Community-Scale Energy Efficiency Assessment for Zero Net Energy Using the URBANopt Simulation Platform

Preprint

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Presented at the ACEEE 2020 Summer Study on Energy Efficiency in Buildings
August 17–21, 2020

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Office of Energy Efficiency & Renewable Energy
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Contract No. DE-AC36-08GO28308

Conference Paper
NREL/CP-5500-77417
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Suggested Citation
Houssainy, Sammy, Ramin Faramarzi, Farhad Farahmand, Abhjieet Pande, and Jon Griesser. 2020. *Community-Scale Energy Efficiency Assessment for Zero Net Energy Using the URBANopt Simulation Platform: Preprint*. Golden, CO: National Renewable Energy Laboratory. NREL/CP-5500-77417. https://www.nrel.gov/docs/fy21osti/77417.pdf.

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303-275-3000 • www.nrel.gov

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This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Support for the work was also provided by the California Energy Commission under grant number LGC-16-005. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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ABSTRACT

This project explored an innovative modeling approach for assessing the energy efficiency potential of the existing low-income Oceano neighborhood, in unincorporated San Luis Obispo County, and its effects on renewable generation requirements for achieving zero net energy (ZNE). One particular challenge faced was ascertaining the technical energy savings potential across a large neighborhood in a timely manner. The project overcame this challenge through the use of the URBANopt simulation platform, developed at the National Renewable Energy Laboratory. URBANopt manages the automated model creation, simulation, and result aggregation for different design scenarios of existing or candidate buildings in a large neighborhood. Customized energy efficiency packages considered for the residential and commercial sector in the neighborhood included lighting, HVAC, plug load, water heating, envelope, and energy education measures. As a result of the analysis for the Oceano community, energy efficiency measures that are available through incentive programs may provide a 7.4% reduction in the required distributed energy resource (DER) size, corresponding to a 25,000 ft^2 decrease in PV array area, to achieve ZNE. Through this work, a computational tool was developed and is being leveraged by the County of San Luis Obispo (CoSLO). The tool has enabled the CoSLO staff to perform similar analysis of the technical potential for energy efficiency, and an understanding of the DER asset requirements and potential savings in other communities within the county.

Introduction

The work presented in this paper focuses on one component of a larger project where TRC Inc., UrbanFootprint, and the National Renewable Energy Laboratory (NREL) collaborated with the County of San Luis Obispo (CoSLO) to identify a feasible transition path to zero net energy (ZNE) for the existing, low-income, Oceano neighborhood in San Luis Obispo County (CSLO 2019). Through the entirety of this project, CoSLO sought to identify a replicable path for converting existing neighborhoods to ZNE, through approaches that leverage energy efficiency (EE), scalable renewable energy (RE) generation, and community engagement. The Oceano neighborhood was the first existing community in San Luis Obispo County to be assessed for the feasibility of conversion into a ZNE neighborhood (ZNEN).

This paper focuses on the community-scale building energy modeling efforts of this project. Physics-based building energy models are useful for producing detailed and customized insights for technology measures to pursue that meet specific ZNEN performance objectives. Traditionally, community energy simulations are achieved by manually aggregating individual detailed building-level models in the region, which is a costly and time-intensive effort as compared with integrated methods that investigate energy demands at community-scales. This project overcame these challenges through the use of URBANopt, an analytics platform for communities and districts that is built upon the U.S. Department of Energy's (DOE's) OpenStudio® and EnergyPlus™ building energy simulation platforms. URBANopt utilizes an automated model generation approach which is capable of modeling from high-level building characteristic information (e.g. square footage, number of floors, building type, and vintage) and the actual geographic data of the community. These simplified building models are generally more appropriate for high level analysis at community scales.

Through this project, packages of energy efficiency measures were developed for each building sector in the Oceano community based on their availability in incentive programs[1] and their URBANopt-predicted energy savings impacts. Several energy efficiency penetration scenarios to achieve ZNE were investigated, and their impacts on DER sizing requirements and associated cost reductions are presented. By leveraging URBANopt-predictions, a custom-built Energy Profile and Conservation Potential Tool was developed and is currently benefiting communities within the San Luis Obispo County beyond the Oceano neighborhood. The tool provides replicable estimates of the technical potential for energy efficiency, and its effects on DER size requirements and cost reductions to meet ZNE. The tool ranks energy efficiency measures based on their energy savings impacts, as well as estimated adoption rates based on cost, ease of implementation, and level of disruption to the occupant.

Study Scope and Objectives

The objectives of this project were twofold. The first objective was to develop an Energy Profile and Conservation Tool that is applicable to communities throughout CoSLO. The tool leverages URBANopt predictions to assess the technical potential of energy efficiency solutions. The second objective was to apply the energy profile tool in order to understand the impacts of various energy efficiency scenarios and associated DER requirements for achieving ZNE in the Oceano neighborhood. This paper focuses on the work related to the use of URBANopt for informing the energy savings potential in the custom-built Energy Profile and Conservation Tool, and for its application in the Oceano community.

This study expanded the ZNE definition adopted by the California Department of General Services for their new construction buildings to include a community of buildings instead (DGS 2019). In this study, ZNE requires renewable generation that offsets the total community energy consumed on-site (including electricity and gas) when accounting for fuel extraction, transmission, delivery, and production losses on an annual source energy basis. While ZNE was the primary objective under the original project scope, the need for explicit emission reductions through electrification became apparent over the project period (CSLO 2019).

