Bay Area Existing Buildings Study

Existing Building Characterization Report

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Acronyms

EUI: Energy Use Intensity, Energy per unit area
NREL: National Renewable Energy Laboratory
PUMA: Public Use Microdata Areas
TMY3: Typical Meteorological Year, Weather data profile
HPWH: Heat Pump Water Heater

Introduction

The purpose of this report is to document the process for data collection and management for the BayREN Bay Area Existing Buildings Dashboard initial deployment, which is focused on the quantity and nature of existing buildings and their energy and emissions totals. The report serves as a compendium of data sources and processes to guide use and understanding of the tool, provide clarity to BayREN for any future updates, explain the assumptions and rationale behind building categorization groupings, and document the conclusions that will form the foundation for subsequent phases of work which will identify potential decarbonization pathways. Therefore, this report focuses on collecting and organizing the primary sources of data for use in the project and setting up an initial digital dashboard to view the baseline jurisdiction building stock and resultant energy consumption and greenhouse gas (GHG) emissions.

The goal of building characterization is to identify the common characteristics of the building stock across all of the jurisdictions that comprise BayREN. To accomplish this goal, the team utilized a bottom-up approach building first from parcel-based information on building use, age, and area, compiling data from a variety of sources. Where gaps exist, supplemental data from regional and national surveys are used. These ultimately are combined with building energy simulations and emissions factors to provide energy and emissions data. An overview of this process is further detailed in the subsequent sections of this document

Methodology

Overview

The following overarching workflow was applied to aggregate and derive relevant building characteristics and estimate baseline building energy use intensity and emissions. This approach is noted in the following sections, with additional process flow diagrams for key steps of the process.

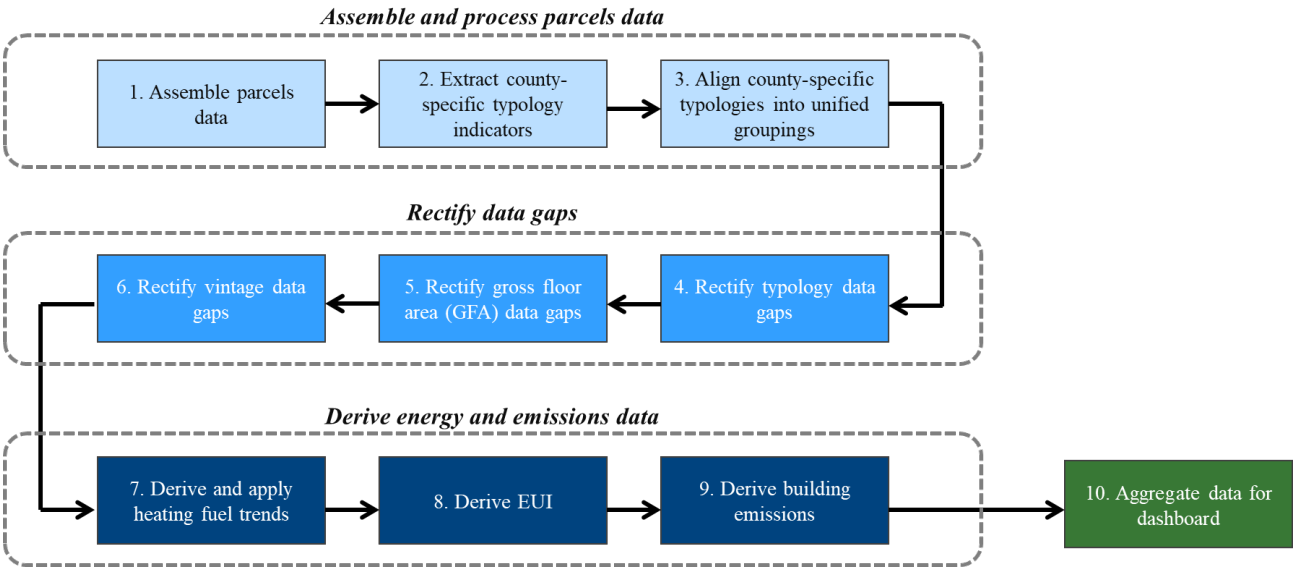

Figure 1 Overall workflow for parcels data collection, data cleaning, and energy/emissions derivation.

The data sources and means of rectifying data gaps are summarized in the table below for both Residential and Commercial buildings. A more detailed description of the residential data sources can be found in the Appendix: Baseline Residential Data.

Table 1: Summary of Data Sources and Calculation Methods for Residential and Commercial Buildings

Parameter	Residential Buildings		Commercial Buildings	
	Primary data source	**Method to rectify data gaps**	**Primary data source**	**Method to rectify data gaps**
Building Count	Parcel data; Building Footprints	Not required (data shown to contain comprehensive building counts)	Parcel data; Building Footprints	Not required (data shown to contain comprehensive building counts)
Building County / City	Location information from building data	Not required (data contains complete county & city information)	Location information from parcel data	Not required (data contains complete county & city information)
Building Typology	Typology indicators from parcel data	Marin: Supplement with census data for missing multi-family	Typology indicators from parcel data	Marin & Napa: Apply typology distribution from the neighboring counties' known commercial buildings parcel data. All other counties: Apply typology distribution from the given county's own known commercial buildings parcel data.

