes
- ~30% of homes have over 90% of flushes < 2.2 gal
- ~ 30% have less than 10% flushes < 2.2 gal
- ~40% have mixtures
- So, up to 70% of homes are still candidates for toilet retrofits.

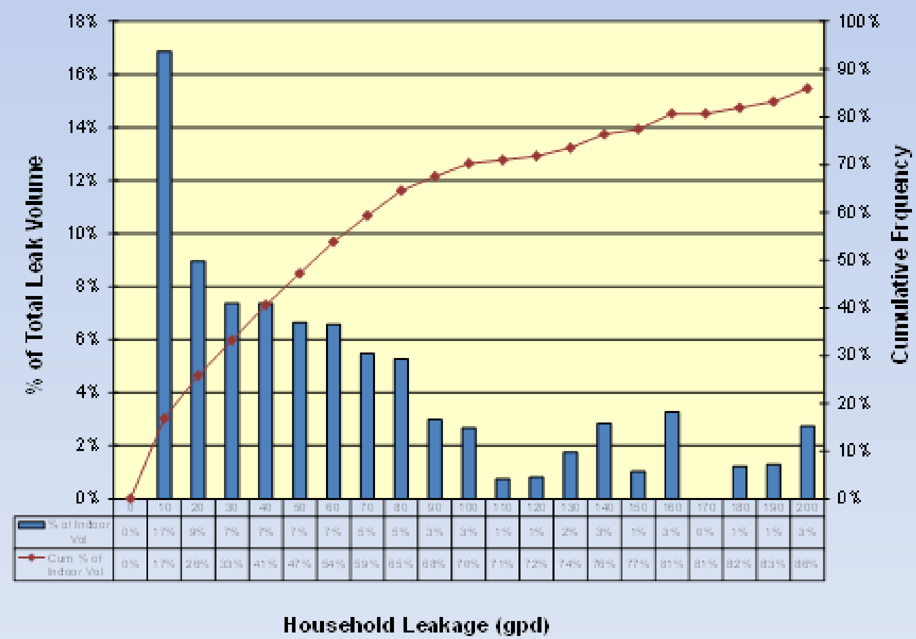


	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100 %
% of Homes	19%	7%	5%	3%	3%	3%	2%	2%	3%	3%	3%	4%	2%	2%	2%	2%	1%	3%	3%	27%
Cum %	19%	27%	31%	34%	37%	40%	43%	45%	48%	51%	53%	57%	60%	61%	63%	65%	67%	70%	73%	100%

Skewed Nature of Leakage

- Leakage is highly skewed by a few homes.
- Average leakage rate was 17 gpd, but median was 4 gpd.
- **Top 21 homes, 3%, accounted for 30% of total leakage in group of 762**
- 10% of the homes were leaking at ~105 gpd; 90% were leaking at 8 gpd.
- Keeping leakage at the median (~5 gpd) would save 12 gpd on average, or 4 kgal per year.