Existing Conditions

The following sections outline our findings of the existing conditions in the study area. The existing conditions of the study area were used to 1) inform the selection of a representative sample of 100+ buildings and the development of their URBANopt energy models, 2) estimate the energy usage and average community energy use intensities (EUI) based on utility data and

[1] Energy efficiency measures offered through incentive programs were deemed suitable for the region, and assumed to be cost-effective in this study

parcel data for comparison against URBANopt-predictions, and 3) size a renewable energy system that achieves ZNE.

Study Area Characteristics

The Oceano study area is in Oceano, California, and is bounded by Cabrillo Highway (Hwy 1), The Pike, 17th street, and 24th street, as shown in Figure 1. San Luis Obispo County contains California Climate Zones (CZs) 4 and 5, where CZ 5 is a moderate coastal climate and includes Oceano, while CZ 4 is more inland and has wider diurnal temperature swings (CBCZ 2017). PG&E serves electricity to the Oceano study area while Southern California Gas Company (SoCal Gas) serves natural gas.

Figure 1. Oceano study area satellite view

An assessment of the built environment was performed through UrbanFootprint (UF 2018), which facilitates the summary of available parcel information within user-defined study areas. Parcel data, census data, publicly available energy data, and Pacific Gas & Electric (PG&E) power infrastructure data was used in the assessment. Parcel data was attained from CoSLO and a comparison was made between the Oceano study area and the rest of the county, as summarized in Table 1. Parcel data contained County Assessor's data on building occupancy, area, and vintage.

Table 1. Oceano parcel characteristics in comparison with San Luis Obispo County

	Oceano Area			San Luis Obispo County		
	Single Family	Multifamily	Nonresidential	Single Family	Multifamily	Nonresidential
Property Count	617	70	28	86,169	8,685	86,169
Distribution (%)	86%	10%	4%	84%	8%	8%
Vintage (%)						
Pre-1975	37%	34%	7%	25%	22%	9%
1975 - 1985	24%	14%	0%	15%	22%	3%
1985 - 1996	7%	20%	0%	18%	25%	5%
1996 - 2003	4%	0%	0%	11%	2%	2%
2003 and after	9%	0%	0%	12%	14%	3%
Unknown	19%	31%	93%	18%	16%	79%

Table 1 shows that residential buildings in the Oceano area tend to be older than residences in the rest of the county. While the nonresidential buildings are listed in the parcel data, including commercial, public, and religious buildings, most appear to have missing floor area and vintage data. Note that there are other types of buildings in the parcel data (e.g., mobile homes) that have a very low representation and are thus not included in the summary table.

Data from the Residential Appliance Saturation Survey was reviewed to assess the heating, ventilation, and air conditioning system types that exist in the Oceano area, with results summarized in Table 2 (RASS 2009). County staff confirmed the data and also commented that nonresidential buildings tend to have gas heating and electric cooling.

Table 2. Cooling system type and primary heating fuel. *Source*: RASS 2009.

Cooling					Heating				
System Type	Single Family		Multifamily		Heating Fuel	Single Family		Multifamily	
	CZ 4	CZ 5	CZ 4	CZ 5		CZ 4	CZ 5	CZ 4	CZ 5
Split DX	47%	11%	34%	11%	**Gas**	90%	84%	49%	58%
No cooling	41%	83%	40%	89%	**Electric**	1%	7%	24%	14%

According to permit data from CoSLO, to date there have been 37 permitted residential and small commercial solar PV installations within the Oceano study area, totaling 143.5 kW of capacity. The permitted solar data aligns with the PG&E utility data that was requested for the analysis, which shows that there are approximately 32 customers with solar PV rate structures within the Oceano neighborhood. All permits are for residential systems less than 10 kW in capacity. Combined, these arrays would produce approximately 250,000 kWh per year according to NREL's PVWatt Calculator (PVW 2017).

Energy Use

Energy consumption in the Oceano study area was estimated from utility data and was used for the sizing of a renewable energy system to achieve ZNE. The utility data was also leveraged for the development of building energy models, which were used to test energy efficiency potential and DER generation scenarios and support the replication of ZNE potential elsewhere/rest of the county. Additionally, the utility data combined with public records were used as a qualitative reference by which simulations were compared against measured energy consumption.

Advanced meter infrastructure based electricity usage and gas consumption data for the Oceano study area were obtained from PG&E and SoCalGas, respectively. The data was then grouped into two categories: 1) publicly available data that was analyzed via UrbanFootprint, and 2) data from each utility's Energy Data Request Program (EDRP), subject to stringent CPUC privacy rules on aggregation and anonymization (P-EDRP 2019; S-EDRP 2019). The CPUC privacy rules limited the comprehensiveness and quality of the data provided by investor-owned utilities (IOU). For example, the provided IOU data had to be aggregated beyond the study area, the customer classes could not be mixed, and each customer's energy consumption had to be less than 10% of the total aggregated usage in order to preserve anonymity. Therefore, accurate mapping of utility data into corresponding buildings within the selected zip codes was not achievable. Consequently, it hampered the development of a proper benchmarking foundation that could have reasonably been used for validating the energy analysis results. Selected zip codes were used for each sector that had the most reasonable overlap with available utility data and had the majority of parcels within the Oceano area. Table 3 and Table 4 summarize the electric and gas data obtained, and their associated data source. As previously mentioned, the dataset in Table 3 and Table 4 correspond to selected zip codes that reasonably overlap with available utility data and therefore do not represent the true number of properties, customers, floor areas, and energy consumption of the Oceano neighborhood. However, this dataset provided a reasonable means for calculating the average utility-based electric and gas EUI's in kWh/ft^2-yr and kBtu/ft^2-yr respectively for each sector in the community.

