

UrbanFootprint Technical Documentation

Energy Use Analysis

Overview

The UrbanFootprint Energy Use module estimates residential and commercial electricity and natural gas use for existing buildings and new growth as represented by land use scenarios. Comparative scenario results demonstrate the impacts of different development patterns on building energy use. Differences are attributable to the types of buildings built to accommodate growth and the location of that growth. Additionally, assumptions about improvements in energy efficiency can be applied to future scenarios to test policies or strategies with respect to energy or climate goals. Modeled energy use is used, in turn, to calculate greenhouse gas (GHG) emissions and household utility costs.

Electricity and natural gas use are calculated on the basis of energy use rates: per dwelling unit by residential type, and per square foot for commercial floor area. The module comes loaded with a default set of baseline rates for electricity and natural gas use that are derived from U.S. Energy Information Administration (EIA) survey data on energy consumption. These baseline rates vary by building type and climate zone, and are appropriate for generalized estimates of energy use. For more accurate assessments of local energy use, users can replace the default inputs with ones based on local data, given its availability. Inputs can also be set for future-year scenarios to estimate the effects of energy efficiency measures.

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

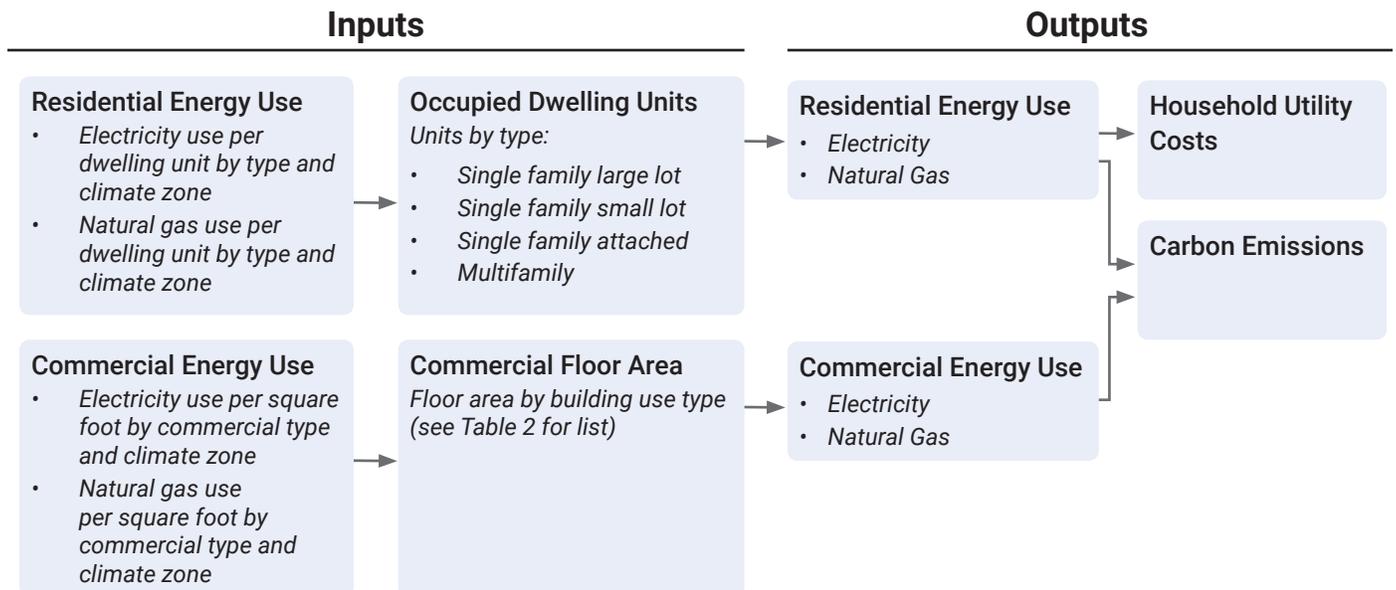
The UrbanFootprint base canvas and painted scenarios represent buildings via building and place types. Residential buildings are described in terms of their type – including small and large lot single family detached, single family attached (townhome), and multifamily units – and their floor area. Commercial buildings are described in terms of floor area by use as linked to employment categories – including subcategories of the retail, office, public, and industrial sectors. (Refer to the Base Canvas documentation for further details about how building area is estimated, and described by canvas attributes.)

