ENERGY STAR® PortfolioManager® EPA WaterSense Technical Reference

Water Score for Multifamily Housing in the United States

OVERVIEW

The objective of the water score is to provide a fair assessment of the water use performance of a property relative to its peers, taking operational characteristics of the property and impact of climate into account. A statistical analysis is performed to identify building parameters that are significant drivers of water use using multivariate regression analysis, resulting in an equation that predicts the Water Use Intensity (WUI) of a property. The actual WUI of a property is then compared with the predicted WUI to fit a distribution in order to yield a 1 to 100 percentile ranking of performance, relative to the national population.

- Property Type. The Water Score for multifamily housing applies to residential buildings that contain 20 or more residential living units. The score applies to single-building properties as well as properties with multiple buildings.
- Reference Data. The analysis for multifamily housing is based on data from the Multifamily Energy and Water Market Research Survey by the Federal National Mortgage Association ("Fannie Mae").
- Adjustments for Weather and Business Activity. The analysis includes adjustments for:
  - Number of Units
  - Number of Bedrooms Per Unit
  - Weather and Climate (using historic evapotranspiration and precipitation based on zip code)
  - Ratio of irrigated area to the gross floor area (RIF)
- Release Date. The EPA water score for multifamily housing was released in October 2017.

The process to develop the EPA water score follows an approach analogous to the ENERGY STAR score. A detailed description of the overall approach to develop ENERGY STAR scores is covered in the Technical Reference for the ENERGY STAR Score, available at www.energystar.gov/ENERGYSTARScore. The subsequent sections of this document offer specific details on the development of the EPA water score for multifamily housing:

REFERENCE DATA & FILTERS

Fannie Mae's *Multifamily Energy and Water Market Research Survey*, available at https://www.fanniemae.com/multifamily/green-initiative-market-research-survey, was used as the source data for this analysis. Fannie Mae surveyed a total of 1,163 properties and collected whole building energy and water use data for the year 2011. The final published dataset has 955 properties. This dataset was further reviewed for properties with a full 12 months of water data as well as complete information in the other categories. As a result, the total number of properties in the analysis varied based on the needed inputs. This resulted in a dataset of 274 properties with complete information required to compute a water score. Of the 681 properties that were removed, half of them were eliminated because they did not report the 12-month total water use data. In many other cases, the survey specified no irrigated area even though outdoor water space served was reported (an apparent contradiction).

From a starting point of 274 properties, additional filters were applied according to the standard EPA protocol. Four types of filters are applied to define the peer group for comparison and to overcome any technical limitations in the data: building type filters, program filters, data limitation filters, and analytical filters. A complete description of each of these categories is provided in the Technical Reference for the ENERGY STAR Score. *Figure 1* presents a summary of each filter applied in the development of the EPA water score for multifamily housing. After all of the filters are applied, the remaining data set has 258 properties.

Figure 1 – Summary of Filters for the Water Score for Multifamily Housing

Condition for Including an Observation in the Analysis	Rationale	Number Remaining
Must have complete data for whole-property water use and operating characteristics	EPA program filter – Complete data is necessary for analysis	274
WUI must be more than 10 gal/ft^2 and less than 250 gal/ft^2	Analytical filter – Values determined to be data entry errors or statistical outliers	262
Unit density must be less than 2.5 units per 1,000 square feet	Analytical filter – Values determined to be data entry errors or statistical outliers	261
Must have at least 20 units	Analytical filter – Analysis could not model behavior for buildings with fewer than 20 units, due to limited data	258

Of the filters applied to the reference data, program filters are used to include only properties that are eligible to receive a score. Analytical filters are applied to eliminate outlier data points that may or may not affect eligibility. In some cases, Analytical filters are used to determine the eligibility in Portfolio manager when a data point will have different behavior from the rest of the properties. In other cases, analytical filters exclude a small number of outliers with extreme values that skew the analysis, but do not affect eligibility requirements.

The final dataset of 258 properties are well distributed throughout the country. It is observed that many of the factors closely associated with regional variation are considered as terms in the regression analysis (such as climate or presence and size of irrigated area). As a result, weighting of the dataset is deemed to be unnecessary.

VARIABLES ANALYZED

The filtered reference data set described in the previous section was analyzed using an ordinary least squares regression, to evaluate WUI relative to operational characteristics (e.g., unit density, bedroom per unit, irrigated area and climate). This linear regression yields an equation that is used to compute WUI (also called the dependent variable) based on a series of characteristics that describe the physical characteristics (also called independent variables). This section details the variables used in the statistical analysis for multifamily housing.