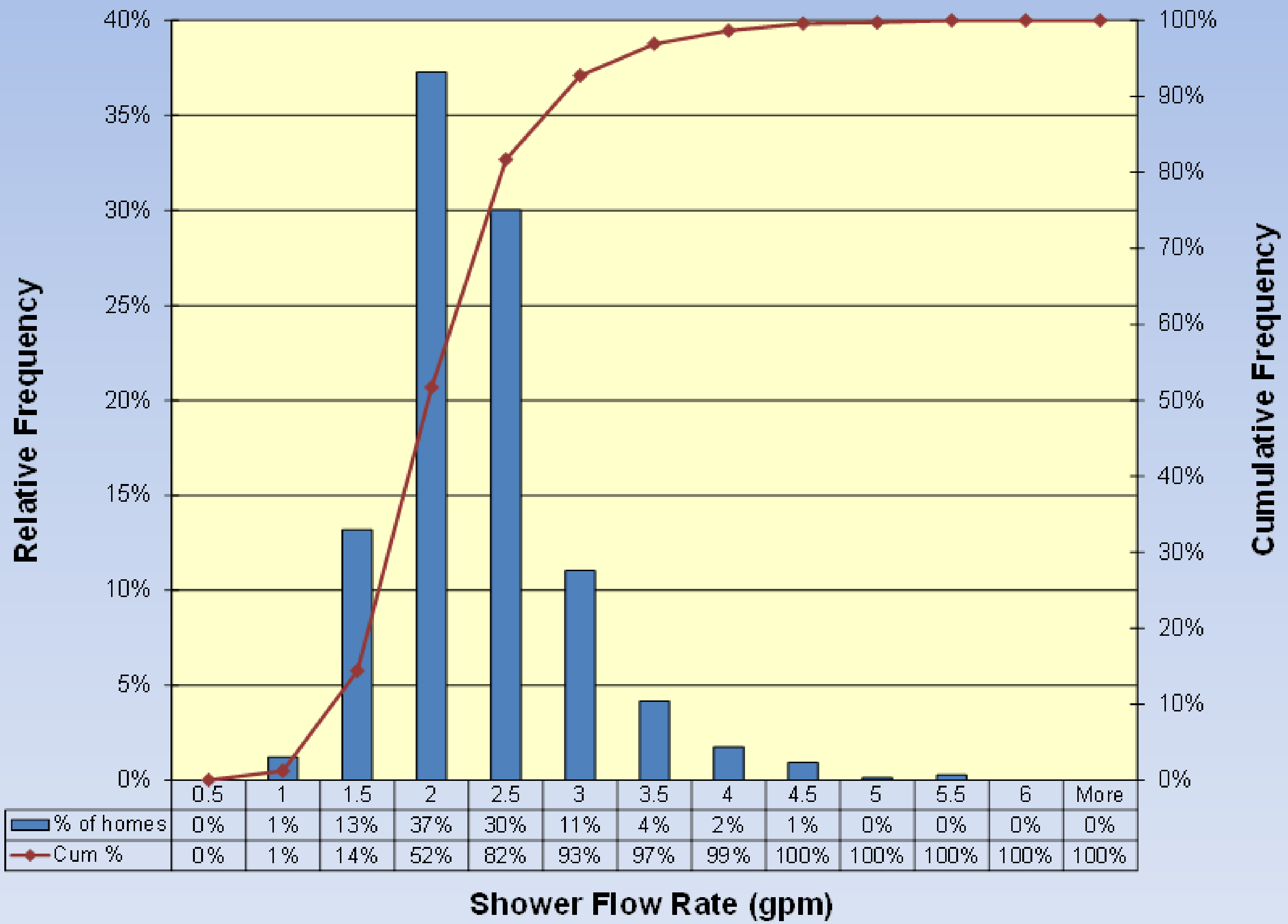




Shower Statistics

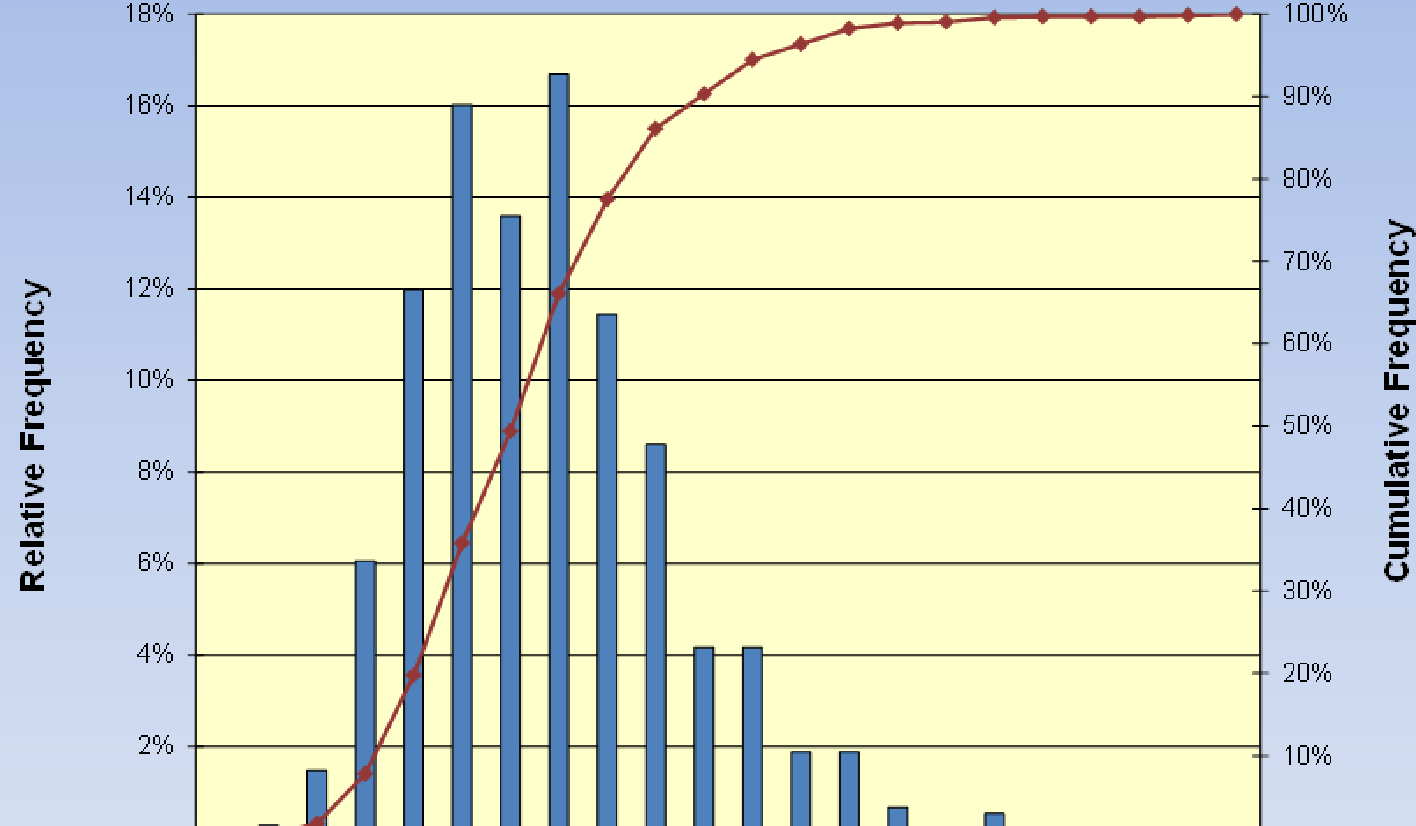
	REUWS2	REUWS1
Number of houses logged	762	1187
Total number of showers recorded	17,066 showers	50,286 showers
Total number of days logged	9,659 days	28,013
Average number of residents per home	2.6	2.7
Average showers/household per day	1.8 showers/household/day	1.8 showers/household/day
Average showers per person per day	0.69 showers/person/day	0.66 showers/person/day
Average shower volume	15.8 ± .5 gal	16.7 ± .3 gal
Average shower duration	7.8 ± .02 minutes	7.8 ± .14 minutes
Average daily use for showering	28 ± 2 gpd	31 ± 1 gpd
Median daily use for showering	22 gpd	26 gpd
Average flow rate for showers (gpm)	2.1 ± .04 gpm	2.2 ± .04 gpm

Shower flow rate distribution



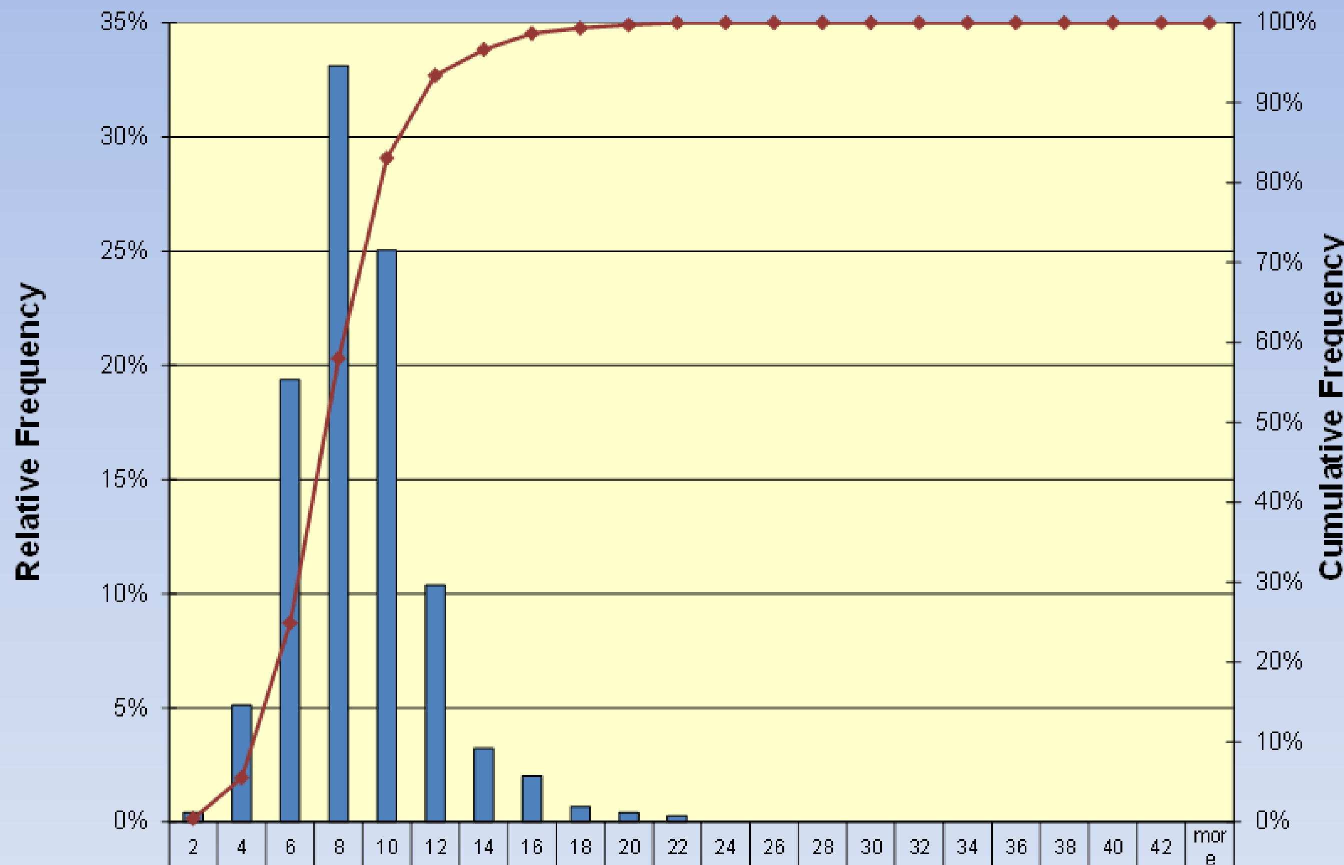
	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	More
% of homes	0%	1%	13%	37%	30%	11%	4%	2%	1%	0%	0%	0%	0%
Cum %	0%	1%	14%	52%	82%	93%	97%	99%	100%	100%	100%	100%	100%

Shower volume distribution



	0	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40	42.5	45	47.5	50	More
% of homes	0%	0%	1%	6%	12%	16%	14%	17%	11%	9%	4%	4%	2%	2%	1%	0%	1%	0%	0%	0%	0%	0%
Cum %	0%	0%	2%	8%	20%	36%	49%	66%	78%	86%	90%	94%	96%	98%	99%	99%	100	100	100	100	100	100

