Residential Water Use

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The Water Research Foundation (WRF) has recently released data that complements the U.S. Department of the Interior's standard water use estimates and makes this an appropriate time to revisit NAHB's 2000 analysis of water used by single-family homes in the U.S.[1]

In this article, NAHB cites the Department of the Interior's latest aggregate estimates and combines them with information from other government sources to show that

- Annual use of water in the U.S. is 355,000 million gallons per day.
- Water delivered to residential customers accounts for over half of the water used by public supplies (like local water utilities)
- However, from a broader perspective, residential use accounts for less than 8 percent of the 355,000 million gallons of water used per day in the U.S.
- On average, a housing unit uses 260 gallons of water per day.
- The amount of water used per home varies considerably from state to state.
- Homes in states that are hot, dry and have large households tend to use more water.

NAHB then uses new and more detailed household level data from the WRF to show, among other things, that

- Almost exactly half of residential water use consists of water used outside the home (e.g., for watering lawns).
- Indoors, the biggest users of water are toilets, followed by showers, faucets, clothes washers and leaks.
- Although homes built before 1960 tend to use less water, possibly because they are less likely to have swimming pools. After that average water use varies only slightly among single-family homes of different vintages.
- Newer homes tend to have more toilets and showers, but statistical models fail to show this has any effect on the amount of water used. In fact,

relatively few of the features that might be controllable by a home builder or developer have an impact on water use.

- Instead, the statistical models show that the number and type of persons in the household and cost of water/sewer service, are powerful drivers of water use.
- Among items that a builder or developer might install, the statistical models imply that newer homes tend to use more water because they are more likely to have water softener or filtration systems and in-ground sprinklers.
- On the other hand, the newer homes tend to use less water because they have more efficient toilets and clothes washers, and are more likely to have hot water recirculating (on-demand) systems.

The rest of this article describes the two sources of data mentioned above and NAHB's analysis of them in more detail. It also discusses how measures shown to reduce water consumption are effectively targeted by the National Green Building Standard.

Total Deliveries and Withdrawals

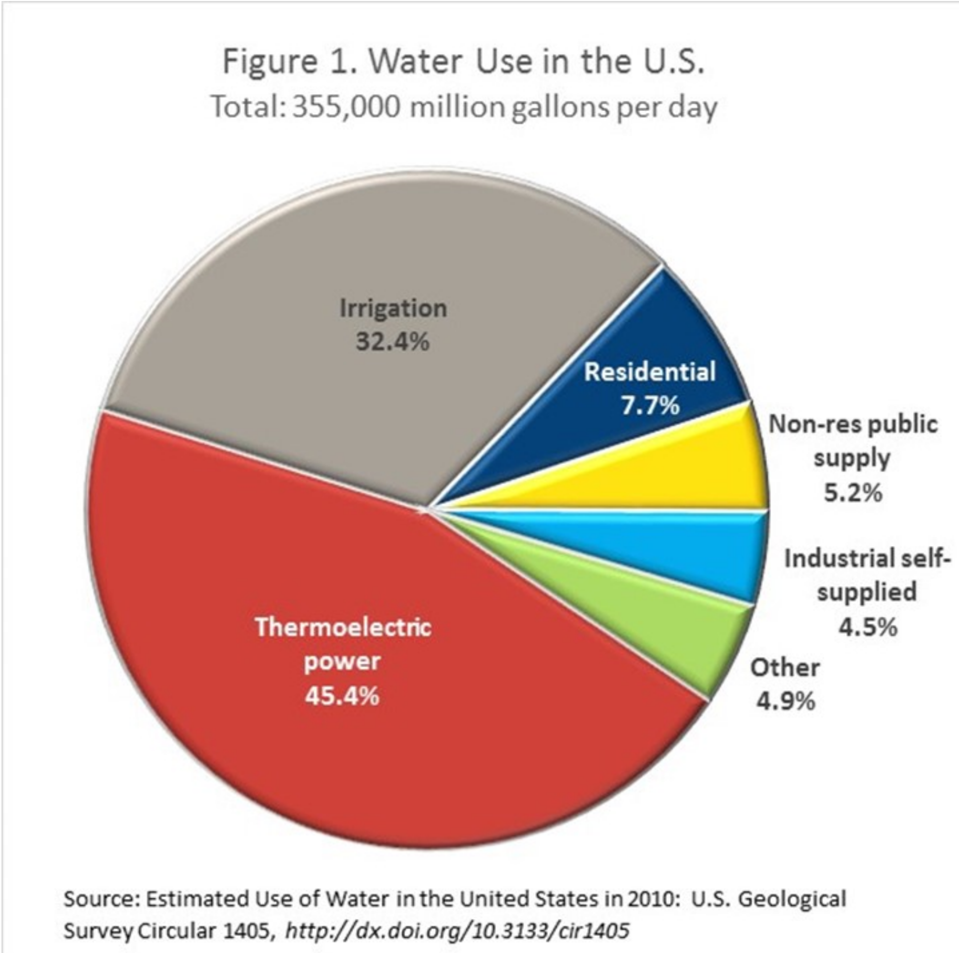
Every five years, the U.S. Geological Survey (USGS, housed in the Department of the Interior) compiles data on water use from various state local and national sources. The latest numbers were published in 2014 in Estimated Use of Water in the United States in 2010.

The USGS defines water use as water withdrawn from a ground water or surface water source by humans for a specific purpose. Hydroelectric power (e.g., as generated by the Hoover Dam) which uses water without diverting it from its source, is not included. The USGS labels water used by residences as "domestic." This article follows terminology that will be more familiar to most readers and refers to water used by homes as "residential" water use.

The USGS report shows that, in 2010, residential water use in the U.S. totaled 27,400 million gallons per day (Mgal/d). The lion's share—23,800 Mgal/d—was delivered to homes by a public supplier (e.g., a water utility) that was in turn responsible for withdrawing the water from its source. The remaining 3,600 Mgal/d were withdrawn by the residences directly, typically from a well.

The importance of residential water use depends on your perspective. From the perspective of an individual utility, residential use can be quite important. Public suppliers withdrew 42,200 Mgal/d of water in 2010, and over 56 percent of this was delivered to residential customers.

