# Web-Based Energy Modeling for California

***Joe DiStefano & Erika Lew, Calthorpe Analytics***

**ABSTRACT**

Measuring state, regional, or local impacts of energy technology and building efficiency measures is a technically challenging undertaking requiring substantial investment in base data development, analytical capability, and domain expertise. The California Energy Commission (CEC) is supporting advancements to the UrbanFootprint software platform to make this kind of analysis possible for land use planners, energy analysts, and other key stakeholders. UrbanFootprint is a web-based software platform developed to facilitate land use, policy, and resource planning across multiple sectors. Its streamlined functions estimate the fiscal, public health, transportation, water, energy, and emissions impacts of scenarios. Scenarios can be used to model variations in land uses as well as changes in policy or technology applied over current or future conditions. A primary goal is to give users the ability to realistically assess the energy savings potential of existing building stock. This paper details the methodological development, pilot testing, and features of building energy modeling and reporting within UrbanFootprint.

UrbanFootprint is undergoing these energy modeling enhancements to connect the platform to state and local building programs, link to new and emerging datasets, and integrate specific energy policy levers. Advancements include the development of statewide, climate-zone specific residential and commercial building energy use baselines (modeled and verified EUIs for buildings of different types and construction eras), peer-reviewed policy sets to test the application of energy efficiency and generation policies, and user-friendly reporting of energy use. New methods and capabilities will allow local, regional, and state users to test policies, bringing energy-aware land use and resource planning to policy-making in ways never before possible. Modeled results can inform high-level policy development and local policy implementation to meet specific energy or climate action targets.

## Introduction

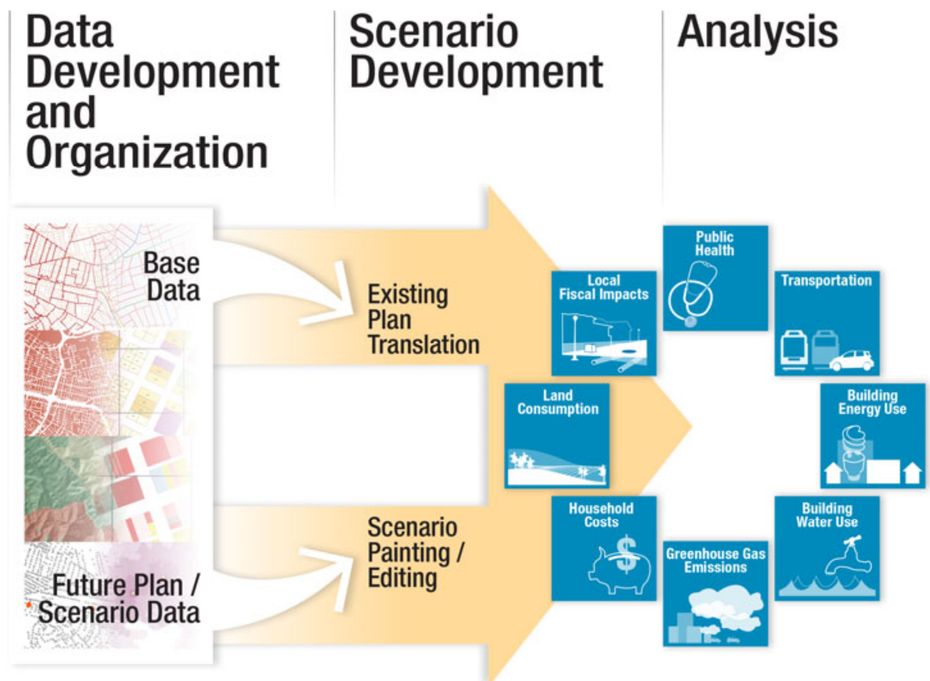
Measuring state, regional, or local impacts of energy technology and building efficiency measures is a technically demanding undertaking requiring substantial investment in base data development, analytical capability, and domain expertise. This paper describes a current effort aimed at making such analysis possible for land use planners, energy analysts, and other key stakeholders in California. State mandates to improve energy efficiency, including the Existing Buildings Energy Efficiency Action Plan (CEC 2015) as required by AB 758[1], prioritize the need for better tools to assess the energy savings potential of existing building stock. With support from the California Energy Commission (CEC), project partners Calthorpe Analytics and energy consultants TRC and Noresco are developing normalized vintage and climate-sensitive data and methods for building energy analysis, pilot testing the methods in Sonoma County (where

[1] Assembly Bill (AB) 758, approved in 2009, required the CEC to develop "a comprehensive program to achieve greater energy savings in the state's existing residential and nonresidential building stock" and periodically update the program. The bill also includes requirements for energy efficiency program development and actions by the California Public Utilities Commission, electrical and gas corporations, and local publicly owned electric utilities.