Building Gross Square Footage (GFA)	GFA from parcel data	Estimate floor area by multiplying footprint * floor count, if available. Otherwise, apply default floor area for given building type. (Default area sources vary by typology; see subsequent section for description of logic)	GFA from parcel data	Estimate floor area by multiplying footprint * floor count, if available. Otherwise, apply default floor area for given building type. (Default area sources vary by typology; see subsequent section for description of logic)
Building Vintage	Year built from parcel data	Apply vintage distribution from census data (for given county and typology)	Year built from parcel data	Apply vintage distribution from ComStock data (for given county and typology)
Building Disadvantaged Status	Location information from building data	Not required (data contains complete information to inform this)	Location information from building data	Not required (data contains complete information to inform this)
Building Heating Fuel	Apply heating fuel trends from census data	N/A	Apply heating fuel trends from ComStock data	N/A
Building EUI	Apply EUI from ResStock for relevant county, typology, vintage, heating fuel	N/A	Apply EUI from ComStock for relevant county, typology, vintage, heating fuel	N/A
Building Emissions	Apply 2022 PG&E Base Plan emissions factor (56 lbs CO2e/MWh)	N/A	Apply 2022 PG&E Base Plan emissions factor (56 lbs CO2e/MWh)	N/A

Geospatial and Building Characteristic Data

Data Sources

To establish the basic building criteria including land use, building square footage, and year built, ReGrid parcel data was assigned to the ReGrid building footprints with County parcel data used to fill in gaps. County parcel data was obtained from open-source repositories and data provided directly by County representatives to BayREN. ReGrid data has data gaps in all categories, with the biggest gaps in building square footage and year built. For residential year built, we made probabilistic distributions using the most recent US Census data (2018-2022 American Community Survey) to fill in gaps. For commercial year built, Comstock & SF EBDO data was used to fill in gaps. Figure 2 illustrates the data workflow.

Data is processed via models that assign County and ReGrid parcel data to buildings, identifies which jurisdiction a building is located in, and assigns the climate zone. In the rare case that building footprints happen to fall on the border between two jurisdictions, these are only assigned to one for the purposes of this study. The data is then aggregated based on jurisdiction, categorizations for land use, year built (decade), and status pertaining to disadvantaged communities.

The following table catalogues all the data sources that were analyzed for this project, whether or not they were determined to be useful to the study, and how the selected sources were used.

Table 2: Data Sources

Source	Dataset	Fields	Purpose
ReGrid	rg_buildings_tbl (joined to parcels with rg_building_join_tbl)	ed_str_uuid ed_bldg_uuid	Building locations and footprint square footage
ReGrid	rg_parcels_source_tbl	parcelnumb usecode Usedesc Zoning Zoning_description Zoning_type Zoning_subtype Yearbuilt Numstories Recrdareano Ll_bldg_count Lbcs_activity Lbcs_activity_desc Lbcs_function Lbcs_function_desc Lbcs_structure Lbcs_structure_desc Lbcs_site Lbcs_site_description	APN, land use, year built, building square footage
Sonoma County	CDR_PARCEL_PUB_vw	BuildingPrimarySize BuildingPrimaryYearBuilt	year built, building square footage
Contra Costa County	Assessment Parcels	YR_BUILT BLDG_SQFT	year built, building square footage
Solano County	Parcels_Public	yrblt total_area	year built, building square footage
San Mateo County	SMC_Land Use Codes_Data.xlsx		Only used for reference due to data completeness in ReGrid
Santa Clara County	BH_Res_Sqft_1.csv BH_Res_Yr_2.csv BH_Com_Sqft_6.xslx BH_Com_Yr_7.xlsx		Only used for reference due to data only being available by zip code
US Census	ACSDT5Y2022.B25034-Data.csv ACSDT5Y2022.B25040-Data.csv ACSST5Y2022.S1901-Data.csv DECENNIALDHC2020.H10-Data.csv		Used for reference, only available as aggregated data for residential uses. Includes data for tenure, income, year built, and heating fuel.
California Bureau of Equalization	California_City_and_County_Boundaries	COUNTY, CITY, COPRI	Jurisdiction
OpenStreetMap	osm_buildings		Did not use due to quality concerns
ASHRAE	county_climate_zones	ASHRAE_CZ	Climate zone
CalEnviroScreen	SB535 Census Tract Designations 2022	DAC_category	Disadvantaged Community

Building Typologies

Specific to the data indicators for parcel use type, the hierarchy of use shown in Figure 2 was utilized to determine the best available source of building use type, prioritizing perceived higher quality data sources. Data was cleaned such that buildings smaller than typical functional areas (500 SF) were removed prior to classification.

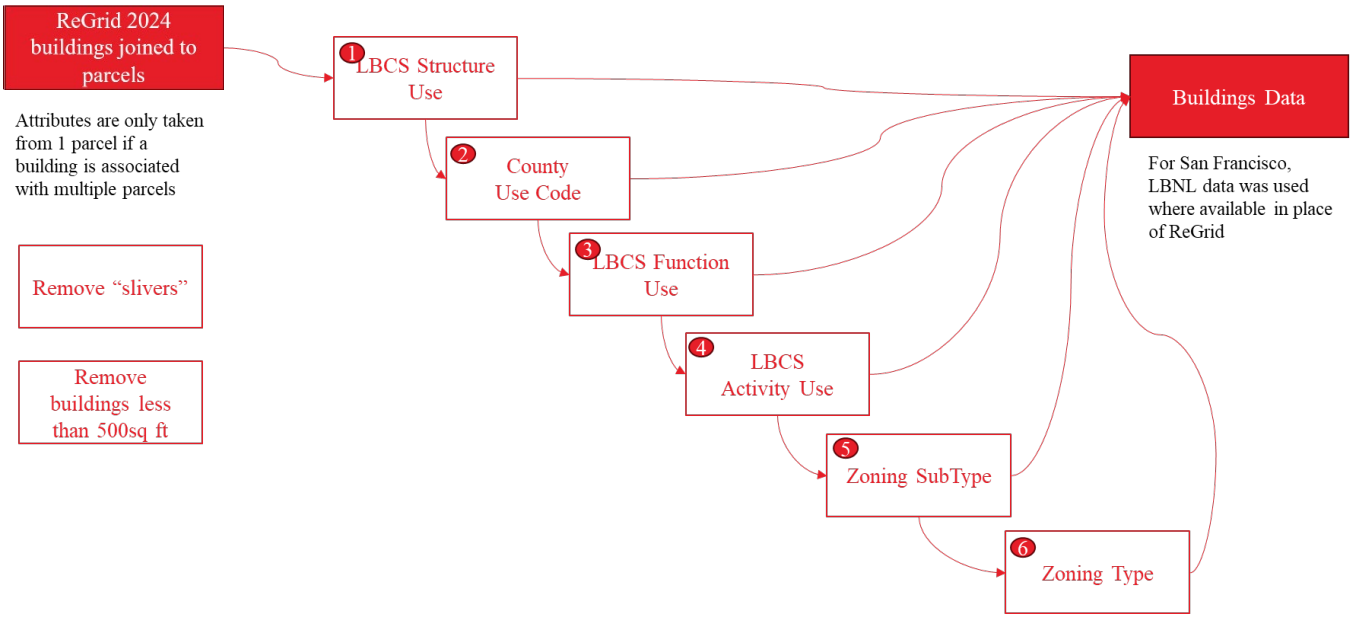

Figure 2 Workflow for classifying building use.