Table 3: Estimated electricity EUI in the Oceano study area based on available utility data

ELECTRIC	Utility and Parcel Data Calculations		
Building Sector	**Data Source**	**Nonresidential**	**Residential**
Floor Area	Parcel Data	Not enough data	628,529
Number of Properties	Parcel Data	31	520
# of Elec Customers	Utility Data	291	822
Total Annual kWh Electricity	Utility Data	10,902,252	3,166,104
Average EUI (in kWh/ft^2-yr)		**-**	**5.0**

Table 4: Estimated gas EUI in the Oceano study area based on available utility data

GAS	Utility and Parcel Data Calculations		
Building Sector	**Data Source**	**Nonresidential**	**Residential**
Floor Area	Parcel Data	93,901	1,460,469
Number of Properties	Parcel Data	113	1,181
# of Gas Customers	Utility Data	343	752
Total kBtu Gas Consumed	Utility Data	Not enough data	23,475,100
Average EUI (in kBtu/ft^2-yr)		**-**	**16**

With insufficient parcel and utility data for the nonresidential sector, we relied on other nationally recognized data sources (presented later in the paper) that are representative of the average building stock's energy consumption. These sources were used instead, for the nonessential sector, as a means for comparison with URBANopt-predicted values and to increase confidence in the URBANopt energy models.

Community Energy Modeling Approach

Optimization of efficiency and distributed energy resources at community scale can identify design alternatives that may be overlooked when only individual buildings are considered. The URBANopt software development kit (SDK) is an analysis platform for communities and districts built upon DOE's OpenStudio® and EnergyPlus™ building energy simulation platforms (OS 2020). Therefore, URBANopt is a useful platform for providing CoSLO with a reasonable understanding of the existing conditions and energy efficiency potential in the Oceano pilot neighborhood.

The following sections summarize the main functionality of the URBANopt SDK, and the procedures used to run and post-process annual building simulations, using URBANopt, for various residential, commercial, and institutional buildings in the Oceano neighborhood and across the county, totaling 117 representative buildings. The URBANopt modeling relied on minimal parcel information such as building occupancy type, square footage, number of floors, and vintage. The 8,760 hourly simulation outputs included annual energy electrical and gas energy use, monthly peak power demands, and average daily electrical load profiles for each season, with simulation outputs disaggregated by building sector. Lastly, this section outlines high-level order of magnitude comparisons made of URBANopt-predicted baseline EUIs with local electric and gas utility data, and other nationally recognized sources of information.

URBANopt Background

URBANopt follows a design philosophy similar to OpenStudio, focused on enabling the development of third-party user interfaces (UIs) that interoperate with a powerful and extensible computation backend via an Application Program Interface (Polly 2016). The open source code and documentation that enables such community-scale modeling application is publicly available (UO 2020) and is built around the concept of small extensible Ruby language scripts that can modify (or create) energy models. These scripts, often referred to as OpenStudio Measures, are most often used to represent EE measures – hence their name. URBANopt's backend OpenStudio Measure concept and OpenStudio Workflow (OSW) files specify which Measures are to be used, in what order, and with what inputs for a given design scenario. OSWs associated with each design scenario are utilized to automatically construct a building energy model for each structure in the community utilizing high level information such as the building footprint, type, vintage, number of floors, etc. Figure 2 illustrates a sample multifamily dwelling model.

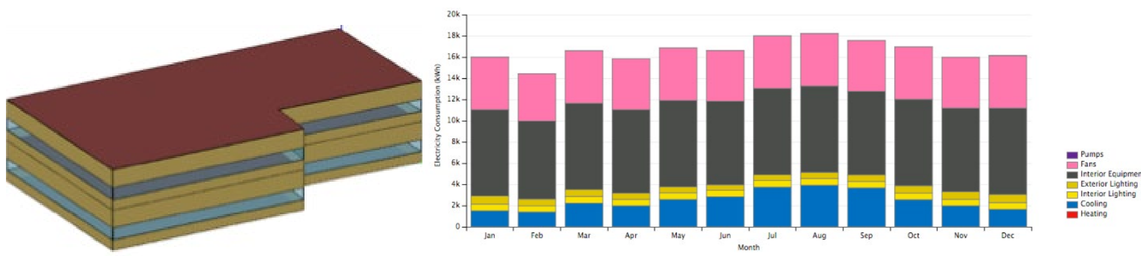


Figure 2. Sample model geometry and predicted monthly electricity consumption for an URBANopt multifamily building model

Each building model is generated using URBANopt input, and fully detailed using modeling assumptions from the California Public Utilities Commission (CPUC) Database of Energy Efficiency Resources (DEER) or ASHRAE 90.1 standards. Simulations outputs include 8,760 hourly simulation results along with monthly or annual aggregations broken down by end use and fuel type (Figure 2). EE retrofits may be applied to the base case models by adding the appropriate OpenStudio Measures to a scenario's workflow specification. Packages of EE Measures would typically be applied to individual (or all) building models to reflect a particular community design scenario.