Calthorpe Analytics is modeling a series of land use and conservation scenarios using the UrbanFootprint platform), and ultimately integrating key data and functions into a web-based analysis tool that connects to Calthorpe Analytics' UrbanFootprint scenario planning platform.

UrbanFootprint is a web-based software platform developed to facilitate land use, policy, and resource planning and engagement across multiple sectors. Its streamlined functions estimate the fiscal, public health, transportation, water, energy, and emissions impacts of scenarios. Scenarios can be used to model variations in land uses as well as changes in policy or technology applied over current or future conditions. Figure 1 illustrates the data, scenario development, and modeling flow of the UrbanFootprint system.

Figure 1. UrbanFootprint Model Flow




A building energy analysis tool built upon the UrbanFootprint system will operationalize data and methods into a system for testing and reporting on the application of building efficiency measures across a full range of residential and commercial building types in California. This project and the energy analysis tool is connecting robust land use and built environment data to defensible peer-reviewed methods to inform high-level policy development and local policy implementation to support state, regional, and local energy and climate action planning. Major project steps, which will be described in the sections that follow, include:

- *Developing a building classification schema and building prototypes*. A set of residential and commercial building floorspace prototypes represent buildings and uses common across California.
- *Building a base data canvas*. A parcel-based existing conditions database serves as the foundation for baseline and policy analysis. This database includes parcel-level details about buildings, higher-level locational characteristics such as climate zone, and other variables used to describe what is on the ground today.

- *Establishing baseline Energy Use Intensities (EUIs)*. Building energy simulation models were utilized to establish baseline energy consumption rates sensitive to climate zone and vintage for a range of residential and commercial building prototypes.
- *Developing building efficiency packages*. A set of predefined packages of building efficiency measures were developed to reflect defensible and relevant combinations of measures for each of the building use categories.
- *Establishing policy-based EUIs*. Building energy simulation models were once again utilized to measure impact of policy packages and rates of implementation on energy consumption rates.
- *Developing modeling methods*. Energy modeling methods were developed and operationalized to measure sensitivity to building efficiency policies and pace of implementation. Methods will be tested and validated through pilot testing in Sonoma County, California.
- *Building a web-based building energy analysis tool*. A web-based modeling and reporting tool is being developed to bring the data, methods, and outcome metrics together into a user-friendly interface.

Note that this paper is focused on providing an overview of the process and covering enough detail for a reader to understand the intent of the undertaking, and the major steps involved in developing a standardized approach to building energy modeling and creating a web-based tool to operationalize the methods and data. It does not describe in great detail the critical processes of building prototype development and simulation modeling, data development, and model calibration, which are each worthy of their own reports; space limitations and a need to describe the overall effort limit the depth to which we could address the more technical components of the project.

## Base Canvas and California Building Energy Prototypes

Scenario development and analysis begins with data describing existing conditions, in terms of built form (buildings, as well as parks, roads, and all other components of urbanized areas), demographics, and the natural environment. The UrbanFootprint base “canvas” consists of parcel-level geographic database tables populated with data either imported directly or derived from a number of sources. These empirical and modeled data, loaded into the canvas as attributes, are the foundation for baseline and future-year modeling, mapping, and comprehensive analysis of environmental, social, and fiscal metrics.

Primary UrbanFootprint base canvas attributes include population, households, housing units by type, and jobs by employment category; parcel area; and building type as interpreted from local land use codes. These attributes alone are not enough to support detailed energy analysis. Additional information is needed, including building floor area, climate zone, and vintage (year of construction), as well as further indication of the uses that occur within buildings.