To estimate energy use, UrbanFootprint applies energy use rates to residential unit counts by type, and commercial floor area by type. Scenarios that feature the same numbers of households and jobs can have different energy use profiles as related to the types of buildings assumed to accommodate those scenarios. While a number of factors contribute to energy consumption patterns, residential energy use differs significantly by home size: more spacious and detached units require more energy. Similarly, commercial energy use is linked to building size, with the amount of floor area per employee varying according to built form assumptions. Thus, scenarios that include more compact development patterns and building types generally exhibit lower energy use profiles than more dispersed scenarios. The process and default assumptions for calculating electricity and natural gas use are described in the following sections.

Energy Use Calculations

To estimate residential or commercial use, the module applies electricity and natural gas use rates, which are measured in kilowatt-hours and therms, respectively, per year per dwelling unit for residential buildings and per square foot of floor area for commercial buildings. Energy use rates differ by dwelling unit type, commercial building category, and climate zone. The Input Parameters describes how default electricity and natural gas use rates are derived from the EIA national building survey datasets.

Figure 1. Energy Use Analysis Flow



For residential energy use, the module accounts for four residential building types: large lot detached single-family dwellings (usually lot sizes over 5,500 sq. ft.), small lot detached single-family dwellings (usually lot sizes under 5,500 sq. ft.), attached single-family dwellings (townhomes), and multifamily dwellings. UrbanFootprint uses 5,500 sq. ft. as the default cutoff between small and large lots. Energy use is calculated by multiplying the number of dwelling units of a given type by the corresponding energy use rate, multiplied by the project average occupancy rate to account for occupied units only. (The occupancy rate refers to the percentage of dwelling units that are occupied by households.) For example, electricity and natural gas use in multifamily dwelling units is given by the following equations.

$$\text{ElectricityUse (kwh)} = \text{Number of Multifamily Dwelling Units} * \text{OccupancyRate} * \text{ElectricityUseRate (kwh/DU)}$$

$$\text{NaturalGasUse (therm)} = \text{Number of Multifamily Dwelling Units} * \text{OccupancyRate} * \text{NaturalGasUseRate (therm/DU)}$$

The electricity use rate is specific to multi-family dwelling units and may depend on the climate zone in which the dwelling units are located. The occupancy rate refers to the percentage of dwelling units that are occupied by households. The logic for estimating commercial energy use is similar. The module includes commercial building use type categories that are determined by their principal employment/activity type (see Table 2 for a list). Energy use is calculated by multiplying building floor area (in square feet) of a given type by the corresponding energy use rate. For example, the electricity use of restaurant building area is given by the following equation:

$$\text{ElectricityUse (kwh)} = \text{RestaurantBuildingArea (sqft)} * \text{ElectricityUseRate (kwh/sqft)}$$

Total annual residential and commercial electricity use are, in turn, calculated by summing up the results for all dwelling unit types, and all commercial building categories. The Output Metrics section summarizes the outputs produced by the module.

Input Parameters

UrbanFootprint comes loaded with a set of default electricity and natural gas use rates, which are derived from the EIA Residential Energy Consumption Survey (RECS)¹ and Commercial Building Energy Consumption Survey (CBECS) datasets². This section describes the development of the EIA-based assumptions.

The default inputs can be replaced with localized baseline inputs, if available, via the Analysis Assumptions editor. Different energy use inputs can be set for each scenario, and can be used to test the impact of energy efficiency measures into the future. By changing the inputs for future-year scenarios, you can test the impact of more efficient buildings in the context of new growth. You can also create scenarios that replicate the base canvas

1 <https://www.eia.gov/consumption/residential/index.php>

2 <https://www.eia.gov/consumption/commercial/>

and change the energy use inputs to test the impacts of efficiency measures for existing buildings.

Default Residential Energy Use Rates

The RECS study provides energy use data linked to residential building characteristics and climate zone based on a sample of residential buildings across the nation. Several steps were taken to transform the dataset for use in the energy use module.