URBANopt manages the automated model creation, simulation, and results aggregation for each design scenario. High level aggregate results are made available in addition to a rich set of detailed simulation results for individual buildings and community energy systems associated with each design scenario for further analysis. The next section discusses the application of URBANopt to the specific community of interest, the Oceano neighborhood.

Applying URBANopt

San Luis Obispo County contains 181,023 properties, 715 of which are located in the Oceano neighborhood, as indicated in Table 1. To avoid excessive computational time, while minimizing modeling inaccuracies, the URBANopt simulations focused on a representative sample, totaling 117 buildings. Our findings of the existing conditions informed the selection of these representative buildings, which reflect the range of building characteristics and geometries in the county and study area. The representative sample provides a diverse inventor of building models that map to the county's building occupancy types, vintages, number of floors, and system types, as summarized in Table 1 and Table 2. The representative sample contains a subset of buildings within Oceano and elsewhere in San Luis Obispo County, and simulations were parametrized in both CZ 4 and CZ 5 to properly inform the energy profile tool and allow flexibility and applicability of the tool to neighborhoods across the county.

Developing Project Input Files

One of URBANopt's core input files is an URBANopt geoJSON, which stores building footprints and higher-level building characteristics information (e.g., building use types, number of stories). An URBANopt geoJSON file was manually developed by tracing the Open Street Map footprints of a representative sample of 87 properties (117 buildings), 38 from Oceano and 49 from elsewhere in San Luis Obispo County, and specifying the available data (summarized in Table 1 and 2) describing building type, vintage, floor area, number of floors, cooling availability, and heating fuel type. Figure 3 visualizes the URBANopt geoJSON input file that defines project-level and building-level inputs for the Oceano study area and the workflow used by URBANopt to create building geometries and articulate models.

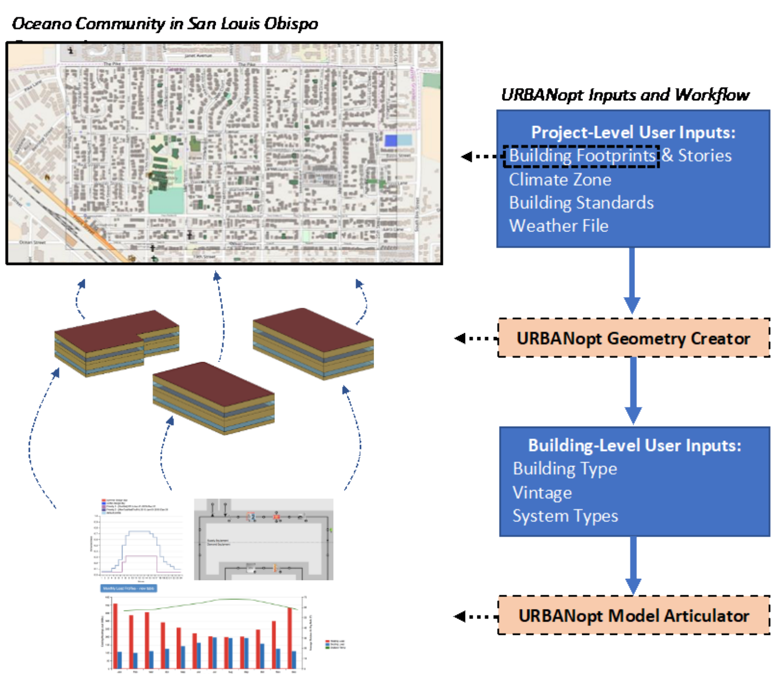


Figure 3. Visualization of the URBANopt geoJSON inputs for the modeled community and the URBANopt modeling workflow. Green colored buildings in the community map are modeled, while grey buildings are visualized from Open Street Map, but not modeled.

Site-specific inputs were populated for URBANopt project input files, such as the weather data and climate zone. The buildings were simulated in both CZs 4 and 5 to inform the neighborhood Energy Profile and Conservation Tool and expand its applicability to communities across the county. The models assume vintage characteristics built upon DEER assumptions.

Input Cleaning

Several discrepancies were identified between building floor areas and number of stories from available public records and traced areas calculated by URBANopt. Likely causes for such discrepancies include building retrofits which had not yet been reflected in the public records, and unconditioned spaces attached to the building that had been traced. To handle discrepancies, model areas were scaled to match the public record areas while preserving the traced aspect ratio, unless the actual traced area is double that of public records area. In these cases, the most discrepant models were reviewed in Google Street-view manually and judged whether the traced area is appropriate to utilize.

Output Processing

The electric, gas and whole-building annual EUI's were outputted from the URBANopt simulation, in addition to the monthly peak power demands for each building individually, and coincident peaks for all buildings. The average daily electrical load profiles for the entire community were also retrieved from the URBANopt simulation outputs. URBANopt results were further disaggregated by building sector (i.e., residential and commercial). These simulation outputs were used to support the existing conditions assessment, energy efficiency and conservation potential, and future DER sizing and impacts. The URBANopt outputs supported the development of the neighborhood energy profile tool, which is described later in this paper.

Comparison of URBANopt Results with Utility Data & Other Sources

Measured energy use data reflects selected zip codes, for each sector, that overlap with available utility data and have the majority of parcels within the Oceano neighborhood. Table 5 and Table 6 summarize the calculated electric and gas EUI's from utility and parcel data for comparison between URBANopt simulations. Due to data availability, limitations, and constraints, the average residential gas and electric EUI values presented in Table 5 and Table 6 reflect the only valid comparisons that can be made between available parcel data, utility data and URBANopt simulation results.