Due to difference in naming conventions and local survey processes, combined residential and commercial building parcel data from all counties included 368 and 683 county-specific typology indicators, respectively. These were aggregated into 105 unified categories for a few purposes: applying building GFA when unknown from parcel data according to an assumed default area per typology (see details in the subsequent section), applying vintage distributions for buildings whose ages were unreported in parcel data, and deriving EUI. These were then grouped further into the 23 distinct typologies that are represented in the dashboard, per the figure below.

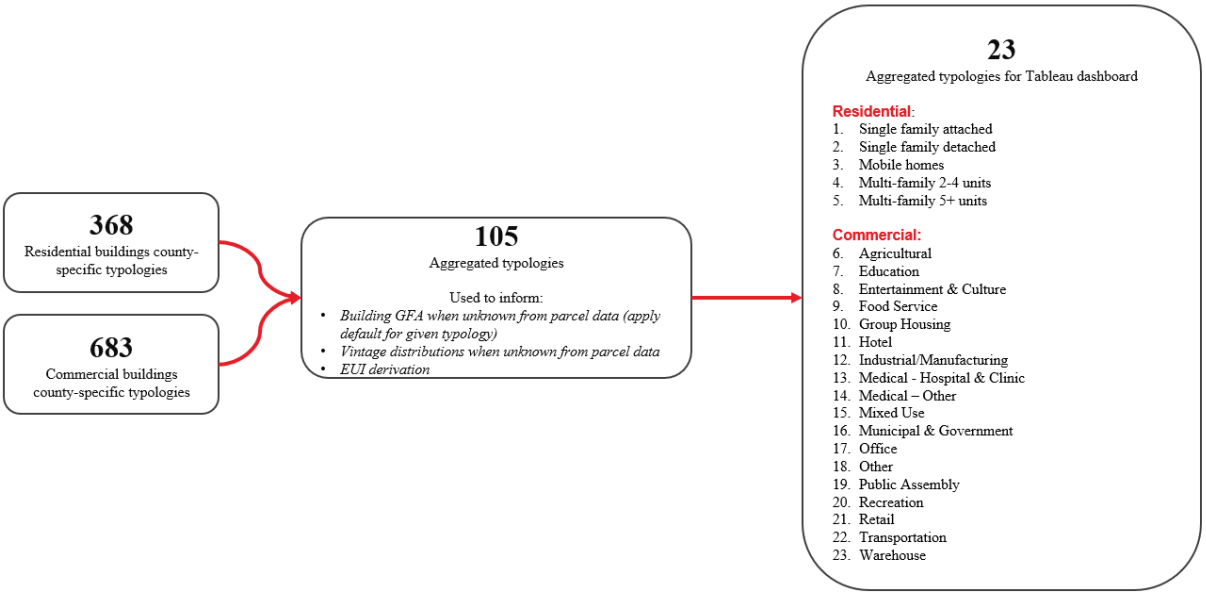

Figure 3 Method to align county-specific typologies from parcel data to unified groupings.

For residential buildings, comprehensive parcel data was assembled for each county except for Marin which was observed to be missing multifamily residential building data. Census data was leveraged to fill these typology gaps for Marin County. The appendix on baseline residential data compares the distributions of building types and vintages in the census data with the original parcel data as well as the combined parcel and census data to show any adjustments made.

For commercial buildings, most counties (all but Marin and Napa) included reasonable distributions of building typologies, with <5% of parcels having non-discernable typologies. For these counties' non-identifiable parcels, building types were inferred based on the given county's trends for known commercial buildings. However, parcel data for Marin and Napa counties was observed to contain high percentages (>30%) of buildings where the typology was unable to be discerned from parcel data records. For these two counties, non-identifiable parcels were assumed to follow the typology trends of neighboring counties. The commercial building breakdown by county is summarized in the table below.

Table 3: Commercial parcels typology breakdown by county with method for applying typology trends to non-identifiable parcels shown in the last row. High percentages of non-identifiable parcels for Marin and Napa counties are highlighted in red.

			Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
		Total County Parcels:	33,218	37,561	10,059	5,733	13,072	16,301	37,527	13,729	18,376
Dashboard Typology	Total Qty	Total Qty Share	County Share	County Share	County Share	County Share	County Share	County Share	County Share	County Share	County Share
Agricultural	12,212	6.6%	3.3%	2.9%	9.9%	13.4%	0.0%	4.9%	11.1%	10.7%	10.0%
Education	9,476	5.1%	1.8%	7.1%	0.0%	0.0%	1.0%	11.1%	5.8%	1.7%	10.3%
Entertainment & Culture	15,286	8.2%	0.0%	39.5%	0.0%	0.0%	0.3%	0.0%	0.7%	0.2%	0.7%
Food Service	2,078	1.1%	2.0%	0.9%	0.0%	1.3%	0.0%	2.0%	0.0%	2.1%	2.0%
Group Housing	1,037	0.6%	0.4%	0.2%	0.0%	0.0%	0.7%	1.6%	1.2%	0.0%	0.0%
Hotel	3,124	1.7%	0.9%	1.8%	0.0%	13.4%	4.6%	1.8%	0.0%	0.9%	2.0%
Industrial/Manufacturing	28,445	15.3%	15.4%	13.1%	6.7%	11.4%	16.3%	13.9%	20.5%	14.9%	16.1%
Medical - Hospital & Clinic	1,418	0.8%	0.6%	1.2%	0.0%	0.0%	0.3%	0.6%	0.4%	0.5%	2.2%
Medical - Other	1,129	0.6%	2.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.6%	0.0%	0.9%
Mixed Use	6,521	3.5%	0.8%	0.6%	0.0%	0.1%	24.0%	9.1%	0.7%	1.4%	5.1%
Municipal & Government	19,264	10.4%	26.4%	10.7%	0.0%	0.0%	1.3%	0.2%	4.8%	28.3%	3.2%
Office	20,682	11.1%	8.1%	3.5%	41.0%	2.1%	22.7%	10.3%	13.1%	10.0%	8.2%
Other	5,992	3.2%	0.0%	3.1%	2.5%	0.0%	1.9%	6.9%	4.6%	4.6%	4.6%
Public Assembly	9,667	5.2%	5.1%	2.4%	4.4%	0.9%	3.9%	5.8%	7.4%	5.6%	8.6%
Recreation	3,914	2.1%	1.9%	2.6%	2.5%	1.2%	0.0%	2.4%	2.4%	0.0%	3.8%
Retail	24,015	12.9%	17.4%	8.0%	0.0%	1.2%	18.7%	10.8%	22.1%	7.4%	8.8%
Transportation	1,828	1.0%	0.5%	0.9%	0.0%	0.0%	1.8%	3.0%	0.5%	0.3%	2.1%
Warehouse	11,002	5.9%	12.5%	1.5%	0.0%	0.7%	1.0%	12.3%	3.8%	6.9%	9.4%
Unspecified Commercial	8,490	4.6%	0.7%	0.1%	32.9%	53.2%	1.4%	3.4%	0.4%	4.6%	1.9%
		Method to allocate unspecified parcels:	*Distribute based on Alameda trends*	*Distribute based on Contra Costa trends*	*Distribute based on Sonoma & San Francisco trends*	*Distribute based on Solano & Sonoma trends*	*Distribute based on San Francisco trends*	*Distribute based on San Mateo trends*	*Distribute based on Santa Clara trends*	*Distribute based on Solano trends*	*Distribute based on Sonoma trends*

Building Areas

Next, the team assessed completeness of building gross floor area (GFA) values in the parcels datasets. Where data gaps existed in parcel data, the GFA was inferred by multiplying footprint by number of stories. Where parcels were missing both GFA and data on number of stories, GFA was estimated using an assumed default GFA for the given typology. Default GFA was assumed based on the following sources, in order of priority:

- Average GFA across complete parcels data when a large sample size exists for a given building type.
- California Building Energy Benchmark Program average GFAs for a given building type.

The following figure illustrates the logical flow for determining GFA.

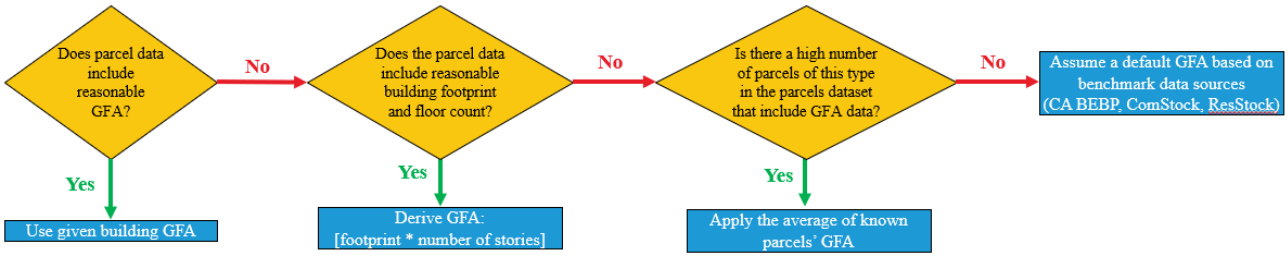

Figure 4. Logic for assembling building gross floor area (GFA) data and deriving GFA estimates where data gaps exist.

Once building areas were derived, some corrections were applied to select residential parcels typology indicators to rectify cases where typologies were clearly mis-assigned in the parcel dataset. The criteria for these corrections included:

- Detected single family residential parcels (attached or detached) whose floor counts were 5 or more; recategorize as multi-family 5+ units (applied to 137 total parcels)
- Detected single family residential parcels (attached or detached) whose derived gross floor areas were >15,000ft2; recategorize as multi-family 5+ units (applied to 530 parcels)
- Detected single family detached parcels whose derived gross floor areas were 7,500ft2 or larger; recategorize as single family attached (applied to 2,198 parcels)

Building Vintages

Next, the team assessed completeness of building age (vintage) data in the parcels dataset. Missing vintage data was distributed based on ResStock and ComStock[1] vintage trends for the given county and building type.

[1] NREL's ResStock and ComStock databases provide comprehensive tools for analyzing residential and commercial building characteristics and energy performance. This data is derived from various sources, including the U.S. Census, the Energy Information Administration, and utility records, enabling accurate modeling of characteristics and energy consumption. Because of regional sampling that helped to compose the data set, these sources are detailed enough to provide statistics that are locally accurate (to the county level).

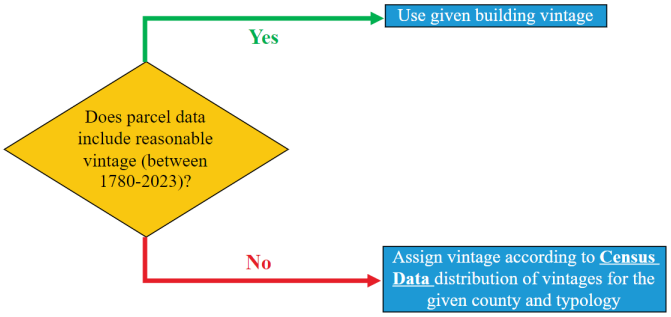

Figure 5. Process for assigning commercial building vintage data.