Shower duration distribution

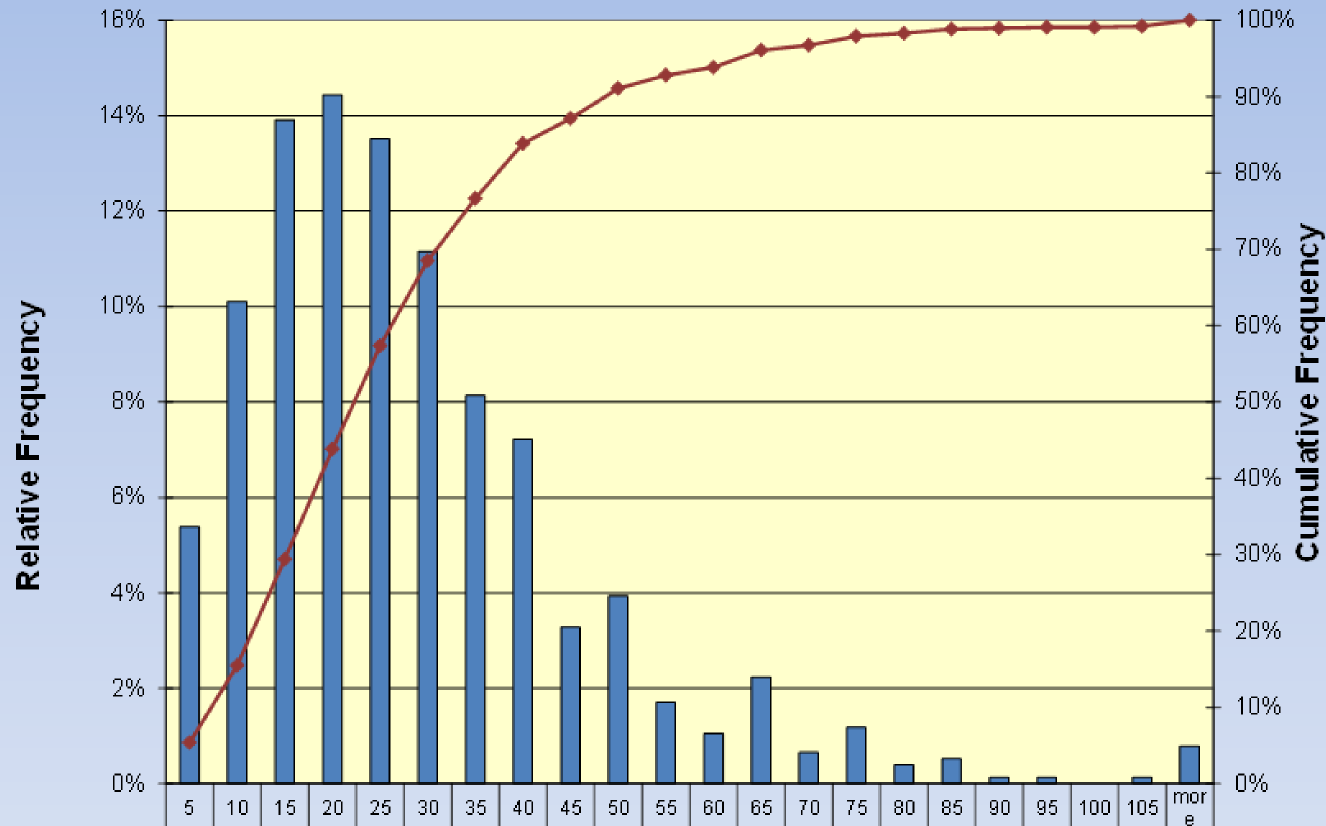


	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	more
% of homes	0%	5%	19%	33%	25%	10%	3%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cum %	0%	6%	25%	58%	83%	93%	97%	99%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Faucet statistics

	REUWS2	REUWS1
Number of houses logged	762	1187
Total number of faucet events recorded	495,958 faucet events	1,150,872 faucet events
Total number of days logged	9,659 days	28,013
Average number of residents per home	2.6	2.7
Average faucet uses/household per day	51 faucet uses/household/day	41 faucet uses/household/day
Average faucet uses per person per day	20 faucet uses/person/day	15 faucet uses /person/day
Average faucet use volume	0.5 gallons per use	0.65 gallons per use
Average faucet duration	30 seconds	30 seconds
Average daily use for faucets	26.3 ± 1.5 gpd	27 ± 1 gpd
Median daily faucet use	22.5 gpd	23 gpd

Faucet use distribution

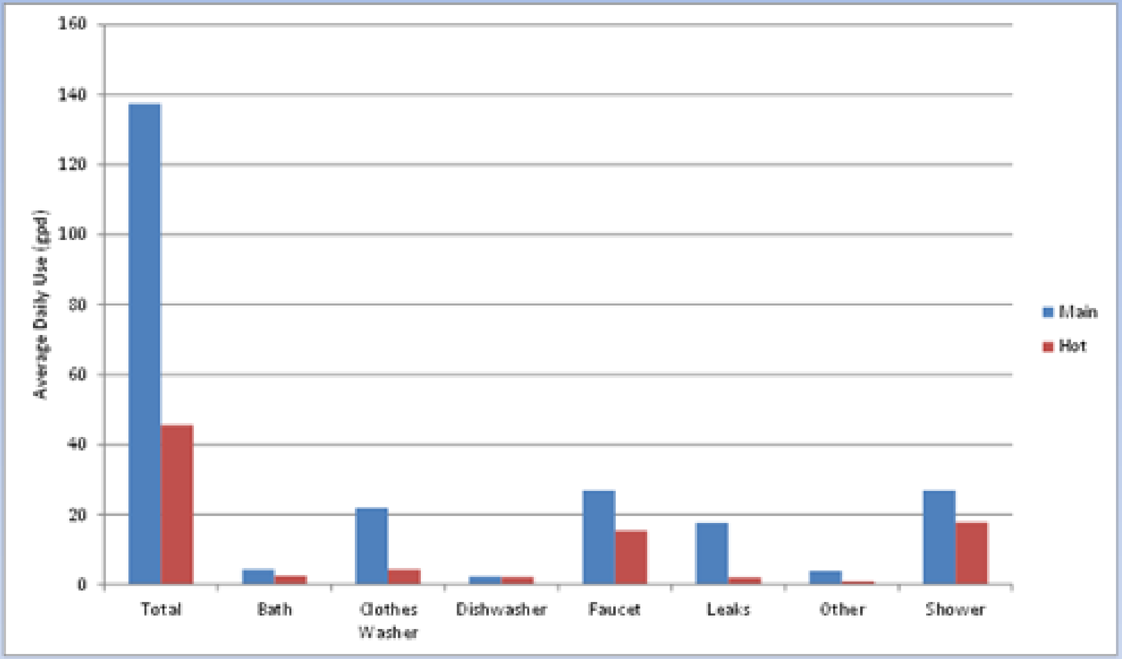


	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	more
% of homes	5%	10%	14%	14%	14%	11%	8%	7%	3%	4%	2%	1%	2%	1%	1%	0%	1%	0%	0%	0%	0%	1%
Cum %	5%	15%	29%	44%	57%	69%	77%	84%	87%	91%	93%	94%	96%	97%	98%	98%	99%	99%	99%	99%	99%	100%

• Hot Water Use

Hot Water by end use

- Average homes used ~42 gpd of hot water
- This was ~30% of total use
- On average the homes use 753,000 BTU/Mo for heating water
- Maximum was 1.06 MBTU in Tacoma
- Minimum was 321,000 BTU in Scottsdale
- Showers are the #1 hot water user, followed by faucet use.
- Clothes washing is a relatively small hot water user.