Table 5. Comparison of average electric EUI's between available utility data and URBANopt

ELECTRIC	Nonresidential	Residential
Utility & Parcel Data EUI *(Avg kWh/ft^2-yr)*	not enough data	5
URBANopt-Predicted EUI *(Avg kWh/ft^2-yr)*	11	7

Table 6. Comparison of average gas EUI's between available utility data and URBANopt

GAS	Nonresidential	Residential
Utility & Parcel Data EUI *(Avg kBtu/ft^2-yr)*	not enough data	16
URBANopt-Predicted EUI *(Avg kBtu/ft^2-yr)*	21	13

Discrepancies in residential model predictions are likely caused by uncertainties in usage schedules, space heating set-points, and gas equipment efficiencies used in the DEER assumptions. Only individually tailored, manually developed, and calibrated models with detailed occupant information would overcome this limitation. In addition, deviations are also a result of the uncertainties in the degree of overlap between available parcel data and utility data, in part due to CPUC's strict anonymization and aggregation rules. While nonresidential utility data was not available for comparison, it is important to note that the majority (96%) of the properties in the Oceano study area, as indicated in Table 1, are within the residential sector. Therefore, commercial utility data is not expected to inform significant energy deviations from the modeled community as a whole.

For further confidence in model predictions, comparisons were made between URBANopt simulation results, California Commercial End-Use Survey (CCEUS 2006), and the Energy Information Administration Residential Energy Consumption Survey (EIA – RECS 2015). Comparisons reveal that for the nonresidential sector, URBANopt-predicted electric, gas, and whole building EUIs are within 19% of CEUSS values. Furthermore, URBANopt-predicted whole-building residential EUI is within 3% of EIA-RECS values. Considering the few and relatively high-level input parameters used to generate the URBANopt models, these findings demonstrate reasonable alignment of model predictions with these nationally recognized sources of information for average building stock energy consumption.

Table 7. Comparing URBANopt-predicted results to CEUSS, RECS, and Utility Data

Data Source	Building Sector	Electric EUI (kWh/ft^2-yr)	Gas EUI ($kBtu/ft^2$-yr)	Whole Building EUI ($kBtu/ft^2$-yr)
Utility and Parcel Data	Nonresidential	not enough data	not enough data	not enough data
	Residential	5	16	33
CEUSS	Nonresidential	13	26	72
EIA-RECS	Residential	-	-	38
URBANopt	Nonresidential	11	21	60
	Residential	7	13	37
URBANopt & CEUSS % Diff	Nonresidential	15%	19%	16%
URBANopt & RECS % Diff	Residential	-	-	3%

Energy Savings Potential Methodology

A detailed and replicable methodology was developed to predict energy efficiency and conservation potentials using URBANopt, UrbanFootprint, and county data, in a custom-built Energy Profile and Conservation Potential Tool. This energy profile tool was developed to support the Oceano study, and future analysis of the energy savings potential in areas throughout San Luis Obispo County. Developed as an Excel workbook, the Tool was designed to be relatively easy to use and share.

The energy profile tool is populated with URBANopt simulated baseline energy use data and peak demand from the 117 representative models which reflect the range of building characteristics and geometries in the county and study area. The tool requires users to specify building inventory information as an input. This information – including building type, vintage, conditioned area, and number of floors– can be gathered using local parcel data. The tool leverages the embedded inventory of representative URBANopt building models to inform energy use based on the users-defined building inventory and climate zone, and maps the embedded representative URBANopt models to approximate the baseline conditions of the user-defined study area. The tool was applied for the Oceano community, which is comprised primarily of residential buildings (as noted in Table 1), by specifying the complete inventory of the study area's buildings and their high-level characteristics (vintage, occupancy type, system fuel type, number of floor area, conditioned floor area), which allowed the tool to map and interpolate from its wider embedded dataset.

The tool also incorporates data for URBANopt projected energy use and peak demand under various energy efficiency measures or packages of measures (described in the next section), allowing users to project future conservation potential subject to various scenarios for energy efficiency program implementation. The tool also projects future greenhouse gas emissions and the residential and commercial costs associated with energy use. Users can specify emissions and cost assumptions or use the preset assumptions. Assumptions can be used to reflect various futures. For example, a study can assume higher energy costs and lowered emissions rates into the future, consistent with an aggressive policy direction. Or, users can assume baseline rates into the future to assess the impact of efficiency measures alone. Additional information on the Energy Profile and Conservation Tool can be found in the final report of the project on the county's website (CSLO 2019). The energy savings potential methodology and the Tool are outlined in Figure 4