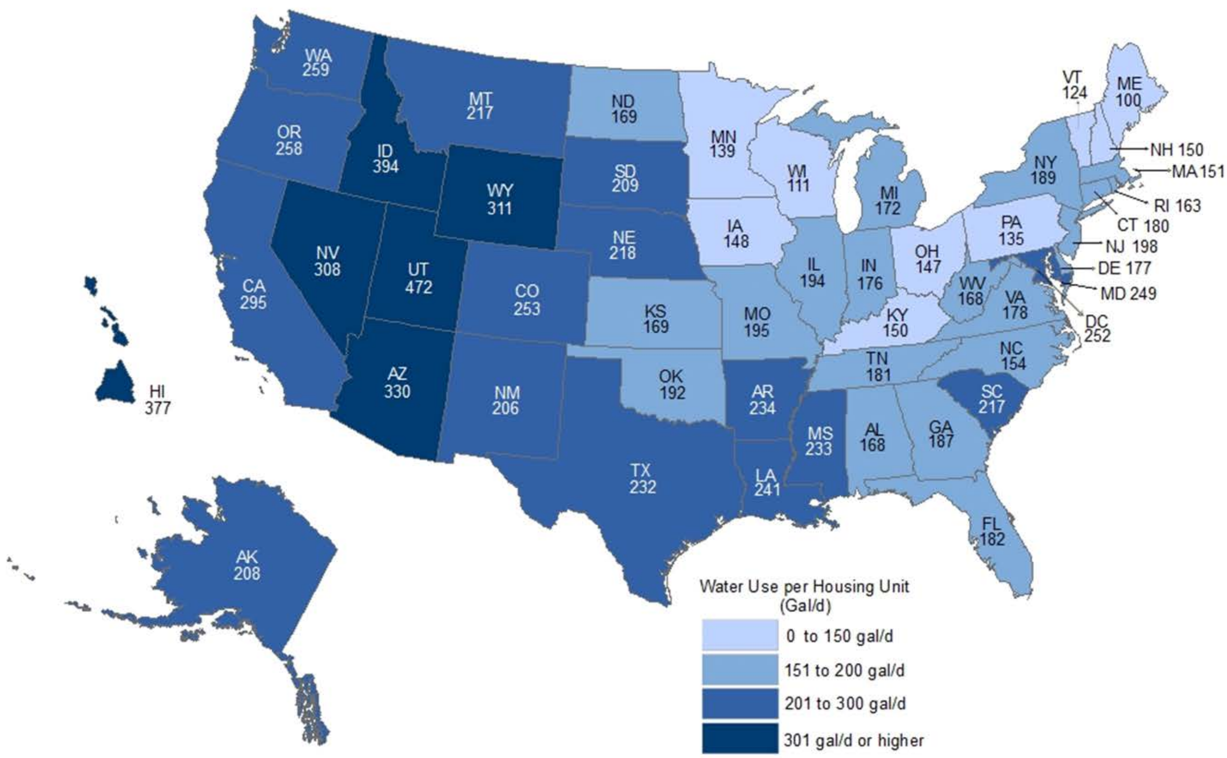
From a more holistic environmental perspective that considers water used for all purposes, residential use constitutes a relatively small share of the nation's thirst. Total withdrawals of water in U.S. in 2010 were 355,000 Mgal/d. The two biggest imbibers by far were thermoelectric power (i.e., steam-driven turbines), which accounted for 161,000 Mgal/d, and irrigation (of crops, pasture, parks, golf courses etc.), which accounted for 115,000. In comparison, the 23,800 Mgal/d used by residences accounts for less than 8 percent of total water use (fig. 1).[2]



According to the decennial Census, there were a little under 132 million housing units in the U.S. in 2010. Combined with USGS use estimates, this works out to an average of about 260 gallons per day (gpd) per housing unit. However, the average varies considerably from state to state, from a low of 100 gpd in Maine to a high of 472 in Nevada.

As Figure 2 shows, there is a fairly distinct geographic pattern to residential water use by state, with relatively low use per home in some upper Midwest and New England states, and higher use per home in the central South and West, especially in mountain and desert states.

Figure 2. Water Use per Housing Unit
Deliveries plus Withdrawals in Gallons per Day



Source: Decennial Census 2010 and U.S. Dept. of the Interior

NAHB investigated several factors that may help explain the observed state-to-state differences in water use per housing unit. Of the variables readily available at the state level, water use per housing unit is positively correlated with average temperature and average household size, negatively correlated with annual rainfall and age of the housing stock. Age of the housing stock, however, is correlated with household size and, to some extent, temperature, and so becomes insignificant when combined in a regression model with other variables (statistical results available in the “additional resources” box at the top of the on-line version of this article).

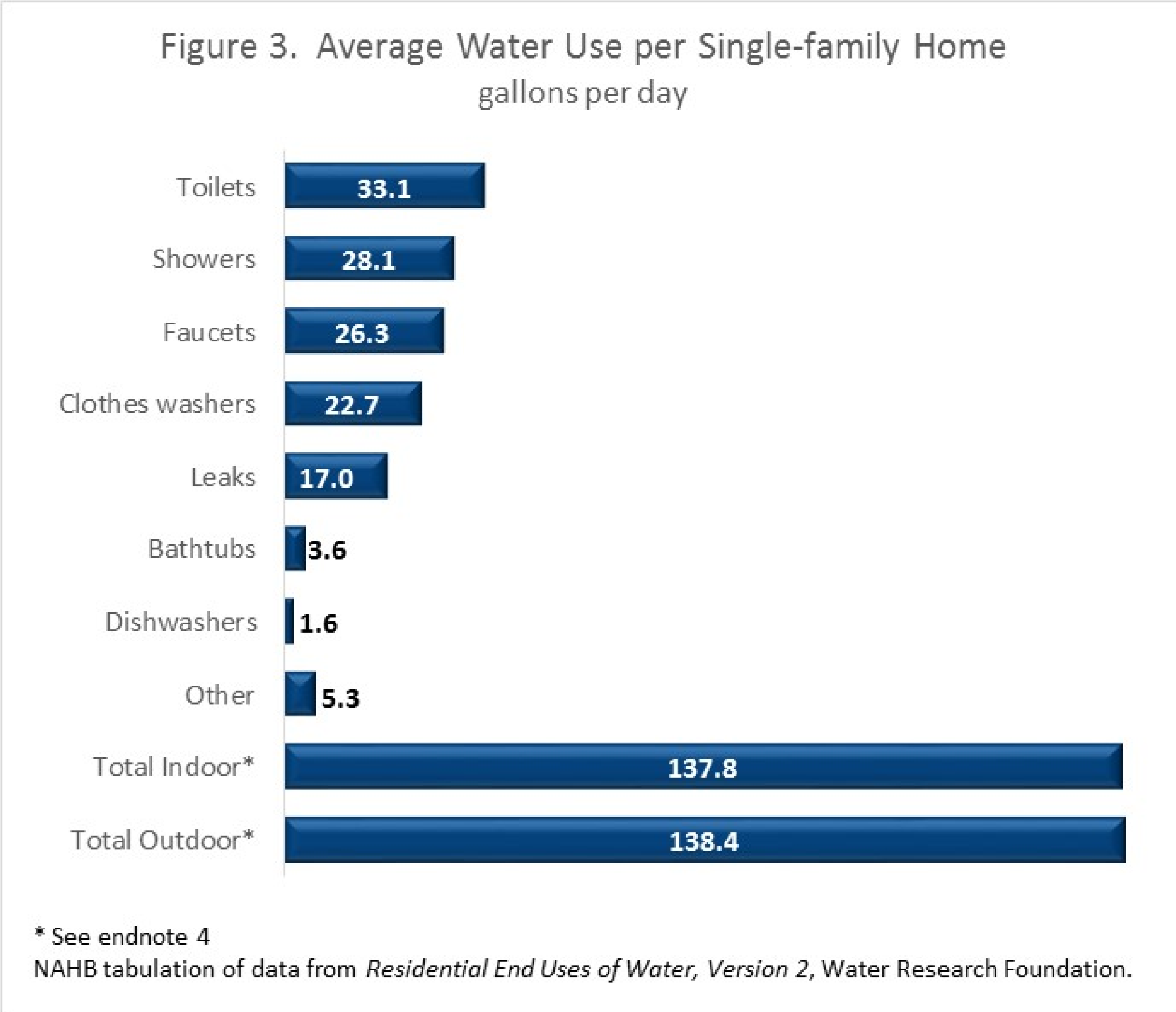
In short, the aggregate state-level data indicate that housing units tend to use more water if they are in states that are hot, dry and have larger households. Going further requires information about individual household water use.