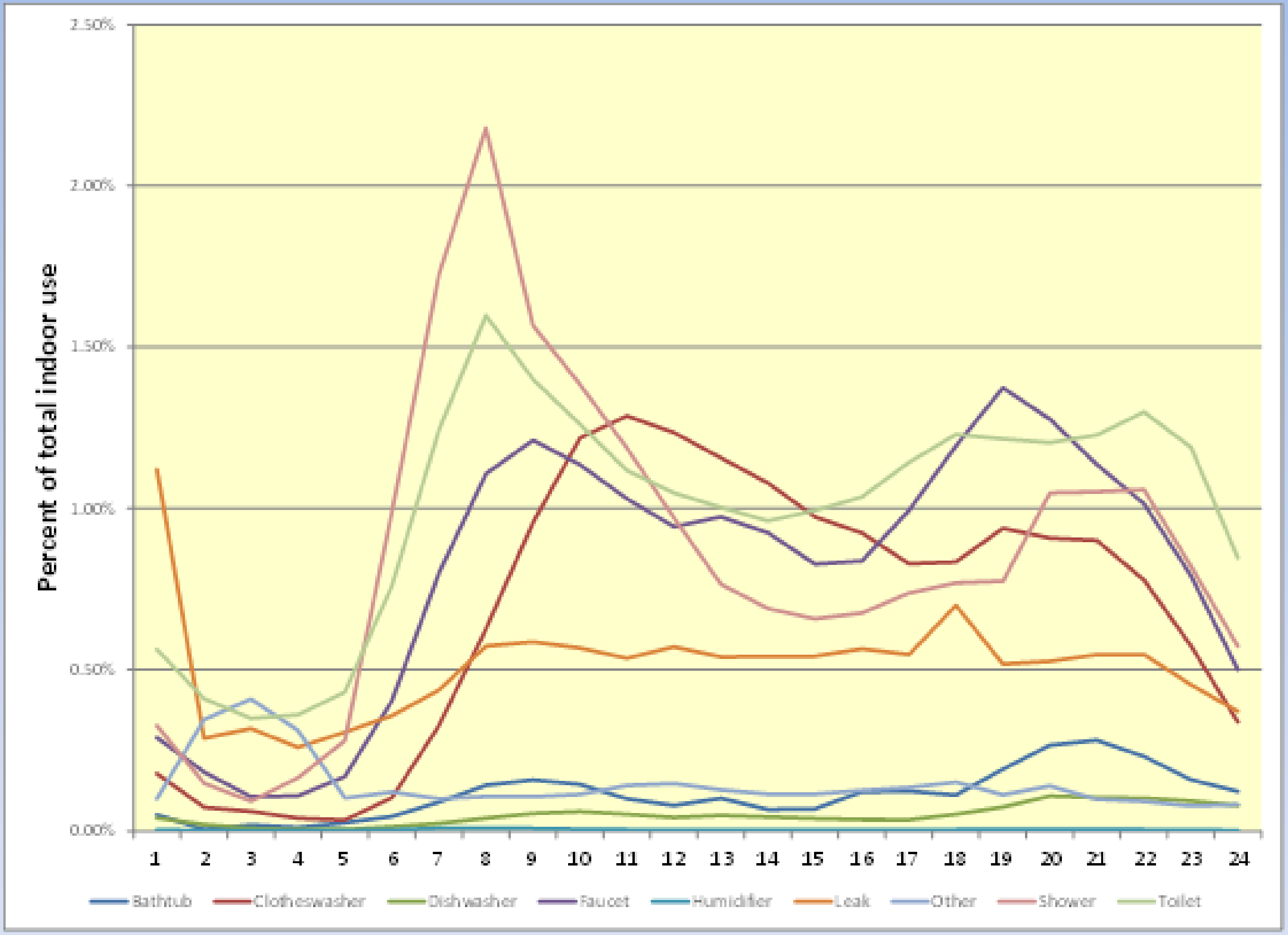
• Diurnal Patterns

Order of Peaking:

Morning Peaks
- Toilets
- Showers
- Faucets
- Clothes Washers

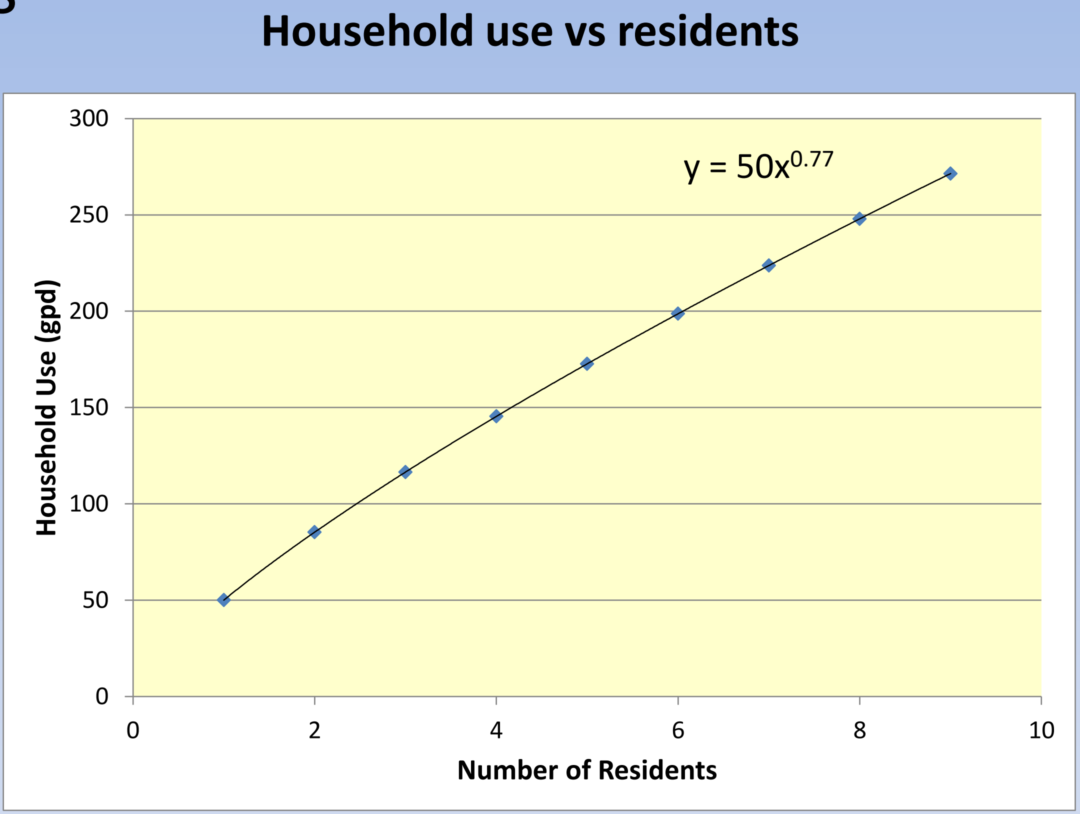
Evening Peaks
- Faucets
- Toilets
- Showers
- Bath tubs
- Clothes washers
- Dish washers

Continuous
- Leaks
- Humidifiers



Non-linear Relationship between household use and number of residents

- Not correct to scale up per-capita use on a linear basis
- Household use relationship follows a power curve
- Exponent is normally less than one
- Curve shown is for high efficiency homes (Class 1)
- Class 2 and 3 homes would have a different curve, but similar form.