The UrbanFootprint model classifies buildings according to a range of building types for the primary purpose of land use planning. Buildings are classified at the parcel scale through a process that incorporates local land use codes, parcel data (i.e. county assessor data), and employment data. While the basic set of approximately 50 UrbanFootprint building types represents a full spectrum of buildings in terms of their built form and land use characteristics, they are not clearly delineated in terms of their energy use profiles. Buildings can encompass a range of uses among or within them – for example, mixed-use buildings can contain retail, restaurant, and office areas, all of which have different energy use intensities.

To enable energy analysis that is sensitive to building uses as well as form, an early project task was to identify a core schema of residential and non-residential *building energy prototypes* to represent the range of building or space types among existing buildings. This schema and the process used to classify existing buildings in terms of the prototypes are described in the following sections.

## California Building Energy Prototype Schema

The project team worked to develop the schema of energy-relevant building use prototypes (hereafter referred to as the California building energy prototypes) and vintage categories by which to represent the spectrum of residential and non-residential buildings common in California. Existing prototypes parameterized in the California Building Energy Code Compliance for Residential Buildings (CBECC-Res) and Commercial/Non-Residential Buildings (CBECC-Com) simulation models, as well as the DOE EnergyPlus simulation model, were used or modified, and new prototypes were created, to represent types as represented in the UrbanFootprint model. The California building energy prototypes are listed in Table 1.

Table 1. California building energy Residential and Non-Residential Prototypes

| **California Residential Building Energy Prototypes** | **California Non-Residential Building Energy Prototypes** |
|---|---|
| • Small single family detached, one story (~1,600 sq ft)<br>• Large single family detached, one story (~2,100 sq ft)<br>• Single family detached, two story (~2,700 sq ft)<br>• Townhome (~1,350 sq ft)<br>• Multifamily low-rise, garden style (8 units at ~870 sq ft each) | • High-rise multifamily residential[2]<br>• Restaurant, quick service<br>• Restaurant, full service<br>• Retail, strip mall<br>• Retail, standalone<br>• Retail, large<br>• Hotel<br>• Office, small<br>• Office, medium<br>• Office, large<br>• School, primary<br>• School, secondary<br>• Warehouse<br>• Retail, ground floor of vertical mixed-use<br>• Retail and food, standalone<br>• Medical office<br>• Refrigerated warehouse<br>• Convenience store and gas station<br>• Hospital<br>• Parking structure |

Building energy specialists at TRC and Noresco performed building simulations and undertook research of existing data[3] to refine and parameterize the schema of prototypes,

[2] High-rise multifamily residential is modeled using the non-residential simulation model.

identifying relevant variations in building characteristics by vintage and climate zone. Building vintage categories were identified with respect to California Title 24[4] code eras and technologies, with the aim of providing enough detail to express relevant vintage variations while minimizing the number of categories. The prototype vintage categories, the building construction years to which they are applied, and the Title 24 vintages to which they correspond are summarized in Table 2.

Table 2. Building Vintage Categories

| California Building Energy Prototype Vintage Category | Construction Years Included | Title 24 Vintage |
|---|---|---|
| **Residential Buildings** | | |
| Old | 1991 and earlier | Before 1978<br>1978 – 1983<br>1984 – 1991 |
| Average | 1992-2005 | 1992 – 1998<br>1999 – 2000<br>2001 – 2003<br>2004 – 2005 |
| Newer | 2006 – 2014 | 2006 – 2009<br>2010 – 2014 |
| New | 2015 | 2015 code |
| **Commercial Buildings** | | |
| Precode (50%) and Retrofit (50%) | Before 1980 | Precode |
| 1980s | 1980-1989 | 1982 |
| 1990s | 1990-1999 | 1995 |
| 2000s | 2000-2009 | 2006 |
| 2010s (New) | 2010- | 2013 |

## California Building Energy Prototype to UrbanFootprint Building Type Crosswalk

Detailed building and land use information are needed to represent existing buildings in terms of the California building energy prototypes. The UrbanFootprint base canvas incorporates this necessary information, such that the classification of existing buildings according to the energy prototypes can be performed through a "translation" process. The California building energy prototypes are linked to the UrbanFootprint building types according to rates specified in

[3] Residential sources: California Statewide Residential Appliance Saturation Study (RASS) on-line database (CEC 2010); Final Report WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012) (CPUC 2014);Evaluation, Measurement And Verification Of The 2002 California Statewide Energy Star® New Homes Program. Non-residential sources: California Commercial End-Use Survey (CEUS) and Energy Star PortfolioManager.