Water Using Home Features

In 2016, new information about individual household water use became available in the form of Version 2 of the WRF's Residential End Uses of Water (REUW) study. The REUW collected billing data for single-family customers from over 20 participating water utilities, and followed this up with a mail survey to a random sample of single-family customers in each utility's jurisdiction. Among the data sets generated from the study is one containing 13,732 responses to this survey.

The REUW in turn followed this up by collecting "flow trace" data from a sample of about 800 of the homes, attaching devices to the water meters that recorded flows every 10 seconds over the course of a year in a way that, according to the experts, makes it easy to distinguish water used for different purposes inside and outside the home.

Water use in these homes averaged 276 gpd.[3] As Figure 3 shows, almost exactly half of this was attributable to water used outside the home (e.g., for watering lawns).[4] It is well known that lawns and gardens need more watering in climates that are hot and get little natural rainfall. This, along with the fact that so much of the water used by homes is allocated to a purpose like outdoor watering, helps explain the climate-related pattern to the state water use averages in Figure 2.

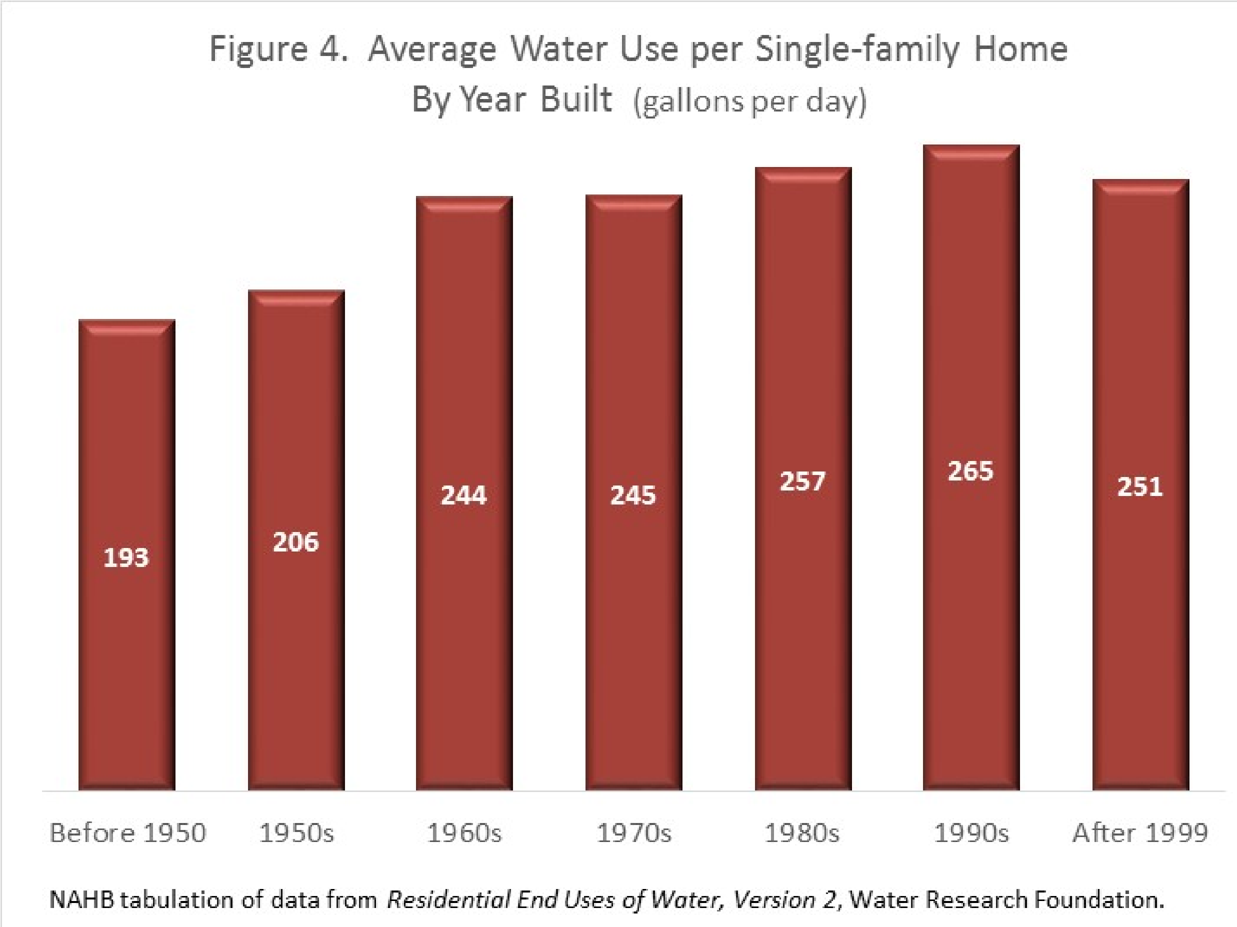


Indoors, as Figure 3 shows, toilets account for the greatest share of water use, but the shares for showers, faucets, clothes washers and leaks are also substantial. The WRF's analysis of the leak data shows that the average of 17 gpd is attributable to large leakage rates for a relatively small share of homes, especially homes that have swimming pools.

The numbers in Figure 3 include both hot and cold water. The water heater in and of itself is not counted as an end use in this analysis; the end use is where the water goes after leaving the heater. If storing water in a tank to heat it increases indoor water use, this would not be characterized as an identifiable end use and would show up in the "other" category in Figure 3. The 2016 REUW study fitted a sample of 94 homes with an extra device that monitored hot water use separately. Results showed that hot water accounted for one-third of total indoor water use, and showers and faucets used accounted for most of the hot water use.