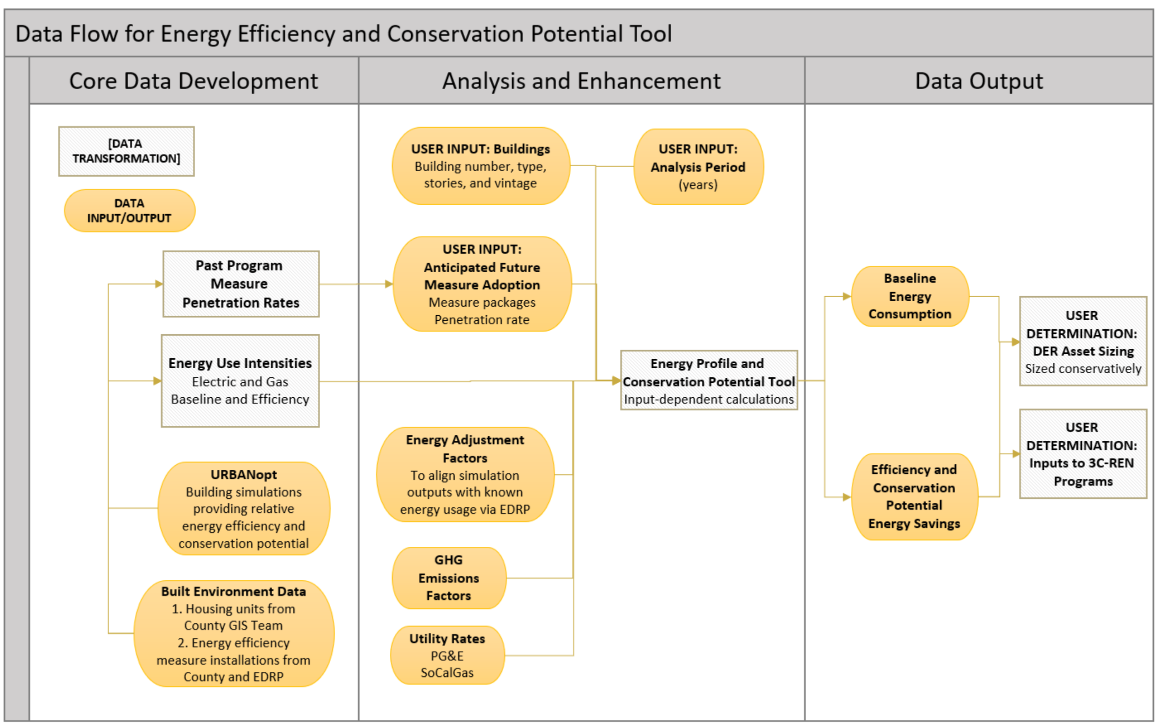


Figure 4. Data flow chart for determining efficiency and conservation potential, and ultimately DER asset sizing

The data flow in the tool, as outlined in Figure 4, is summarized below:

- **Core Data Development:** Estimates of energy usage within the Oceano area were established based on EDRP data and parcel data, and URBANopt models were developed for comparison to these ‘baseline’ energy use estimates. Measure penetration rates were estimated through utility EDRP and CoSLO data and by estimating the technical potential of energy efficiency measures using URBANopt. Core data yielded estimates for past program penetration rates, as well as ‘baseline’, and ‘efficiency’ EUI’s.

- **Analysis and Enhancement:** Building on the Core Data, the Energy Profile and Conservation Potential Tool takes both user inputs and embedded inputs. User inputs include study area characteristics, anticipated future measure adoption, and analysis period. Embedded inputs include utility rates, GHG emissions factors, and adjustment factors that true-up the URBANopt outputs to the EDRP-supported baseline energy usage estimates based on the existing conditions.
- **Data Output:** Based on the preceding inputs, the Tool outputs both the baseline energy profile of the study area, as well as the predicted energy efficiency and conservation potential.

To estimate the energy savings potential in Oceano, a list of measures that are available through incentive programs was compiled. Incentives for the measures are provided by the San Luis Obispo County Energy Watch Partnership (SLOEW 2019), the Tri-County Regional Energy Network Residential Direct Install program (3C-REN 2019), Energy Savings Assistance Program (ESAP 2019), and Low-Income Home Energy Assistance Program (LIHEAP 2019).. The list of measures were ranked qualitatively in terms of energy savings impact, as well as estimated adoption rate based on cost, ease of implementation, and level of disruption to the occupant. The list was further narrowed by the measures that were able to be modeled in URBANopt, which consisted of most high-ranking measures.

URBANopt Energy Simulations

Measures were packaged into envelope, lighting, plug load, or HVAC bundles for simulation. The measure packages are intended for users to understand the technical potential of efficiency and conservation for each end use. These packages also reduce the number of total simulations needed to a manageable amount. The measure packages that were simulated are described below:

- All packages assumed that Energy Education is performed. To mimic occupant understanding of HVAC energy impacts and quantify the maximum feasible potential corresponding to behavioral adjustments, this measure was simulated by reducing the heating set point by 1°F to 68°F and increasing the cooling setpoint by 4°F to 78°F (values based on DOE-T 2018).
- Lighting Package:
  - **LED Lamps**: Lighting Power Density (LPD) was reduced by 72%, corresponding to savings associated with LEDs compared with halogen or incandescent that provide similar lighting levels.
  - **Vacancy/Occupancy Sensor**: LPD was reduced by 20%, corresponding to the prescriptive energy compliance method for occupant sensing controls in Title-24.
- Plug Loads: The Plug Load Density (PLD) of all electric equipment was reduced according to the minimum efficiency increase to Residential ENERGY STAR Appliances (ESA 2018), compared with the baseline standard equipment.
  - Residential: 9% reduction. Nonresidential: 20% reduction