First, the residential dwelling unit types in RECS, which correspond with census housing designations, were categorized to correspond with UrbanFootprint’s housing type categories. Apartments with 2 to 4 units and 5 or more units were grouped together as multifamily units. Mobile homes were grouped with detached single-family homes. Detached single-family homes were further divided into small lots and large lots, with an assumed threshold of 2,000 sq. ft. in unit size to differentiate between the two. See Table 1 for the crosswalk between UF’s and RECS’s residential categories.

Table 1: UrbanFootprint Residential Category to RECS Category Crosswalk

RECS Residential Dwelling Unit Type	UF Residential Dwelling Unit Type
Mobile Home	Detached Single Family Small Lot
Detached Single Family under 2,000 sq. ft.	Detached Single Family Small Lot
Detached Single Family over 2,000 sq. ft.	Detached Single Family Large Lot
Attached Single Family	Attached Single Family
Apartment in building with 2–4 units	Multifamily
Apartment in building with 5+ units	

Second, weighted averages for electricity and natural gas use per dwelling unit were calculated according to dwelling unit type and climate zone. RECS and CBECS use climate zones that are defined by the Building America program and based on several factors, including heating degree-days, average temperatures, and precipitation (Figure 2).

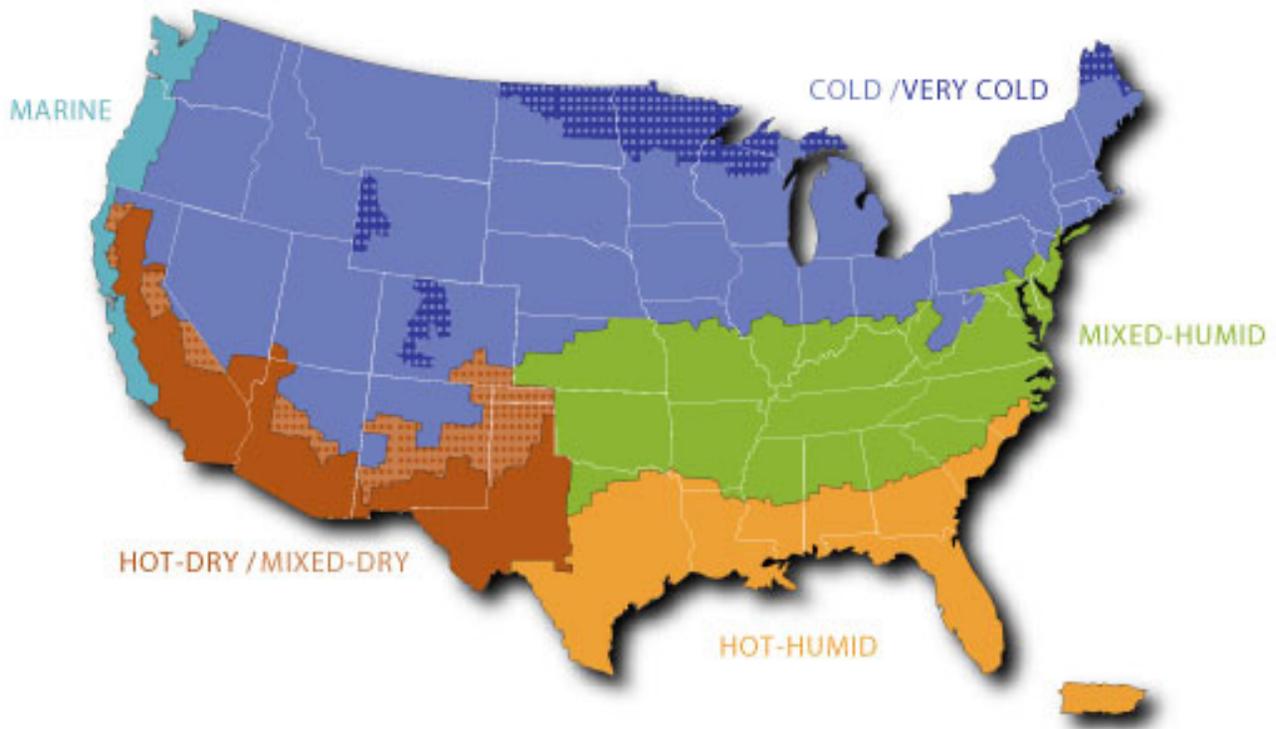
RECS data includes total building area, climate zone, energy consumption, and a sample weight for each collected sample. A sample weight of 1000 means that the sample building data is representative of itself and 999 other buildings across the nation. The sample weights are updated to incorporate dwelling unit size. For example, the weighted average electricity per dwelling unit for a multi-family dwelling unit in the cold climate zone is calculated as follows:

$$\overline{ElectricityUseRate}_{multifamily, cold} (kwh/du) = \frac{\sum_i (ElectricityUse_{du_i} (kwh) * Weight_{du_i} * TotalSqft_{du_i} (sqft))}{\sum_i (Weight_{du_i} * TotalSqft_{du_i} (sqft))}$$

where du_i represents all multi-family dwelling units that are in the cold climate zone.