The average of 138 gpd for total indoor use is down from 177 gpd for the homes in version 1 of the REUW study released in 1999. The WRF's analysis shows that, between the 1999 and 2016 studies, there was a statistically significant reduction in water used per household for toilets, clothes washers, showers, leaks and dishwashers. Among the major indoor categories, the only one not showing a significant reduction over that 17-year span was faucet water use. In most cases, the declines are easy to understand given efficiency standards for water using fixtures and appliances that governments began to implement in the 1990s.

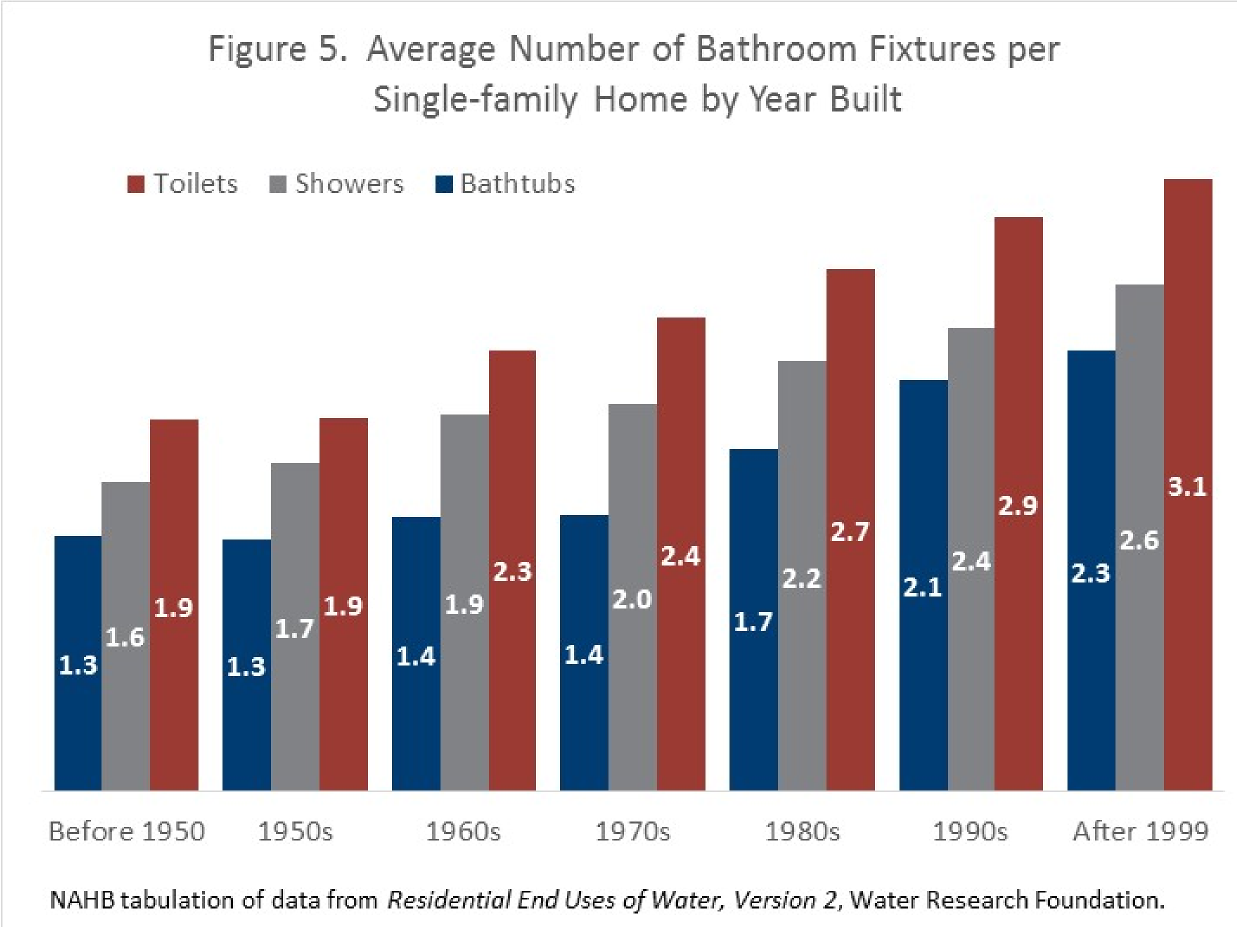
Standards that have been promulgated and modified since 1990 raise a question about whether newer homes might in some sense be more efficient than older ones in their use of water. There are not enough observations in the REUW flow trace data to parse specific indoor uses by age of structure, but it is possible to do this for total water use with the larger sample of single-family households that responded to the WRF's water use in the survey. The results show less water used by homes built before 1960, but relatively small differences among homes built after that. For example, there is less than a 3 percent difference between the 244 gpd used by homes built in the 1960s and the 251 gpd used by homes built after 1999 (fig. 4).