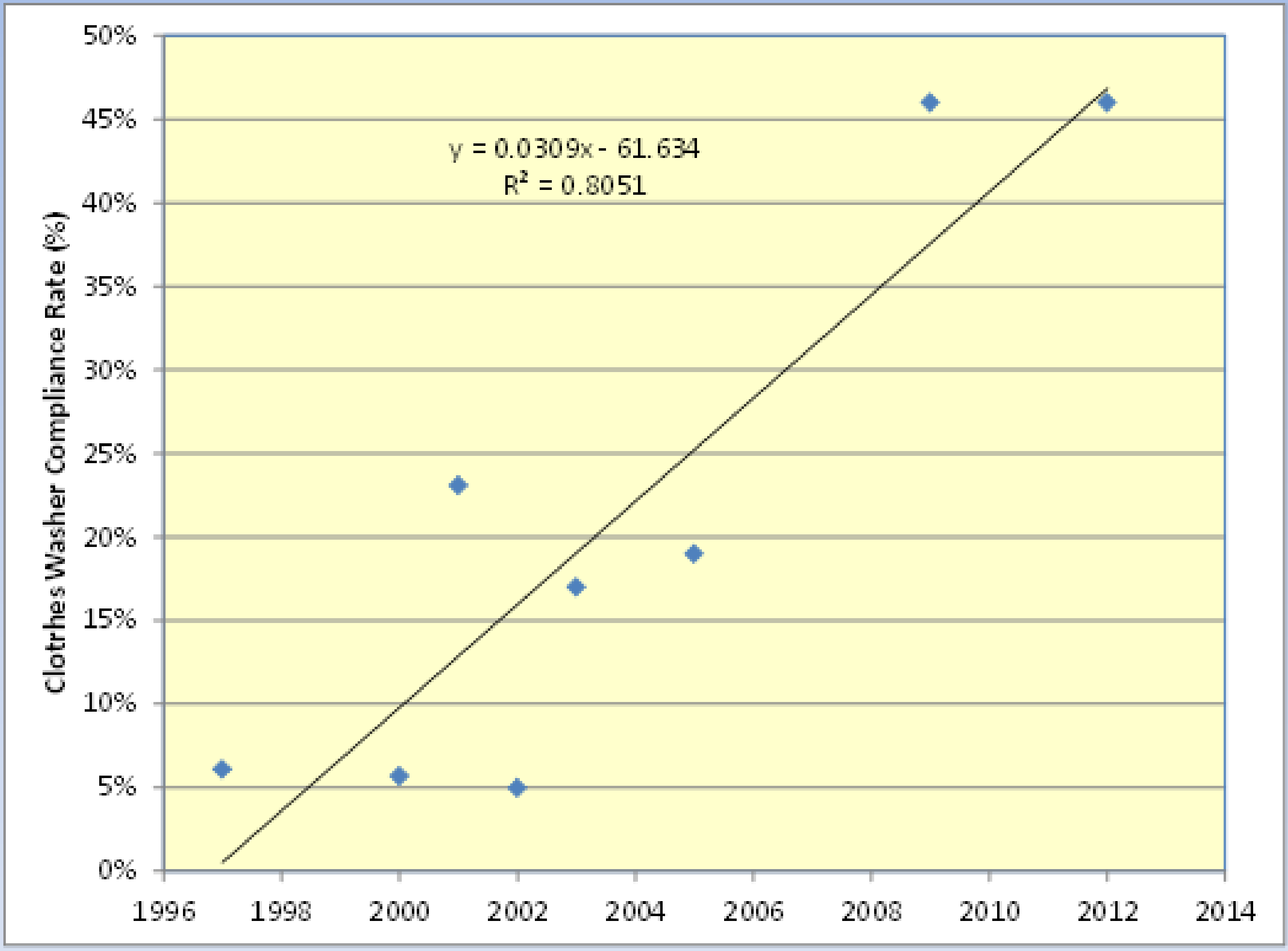


Efficiency of fixtures/appliances

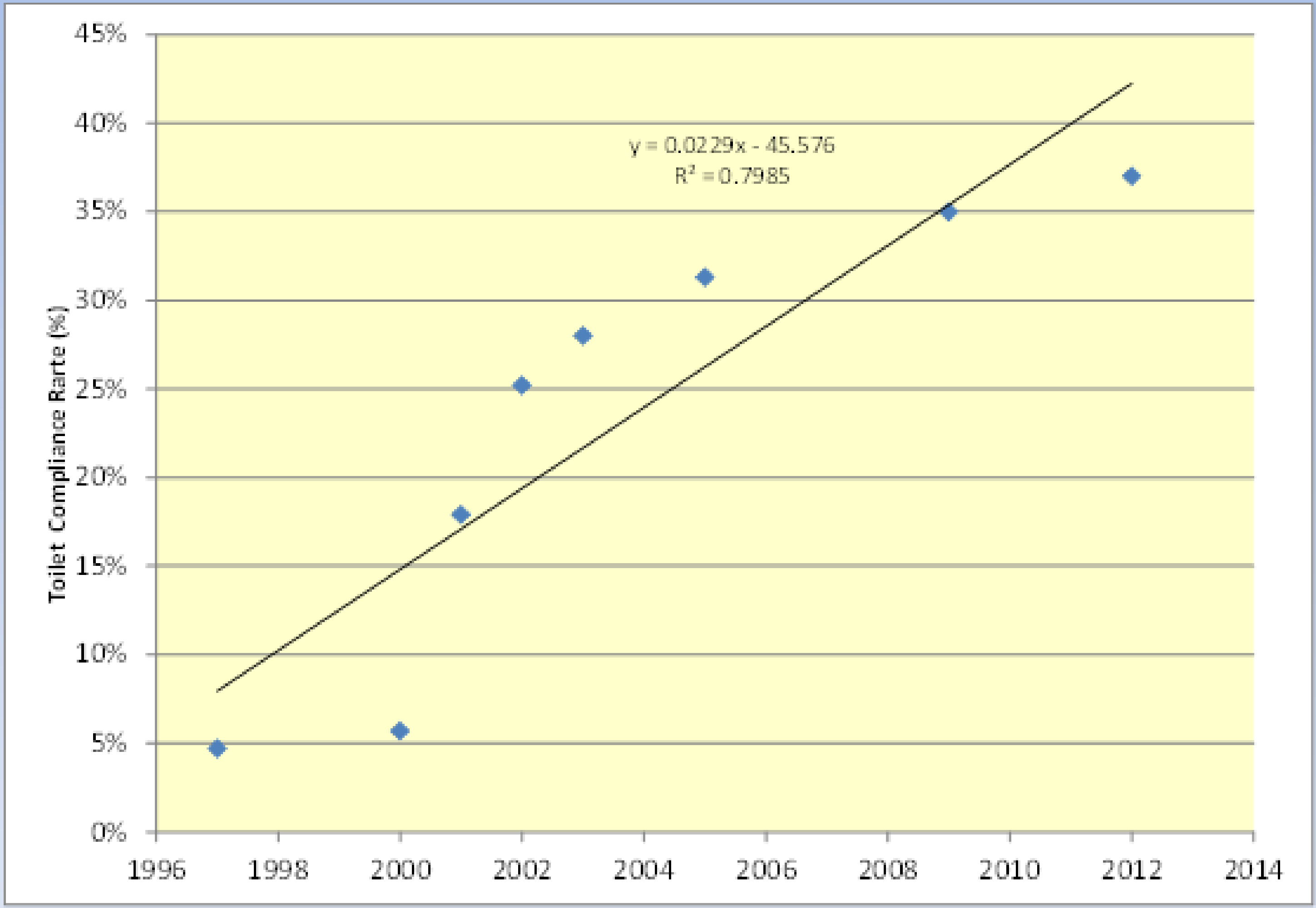
Device	Criteria for qualification as high efficiency
Clothes washer	Average gallons/load < 30 gal
Shower	Average mode flow < 2.5 gpm
Toilet	Average flush volume < 2 gpf

