UrbanFootprint Technical Documentation
Water Use Analysis

Overview

The UrbanFootprint Water Use module estimates the residential and commercial water use for existing buildings and new growth as represented by land use scenarios. Comparative results demonstrate the impacts of different development patterns on water use. Differences are attributable to the types of buildings built to accommodate growth, which may feature more or less outdoor landscaping, and the location of growth with respect to climate zone variations. Additionally, assumptions can be made to represent reductions in water use due to efficiency and conservation measures and applied to future scenarios to test policies or strategies with respect to conservation goals. Modeled water use, in turn, is used by the by the UrbanFootprint Emissions and Household Costs modules to calculate water-related greenhouse gas emissions and household utility costs.

Residential and commercial indoor water use are calculated on the basis of water use rates that vary by residential building type or employment category. Outdoor water use is calculated on the basis of assumptions about irrigated areas linked to building and place types, and theoretical watering needs as indicated by reference evapotranspiration values, which vary by location based on climate. The resulting estimates are appropriate for generalized estimates of water use. For more accurate assessments of local water use and the associated costs and GHG emissions, users can replace the default rates with rates that are based on localized data.

Analysis is run at the scale of the project canvas (generally parcels or census blocks), yielding a mapped spatial output layer and corresponding data table; both can be used within UrbanFootprint for mapping and data exploration, and exported. The module also reports individual and comparative scenario results via summary charts, and generates a spreadsheet summary in Excel format.

Methodology

The UrbanFootprint base canvas and painted scenarios represent buildings via building and place types. For the purposes of water use modeling, residential buildings are described in terms of their type – including small and large lot single family detached, single family attached (townhome), and multifamily units. Commercial buildings are described in terms of employees by category – including subcategories of the retail, office, public, and industrial sectors. All buildings are further described by landscaped area characteristics as defined by building types.

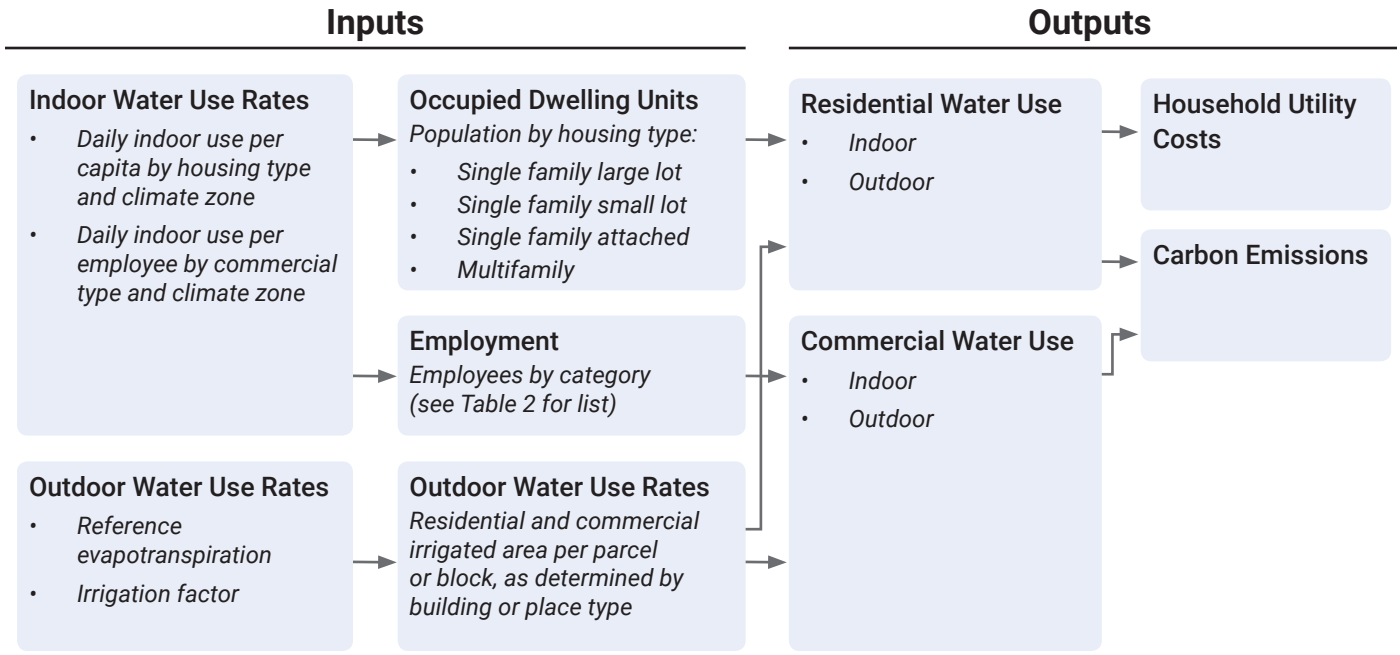
To estimate water use, UrbanFootprint applies water use rates to population counts by housing type, and commercial employees by employment category. Scenarios that feature the same numbers of population, households, and jobs can have different water use profiles as related to the types of buildings and places assumed to accommodate those scenarios. While a number of factors contribute to water consumption patterns, residential water use differs significantly by housing type, lot size, and the associated extent of irrigated landscaping.