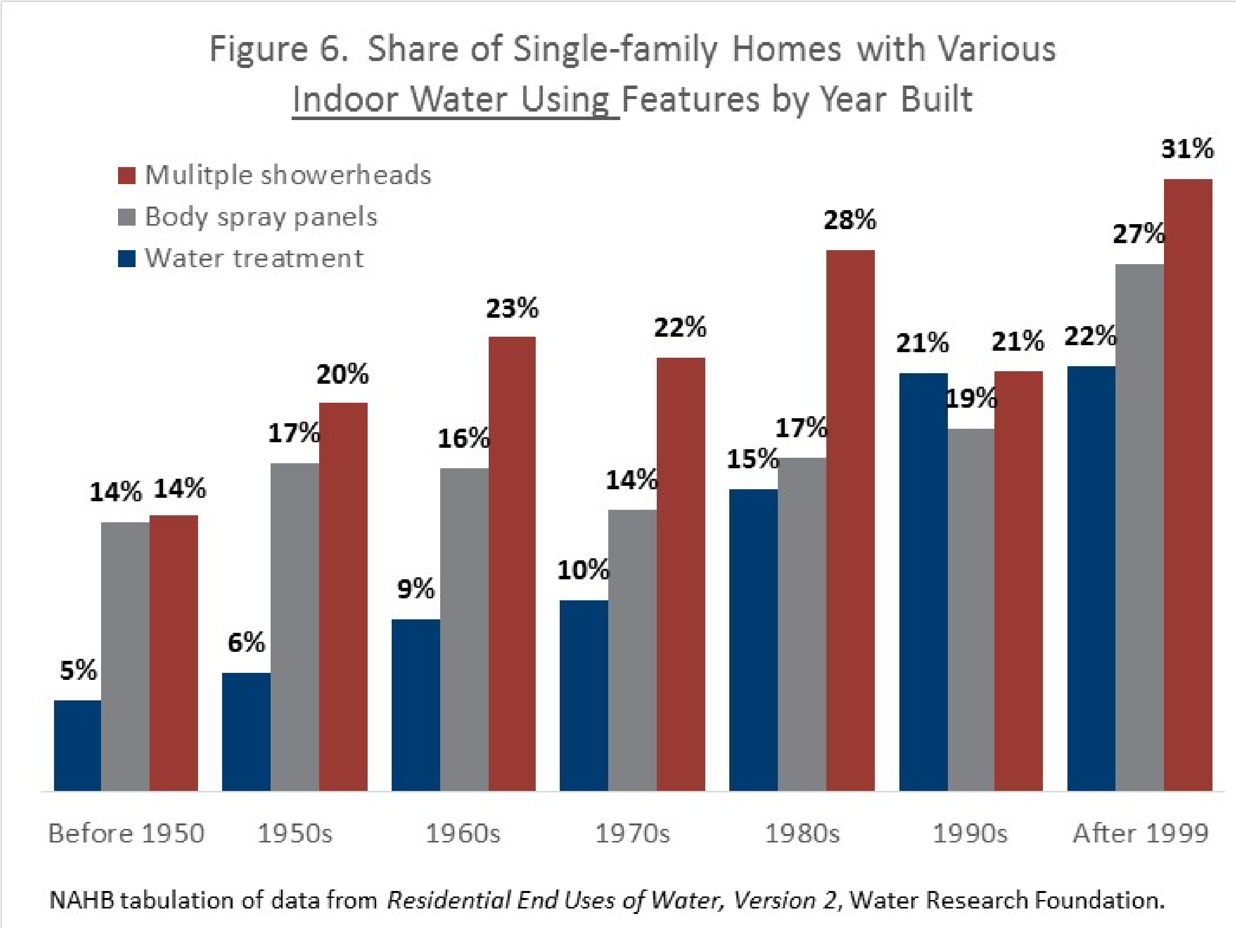
Features in New vs. Old Homes

It is well known that newer and older homes differ in a number of important ways that might affect water use. One is the general tendency for newer homes to have more bathrooms. As the standard tables from the Survey of Construction[5] show, the share of single-family homes built with at least 2 bathrooms has increased regularly from 60 percent of homes completed in 1973 to 97 percent of homes completed in 2016.

This can be investigated in greater detail by using the REUW survey, which contains data on specific bathroom fixtures. Consistent with the increase in number bathrooms, the average number of toilets, showers and bathtubs all increase regularly as single-family homes become newer (fig. 5).



Similarly, showers with multiple shower heads and body spray panels are more common in homes built more recently, as are water treatment systems such as a water softener or drinking water filtration system (fig. 6).



In NAHB's most recent Home Buyer Preference Survey, multiple shower heads in the master bath were moderately popular, ranking 7th out of 16 bath features listed in the survey and rated essential or desirable by 55 percent of recent and prospective home buyers. Drinking water filtration scored somewhat higher, ranking 6th out of 31 kitchen features and rated essential or desirable by 70 percent of recent and prospective home buyers.

Of the features in figures 5 and 6, the water treatment system is interesting because it is the only one that appears as an explanatory variable in any of the WRF's statistical models that estimate water use. The WRF constructed several such models from REUW data, estimating outdoor water use, total indoor use, and a number of different individual indoor uses. NAHB economists reviewed these models and judged them to be generally well constructed and a good use of the available data. So, rather than provide a critique or suggest alternatives, Table 1 simply lists the variables used in the WRF models and indicates whether their impact on water use was positive (tending to increase water use) or negative.

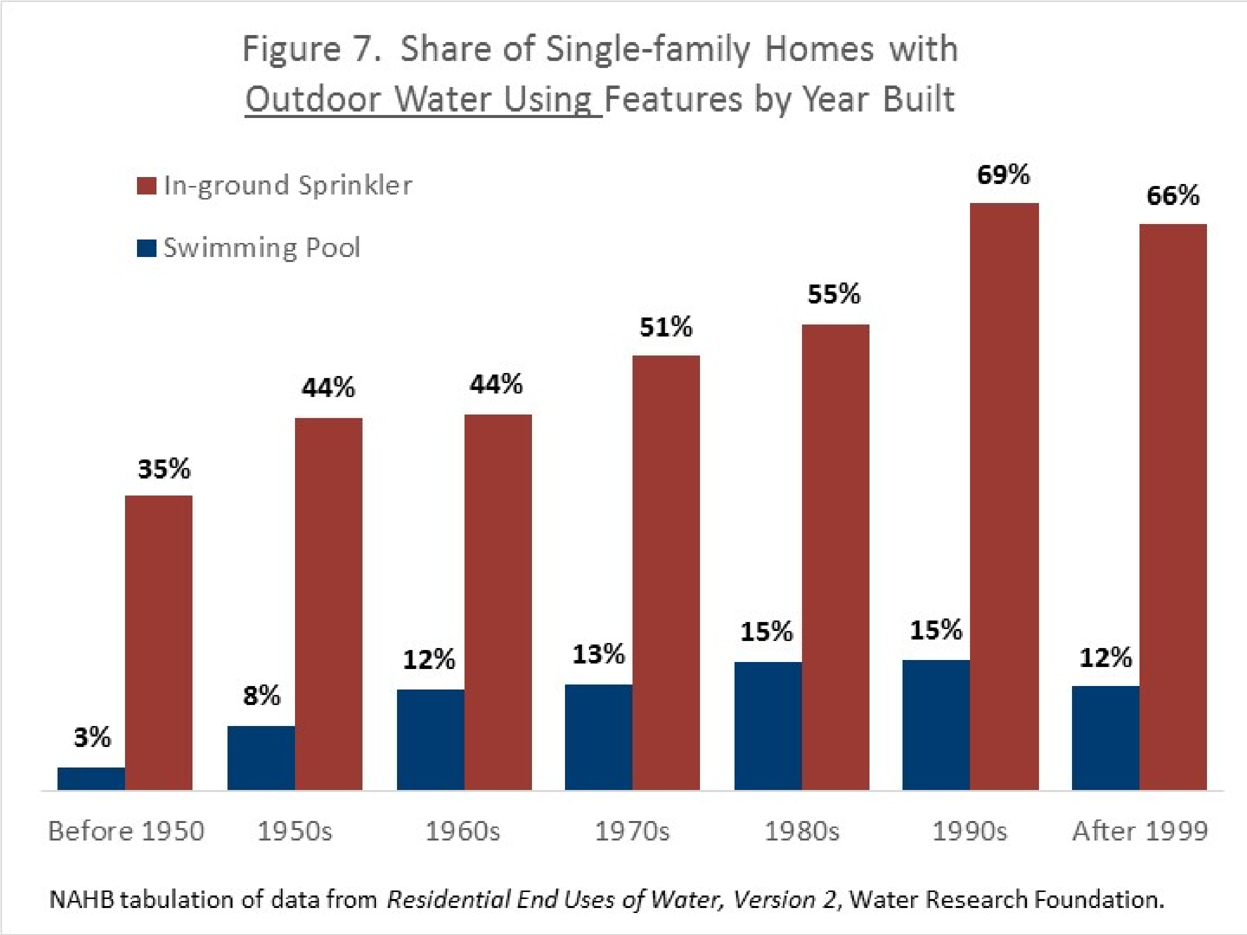
Table 1.
Variables with a Statistically Significant Impact in Models of Water Use