The percentage of homes that meet these criteria has been increasing over time…

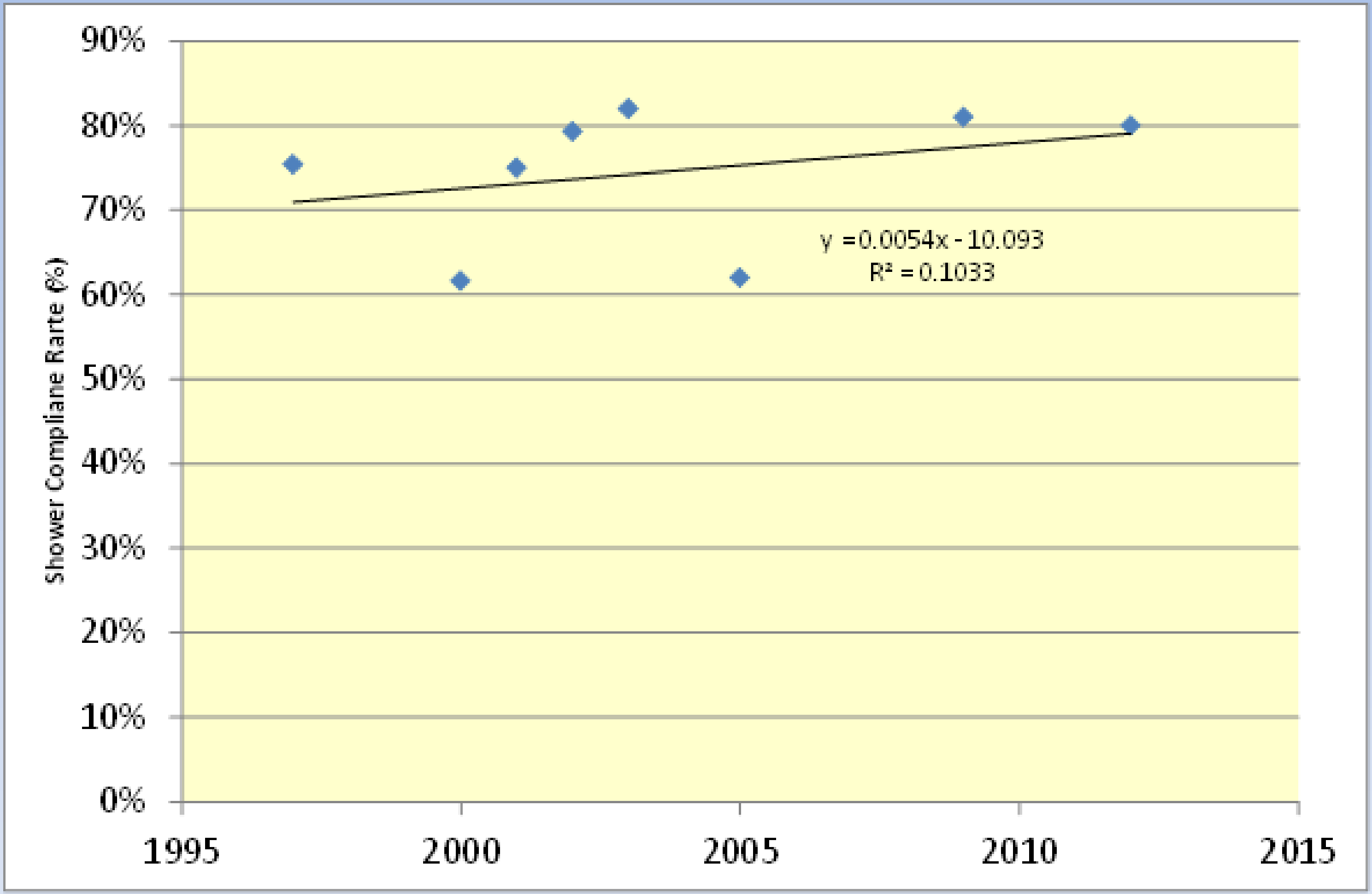
% of Homes w/efficient CW



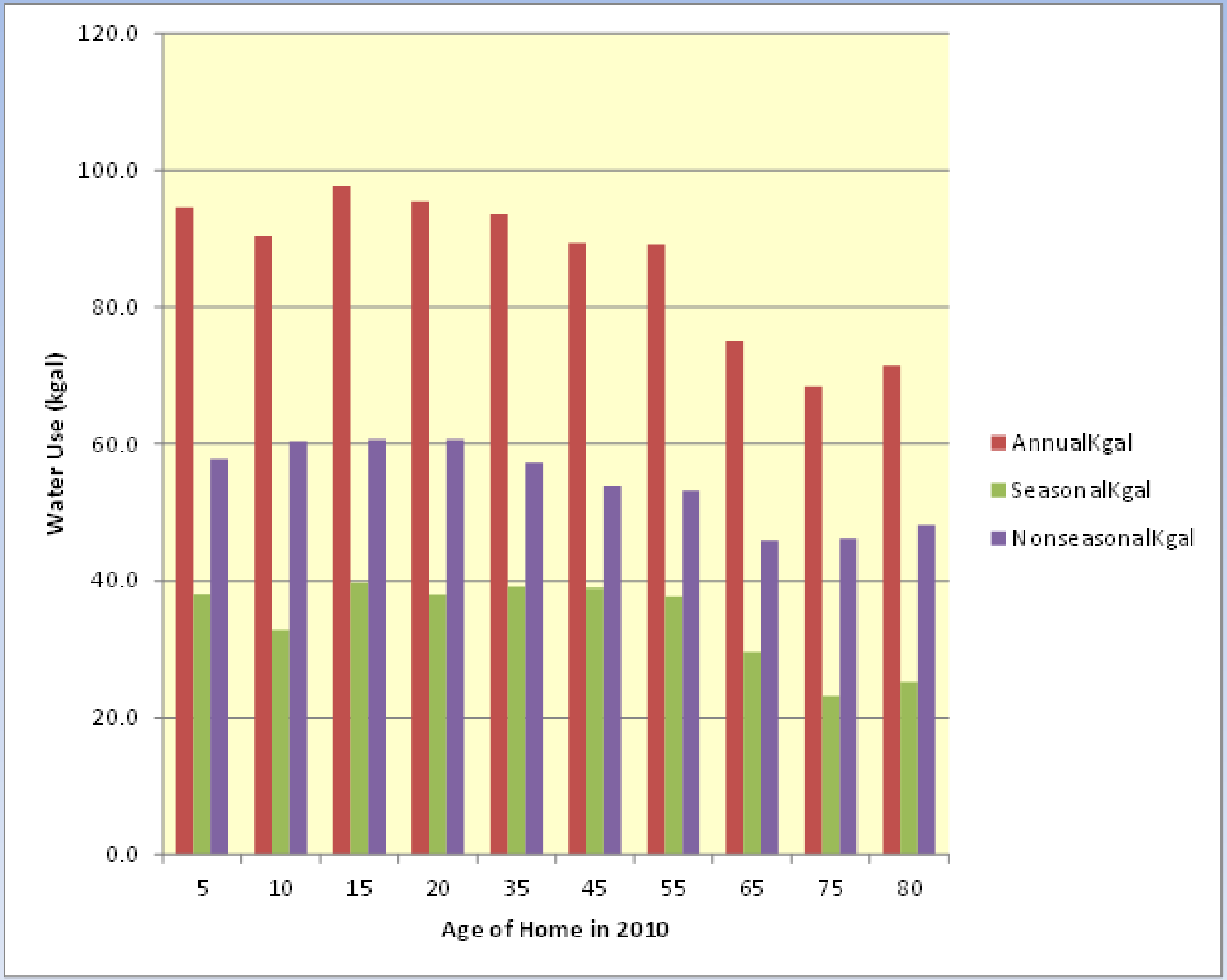
% of homes w/efficient toilets



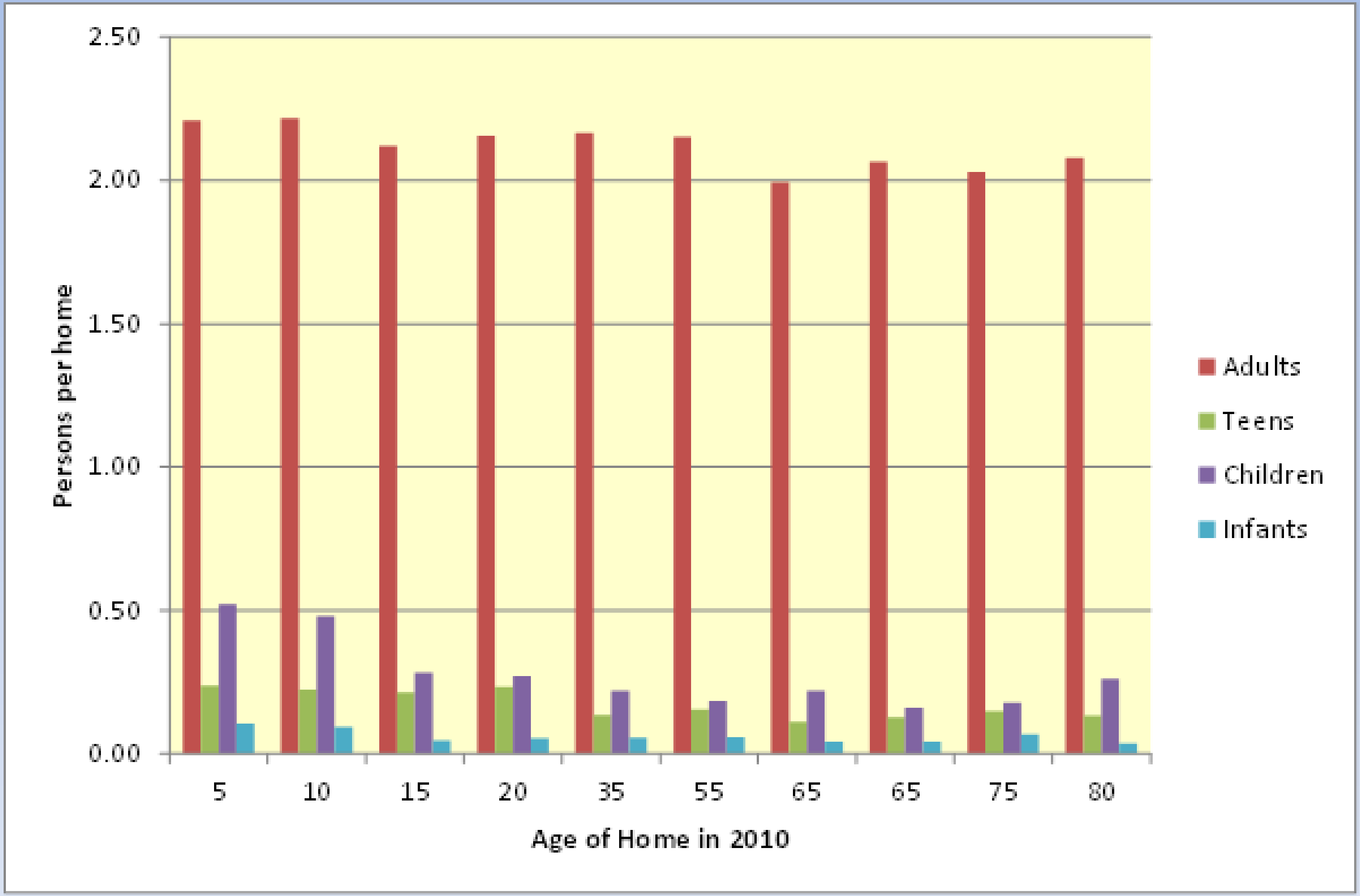
% of homes w/efficient showers



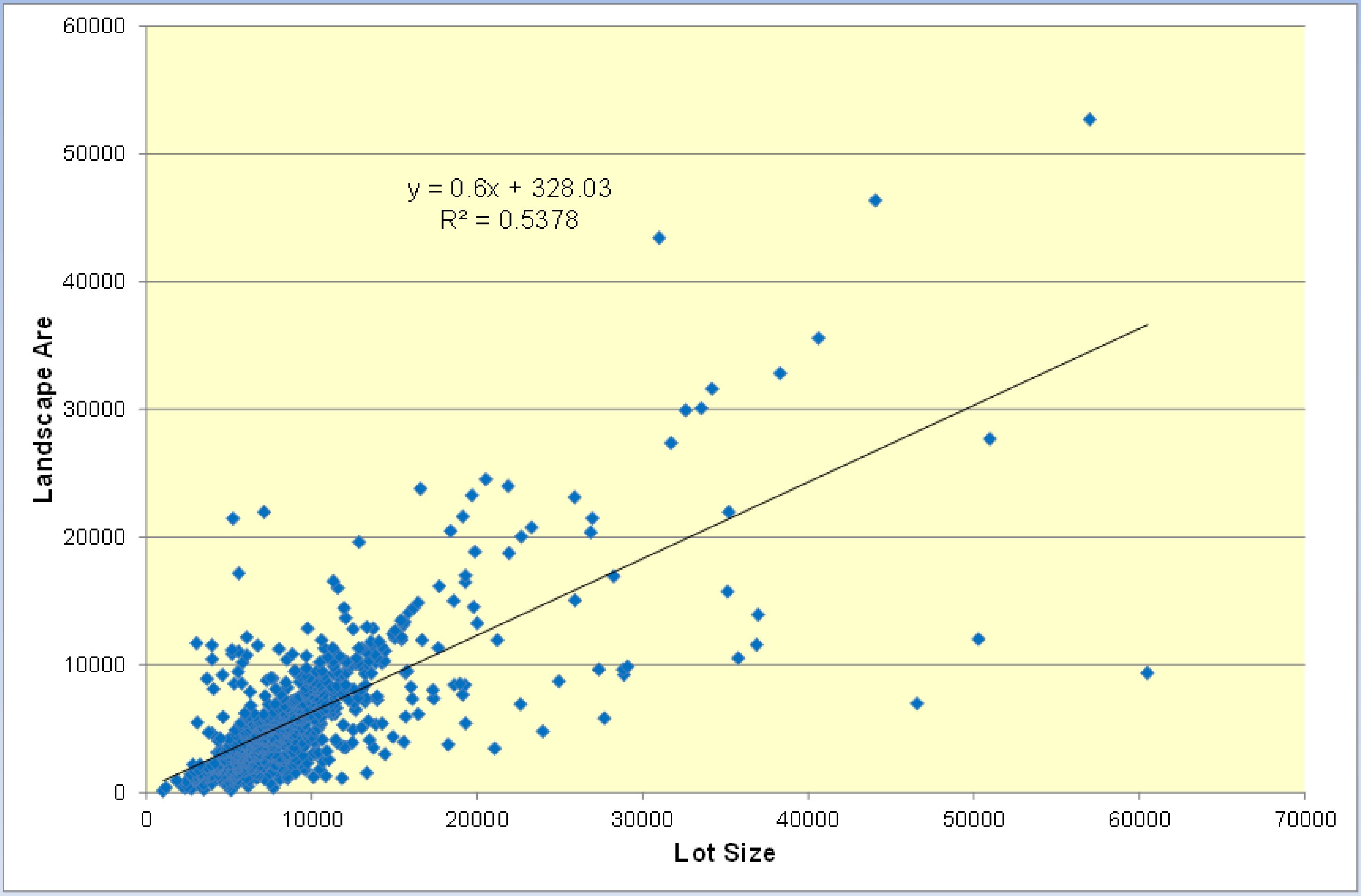
Water use by age of home



Persons per home by age of home



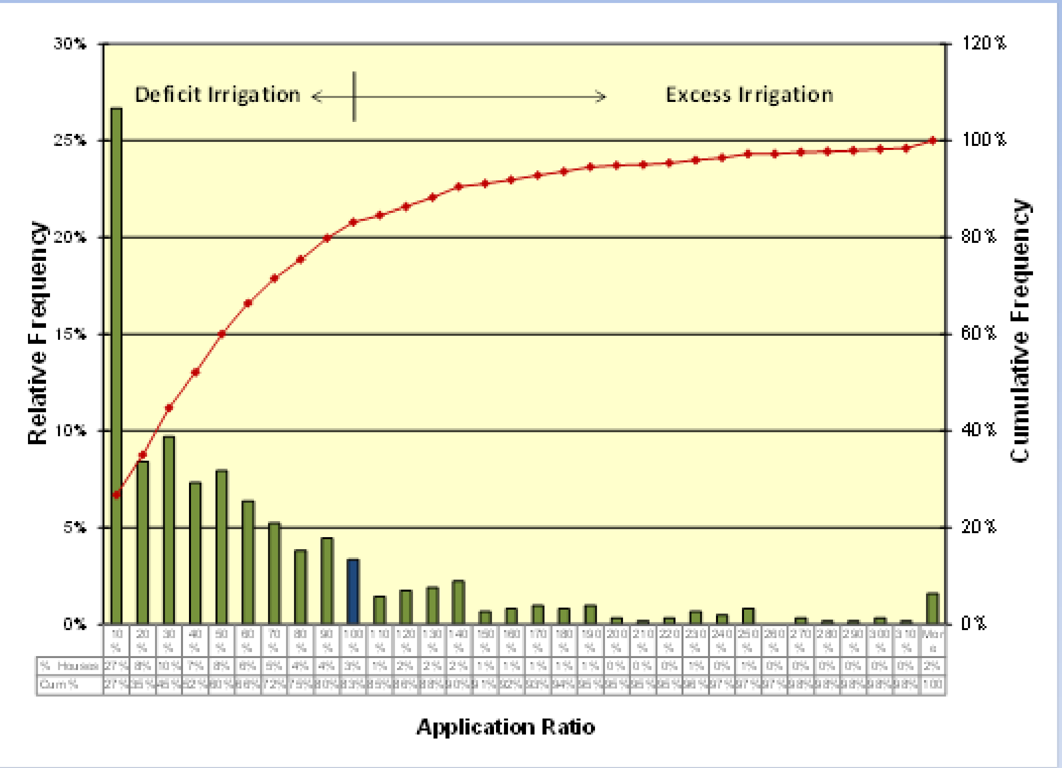
Landscape Areas vs Lot Size



- # Skewed Irrigation Applications

Application ratios are biased by high users

- **Most homeowners are UNDER irrigating**.
- Nearly 80% of homes in the study were applying less than the theoretical irrigation requirement.
- Irrigation is a lot like leakage in that a few large users are accounting for the bulk of the excess irrigation.
- Analysis is based on aerial photos using a consistent set of procedures for estimating irrigated areas and plant types plus Local Net ET with allowanced for irrigation system efficiencies.



Model of Indoor water use

Variable	Study Average	Input	Independent parameter	LN of Input Value= Ln(Col 3)	Coefficient	ln term = Col 5 x Col 6	Indoor gpd
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Intercept	1	3.33	3.365	
Persons residing at the home	2.60	2.60	ln (persons residing at the home)	0.96	0.748	0.715	