The resulting energy use rates for residential buildings are expressed in terms of kilowatt-hours (kWh) of electricity and therms of natural gas per unit.

Figure 2. Climate zones defined by the Building America program³



Default Commercial Energy Use Rates

Similarly, CBECS collects energy consumption data for a sample of commercial buildings across the nation. To comply with the building categories used in UF’s module, building principal activities were categorized as shown in Table 2.

Table 2: UrbanFootprint Employment Category to CBECS Crosswalk Table

CBECS Commercial Building Principal Activities	UF Commercial Building Use Type Category
Office	Office services
Laboratory	Other services
Religious worship	
Service	
Other	Transport warehousing
Non-refrigerated warehouse	
Refrigerated warehouse	Wholesale
Food sales	
Public order and safety	Public admin

³ <https://energy.gov/eere/buildings/climate-zones>

CBECS Commercial Building Principal Activities	UF Commercial Building Use Type Category
Outpatient health care	Medical services
Inpatient health care	
Nursing	
Public assembly	Arts and entertainment
Education	Education
Food service	Restaurant
Lodging	Accommodation
Strip shopping mall	Retail services
Enclosed mall	
Retail other than mall	
Vacant	N/A

CBECS data includes building area, climate zone, energy consumption, and a sample weight for each collected sample. The electricity and natural gas use rates (or energy use intensities) for each sampled building are calculated by dividing electricity and natural gas use by building area. Energy use rates are then calculated for each UrbanFootprint commercial building use type and climate zone as the weighted average of representative buildings, as illustrated by the equation below.

$$\overline{ElectricityUseRate}_{multifamily, cold} (kwh/du) = \frac{\sum_i (ElectricityUse_{du_i} (kwh) * Weight_{du_i} * TotalSqft_{du_i} (sqft))}{\sum_i (Weight_{du_i} * TotalSqft_{du_i} (sqft))}$$

The resulting energy use rates for commercial buildings are expressed as energy use intensities: kilowatt-hours (kWh) of electricity and therms of natural gas per square foot.

Energy use rates are calculated for all building types and climate zones. Currently, default residential energy use rates are based on RECS 2009 data⁴, while commercial energy use rates are based on CBECS 2012 data⁵.

Adjustment Factors

The energy use module also includes a set of adjustment factors that allow you to calibrate energy use to given data by scaling aggregate results for residential electricity use, residential natural gas use, commercial electricity use, and commercial gas use. This ability is useful because it allows you to scale the outputs while assuming the same relative differences in energy use among residential and commercial building types.

4 <https://www.eia.gov/consumption/residential/data/2009/>. The 2009 dataset was used in place of the most recent version of the RECS survey (2015) because the most recent version does not include lot size for the sampled data.
5 <https://www.eia.gov/consumption/commercial/data/2012/>

Output Metrics

The Energy 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 3.

Table 3: Energy Use Module Outputs

Attribute(s)	Description
Total Energy Use	Total annual energy use, including residential and commercial building electricity and natural gas use
Total Electricity Use	Total annual residential and commercial building electricity use
Total Natural Gas Use	Total annual residential and commercial building natural gas use
Residential Energy Use	Total annual residential building electricity and natural gas use
Residential Electricity Use	Total annual residential building electricity use
Residential Natural Gas Use	Total annual residential building natural gas use
Per Household Residential Energy Use	Average annual residential building energy use per household
Per Capita Residential Energy Use	Average annual residential building energy use per capita
Commercial Energy Use	Total annual commercial building electricity and natural gas use
Commercial Electricity Use	Total annual commercial building electricity use
Commercial Natural Gas Use	Total annual commercial building natural gas use