Building Heating Fuels

Heating fuel (fossil fuel vs. electric) does not appear in parcels dataset, so these properties were inferred based on trends from select building databases (census data and ComStock). The following table summarizes the method of inferring heating fuels for each dashboard typology. For the purpose of the dashboard display, all fossil heating sources (natural gas, propane, fuel oil, etc.) were grouped under the category of "Mixed Fuel."

Table 4: Method for inferring building heating fuel per typology

	Dashboard typology	Source of heating fuel lookup
Residential	Single family detached	Census data
	Single family attached	Census data
	Mobile homes	Census data
	Multi-family 2-4 units	Census data
	Multi-family 5+ units	Census data
Commercial	Agricultural	All ComStock typology trends (Agricultural buildings not present in ComStock)
	Education	ComStock trends for Primary School / Secondary School
	Entertainment & Culture	All ComStock typology trends (Entertainment buildings not present in ComStock)
	Food Service	ComStock trends for Full Service Restaurant / Quick Service Restaurant
	Group Housing	All ComStock typology trends (Group Housing buildings not present in ComStock)
	Hotel	ComStock trends for Large Hotel / Small Hotel
	Industrial/Manufacturing	All ComStock typology trends (Industrial buildings not present in ComStock)
	Medical - Hospital & Clinic	ComStock trends for Hospital / Outpatient
	Medical - Other	ComStock trends for Hospital / Outpatient
	Mixed Use	All ComStock typology trends (Mixed Use buildings not present in ComStock)
	Municipal & Government	ComStock trends for Small Office / Medium Office / Large Office
	Office	ComStock trends for Small Office / Medium Office / Large Office
	Other	All ComStock typology trends
	Public Assembly	All ComStock typology trends (Public Assembly buildings not present in ComStock)
	Recreation	All ComStock typology trends (Recreation buildings not present in ComStock)
	Retail	ComStock trends for Retail Strip Mall / Retail Standalone
	Transportation	All ComStock typology trends (Transportation buildings not present in ComStock)
	Warehouse	ComStock trends for Warehouse

Disadvantaged Communities Status

Buildings were identified as falling within a disadvantaged community if any part of the building intersected the SB 535 Disadvantaged Communities 2022 (Census Tracts) data from CalEnviroScreen.

Energy Use Intensity

Residential Buildings EUI

To determine the baseline energy use of residential buildings, the team utilized the National Renewable Energy Laboratory's (NREL) ResStock tool. This tool contains a set of residential building models that collectively represent characteristics of the national building stock. The ResStock database was generated using data from the following sources:[2]

- Energy Information Administration's (EIA) 2009 and 2020 Residential Energy Consumption Survey (RECS)
- U.S. Census and American Community Survey
- Homeland Infrastructure Foundation-Level Data (HIFLD)
- Historic energy code requirements
- Regional building stock assessments and field studies
- Component-specific studies produced by national labs or adjacent organizations
- Engineering calculations and assumptions

The building types available in ResStock are: single family (attached or detached), multi-family including those with 2-4 units, 5+ units spanning 1-3 stories, and 5+ units spanning 4+ stories, and mobile homes. Each of these are further divided by vintage, which is available by decade from pre-1940s to post-2010s. Since ResStock includes a wide range of energy efficiency packages (including various levels of envelope and electrification measures) it can be used to generate both the baseline and retrofit energy use and emission results.[3]

ResStock default distributions for building type, location, and vintage are primarily determined from samples such as RECS and the U.S. Census. Building characteristics for the models are determined using a probability distribution based on dependent variables which can include building type, location, home vintage, income level, household size, occupant type (owner or renter), or other component characteristics. The characteristics assigned to the models include envelope components, HVAC types, and fuels used but also behavioral characteristics such as thermostat setpoints and occupancy patterns. Buildings are modeled in OpenStudio and EnergyPlus with Typical Meteorological Year (TMY3) weather files to determine both annual and 15-minute energy consumption by end use and fuel type for every combination of characteristics that may be present in a home within the scope of characteristics considered in ResStock. The appendix on baseline residential data compares the distributions of ResStock with more recent census data to identify the differences between the ResStock weights and what is used to fill in gaps of the parcel data, as described in the previous sections.

The weights of the models, also determined through the sources above, can be used to aggregate the energy results based on desired groupings, such as county, building type, fuel type, and vintage.[4] [5] The most granular geographical areas available for aggregation in ResStock are cities (only those with more than 15,000 dwelling units, which accounts for 47 cities in BayREN territory) and Public Use Microdata Area (PUMA) from 2019 U.S. Census (55 distinct PUMAs in BayREN territory).

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[2] NREL. "Housing Characteristics." 2024. https://github.com/NREL/resstock/blob/v3.1.1-2024.1/docs/read_the_docs/source/workflow_inputs/characteristics.rst

[3] ResStock models include rooftop photovoltaic systems in some of the baseline detached single-family models (varying in system size and orientation based on an LBNL survey of rooftop solar installations) and outputs the generation in kWh.

[4] Present, Elaina, Philip R. White, Chioke Harris, Rajendra Adhikari, Yingli Lou, Lixi Liu, Anthony Fontanini, Christopher Moreno, Joseph Robertson, and Jeff Maguire. 2024. ResStock Dataset 2024.1 Documentation. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-88109. https://www.nrel.gov/docs/fy24osti/88109.pdf.

[5] The results available from ResStock are based on the 2018 national building stock. ResStock does allow users to customize the probability distributions used to develop the models and aggregate the results, although this requires substantial computational time.