number of persons 12 years of age and under	0.40	0.40	ln (number of persons 12 years of age and under + 1)	0.34	-0.186	-0.063	
size of parcel in sq ft	9,554	9,554	ln (size of parcel in sq. ft.)	9.16	0.122	1.118	
swimming pool	1%	0.01	Indicator for swimming pool (0/1)	0.01	0.082	0.001	
sewer rate, $/kgal		3	ln (sewer rate, $/kgal)	0.92	-0.112	-0.103	
efficient toilets	37%	0.37	Indicator for presence of efficient toilets/flushes (0/1)	0.33	-0.174	-0.064	
efficient clothes washer	46%	0.46	Indicator for presence of efficient clothes washers/washloads (0/1)	0.46	-0.073	-0.034	
water treatment	3%	0.03	Indicator for home water treatment system (0/1)	0.03	0.155	0.005	
hot water on demand	11%	0.11	Indicator for hot water on demand system (0/1)	0.11	-0.109	-0.012	
Total Household Use						4.928	138.1
Average Per Capita Use							53.12

Model of Landscape Water Use

Parameter	Coefficient	Study Ave	Assumed Value	Term
Intercept	-4.831			-4.250
Ln (Irrigated Area +1)	0.685	5836	5836	5.940
Ln (Net ET) (inches)	0.907	34.81	34.82	3.220
ln (Ave Cost of water at 25 kgal consumption) $/kgal	-0.923	6.4023	6.4023	-1.714
Indicator for In Ground Sprinkler system	0.981	0.515	0.515	0.505
Indicator for Over-irrigation	1.516	0.17	0.17	0.258
Number of Observations	742			
R-Squared	0.452			
Sum = Ln Outdoor use kgal/yr				3.96
Outdoor kgal/yr				52.4