Similarly, commercial water use is linked to the urban form of commercial development and its associated extent of irrigated, landscaped area. Commercial water use also varies according to the distribution of employment by sector. All else being equal, scenarios that include more compact development patterns and building types generally exhibit lower water use profiles than more dispersed scenarios. The process and default assumptions for calculating indoor and outdoor water use are described in the following sections.

Indoor Water Use Calculations

Residential indoor water use varies based on household size and housing type, with multifamily homes generally requiring slightly less water per capita than single family

Figure 1. Water Use Analysis Flow



homes. Residential indoor water use is calculated based on per-capita rates by housing type; commercial indoor water use is calculated based on per-employee rates by sector.

The Water Use model applies baseline per capita water use rates according to four residential categories: large detached single-family lots, small detached single-family lots, attached single-family lots, and multi-family lots. Baseline indoor water use rates are expressed in terms of gallons per capita per day (gpcd). For calculating commercial water use, per-employee factors are applied to the 17 employment categories. The factors represent the average usage of all the North American Industry Classification System (NAICS) subsectors of the corresponding commercial category.

Indoor water use is calculated separately for residential and commercial buildings. Annual residential indoor water use is calculated by applying the per-capita water use rates to the population of dwelling units of each of the four housing types: large lot detached single family units (usually lot sizes greater than 5,500 sq. ft.), small lot detached single family units (usually lot sizes under 5,500 sq. ft.), attached single family units (townhouses), and multifamily units. UrbanFootprint uses 5,500 sq. ft. as the default cutoff between small and large lots. Annual indoor water use is calculated as the product of the water use rate associated with each housing type in a given scenario, the population by housing type, an annualization factor, and a variable conservation factor.

These calculations occur at the scale of the scenario canvas (parcel or block). For example, the total residential indoor water use across all dwelling unit types present on a parcel or block is calculated using the following equation:

$$\sum_{i=0}^{N} NumberPeoplePerDwellingUnitCategory_i \times WaterPerCapitaOfDwellingUnitCategory_i \times ResidentialConservationFactor \times AnnualizationFactor$$

for *i* in dwelling types categories

The process for estimating commercial water use is similar. Commercial water use is the product of the number of employees per employment sector, the associated water use rate for the employment category, the annualization factor, and a conservation factor as shown below:

$$\sum_{i=0}^{N} NumberEmployeesPerEmploymentCategory_i \times WaterPerEmployeePerEmploymentCategory_i \times CommercialConservationFactor \times AnnualizationFactor$$

for *i* in employment categories

Outdoor Water Use Calculations

Outdoor water use calculations are based on assumptions about the irrigated area associated with development, and climate-based watering needs. The irrigated land area of each canvas geometry (parcel or block) is multiplied by the location-specific irrigation demands described by the relevant region's reference evapotranspiration. Reference evapotranspiration (ET_0), is a measure of turf grass water loss to the atmosphere and

depends on climate. Expressed in inches of water per year[1], these values are used to determine outdoor water demand.

Residential and commercial outdoor water uses are calculated separately. Residential outdoor use of a given location is the product of the residential irrigated acreage of each geometry, the location's annual reference evapotranspiration, a conversion factor to convert evapotranspiration to gallons per year, and the residential irrigation factor, which can be adjusted by the user. The annual residential outdoor water use for a given geometry is calculated as follows:

$$ResidentialIrrigatedAcresPerGeometry \times AnnualEvapotranspiration \times InchesToGallonsConversion \times IrrigationFactor$$

Similarly, the commercial outdoor water use calculations are based on commercial irrigated acres:

$$CommercialIrrigatedAcresPerGeometry \times AnnualEvapotranspiration \times InchesToGallonsConversion \times IrrigationFactor$$

Input Parameters

UrbanFootprint comes loaded with a set of default parameters to estimate water use, as described in this section. The default inputs can be replaced with localized baseline inputs, if available, via the Analysis Assumptions editor. Different water use inputs can be set for each scenario, and can be used to test the impact of efficiency and conservation measures into the future. By changing the inputs for future-year scenarios, you can test the impact of water efficiency measures in the context of new growth. You can also create scenarios that replicate the base canvas and change the water use inputs to test the impacts of efficiency measures for existing buildings.