To summarize the modeled energy results from ResStock for BayREN territories, the team aggregated building EUI within the following categories:

- County
  - 9 BayREN counties
- Residential Building Type
  - Mobile Home
  - Multi-Family with 2 - 4 Units
  - Multi-Family with 5+ Units
  - Single-Family Attached
  - Single-Family Detached
- Vintage
  - By decade from pre-1940s to post-2010s
- Heating fuel
  - Electric or mixed fossil fuel (an aggregation of all non-electric heating fuels)

The average EUI aggregated for each of the category combinations listed above are available in spreadsheet format and included in the data dashboard. To summarize the range of the modeled EUIs, Figure 6 shows box and whisker plots for the EUI of each building type across all BayREN counties, vintages, and heating fuels.[6]

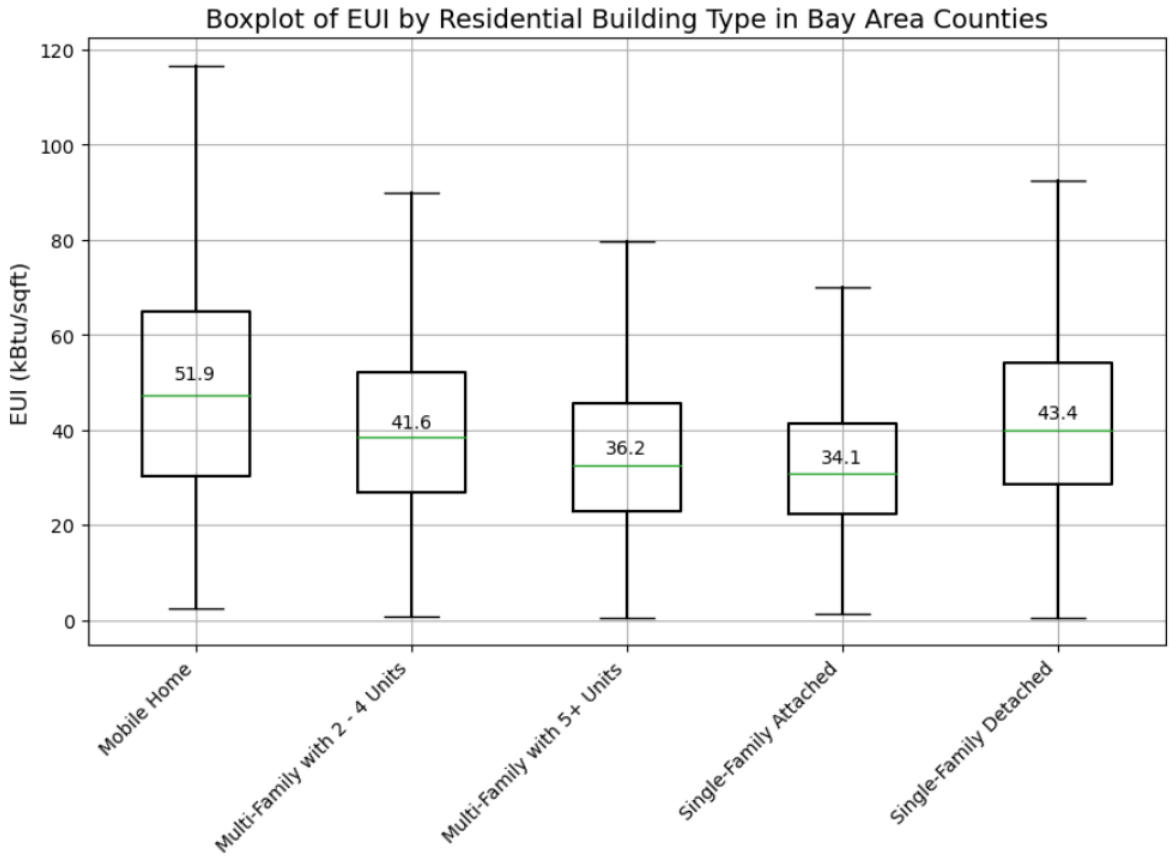

Figure 6: Residential EUIs per ResStock

[6] The mean EUI for each type is labeled within the box. The figure omits outliers, which stretch past 300 kBtu/ft2 for some building types, as they are a function of very small units with highly inefficient equipment and only represent a very small fraction of homes within each type. A literature review performed by the team found an average EUI of 36.7 kBtu/sqft for single-family homes and 44.4 kBtu/sqft for multifamily homes. While the ResStock average values differ slightly, these are well within the middle 50th percentile of the different single-family and multi-family EUI ranges.

Commercial Buildings EUI

For commercial buildings, the team leveraged three primary data sources to accurately represent the distribution and energy intensities of Bay Area buildings:

- Tax parcel data: County parcel data combined with the ReGrid data set was used to inform quantities of commercial buildings in each of the 9 Bay Area counties, by use type.[7]
- ComStock: Developed by NREL, ComStock provides a highly granular model based on statistical sampling methods to estimate energy consumption of U.S. commercial building stock.[8]
- EUI benchmarking data: As a benchmarking reference for energy consumption, commercial building energy data was pulled from the sources listed below. For any given typology, the benchmarking source with the greatest sample size of corresponding buildings was selected:
    - California Energy Commission Building Energy Benchmark Program[9]
    - Lawrence Berkeley Lab (LBL) Building Performance Database, filtered to include Bay Area region only[10]
    - 2022 California Commercial End-Use Survey (CEUS)[11]
    - San Francisco Existing Buildings Energy Performance Ordinance Report[12]

[7] ReGrid Support

[8] ComStock Reference Documentation: Version 1. NREL, 2023. https://www.nrel.gov/docs/fy23osti/83819.pdf

[9] https://www.energy.ca.gov/programs-and-topics/programs/building-energy-benchmarking-program

[10] https://bpd.lbl.gov/

[11] https://www.energy.ca.gov/publications/2023/2022-california-commercial-end-use-survey-ceus-final-report#:~:text=The%202022%20California%20Commercial%20End,to%20the%20California%20Energy%20Commission.