[4] Title 24 of the California Code of Regulations, known as the California Building Standards Code, are the means by which the state sets standards for building energy efficiency. Since the initial enactment of Title 24 in 1978, successive updates have been made to specify new construction standards and technologies. The characteristics of the building prototypes for different construction years are connected to the Title 24 regulations of different periods.

a “crosswalk” table. For example, the “Large Single Family Detached, One Story” and “Single Family Detached, Two Story” California building energy prototypes are mapped in varying proportions to the range of UrbanFootprint building types for single family detached units, from “Very Small Lot 3000” to “Rural Ranchette.”

Most building types are not mapped on a 1:1 basis because the UrbanFootprint building types, which are characterized by their built form, are not indicative of specific use – for example, the average UrbanFootprint Mid-Rise Mixed Use building is comprised of residential and commercial areas, with residential occurring as Multifamily and commercial being divided among Retail Groundfloor, Small Restaurant, and Office areas. The crosswalk, then, specifies how floor area by UrbanFootprint building type is distributed among the California building energy prototypes. An illustrative snapshot of the crosswalk developed for the Sonoma County pilot is shown in Table 3. The percentage allocations to the California building energy prototypes were calibrated as part of the base canvas development process, described in the next section.

Table 3. Sample view of UrbanFootprint Building type to California Building Energy Prototype crosswalk

| CEC Prototype / UrbanFootprint Building Type | Retail Standalone | Retail Strip Mall | Retail Groundfloor | Retail Large | Retail Grocery | Small Restaurant | Large Restaurant | Retail Gas Station | Small Office | Medium Office | Large Office | Medical Office | Hospital | Small School | Large School |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skyscraper Residential | 0% | 0% | 95% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Urban High-Rise Residential | 0% | 0% | 95% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Urban Mid-Rise Residential | 0% | 0% | 95% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Urban Low-Rise Residential | 0% | 0% | 95% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Urban Podium Multi-Family | 0% | 0% | 95% | 0% | 0% | 5% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Suburban Podium Multi-Family | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Suburban Multifamily Apt/Condo | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Garden Apartment | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Urban Townhome/Live-Work | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% |
| Suburban Townhome | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Very Small Lot 3000 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Small Lot 4000 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Medium Lot 5500 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Large Lot 7500 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Estate Lot | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Rural Residential | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Rural Ranchette | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mobile Home Park | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Skyscraper Mixed Use | 0% | 0% | 75% | 0% | 5% | 20% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% |
| High-Rise Mixed Use | 0% | 0% | 75% | 0% | 5% | 20% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% |
| Mid-Rise Mixed Use | 0% | 0% | 75% | 0% | 5% | 20% | 0% | 0% | 0% | 20% | 80% | 0% | 0% | 0% | 0% |
| Low-Rise Mixed Use | 0% | 0% | 75% | 0% | 5% | 20% | 0% | 0% | 20% | 80% | 0% | 0% | 0% | 0% | 0% |
| Main Street Mixed Use High (3-5 Floors) | 0% | 5% | 60% | 0% | 10% | 25% | 0% | 0% | 20% | 80% | 0% | 0% | 0% | 0% | 0% |
| Main Street Mixed Use Low (1-2 Floors) | 0% | 15% | 50% | 0% | 10% | 25% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% |

## Base Canvas Development

For building energy analysis, the base canvas includes residential dwelling unit counts and residential and non-residential building floor area by California building energy prototype and vintage. The UrbanFootprint building type designation, the result of a process that references local land use classifications and evaluates residential and employment mix and densities to identify the building type of each parcel, is used as the starting point for the “translation” or crosswalk to the California building energy prototypes. To produce the Sonoma County pilot base data canvas, a new process was developed to reference the UrbanFootprint building types and incorporate empirical data from other sources to quantify existing building floor area by California building energy prototype and vintage.