Indoor Water Use Inputs

Residential indoor water use may not vary significantly by climate, given the same building/fixture standards. For this reason, UrbanFootprint uses a single default set of residential indoor water use rates for all projects across the US. These per-capita rates can be changed given local data or policy targets for water use efficiency or conservation. Table 1 shows the default residential rates used.

Commercial indoor water use (inclusive of institutional and industrial uses in UrbanFootprint) is estimated on a per-employee basis. This approach is based on existing research and data that estimates commercial, institutional, and industrial water use by employment sector[2], in units of gallons per employee per day. These estimates

1 The factor for converting between inches of precipitation and gallons of water applied is 0.62 gallons/inch-sf, as reported by the United States Geological Survey (USGS): https://water.usgs.gov/edu/activity-howmuchrain.html

2 Factors based on studies published by the Pacific Institute and others, which have yielded estimates for water use classified by standard industrial classification (SIC) code (Dziegielewski et al. 2000 as published by Pacific Institute, 2003). Factors are expressed in gallons per employee per day, assuming a 365-day year. In most cases, the factors are converted from data expressed in gallons per employee day for other year lengths (for example, a 225-day year that accounts for work days only).

were derived from a combination of modeled and survey data, including general water uses (such as building, cooling, and restroom use) and water uses that relate to specific employment sectors (such as food service and medical care). Table 2 shows the default commercial rates used.

Table 1: Default Residential Indoor Water Use Parameters

Parameter	Default Value
Detached Single-Family Use Per Capita - Large Lot	55 gallons/person/day
Detached Single-Family Use Per Capita - Small Lot	55 gallons/person/day
Attached Single-Family Use Per Capita	45 gallons/person/day
Multi-Family Use Per Capita	45 gallons/person/day

Table 2: Default Commercial Indoor Water Use Parameters

Parameter	Default Value
Retail Services Use Per Employee	29 gallons/person/day
Restaurant Services Use Per Employee	161 gallons/person/day
Accommodation Services Use Per Employee	161 gallons/person/day
Arts Entertainment Use Per Employee	161 gallons/person/day
Other Services Per Use Employee	29 gallons/person/day
Office Employment Use Per Employee	29 gallons/person/day
Education Employment Use Per Employee	121 gallons/person/day
Public Administration Use Per Employee	29 gallons/person/day
Medical Services Use Per Employee	121 gallons/person/day
Wholesale Use Per Employee	62 gallons/person/day
Transport Warehousing Use Per Employee	62 gallons/person/day
Construction Per Use Employee	25 gallons/person/day
Utilities Use Per Employee	25 gallons/person/day
Manufacturing Use Per Employee	284 gallons/person/day
Extraction Use Per Employee	19 gallons/person/day
Military Use Per Employee	62 gallons/person/day
Agriculture Use Per Employee	0 gallons/person/day

Adjustment Factors

The water use module also includes a set of factors that allow you to calibrate water use to given data, or test conservation targets, by scaling aggregate results for residential and commercial indoor water use. This ability is useful because it allows you to scale the outputs while assuming the same relative differences in water use among residential building types and commercial employment types.

Outdoor Water Use Inputs

Outdoor water use is calculated based on irrigated area and reference evapotranspiration. Irrigated area is determined by the building and place types used in the base canvas and for new scenarios, while reference evapotranspiration varies according to climate zone.

Irrigated Area

Irrigated area at the parcel or block scale is imputed for the base canvas via the building and place types used to represent existing development. Likewise, irrigated area for future scenarios is calculated based on the irrigated area characteristics defined for building and place types.

Maximum irrigated area limits are applied to these values to ensure there are no major outliers. The limits are as follows:

- Residential irrigated area is capped at 5000 ft2 per household
- Residential and commercial irrigated areas a capped at half of the total parcel or block area
- Residential and commercial area is capped at the irrigated ft2 per acre rate for the built form type