Indoor Efficiency Benchmarks

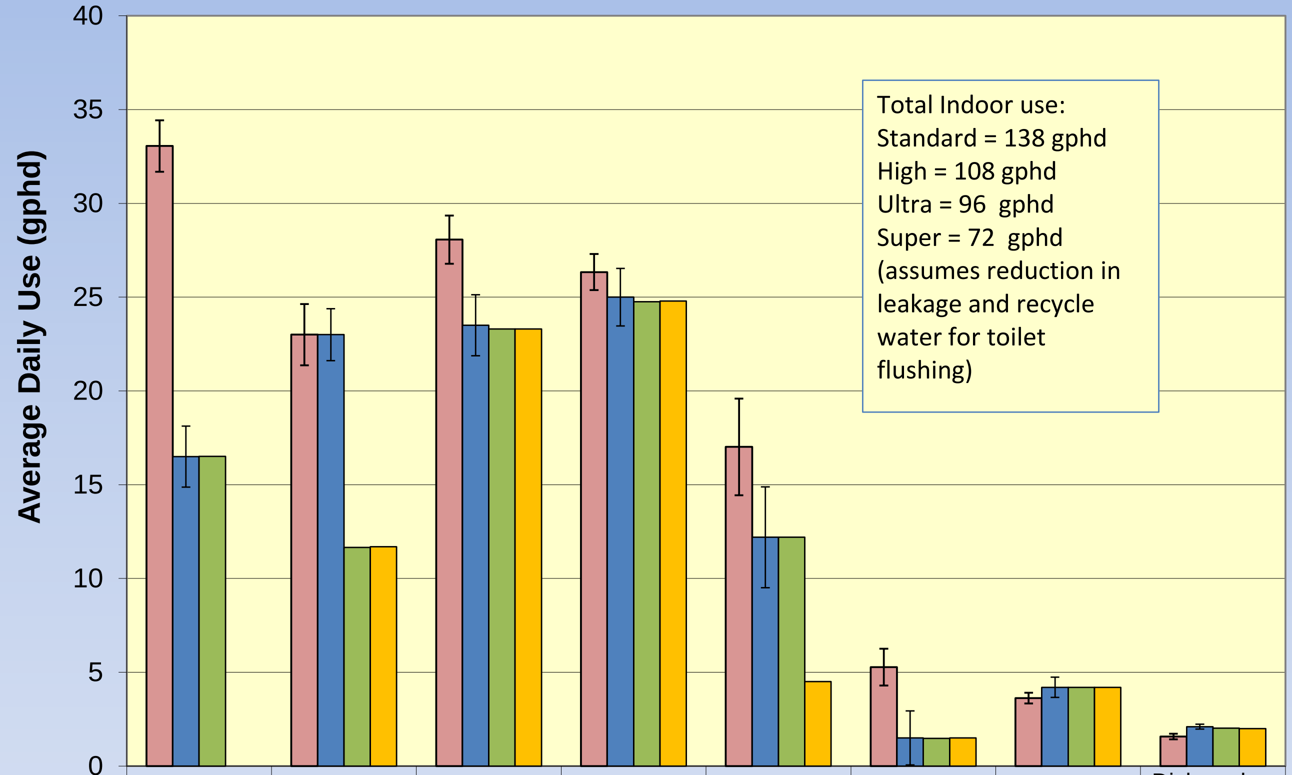
Product	Standard	Efficient	Ultra Efficient
Toilet	+3.5 gpf	1.6 gpf	1.28 gpf
Clothes Washer	> 30 gpl	< 30 gpl	<15 gpl
Showers	>2.5 gpm	< 2.5 gpm	<1.6 gpm
Faucets, kitchen	>2.5 gpm	2.5 gpm	< 2.2 gpm
Faucets, bathrooms	>1.5 gpm	1.5 gpm	<1.0 gpm

Household savings estimates

Benchmarks best for indoor; models for outdoor

Source	Indoor savings (gphd) (from 138 gpd starting point)	Indoor savings (kgal/yr) (from 50 kgal/yr starting point)	Outdoor savings (kgal/yr) (from 50 kgal/yr starting point)
From Models	26[a]	10	10 (moderate)[g] 25 (aggressive)[h]
From Benchmarks	30 high[b] 42 ultra[c] 50 with leak control[d] 66 with toilet recycle[e]	11 15 18 24	8[f]
From Household Demand Curves	28	10	na

Four efficiency levels for indoor use



	Toilet gpd	Washer gpd	Shower gpd	Faucet gpd	Leak gpd	Other gpd	Bathtub gpd	Dishwasher gpd
Standard	33.1	23.0	28.1	26.3	17.0	5.3	3.6	1.6
High	16.5	23.0	23.5	25.0	12.2	1.5	4.2	2.1
Ultra	16.5	11.7	23.3	24.8	12.2	1.5	4.2	2.0
Super	0.0	11.7	23.3	24.8	4.5	1.5	4.2	2.0

Conclusions & Recommendations

- It is important to recognize the non-normal distribution of water use and to design conservation programs that are properly targeted.
- Since the actions of a few households have such a significant impact on average use for the entire service population, the establishment of water budgets linked to progressive rate structures offers a promising way to send strong price signals that discourage excess use.
- Household water use does not vary linearly with the number of residents, but follows a power curve with the exponent equal to 0.65 (for this group). This should be kept in mind when establishing household water use targets.
- Non-seasonal water use, calculated from monthly billing data, will normally over-estimate indoor water use, and under-estimate outdoor use. The warmer the climate the larger the effect. This approach should be used with caution, especially in warmer climates with year round irrigation.
- Toilet flushing still represents the number one indoor water use, and the data show that approximately 1/3rd of the homes still are not equipped with any efficient toilets (that at least meet the 1992 EPAct). Another 1/3rd of the homes have mixtures of efficient and inefficient toilets.
- This suggests that continued focus on toilet replacement programs will be worthwhile. This does not necessarily have to take the form of a cash payment or rebate since the natural change in occurrence rate is over 2% per year.

C&R_2

- There are systems on the market that collect, treat and store graywater for toilet flushing. This type of recycling is worth investigating because if a practical system was available it would eliminate the toilet demands.
- Clothes washing, which used to be the second place indoor use is now the number four use, just ahead of leakage. Since new machines are constantly using less water, and it is difficult to find high volume machines, it seems unnecessary to pay rebates for clothes washers.
- There has been a decrease in average shower use. Additional studies should be done on the impact of 1.6 and 1.1 gpm shower heads on this category of use. It seems probable that as more of these devices are placed into service the reduction in daily shower use from the 1999 benchmark will become more significant.
- More detailed studies need to be done to clarify what is causing the leakage patterns that have been observed in this and other end use studies. The short duration and intermittent leak events are not the problem, but the few homes with very long duration, low flowrate leaks should be studied to determine if they are true leaks or derive from some water use that was not evident from the data logging and surveys.

C&R_3

- If the long duration leak-like events are truly due to unintended leakage then additional studies need to be done to determine how best to reduce this water loss.
- Devices that detect leaks, set off alerts, and even turn the water off should be investigated. These devices seem analogous to electrical circuit breakers, ground fault interrupters, or smoke detectors that are required by code in most areas.
- Studies of the practicality of use of AMI systems for leak detection and alerting resident should also be undertaken.
- Most households responding to the survey indicated that water conservation was important to them. Studies should be done on the impact of providing households with water budgets and real time information on their water use. These studies should be done first in the high consumption households.
- Water features, swimming pools and irrigation systems all are related to high leakage rates. Studies should be done to determine if these systems are really leaking or are using water in a way that appears to be leakage. For example a pool with an auto-fill system may have long duration draws, but these could be due to either normal use of the pool or leakage in the pool, or a malfunction of the valve itself.
- Sub-metering of pools and irrigation systems would eliminate much of the uncertainty about their usage, but studies should be done on samples of homes to determine if this would be a practical and useful way to expend resources.

C&R_4

- Many of the people in high leakage homes reported on the survey that they were aware that the leaks were present. This suggests that the cost of the water was too low for these households to take action to eliminate the leaks, which is further reason to implement water budget rate structures.
- Studies should be done to determine if there is a measurable relationship between the intensity of the water conservation programs of various communities and objective measures of water use efficiency. These studies would seek to determine if agencies with higher levels of effort or expenditures for water conservation have lower water use and higher efficiencies. Given that over 20 years have passed since the 1992 NEPact there is enough data to make such studies possible.
- This study found a linkage between recirculating hot water systems and lower faucet and shower hot water use, but the numbers of homes with the devices was small and they tended to be clustered in one or two cities. A properly designed pre-post analysis from a large sample of homes, using data from water meters installed on the water heater inlets, should be done to get better information on whether these devices truly save water, and if so, how much. Agencies should not require them, or pay rebates for them until such definitive studies have been done.
- Landscape water budgets with high charges for excessive use should be given serious trials, both for normal demand management and as part of drought response programs.
- Outdoor conservation program should focus on elimination of excess irrigation where it is occurring, reduction of the effective irrigated areas, use of price signal to curtail excess use coupled with better information to the household on their real time water use.

Thank you

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