[12] https://www.sfenvironment.org/existing-buildings-energy-performance-ordinance

ComStock categorizes buildings according to the following criteria:

Table 5: ComStock Building Categorization and Available Measures

Typologies:	Vintages:	Number of Stories:	Floor Area:	Measures Included (Latest dataset)
• Full-Service Restaurant • Hospital • Large Hotel • Large Office • Medium Office • Outpatient • Primary School • Quick Service Restaurant • Retail Standalone • Retail Strip Mall • Secondary School • Small Hotel • Small Office • Warehouse	• Pre-1946 • 1946-1959 • 1960-1969 • 1970-1979 • 1980-1989 • 1990-1999 • 2000-2012 • 2013-2018	• 1 through 14 • 20 • 30	• <1000 • 1000-5000 • 5000-10,000 • 10,001-25,000 • 25,001-50,000 • 50,001-100,000 • 100,001-200,000 • 200,001-500,000 • 500,001-1,000,000 • >1million	• HP RTU (Multiple Configurations) • VRF (Multiple Configurations) • DOAS HP Minisplits • HP Boiler, Electric or Gas Backup • Air Side Economizers for AHUs • Demand Control Ventilation • Energy Recovery for AHUs • Advanced RTU Controls • Unoccupied AHU Control • Geothermal HP (Multiple Configurations) • Demand Flexibility (Multiple Mechanisms) • Exterior Wall Insulation • Roof Insulation • Secondary Windows • Window Film • New Windows • LED Lighting • Electric Kitchen Equipment

As noted in ComStock documentation, the ComStock data set does not account for every commercial typology. To quantify the share of missing typologies, ComStock documentation summarizes the commercial building types represented in the Commercial Buildings Energy Consumption Survey (CBECS) 2012 dataset, generally deemed to be a comprehensive representation of the range of commercial building types. Of the types represented in CBECS, building types that total 36% of US energy consumption are not included in ComStock. This breakdown is summarized in Figure 7 below.

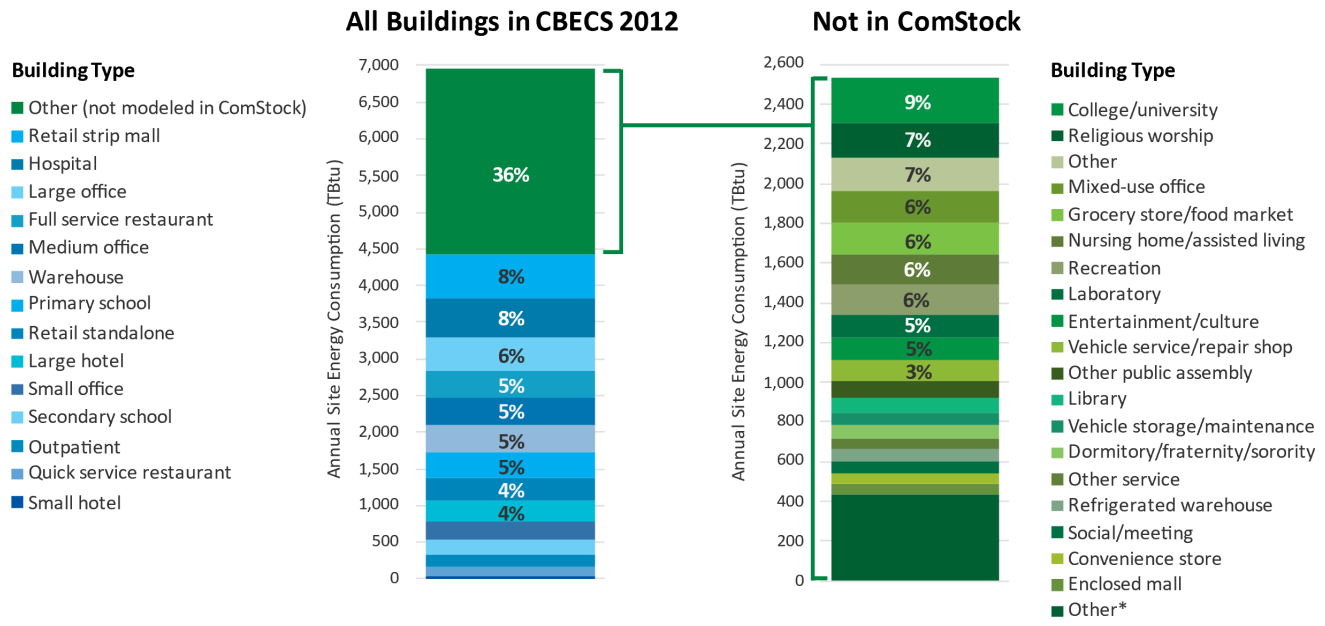

Figure 7: Commercial building typologies represented in the CBECS 2012 data set compared to those represented in ComStock (indicating that ComStock omits approximately 36% of commercial building typologies on the basis on energy consumption)

Tax parcel data was assembled for a preliminary aggregation of commercial building quantities and typology breakdowns for Bay Area counties. Across 9 Bay Area counties, 683 county-specific typologies were observed, which were aggregated into 100 aligned typologies. These were further grouped into 18 building types to be displayed in the Tableau dashboard.

A complete list of the 100 aligned typologies and corresponding dashboard categorizations and EUI derivation sources are provided in the appendix.

EUIs were derived for each of the 100 commercial buildings sub-typologies with variation to account for vintage and heating fuel. Subsequently, for each county, the weighted average EUI was calculated for the 18 typologies represented in the dashboard. Each county's EUI for a particular dashboard typology, vintage, and heating fuel are a result of the unique breakdown of detailed typologies that are present within the county.

The team applied the ComStock dataset for an initial estimation of EUI by building type. According to ComStock documentation published by NREL, "ComStock quantifies energy use across geographical locations, building types and end uses, and time of day. Additionally, it identifies the impact of efficiency measures: how much energy different efficiency measures save; where or in what use cases efficiency measures save energy; when or at what times of day savings occur; and which building stock segments have the biggest savings potential." ComStock is based on two primary data sources: CoStar (a commercial building real estate intelligence broker) and Homeland Infrastructure Foundation-Level Data (HIFLD) (a Department of Homeland Security database of United States buildings infrastructure).