The floor area of existing buildings by building type is a key data point for energy analysis connected to local and regional planning and policy making, as home sizes and the form of commercial buildings, and thus energy use, vary according to development pattern. Empirical floor area data in particular improves the accuracy of baseline modeling, as well as the sensitivity of results to future-year assumptions about energy efficiency; however, the availability of reliable data is often limited. Building square footage can be assembled or derived from a variety of sources, including county assessor's data, the processing of LIDAR[5] data, or other existing and emerging public or privately developed datasets. For Sonoma County, assessor's parcel data for residential and commercial building floor area, where available, was incorporated into the base canvas. The use of existing LIDAR data for Sonoma County was also explored, and while it was determined that processing the data to accurate levels was beyond the scope of the project, LIDAR data is seen as a promising source of building space data.

Where empirical parcel-level data was not available, an UrbanFootprint-based imputation methodology was utilized. This method models floor area on the basis of residential unit counts by simplified housing type (small lot single family, large lot single family, townhome, and multifamily) and jobs by employment category, using rates linked to building and place types that have been calibrated to aggregate totals for a number of regional scenario planning processes. The resulting estimates link closely with built form assumptions, and provide a reasonable basis upon which to estimate energy use.

Building vintage, or year of construction, is also a fundamental component of energy use analysis that is subject to data availability. As with building floor area, county assessors may track year of construction, though not always reliably. In the absence of assessor's data, building vintage can be approximated using US Census American Community Survey data that denotes, at the block group level, the median year that residential structures were built. The base loading process for Sonoma County incorporated accessor's data for all parcels where it was available, and filled in gaps using Census data. For lack of a better data source, the Census vintages were applied to non-residential as well as residential buildings in areas where parcel-level vintage data was lacking.

As a geographic data layer, the loaded base canvas supports visualization, analysis, and reporting via the UrbanFootprint tool, as discussed later in this paper.

## Baseline Energy Use Intensities

Modeling of baseline energy use intensities (EUIs) for the California building energy prototypes was a significant technical undertaking justified by the capacity it brings to energy and climate action planning in California. Along with the parameterized prototype buildings, the baseline EUIs developed for this project comprise a valuable asset for energy use analysis and planning from the local to the state levels. Previous versions of the UrbanFootprint model used per-housing unit residential energy use factors and commercial EUIs derived or taken from CEC Residential Appliance Saturation Study (RASS) and Commercial End-Use Survey (CEUS) data; these were limited with respect to the range of building types and vintages represented, and sensitivity to energy efficiency measures into the future. While suitable for broad comparisons of energy use as associated with large-scale land use scenarios, better sensitivity to the makeup of the existing building stock is necessary for targeted policy development and implementation.

Baseline EUIs, expressed as site electricity (in kilowatt-hours) and natural gas use (in therms) per square foot of building area, were modeled for each California building energy prototype, vintage category, and Title 24 climate zone permutation. Residential prototypes were simulated using the CBECC-Res model, while the non-residential prototypes were simulated using the DOE EnergyPlus v8.2.0 model. For a first round of calibration, results were iteratively compared with EUIs indicated by RASS, CEUS, and Energy Star data, leading to informed

[5] LIDAR is a surveying technology that uses lasers to detect and image land cover surfaces. LIDAR data can be processed to identify building footprints and heights.

adjustments of assumed plug loads, or in some cases other building parameters, to account for differences between simulated results and empirical data.

The simulated, calibrated site EUIs were then applied to the existing buildings in Sonoma County as represented by the base data canvas. The resulting countywide total electricity and natural gas use results were verified against utility data from PG&E[6] and California Energy Consumption Data Management System (ECDMS)[7] data for the years 2013 and 2014. Site EUIs for buildings in the two Title 24 building climate zones found in Sonoma County were subsequently reassessed and calibrated with guidance from the CEC. It is anticipated that baseline EUIs for other climate zones would be assessed similarly as they are employed through future planning processes or policy explorations in other locations.

The EUIs for all of the prototype/vintage/climate zone permutations (for a total of 768 residential values and 3840 non-residential values) are stored in a database table that can be spatially linked to the Title 24 climate zone geographies, or any geography already associated with a climate zone.

## Building Energy Efficiency Measures and Policy-Based EUIs

Giving users the ability to realistically assess the energy savings potential of existing building stock was a fundamental goal of this project. In the context of climate goals, energy efficiency targets may be broadly defined – California's recently adopted SB 350[8] specifies the doubling of energy efficiency of existing buildings by 2030 – as can the range of energy efficiency measures to achieve them. Through this project, the CEC is providing guided support for future-year energy use and impacts analysis by developing and modeling "policy packages" – pre-defined bundles of individual building energy efficiency measures (such as HVAC system retrofits, solar hot water heaters, and new insulation) that have been tested and configured with respect to different policy goals.