Variable	Impact on Water Use
A. Models of Indoor water use*	
Number of persons in the household	+
Persons age 12 and under	–
Person age 13-17	varies
Adults employed outside the home	+
Persons home during the day	+
Home rented rather than owned	–
Sewer rate ($/kgal)	–
Size of the lot	+
Home water treatment system	+
Swimming pool	+
Swimming pool with automatic refill	+
Presence of efficient toilets	–
Presence of efficient clothes washer	–
Hot water recirculating system	–
B. Models of outdoor water use	
Irrigated area of the lot	+
Evapotranspiration (water requirement of plants)	+
In-ground sprinkler system	+
Swimming pool	+
Household that irrigates more than necessary	+
Cost of water ($/kgal)	–
C. Not in model, but still some evidence of an impact on outdoor use	
Irrigation timer managed by a service professional	–
Drip irrigation	–

** Excludes results from the faucet use model, which contains some anomalies*
Source: NAHB summary of results presented in Chapter 7 of Residential End Uses of Water, Version 2, Water Research Foundation.

As the table indicates, the WRF models found that the price local utilities charge for water and sewer service and the number and type of people living in the home had powerful impacts on water use. After controlling statistically for these factors, relatively few of the features that might be installed by a builder or developer have an impact. This is similar to results from NAHB's analysis (November 5, 2014 Special Study) of Department of Energy data, which showed that the price of energy and household characteristics tended to have a larger impact on energy use than features that might be installed by a home builder. The estimated impact of number of occupants on water use is also consistent with NAHB’s analysis of the USGS state-level data discussed above, which finds a positive relationship between water use per home and average household size in the state.

In addition to a water treatment system, the statistical models summarized in Table 1 indicate that the presence of swimming pools and in-ground sprinklers increase the amount of water used by a single-family household. Understandably, the impact of swimming pools on household water use is particularly strong. Although 12 to 15 percent of homes built after 1959 have swimming pools, swimming pools are present on only 8 percent of homes built in the 1950s and only 3 percent of homes built before 1950. This may go a long way toward explaining why Figure 4 shows lower water use for homes built before 1960. The incidence of in-ground sprinklers tends to rise as homes become newer, although in-ground sprinklers are slightly more common in homes built during the 1990s than in homes built after 1999 (fig. 7).

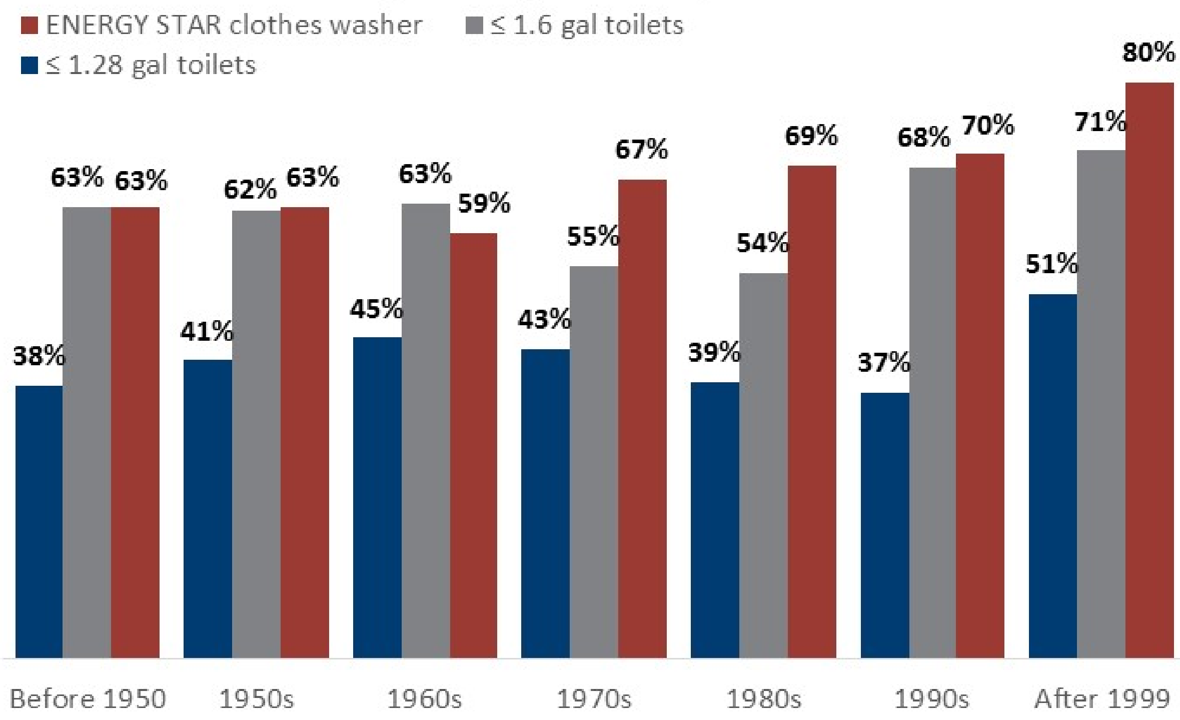


Other factors that determine outdoor water use significantly in the WRF models are evapotranspiration, or the water requirements of plants, and irrigated area of the lot. Evapotranspiration depends on climate, so this result is consistent with the analysis of USGS data described previously, showing that water use per home is higher in states with hot, dry climates. Although there is no central source of data specifically on the irrigated area of lots, data from the Survey of Construction show that the overall size of lots for new single-family detached homes has been declining over time. As reported in an NAHB blog post, lots on homes sold in 2015 were the smallest on record.

Conservation in New vs. Old Homes

Although the number of bathroom fixtures does not affect water use in any of the WRF models, the presence of <u>efficient</u> toilets and clothes washers does, and these water conserving features were most common in the newest homes in the 2016 REUW survey sample. For example, of the homes built after 1999, 71 percent had toilets that averaged less than 1.6 gallon per flush, 51 percent had toilets that averaged less than 1.28 gallons per flush and 80 percent had ENERGY STAR rated clothes driers. All three percentages are higher here than they are for homes in any of the earlier vintage categories (fig 8).

Figure 8. Efficient Share of Water Using Features in Single-family Homes by Year Built



NAHB tabulation of data from *Residential End Uses of Water, Version 2*, Water Research Foundation.