Dependent Variable

The dependent variable is what the regression equation is attempting to predict. For the multifamily housing analysis, the dependent variable is WUI. This is equal to the total water use of the property divided by the gross floor area. The regression analysis identifies the key drivers of WUI, factors that explain the variation in water consumption per square foot in multifamily housing.

Independent Variables

The reference survey collected numerous property operating characteristics that were identified as potentially important for multifamily housing water use. Based on a review of the available variables in the data, in accordance with the criteria for inclusion in Portfolio Manager[1], the following variables were considered in the analysis for their potential impact on WUI in the property:

- Number of Buildings
- Building Type (Low-rise, Mid-rise or High-rise)
- Square Footage
- Number of Floors
- Number of Units
- Number of Bedrooms
- Climate variables- Evapotranspiration and Precipitation
- Presence of an Outdoor irrigated area
- Presence of a Swimming Pool
- Presence of Cooling tower
- Heating Degree Days
- Cooling Degree Days
- Presence of a Fitness Center
- Presence of Laundry and its Location (In-Unit vs. Common Area)
- Number of Laundry Hook-Ups
- Presence of Dishwasher and its location (In-Unit vs. Common Area)
- Number of Dishwasher Hook-Ups

These operational characteristics were reviewed individually as well as in combination with each other to evaluate their impact on WUI. As part of the analysis, some variables are reformatted to reflect the physical relationship of building components. For example, the total number of units on a property is evaluated as unit density. The value of unit density represents the number of residential units *per 1,000 square feet*. The number of residential units per square foot is expected to be more closely correlated with the water use per square foot than the gross number of units. In addition, based on analytical results and residual plots, variables are examined by running multiple iterations to find the combination of statistically significant operating characteristics that explain the greatest amount of variance in the dependent variable: WUI.

[1] For a complete explanation of these criteria, refer to Technical Reference for the ENERGY STAR Score, at www.energystar.gov/ENERGYSTARScore.

The final regression equation includes the following variables:

- Number of units per 1,000 square feet
- Number of bedrooms per unit
- Historic peak reference evapotranspiration value
- (Ratio of Irrigated area to floor area) times historic peak reference evapotranspiration value
- (Ratio of Irrigated area to floor area) times historic peak precipitation value

These variables are used together to compute the predicted WUI for multifamily housing properties. The predicted WUI given by the model is the mean water use intensity for a hypothetical population of buildings that share the same values for each of these variables. That is, the mean water use intensity for a building that operates just like your building.

Analysis of climate variables (Evapotranspiration and Rainfall) and irrigated area

In multifamily housing total water use is an aggregate of indoor and outdoor water use. Various studies have already established that climate of the geographical location greatly influences outdoor water use and the seasonality of total water use. To capture this impact, the irrigated area variable is utilized in conjunction with climate variables- peak reference evapotranspiration (ET) and peak rainfall (P50).

The Irrigated area term provides information about the portion of landscape area that is watered. As the dependent variable is an intensity (gal/ft^2), irrigated area is included as Ratio of Irrigated area to Floor area (referred as RIF). This value indicates the size of a property's landscape relative to the size of the building. However, Irrigated area (or RIF) alone is insufficient to describe how much water a property is likely to use as climate also plays an important role in determining outdoor irrigation. As a result, RIF is multiplied with the climate factors for ET and P50 respectively to develop two new terms- (RIF*peak ET and RIF*peak P50) that serve as strong indicators for outdoor water use of the property.

Peak values of ET and P50 are determined based on the location or zip code of the property. The peak values are average values for evapotranspiration and precipitation for a property at a given location in the month of the highest irrigation demand and based on the historic data which spans over the period of 30- years (1961-1990).

During the analysis, other weather and climate related variables such as heating degree days (HDD), cooling degree days (CDD), annual ET/rainfall (both observed and historic), net ET, and length of watering season were also considered. Peak ET and Peak P50 displayed statistically stronger relationships with WUI. Peak ET is present as an individual term in addition with RIF. Many will be familiar with ET as a term used to estimate irrigation water use; but it was evident in the analysis that it also serves as an estimate of the evaporative potential of a given climate and expresses the combined influence of temperature, solar radiation, wind speed and humidity at a given location. This indicates that ET is an extensive climate term that reflects a multitude of variables.

ET came out as a strong overall climate indicator even when there is no irrigation in the property as it captures the influence of climate on both the building systems and the behavioral and operational characteristics of the property. It is worth noting that even though other climate terms mentioned above proved to be statistically significant during analysis, none of them proved to be as significant as ET.