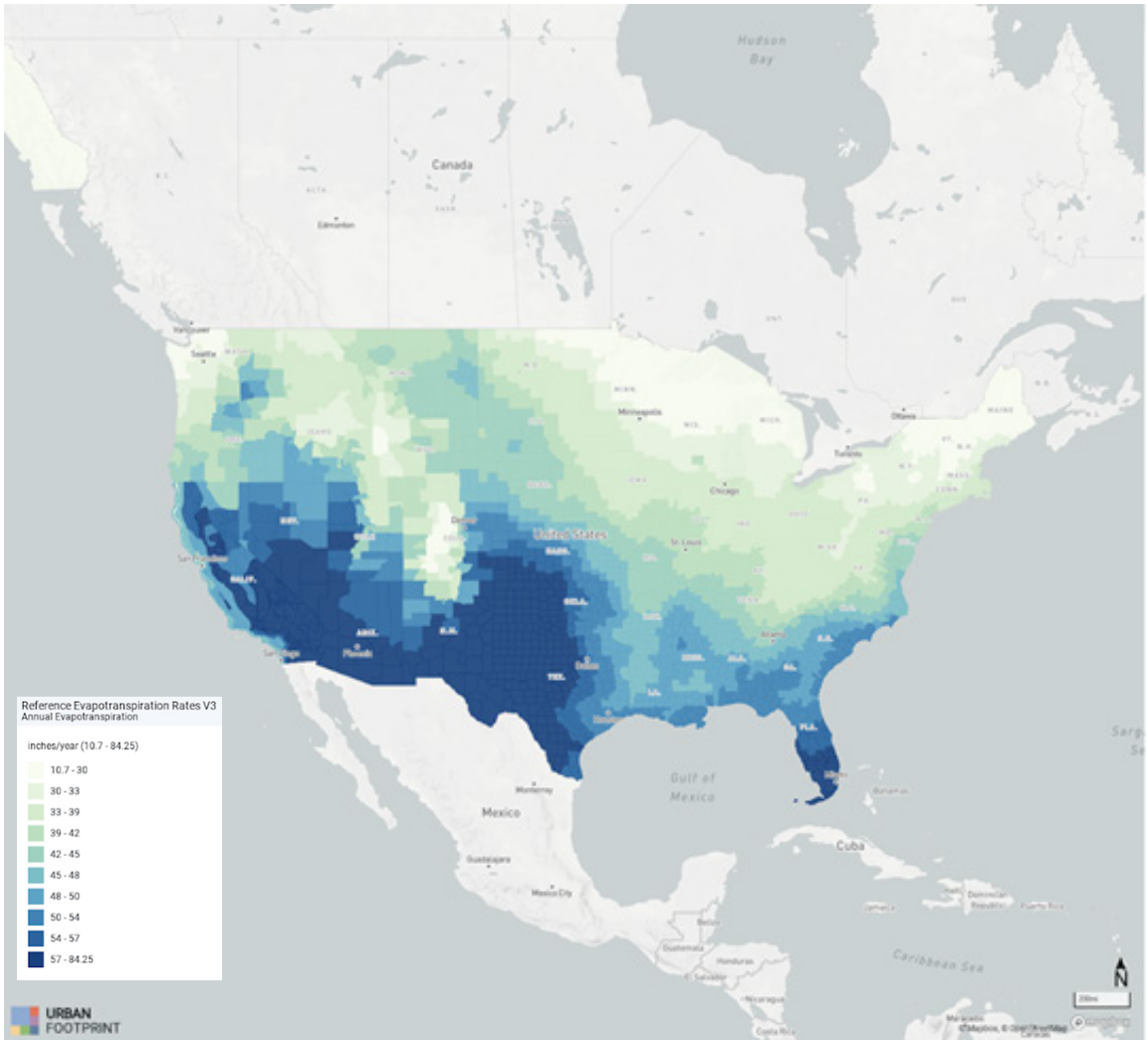
The residential and commercial irrigation factor parameters can be used to scale these irrigated area assumptions to empirical data for a given project area, if available.

Reference Evapotranspiration

Reference evapotranspiration is defined as "the rate of evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m (4.72 in), a fixed surface resistance of 70 sec m-1 (70 sec 3.2ft-1) and an albedo of 0.23, closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, well-watered, and completely shading the ground"[3]. This value was used to estimate the amount of water required for each irrigated land area. Default evapotranspiration (ET_0) rates are derived from the TerraClimate dataset generated by the Climatology Lab at the University of Idaho[4]. The original data separates ET_0 rates by month at a grid scale of roughly 4 km2. Rates are summed to annual totals, converted to inches per year, and averaged across US counties. Default annual ET_0 rates are shown in Figure 2.