The impacts of the grouped energy efficiency measures are estimated from the ground up (rather than in terms of percentage savings) using simulation models to model the specific technology and building envelope assumptions chosen for each building prototype and vintage. The resulting "policy-based" EUIs parallel the baseline EUIs, with results for every combination of building prototype, vintage, and climate zone. The design and simulation of a defensible set of policy packages applicable for planning and policy development in California was a project priority, and like the baseline EUIs represent a significant project outcome.

Provided as default options, the California policy packages developed through the Sonoma County pilot project provide local, regional, state, and other users with ready-to-go assumptions that can be applied to estimate energy use in the context of energy, land use, and climate planning and policy development. The UrbanFootprint-based tool developed in this project allows for the application of policy packages to all buildings, or selected building cohorts as defined by building type, vintage, climate zone, jurisdiction, or other distinction as specified through the model.

---

[6] PG&E energy usage data made available pursuant to California Public Utilities Commission Decision 14-05-016. Available at https://pge-energydatarequest.com/public_datasets

[7] ECDMS data available at http://ecdms.energy.ca.gov/

[8] For an overview of SB 350 by the California Energy Commission, see http://www.energy.ca.gov/sb350/.

## California Policy Package Options

The modeled policy packages are oriented around California state policy and goals for energy efficiency and carbon emissions reductions. They include a doubling of energy efficiency, maximization of efficiency, electrification of building end uses, and supplemental behavioral programs. In all cases, building systems were analyzed for each prototype and vintage to identify applicable efficiency and design options. Options were also evaluated relative to projected energy portfolio assumptions and GHG emissions rates. The policy packages were reviewed by the Sonoma County Pilot working group with an eye towards identifying policies or considerations particularly applicable for the local or regional context (specific to Sonoma County, as well as generally within California).

### Package A – Double Energy Efficiency / Meet SB 350 Goal

This package is based on the recent adoption of SB 350, which aims at doubling the energy efficiency of buildings by 2030. Measures evaluated in this package assume available technology for new construction and existing building retrofit projects. The components of this policy package are a subset of those included in Package B, which is geared towards achieving maximum efficiency potential. Among others, efficiency measures that comprise this policy package include envelope upgrades, lighting upgrades, and more efficient plug loads.

### Package B –Maximum Efficiency

This package builds on the measures included in Package A, achieving maximum efficiency by including the most efficient yet still cost-effective technology options currently available, or which have high feasibility of market availability in the near future. Efficiency measures that comprise this policy package include envelope upgrades, lighting upgrades, more efficient plug loads, HVAC system upgrades, and solar hot water systems.

### Package C – Electrification

This package aims to achieve GHG emission reductions through building electrification and on-site renewable energy generation. The non-residential building prototypes were modified such that building end uses are completely or predominantly electricity-based. Building simulations were run to investigate the impact on site energy consumption of converting existing natural gas equipment to electric equipment, and using all or mostly electric equipment in new construction. The resulting EUI for each type is the basis for determining the scale of photovoltaic systems (PV) that would be required to offset the energy use to achieve zero net energy. Efficiency measures that comprise this policy package share envelope upgrades, lighting upgrades, more efficient plug loads, HVAC system upgrades, and solar hot water systems as specified for the Maximum Efficiency package, with the use of and conversion to gas to electric equipment in new and existing buildings, respectively.

### Sub-Package D – Behavioral Programs

This package includes adjustments to unregulated miscellaneous loads (a significant proportion of energy use) as may be achieved through incentive-based or other programs that result in efficiency upgrades and conservation behaviors. This policy package is applicable in combination with packages A, B, and C.

## Modeling Methods

The base canvas, baseline EUIs, and policy-based EUIs, together with user specifications as to the rates of policy application, comprise the inputs necessary for modeling baseline and projected energy use. The energy analysis tool outputs results for baseline and future-year electricity and natural gas use and associated emissions and costs, in total and on per-capita, per-unit, or per-square foot bases.