Testing

To verify and test the developed model for predicted WUI, EPA conducted a supplemental survey to collect additional water usage and building data. This process provides another set of buildings to examine in addition to the Fannie Mae data and evaluate how the water score responded. This process also offered EPA the ability to collect additional data to verify hypothesis about why certain buildings scored the way they did. This analysis provided a second level of confirmation that the final regression equation produces robust results that are unbiased with respect to the key operational characteristics such as unit density, bedrooms per unit, and peak ET.

REGRESSION EQUATION RESULTS

The final regression is an ordinary least squares regression across the filtered data set of 258 observations. The dependent variable is actual WUI. Each independent variable is centered relative to the mean value, presented in *Figure 2*. The final equation is presented in *Figure 3*. All variables in the regression equation are significant at the 95% confidence level or better, as shown by the significance levels (a p-level of less than 0.05 indicates 95% confidence).

The regression equation has a coefficient of determination (R^2) value of 0.2782, indicating that this equation explains 27.82% of the variance in WUI for multifamily housing properties. Because the final equation is structured with water use per square foot as the dependent variable, the explanatory power of square foot is not included in the R^2 value, thus this value appears artificially low. Re-computing the R^2 value in units of actual water use, demonstrates that the equation actually explains 67% of the variation of water use of multifamily properties.[2]

Detailed information on the ordinary least squares regression approach is available in the Technical Reference for the ENERGY STAR Score.

Figure 2 - Descriptive Statistics for Variables in Final Regression Equation

Variable	Mean	Minimum	Maximum
Actual WUI (gal/ft²)	53.097	12.494	174.208
Unit Density	1.113	0.367	2.062
Bedrooms per Unit	1.451	1.000	2.500
Peak ET	6.769	4.627	14.244
Peak ET*Rif	2.275	0.000	35.477
PeakP50*Rif	0.548	0.000	9.313

[2] The R^2 value in total water use is calculated as: 1 – (Residual Variation of Y) / (Total Variation of Y). The residual variation is sum of (Actual Water Use_i – Predicted Source Water Use_i)^2 across all observations. The Total variation of Y is the sum of (Actual Water Use_i – Mean Water Use_i)^2 across all observations.

Figure 3 - Final Regression Results

Summary				
Dependent Variable		Water Use Intensity (gal/ft²)		
Number of Observations in Analysis		258		
R^2 Value		0.2782		
Adjusted R^2 value		0.2638		
F Statistic		19.422		
Significance (p-level)		0.0000		
	Unstandardized Coefficients	Standard Error	T value	Significance (p-level)
Constant	53.097	1.685	31.504	< 0.000
C_Unit Density	42.985	6.809	6.313	< 0.000
C_Bedrooms per Unit	25.835	5.524	4.677	< 0.000
C_peakET	2.655	1.213	2.188	0.030
C_peakET*RIF	1.639	0.516	3.176	0.002
C_peakP50*RIF	-3.426	1.643	-2.085	0.038

Notes:
- *The regression is an ordinary least squares regression*
- *The prefix C_ on each variable indicates that it is centered. The centered variable is equal to difference between the actual value and the observed mean. The observed mean values are presented in Figure 2.*

WATER SCORE LOOKUP TABLE

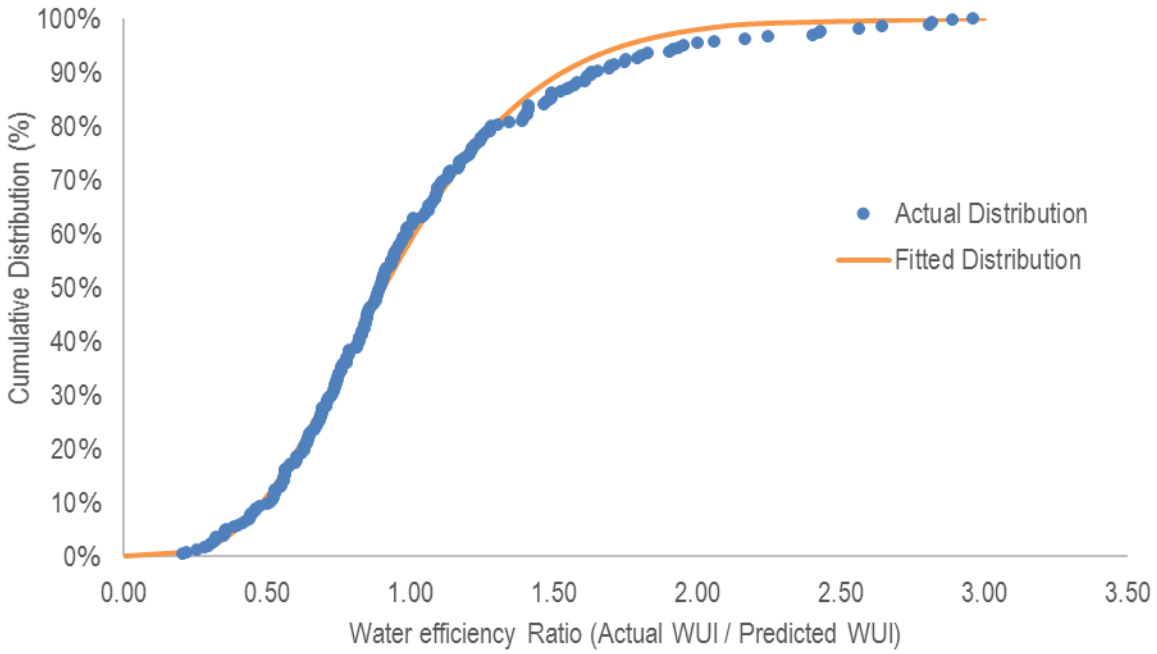
The final regression equation (presented in ***Figure 3***) yields a prediction of WUI based on a property's operating characteristics. The actual WUI of each reference data observation is divided by its predicted WUI to calculate a water use efficiency ratio:

$$Water\ Use\ Efficiency\ Ratio = \frac{Actual\ WUI}{Predicted\ WUI}$$

A lower efficiency ratio indicates that a building uses less water than predicted, and consequently is more efficient. A higher efficiency ratio indicates the opposite.

The efficiency ratios are sorted from smallest to largest and the cumulative percent of the population at each ratio is computed using the individual observations from the reference data set. ***Figure 4*** presents a plot of this cumulative distribution. A smooth curve (shown in orange) is fitted to the data using a two parameter gamma distribution. The fit is performed in order to minimize the sum of squared differences between each building's actual percent rank in the population and each building's percent rank with the gamma solution. The final fit for the gamma curve yielded a shape parameter (alpha) of 5.293 and a scale parameter (beta) of 0.183. For this fit, the sum of the squared error is 0.0828.

Figure 4- Distribution for Multifamily Housing



The final gamma shape and scale parameters are used to calculate the efficiency ratio at each percentile (1 to 100) along the curve. For example, the ratio on the gamma curve at 1% corresponds to a score of 99 that means 1% of the population has a smaller actual WUI relative to predicted WUI. Using this lookup table, water efficiency ratios for each observation can be used to find a corresponding score assigned to that particular ratio in the look up table. The complete score lookup table is presented in ***Figure 5***.

Figure 5 – EPA Water Score Lookup Table for Multifamily

Water Score	Cumulative Percent	Water Efficiency Ratio > =	Water Efficiency Ratio <	Water Score	Cumulative Percent	Water Efficiency Ratio >=	Water Efficiency Ratio <
100	0%	0.0000	0.2601	50	50%	0.9075	0.9177
99	1%	0.2601	0.3089	49	51%	0.9177	0.928
98	2%	0.3089	0.343	48	52%	0.928	0.9384
97	3%	0.343	0.3705	47	53%	0.9384	0.9488
96	4%	0.3705	0.394	46	54%	0.9488	0.9594
95	5%	0.394	0.4148	45	55%	0.9594	0.9701
94	6%	0.4148	0.4337	44	56%	0.9701	0.9809
93	7%	0.4337	0.4511	43	57%	0.9809	0.9918
92	8%	0.4511	0.4674	42	58%	0.9918	1.0028
91	9%	0.4674	0.4828	41	59%	1.0028	1.0141
90	10%	0.4828	0.4974	40	60%	1.0141	1.0254
89	11%	0.4974	0.5113	39	61%	1.0254	1.037
88	12%	0.5113	0.5247	38	62%	1.037	1.0487
87	13%	0.5247	0.5376	37	63%	1.0487	1.0606
86	14%	0.5376	0.5501	36	64%	1.0606	1.0727
85	15%	0.5501	0.5623	35	65%	1.0727	1.085
84	16%	0.5623	0.5741	34	66%	1.085	1.0976
83	17%	0.5741	0.5857	33	67%	1.0976	1.1104
82	18%	0.5857	0.597	32	68%	1.1104	1.1235
81	19%	0.597	0.6081	31	69%	1.1235	1.1369
80	20%	0.6081	0.619	30	70%	1.1369	1.1506
79	21%	0.619	0.6298	29	71%	1.1506	1.1646
78	22%	0.6298	0.6404	28	72%	1.1646	1.179
77	23%	0.6404	0.6508	27	73%	1.179	1.1938
76	24%	0.6508	0.6612	26	74%	1.1938	1.209
75	25%	0.6612	0.6714	25	75%	1.209	1.2246
74	26%	0.6714	0.6815	24	76%	1.2246	1.2407
73	27%	0.6815	0.6916	23	77%	1.2407	1.2574
72	28%	0.6916	0.7015	22	78%	1.2574	1.2747
71	29%	0.7015	0.7115	21	79%	1.2747	1.2926
70	30%	0.7115	0.7213	20	80%	1.2926	1.3113
69	31%	0.7213	0.7311	19	81%	1.3113	1.3307
68	32%	0.7311	0.7409	18	82%	1.3307	1.3511
67	33%	0.7409	0.7506	17	83%	1.3511	1.3724
66	34%	0.7506	0.7603	16	84%	1.3724	1.3948
65	35%	0.7603	0.77	15	85%	1.3948	1.4185
64	36%	0.77	0.7797	14	86%	1.4185	1.4437
63	37%	0.7797	0.7894	13	87%	1.4437	1.4706
62	38%	0.7894	0.7991	12	88%	1.4706	1.4994
61	39%	0.7991	0.8088	11	89%	1.4994	1.5306
60	40%	0.8088	0.8185	10	90%	1.5306	1.5647
59	41%	0.8185	0.8282	9	91%	1.5647	1.6022
58	42%	0.8282	0.838	8	92%	1.6022	1.6441
57	43%	0.838	0.8477	7	93%	1.6441	1.6917
56	44%	0.8477	0.8576	6	94%	1.6917	1.7471
55	45%	0.8576	0.8675	5	95%	1.7471	1.8136
54	46%	0.8675	0.8774	4	96%	1.8136	1.8975
53	47%	0.8774	0.8874	3	97%	1.8975	2.0128
52	48%	0.8874	0.8974	2	98%	2.0128	2.2032
51	49%	0.8974	0.9075	1	99%	2.2032	> 2.2032