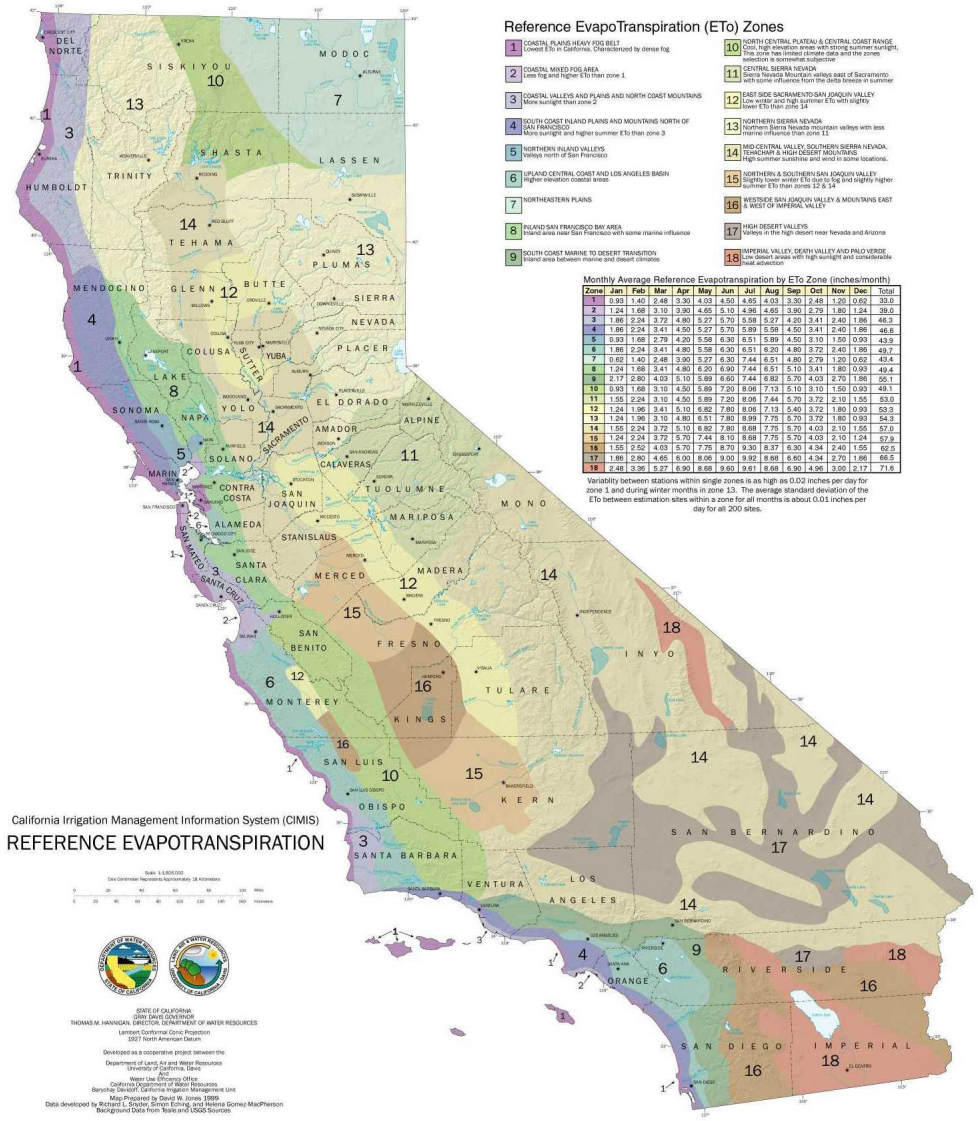
3 https://edis.ifas.ufl.edu/ae256
4 http://www.climatologylab.org/terraclimate.html

Figure 2. Default National Reference Evapotranspiration



For projects in California, default ET_0 rates are sourced from the California Department of Water Resources[5], which provides monthly and yearly averages for 18 state zones, as shown in Figure 3.

Figure 3. California Reference Evapotranspiration Zones



5 https://cimis.water.ca.gov/SpatialData.aspx?t=1

Output Metrics

The Water Use module generates a mapped spatial output layer and corresponding data table; both can be used within UrbanFootprint for mapping and data exploration, and exported. The module also reports individual and comparative scenario results via summary charts, and generates a spreadsheet summary in Excel format. The attributes of the spatial output/data table are summarized in Table 2.

Table 2: Water Use Module Outputs

Attribute(s)	Description
Total Water Use	Total annual residential and commercial indoor and outdoor water use
Residential Water Use	Annual residential indoor and outdoor water use
Residential Water Use per Capita	Annual residential indoor and outdoor water use, per capita
Residential Water Use per Household	Annual residential indoor and outdoor water use, per household
Commercial Water Use	Total commercial indoor and outdoor water use
Residential Indoor Water Use	Annual residential indoor water use
Commercial Indoor Water Use	Annual commercial indoor water use
Residential Outdoor Water Use	Annual residential outdoor water use
Commercial Outdoor Water Use	Annual commercial outdoor water use