Energy use calculations, which take place via scripted processes that employ a database system to store, manage, and process data, involve applying baseline and future policy-based EUIs to buildings as identified by prototype, vintage, and climate zone. How policy packages are applied, in terms of their timing and the percentage of building population that they ultimately impact, is controlled through the web-based user interface described in the next section. Through the interface, users are also able to specify energy cost and GHG emission rate assumptions to analyze the climate and household cost impacts of energy use.

### Rate of Policy Package Application

The mechanism for modeling policy package implementation (e.g., achieving Package A efficiency by the year 2030) will allow for user specification of two variables: the percentage of buildings retrofitted to the level of a selected policy package, and the target year(s) by which that occurs. (These inputs can also be specified in terms of the percentage of buildings being retrofit annually up to a target year, resulting in an overall percentage retrofit by the target year.) Retrofit rates can be specified by vintage category, such that a higher rate may be specified for older buildings than for more recently constructed buildings. The model uses these inputs to quantify floor area for each building cohort, delineated by California building energy prototype, vintage category, and climate zone, that will undergo retrofits according to the selected policy packages.

Energy use is then calculated separately for unchanged existing building stock and retrofit building stock. For unchanged buildings, baseline EUIs, expressed in kilowatt-hours or therms per square foot, are applied as factors to total building square footages by California building energy prototype, vintage, and climate zone. For retrofit buildings, policy-based EUIs, developed for the policy packages as described earlier, are applied to the square footages resulting from the specification of the retrofit rates. The resulting energy use totals are used as the basis for calculating GHG emissions and costs.

### Building Energy GHG Emissions

Energy-related greenhouse gas emissions are calculated as a function of energy use and type. A user can specify input assumptions for the emissions rates of electricity and natural gas for any year into the future – which for electricity may be region-specific – or choose from default assumptions associated with different technological pathways and policy scenarios. For example, the user could utilize the Energy + Environmental Economics (E3) California PATHWAYS (E3 2015) study, commissioned by California state policymakers in 2015, which provides projections for statewide emissions rates associated with technological pathways towards a low-carbon energy portfolio. Emissions rates are expressed in pounds of $CO_2$-equivalent per kilowatt-hour or therm. As with the energy efficiency policy packages, default emissions assumptions may be oriented to state energy and climate policy.

### Building Energy Costs

Energy costs to households and businesses are a function of energy use and retail price assumptions. Price assumptions are expressed in current (2016) dollars per kilowatt-hour or therm. Through the model, users can specify price assumptions for residential and commercial electricity and natural gas for any year into the future. Energy use in the model is not sensitive to costs.