The 1.6 and 1.28 gallon per flush cut-offs for toilets in Figure 8 are not identical to the criterion in the WRF's statistical models of water use, but they are the ones available in the larger survey sample that can be tabulated by year built. The 1.6

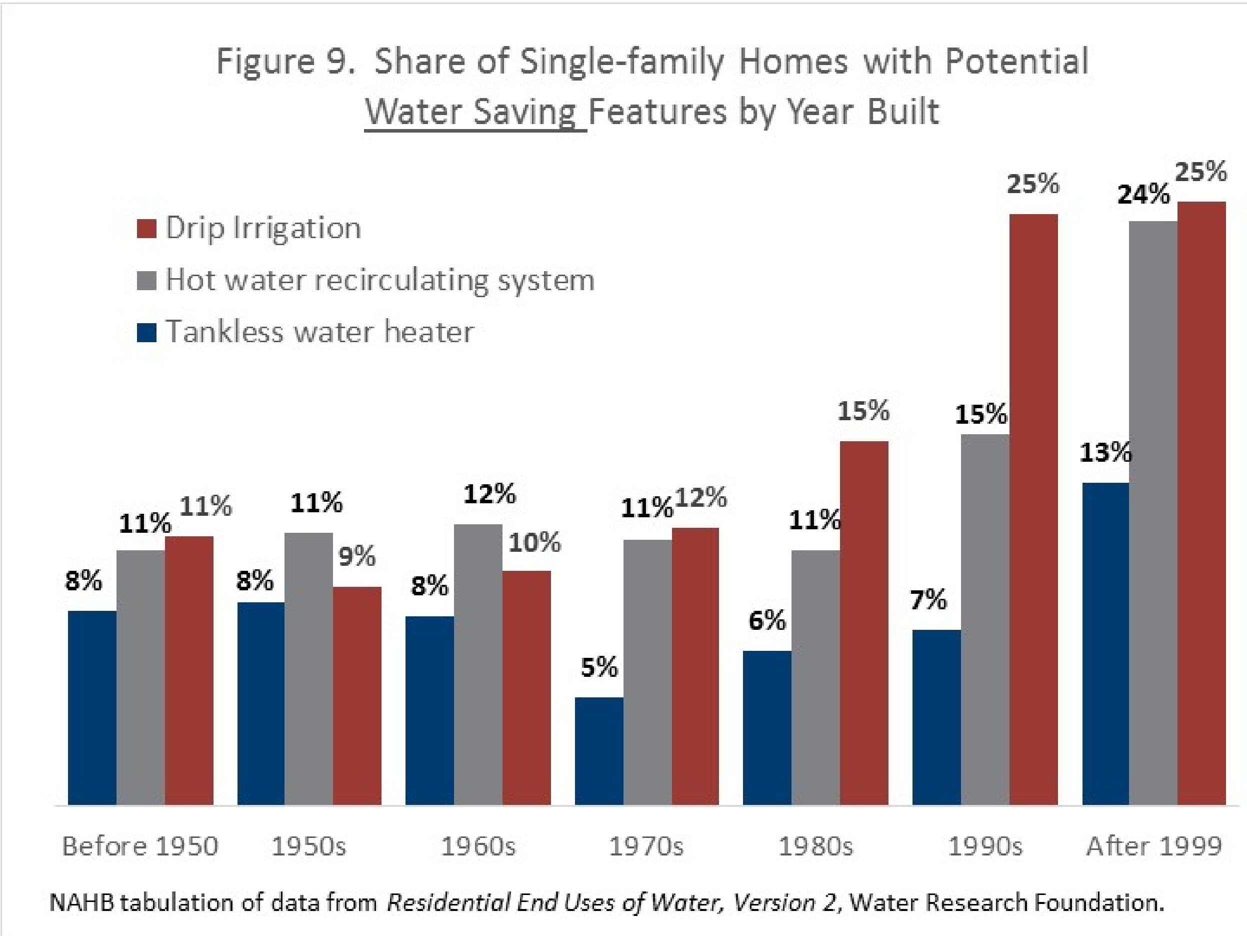
gallon threshold is the federal standard established by Congress in the Energy Policy Act of 1992. The threshold at 1.28 gallons is the criterion a toilet must meet to quality for a WaterSense label; WaterSense being a voluntary program run by the Environmental Protection Agency (EPA).

Figure 8 shows also that, in some respects, the toilets in homes built in the 1970s and 1980s are less efficient than the toilets in homes built before 1970, suggesting toilets in homes that old are more likely to have been replaced by fixtures manufactured to post-1990 standards.

Like WaterSense, ENERGY STAR is a voluntary program administered by EPA. According to EPA, clothes washers that are ENERGY STAR certified use about 25% less energy and 45% less water. ENERGY STAR appliances in general tended to be very popular in the NAHB buyer preference survey. They came in second among all of the roughly 150 home and community features listed in the survey, rated essential or desirable by 90 percent of recent and prospective home buyers. The result was driven largely by the home buyers who rated ENERGY STAR appliances as desirable: 58 percent vs. 32 percent who rated them essential. More than 32 percent of the buyers gave an essential rating to home features such as a ceiling fan, full bath on the main level, and exterior lighting.

One home feature that was shown to reduce water use in WRF statistical models is a hot water recirculating system (which uses a pump to move water quickly from the heater to the fixture, reducing the wait time). These are often also called "on-demand" hot water systems, and are distinct from tankless water heaters, that heat water instantly as it flows through the device without storing water internally.

Figure 9 shows the incidence of hot water recirculating systems, tankless water heaters, and drip irrigation (a system that drips water into or onto the soil at a slow rate). Neither tankless heaters or drip irrigation were proven to reduce water usage in any of the WRF statistical models. In the REUW flow trace data, homes with drip irrigation did in fact use less water, but the result was not quite statistically significant according to a conventional criterion. So the WRF excluded drip irrigation from the models that estimated water use, but still believed it to be a promising way to reduce outdoor water use. Drip irrigation is also the only one of a large number of irrigation features in the study that provided any evidence at all of an ability to reduce water use outdoors.



Even though they weren't shown to have a statistically significant effect on water use in the REUW study, tankless water heaters may be of interest from an energy efficiency standpoint. In fact, that is the primary virtue the Department of Energy (DOE) emphasizes when describing them. As DOE's web site states, tankless water heaters "don't produce the standby energy losses associated with storage water heaters, which can save you money."

As figure 9 shows, 24 percent of homes built after 1999 have hot water recirculating systems and 13 percent have tankless water heaters, percentages that are substantially higher than for homes built in the 1990s or earlier. Drip irrigation systems are present in one-fourth of the homes built in the 1990s or later, but are much less common in homes built earlier than that.

Summary and Conclusion

State-level data from the USGS shows that homes in states with hot dry climates and large household sizes tend to use more water. This is consistent with the more detailed results available from the REUW study, showing that half of water used by single-family homes is used outdoors for purposes like watering lawns and gardens, where climate is a factor. Statistical models developed in the REUW also show that the number (and type) of people living in a home are a powerful determinant of water use.