- HVAC: The cooling Energy Efficiency Ratio (EER) of the HVAC System was increased to 12 (only applied to buildings with cooling), and the gas burner efficiency was increased to 95% (only applied to buildings with gas heating), corresponding to commercially available ENERGY STAR equipment.[2]
- Envelope Package
  - **Attic/Ceiling Insulation R30**: The R-Value of roof insulation is set to R30 from no insulation.
  - *Residential*
    - **Wall Insulation R13**: The R-Value of exterior wall insulation is set to R13, from no cavity insulation.
    - **Weather Sealing/Stripping**: The infiltration rate is reduced by 20%.
  - *Nonresidential*
    - **Weather Sealing/Stripping**: The infiltration rate is reduced by 9%.
- Heat Pump Water Heater (residential only): replaced a gas-fired water heater with a heat pump water heater (HPWH). This simulation was done using The California Building Energy Code Compliance – Residential (CBECC-Res) software, because URBANopt did not have this modeling capability at the time this analysis was performed. The EUI impacts of the measure were applied directly to URBANopt results.

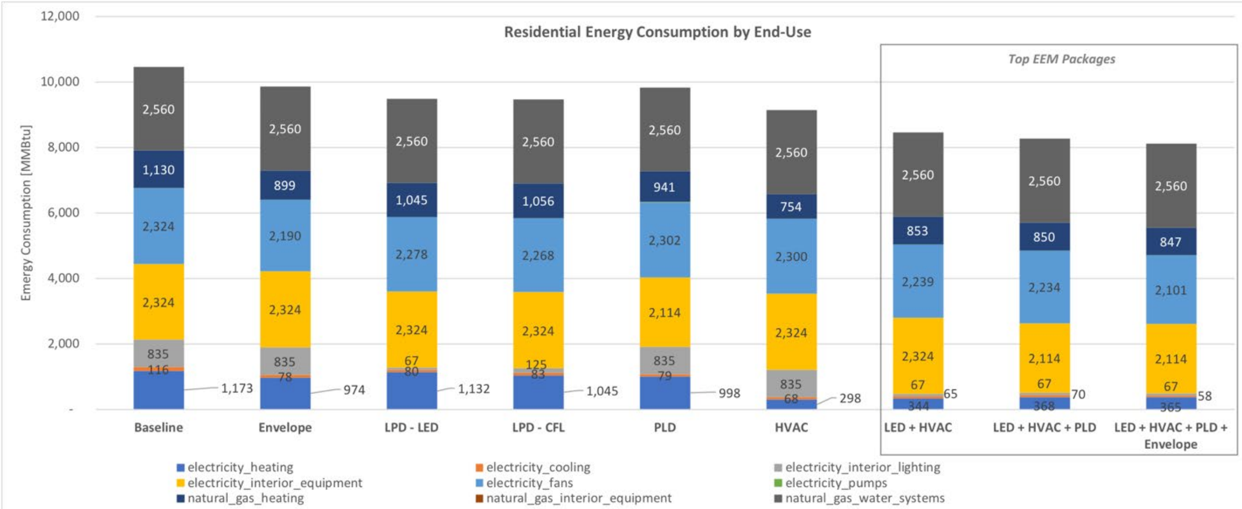
To limit the number of simulations being performed, packages were simulated individually per building sector, and then rank-ordered based on their energy savings potentials. Subsequent package groups were created based on the ranked ordered results, with the first group combining the top two packages (e.g., Lighting and Plug Loads), the second group combining the top three (e.g., Lighting + Plug Loads + HVAC), followed by the top four packages (e.g., Lighting + Plug Load + HVAC + Envelope). Rank-order and package grouping were simulated for both California climate zones 4 and 5. The lone exception to this method is the HPWH measure, which was not rank-ordered but added to the final group in each climate zone.

Analysis Results

URBANopt Energy Efficiency Analysis Results

URBANopt energy consumption simulation results of the 117 representative building models in the county by end-use, for each EE package, and for both residential and nonresidential sectors in CZ 5 are shown in Figure 5. In addition, Figure 5 illustrates the top 3 EE package combinations. Similar results were obtained for CZ4. Energy simulations yielded the average energy savings results per building in Table 8, where lighting, HPWH, and HVAC efficiency packages showed the highest whole-building kBtu savings.

[2] Incentive programs for electrification of heating systems became available at the end of the project life due to revisions of CPUC's 3-prong test for cost-effectiveness. Hot water was determined to be a much larger energy load than space heating, due to the county's climate, and the project budget/resources only allowed for analysis of highest priority electrification measures.