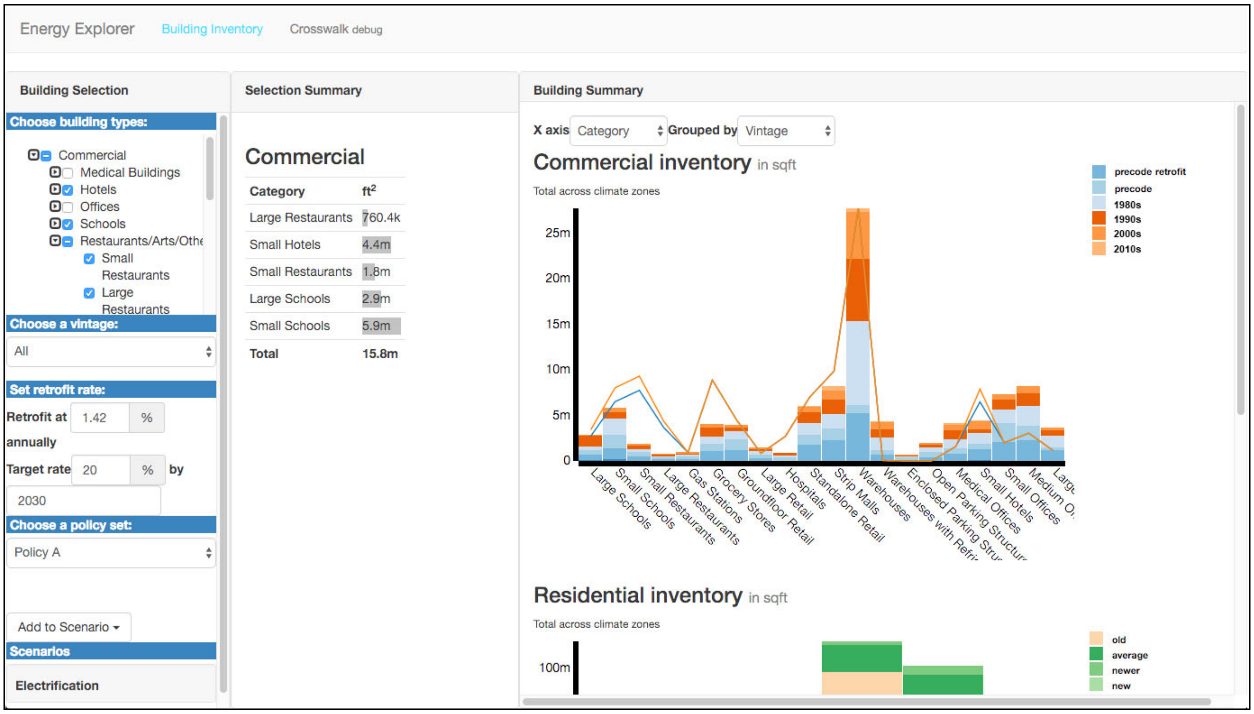
## Web-Based Model Development

The data, methods, and policy variables developed for this project are being integrated into a web-based analysis tool built upon the UrbanFootprint modeling platform. In addition to the CEC and other project team members, stakeholders in Sonoma County, including the Regional Climate Protection Authority, the Sonoma County Water Agency, and the Sonoma County Energy Independence Office, are providing input on the model functionality and user interface as it is being developed.

The Sonoma County pilot application of this tool, includes a user-friendly interface that allows for streamlined analysis and results reporting. The tool operationalizes data and peer-reviewed methods into a system for testing and reporting on the application of building efficiency measures across a full range of residential and commercial building types in California. It presents users with a baseline report of existing conditions and relevant energy metrics. It then allows for the selection of buildings by prototype and vintage and the application of policy variations. Baseline and policy-adjusted energy use, emissions, and related metrics are displayed in map- and chart-based reports. Bringing this functionality, including with the CEC/expert-reviewed baseline EUIs and policy sets, represents a significant advancement in technical capacity for high-level policy development or the local application and implementation of policies.

Like the larger UrbanFootprint platform, this pilot energy analysis tool is developed using open source software products such as Linux, PostgreSQL, PostGIS, Leaflet, and a host of other software tools.

Figure 2. Preliminary screenshot of the web-based energy analysis tool (beta release expected in August 2016)




## Conclusion

This project is aimed at standardizing an approach to policy-relevant building energy analysis in California. It identifies key data requirements, builds a canvas of required data components, and integrates defensible modeled baseline and policy-sensitive energy use intensities (EUIs) into a standardized energy modeling method. It then focuses on operationalizing the data, assumptions, policy options, and methods into a web-based toolset that allows users to explore baseline conditions, test relevant policies, and receive clear reports on the impacts of building efficiency interventions. It represents an important step forward in advanced modeling and bringing relevant and timely analysis to energy and climate planning at state, regional, and local levels in California.

## References


Assembly Bill 758. 2009. http://www.energy.ca.gov/ab758/documents/ab_758_bill_20091011_chaptered.pdf

California Energy Commission Energy Consumption and Data Management System. 2016. California Energy Consumption Database. http://ecdms.energy.ca.gov/

California Energy Commission. Existing Buildings Energy Efficiency Action Plan. 2015. http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-05/TN206015_20150904T153548_Existing_Buildings_Energy_Efficiency_Action_Plan.pdf

California Energy Commission 2009 Residential Appliance Saturation Study (RASS). 2010. http://www.energy.ca.gov/appliances/rass/

California Energy Commission Commercial End-Use Survey (CEUS). 2006. http://www.energy.ca.gov/ceus/

California Public Utilities Commission, Energy Division. 2014. Final Report WO21: Residential On-site Study: California Lighting and Appliance Saturation Study. http://www.energydataweb.com/cpucFiles/pdaDocs/1096/2014%2005_21%20WO21%20CLASS%20Final%20Report.pdf

Energy + Environmental Economics (E3). 2015. California PATHWAYS model inputs and scenario results. https://ethree.com/public_projects/energy_principals_study.php