EXAMPLE CALCULATION

There are five steps to compute a score as detailed in Technical Reference for the ENERGY STAR Score. Users can receive a water score for the property by entering building data into the Portfolio Manager tool managed by ENERGY STAR. A user needs to have information regarding twelve months of total water use with water space served (indoor only or indoor/outdoor both), physical information like size and location of the building etc.

1 User enters building data into Portfolio Manager

- 12 months of water use information for all types (annual values, entered in monthly meter entries)
- Physical building information (size, location, etc.)

Water Use data	Value
Total water use for 12 months (in gallons)	3,510,960

Property Use Details	Value
Gross floor area (ft^2)	131,450
Total Number of Units	145
Total Number of Bedrooms	163
Irrigated area (ft^2)	21,780
Peak ET (based on zip code entered in Portfolio Manager)	6.39
Peak P50 (based on zip code entered in Portfolio Manager)	3.06

2 Portfolio Manager computes the actual WUI

- Total water use is divided by gross floor area to determine actual WUI. If required, PM will convert water use in gallons to calculate WUI which is always in gal/ft^2.

$$\text{Actual WUI} = \text{Total Water Use (in gallons)/gross floor area } (ft^2) = 26.7 \text{ gal/ft}^2$$

3 Portfolio Manager computes the predicted WUI

- Using the property use details from Step 1, Portfolio Manager computes each building variable value in the regression equation.
- The centering values are subtracted to compute the centered variable for each operating parameter.
- The centered variables are multiplied by the coefficients from the regression equation to obtain a predicted WUI.

Computing Predicted WUI

Variable	Actual Building Value	Reference Centering Value	Building Centered Variable	Coefficient	Coefficient * Centered Variable
Constant	-	-	-	53.097	53.097
Unit density	1.10	1.113	-0.0099	42.985	-0.4243
Bedroom per unit	1.1	1.451	-0.3267	25.835	-8.4413
Peak ET	6.39	6.769	-0.3797	2.655	-1.0081
Peak ET*RIF	1.06	2.275	-1.2161	1.639	-1.9932
Peak P50*RIF	0.51	0.548	-0.04049	-3.426	0.1387
				Predicted WUI (gal/ft²)	41.37

4 Portfolio Manager computes the water efficiency ratio

- The ratio equals the actual WUI (Step 2) divided by predicted WUI (Step 3)
- Ratio = 26.7 / 41.37 = 0.6458

5 Portfolio Manager uses the efficiency ratio to assign a Water Score via a lookup table

- The ratio from Step 4 is used to identify the score from the lookup table.
- A ratio of 0.6458 is greater than or equal to 0.6404 but less than 0.6508.
- *The Water Score for the property is 77.*