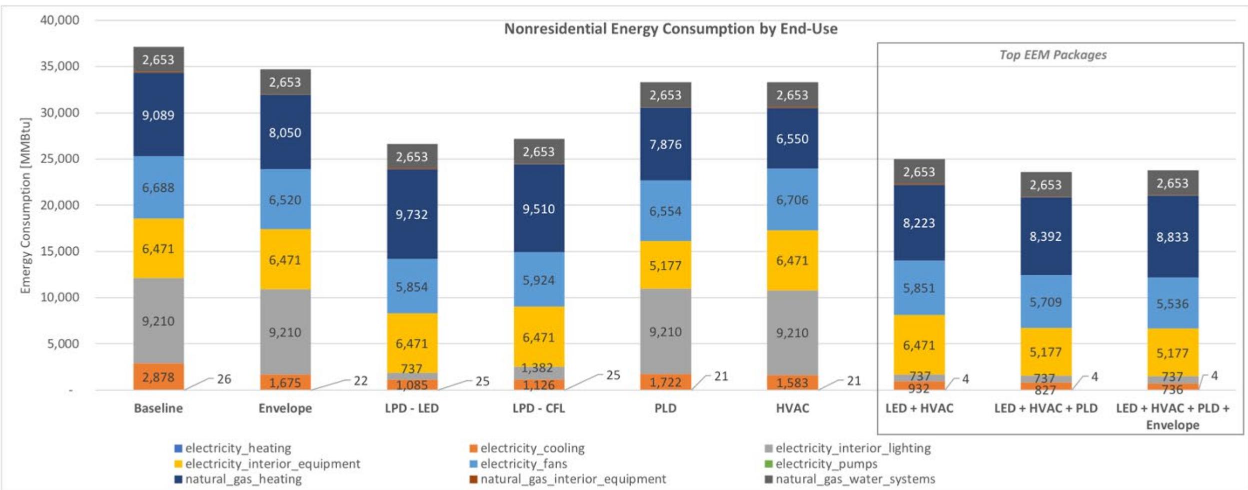


Figure 5. URBANopt site energy consumption simulation results by end-use, for each EE package, and for both residential and nonresidential sectors in California CZ 5

Table 8. Simulated percent whole-building site energy savings of energy efficiency packages[3]

% kBtu Energy Savings	Residential		Commercial	
	CZ4	CZ5	CZ4	CZ5
Lighting	13%	9%	29%	28%
Plug Loads	8%	6%	10%	10%
HVAC	11%	13%	10%	10%
Envelope	9%	6%	6%	7%
Heat Pump Water Heater	18%	19%	n/a	n/a

As previously noted, the HPWH simulation was done using CBECC-Res because URBANopt did not have this modeling capability at the time this analysis was performed. The EUI impacts of the measure were applied directly to URBANopt results. Note that potential HVAC savings are higher in CZ5 (the coast) than CZ4 (inland), which may be unexpected given that coastal climates are typically milder than inland climates. Further disaggregation of results

[3] As noted in the *URBANopt Energy Simulation* section, all packages include the Energy Education measure

showed that electric heating and furnace fan savings were the primary contributor to these savings estimates, indicating that CZ5 has higher heating loads than CZ4.

Although lighting and plug load end-uses are not weather dependent, their corresponding energy efficiency packages resulted in different energy savings across CZ 4 and CZ 5. These differences in energy savings are a result of the interactive effects that plug load and lighting end-uses have on heating and cooling requirements. The energy education measure is also applied to all measure packages, including lighting and plug loads. The energy education measure resets the thermostat setpoints and further contributes to the difference in energy savings across CZs.

Energy Efficiency Impact on DER Sizing

Through the method outlined in Figure 4, three scenarios were developed to support estimates for energy efficiency and conservation potential within the Oceano area over seven years. Scenarios range from limited measures at low penetration, to a wide range of measures at high penetration. Scenarios apply both to residential and nonresidential buildings and result in electricity and natural gas savings estimates. Table 9 provides an overview of both electricity and gas energy savings. This energy savings potential was then translated into potential impacts on the distributed energy resource (DER) generation capacity according to the California Department of General Services (DGS) definition of ZNE (DGS 2019). Based on Oceano's existing conditions, a 5.0 – 5.7 MW DER would be necessary to achieve ZNE per the California DGS definition. Table 9 shows that the County may choose to reduce the ZNEN DER size by roughly 12 kW to 370 kW, depending on how aggressively energy efficiency measures will be installed in the Oceano area. This corresponds to a 0.2% – 7.4% reduction in the DER size - an approximate 800 ft^2 – 25,000 ft^2 decrease in the required PV array area - which translated to a reduction of 4 – 123 residential rooftop PV systems, given an average system size of 3kW/roof.

Table 9. Estimated energy efficiency and conservation potential in Oceano area over 5 years

Energy Savings Scenario	Measure Group	Annual Penetration[4] (for 7 years)	% kBtu Energy Savings			DER Generation Capacity Reduction
			Res.	NonRes	Combination	
Low penetration	Lighting only	0.25%	0.1%	0.3%	0.1%	12 kW
Medium penetration	Lighting + HVAC + Plug Loads	2.5%	2.4%	4.1%	2.7%	180 kW
High penetration	Lighting+ HVAC+ Plug Loads + Envelope + HPWH	6%	7.2%	8.5%	7.4%	370 kW

Conclusion

The technical potential for energy efficiency, and an understanding of the DER asset requirements for achieving a zero net energy community were outlined for the low-income neighborhood of Oceano in unincorporated San Luis Obispo County, California. As a result of

[4] Four-year (2014-2018) program datasets from PG&E, SoCalGas, and CoSLO that overlap with the Oceano area were used to inform reasonable estimates for potential penetration rates of future energy efficiency programs. Baseline penetrations varied by program, where annual penetration rates were found to range between 0.5% to 6%.

the analysis for the Oceano community, energy education, lighting, HVAC, plug load, water heating, and envelope energy efficiency measures that are available through incentive programs may provide a 7.4% reduction in the required DER size to achieve ZNE as defined by the California Department of General Services. Through this work, a computational tool was developed and is being leveraged by the County of San Luis Obispo to perform similar analysis of the technical potential for energy efficiency and conservation, and an understanding of the DER asset requirements and savings in other communities within the county.

Acknowledgements

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Support for the work was also provided by the California Energy Commission under grant number LGC-16-005. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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