The REUW data show that homes built before 1960 use less water, which may be largely explainable by the small share of them that have swimming pools. After 1959, homes of different vintages show relatively similar water use. The WRF statistical models imply that newer homes should tend to use more water, because they are more likely to have water treatment systems and in-ground sprinklers. However, the same models also imply that newer homes should use less water, because they have on average more efficient toilets and clothes washers and are more likely to have hot water recirculating systems.

Many of these results help illustrate why certain building and landscaping practices earn points under the National Green Building Standard (NGBS). Like WaterSense and ENERGY STAR, the NGBS is a voluntary program that seeks to encourage green practices. The NGBS is also the only residential green building rating system approved by the American National Standards Institute.

As noted above, outdoor use on average accounts for half of all water used by a single-family home, and irrigated area of the lot and in-ground sprinklers are important determinants of outdoor use. In the NGBS Chapter on Lot Design, homes earn points for practices that reduce the irrigated area of the lot and the water requirements of plants on it. In the NGBS Chapter on Water Efficiency, homes earn points for features that increase the efficiency of irrigation systems, up to 15 points if no irrigation system at all is installed (provided a landscape plan is also developed that conforms to requirements in the Lot Design Chapter).

REUW also shows that toilets account for the greatest share of indoor water use, and that increasing the efficiency of toilets and clothes washers significantly reduces the amount of water used indoors. In the NGBS Chapter on Water Efficiency, a clothes washer can earn up to 24 points if it has a low enough water factor (gallons per cycle per cubic foot), and toilets with that meet the 1.28 gallon per flush requirement can earn up to 11 points (more if they use 1.20 gallons or less per flush). These point awards are substantial. To put them in perspective, a total of 25 points is needed to reach the NGBS bronze criterion for water efficiency.[6]

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[1] Paul Emrath, "Residential Water Use." *Housing Economics*, June 2000, NAHB.
[2] In Figure 1, the "other" category includes acquaculture (e.g., fish hatcheries), mining, and watering livestock.
[3] This is slightly above the 260 gpd calculated from the USGS estimates. The USGS estimates, however, include vacant homes as well as all types of structures. The REUW data, in contrast, is confined to occupied single-family homes.
[4] In the 2016 REUW study, total outdoor and indoor water use is available for a sample of 838 homes. A breakdown of indoor water use is available for a subsample of only 737. However, average indoor use for the full sample and subsample differed only by 0.1 gallon per day, so for simplicity this article ignores the distinction and treats the use averages as if calculated on the same base.
[5] The Survey of Construction is the instrument used to generate the familiar series on housing starts. The survey is conducted on an ongoing basis by the U.S. Census Bureau with partial funding from the Department of Housing and Urban Development.
[6] The NGBS is a comprehensive standard. To qualify for a rating under it, a home must meet an overall point total, as well as satisfy specific requirements for a green lot design, overall resource efficiency, energy efficiency and indoor environmental quality, in addition to water efficiency. The builder is also required to provide sufficient education to the home buyer on building operation and maintenance.

Appendix: Regression Results

Variable Correlations Matrix

Pearson Correlation Coefficients, N = 51 Prob > |r| under H0: Rho=0							
	Water_Use	**Fahrenheit**	**Inches**	**HH_Size**	**Age**	**SF_Share**	**Vacancy_Rate**
Water_Use	1	0.17563 0.2177	-0.38076 0.0058	0.64768 <.0001	-0.3702 0.0075	-0.09786 0.4945	-0.13468 0.346
Fahrenheit	0.17563 0.2177	1	0.54487 <.0001	0.38919 0.0048	-0.28562 0.0422	-0.10249 0.4742	0.09942 0.4876
Inches	-0.38076 0.0058	0.54487 <.0001	1	-0.03532 0.8057	0.17189 0.2278	-0.16158 0.2573	0.1512 0.2896
HH_Size	0.64768 <.0001	0.38919 0.0048	-0.03532 0.8057	1	-0.42262 0.002	0.03241 0.8214	-0.14256 0.3183
Age	-0.3702 0.0075	-0.28562 0.0422	0.17189 0.2278	-0.42262 0.002	1	-0.47413 0.0004	-0.35994 0.0095
SF_Share	-0.09786 0.4945	-0.10249 0.4742	-0.16158 0.2573	0.03241 0.8214	-0.47413 0.0004	1	0.03287 0.8189
Vacancy_Rate	-0.13468 0.346	0.09942 0.4876	0.1512 0.2896	-0.14256 0.3183	-0.35994 0.0095	0.03287 0.8189	1

Regression One

Parameter Estimates				
Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	-446.83769	141.06619	-3.17	0.0027
Fahrenheit	1.9747	1.16153	1.7	0.0959
Inches	-2.45884	0.64063	-3.84	0.0004
HH_Size	250.17812	52.37725	4.78	<.0001
Age	0.08984	0.91209	0.1	0.922

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	151521	37880	15.65	<.0001
Error	46	111362	2420.92082		
Corrected Total	50	262883			

Root MSE	49.20285	R-Square	0.5764
Dependent Mean	210.03993	Adj R-Sq	0.5395
Coeff Var	23.42548		

Number of Observations Used	51

Regression Two

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	439.12876	116.12395	-3.78	0.0004
Fahrenheit	1.93812	1.08892	1.78	0.0816
Inches	-2.43787	0.59782	-4.08	0.0002
HH_Size	248.85241	50.08251	4.97	<.0001

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	151497	50499	21.31	<.0001
Error	47	111386	2369.91166		
Corrected Total	50	262883			

Root MSE	48.68174	**R-Square**	0.5763
Dependent Mean	210.03993	**Adj R-Sq**	0.5492
Coeff Var	23.17737		

Number of Observations Used	51

Variable Descriptions

Water_Use: Water use (withdrawals and deliveries) per housing unit measured in gallons.
Source: *Estimated Use of Water in the United States in 2010*, U.S. Department of the Interior & U.S. Geological Survey.

Fahrenheit: Annual average temperature measured in Fahrenheit.
Source: Current Results: Weather and Science Facts.
https://www.currentresults.com/Weather/US/average-state-weather.php
Source: U.S. Climate Data.
https://www.usclimatedata.com/climate/washington/district-of-columbia/united-states/usdc0001

Inches: Annual average precipitation measured in inches.
Source: Current Results: Weather and Science Facts.
https://www.currentresults.com/Weather/US/average-state-weather.php
Source: U.S. Climate Data.
https://www.usclimatedata.com/climate/washington/district-of-columbia/united-states/usdc0001

HH_Size: The average number of people in a household. The Census Bureau defines a household as all people who occupy a housing unit.
Source: American Community Survey, 2010 (one year survey).

Age: The median year a structure was built subtracted from the year, 2010.
Source: American Community Survey, 2010 (one year survey).

SF_Share: Single-family detached units as a share of total housing units.
Source: American Community Survey, 2010 (one year survey).

Vacancy_Rate: Total vacant units as a share of total housing units.
Source: American Community Survey, 2010 (one year survey).