To summarize the range of the commercial EUIs modeled in the ComStock data set, the figure below shows box and whisker plots for the EUI of each building type across all BayREN counties, vintages, and heating fuels.[13]

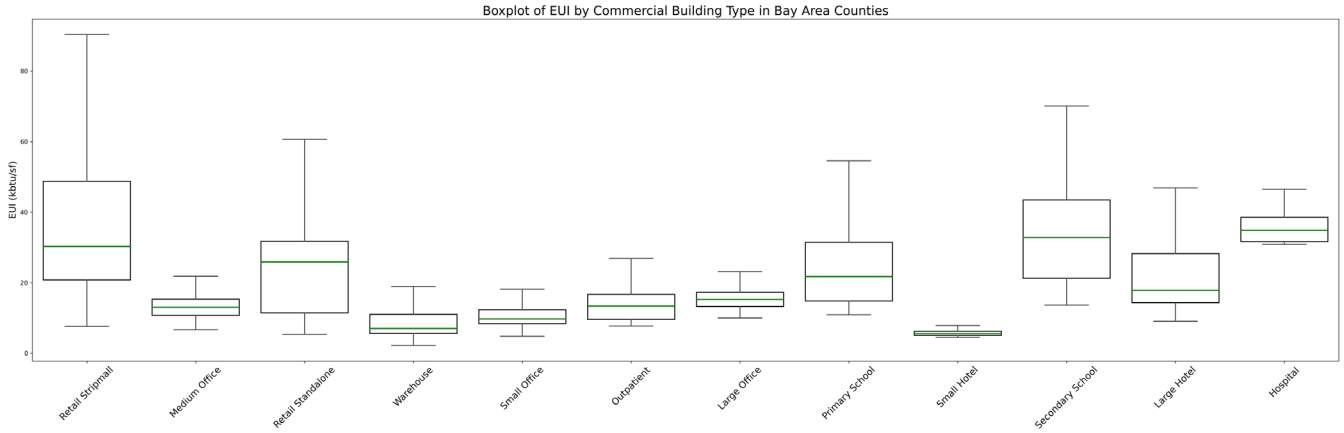

Figure 8: Bay Area commercial building EUIs as represented in the ComStock data set, by typology (restaurant typologies omitted)

The team then mapped the 100 sub-typologies represented in tax parcel data to other building energy databases and benchmarking sources. Given the high level of detail of the tax parcel sub-typologies, there are cases where a typology is not adequately represented by one of the available ComStock typologies. In these cases, the team correlated with the closest-matching ComStock typology (or a blend of numerous ComStock typologies).

For parcel typologies which were not well represented by the 14 available ComStock typologies, the team used benchmarked EUI data from existing building surveys to calibrate ComStock models as needed. In such cases, the closest-matching ComStock typology was applied, with the ComStock-informed EUI being scaled up or down to better align with the EUI determined through the benchmarking exercise. Commercial energy use baselines were acquired from the 2022 California Commercial End-Use Survey (CEUS) and the San Francisco Existing Buildings Energy Performance Ordinance Report. To get values more closely aligned to BayREN territory, the California CEUS was further segmented to only include PG&E data, allowing the team to exclude values for LADWP, SMUD, and SDG&E. This was accomplished by utilizing Appendix K – Results at Building-type and End-Use Levels.

Table 6: Commercial buildings EUI derivation and benchmarking data sources

Group	Energy derivation description	End use breakdown source	EUI source
1	Disregard due to near-zero energy consumption or niche use type / non prevalence	N/A (Include in dashboard building counts but assume little-to-no energy)	N/A (Include in dashboard building counts but assume little-to-no energy)
2	Strong alignment with one or multiple ComStock typologies	ComStock (One typology or blended multiple typologies)	ComStock (One typology or blended multiple typologies)
3	Partial alignment with Comstock / Scaling required	ComStock (Blended multiple typologies)	ComStock (Blended multiple typologies) Calibrate using: • CA Benchmark Data • Energy Atlas
4	Partial alignment with Comstock / Add Manual Process Loads & End Uses	ComStock (Blended multiple typologies) + Additional Process Loads / End Uses	ComStock (Blended multiple typologies) Calibrate against CA Benchmark Data

[13] The median EUI for each type is shown with green lines within each box. The figure omits outliers and omits the typologies "Quick Service Restaurant" and "Full-Service Restaurant" which have a wide range of EUIs based on the highly variant activities in restaurants. For these typologies, the team employed an averaging approach based on benchmarking data for Bay Area restaurant buildings to assign representative, weighted-average EUIs.

Building Emissions

After deriving electricity and mixed-fuel EUIs for each residential and commercial building type, the team applied emissions factors for each fuel to derive total building emissions. Electricity and gas emissions factors are summarized below.

Fuel	Emissions Factor	Source
Electricity	56 lbs CO2e/MWh	PG&E Power Content Label (2022)[14] Base Plan emissions (2022 represents the most recent data released from PG&E)
Natural Gas	399 lbs CO2e/MWh	U.S. EPA Greenhouse Gas Equivalencies Calculator, Natural Gas fuel[16]

As a separate exercise, the team will study the impact of more detailed hourly emissions factor assumptions on the calculated savings from building decarbonization measures; this exercise will inform the extent to which certain time-of-use measures show improved performance when variable emissions factors are applied.

Data Storage and Management

To make the processed data accessible and understandable to users, the team developed a Tableau dashboard. Data extract (a snapshot of the data that is optimized for fast querying and visualization) is created within Tableau. The tableau dashboard is published publicly ensuring that users can easily consume and interpret insights derived from the data, without needing a log in. Moving forward the team will push the final data to Amazon Redshift which will be connected to the Tableau dashboard.

[14] https://www.pge.com/assets/pge/docs/account/billing-and-assistance/bill-inserts/1023-Power-Content-Label.pdf
[16] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Implementation and Next Steps

- Data is displayed in a Tableau dashboard which includes filters for attributes such as County, City, Type, and Age Class. The dashboard includes a map showing jurisdictions, graphs and a summary table showing data aggregated by jurisdiction. All visualizations respond to the filter selections.
- Moving forward, the team will use insights from GIS data aggregation to add nuance to our understanding of the Bay Area building stock in relation to ResStock and ComStock data and categorization groupings and to refine benchmarking EUI and GHG emissions predictions.
- In further iterations of the dashboard, the team will use ResStock and ComStock EnergyPlus models to evaluate high impact energy conservation measures.

Task 2 Appendix: Baseline Residential Data

Overview

In earlier tasks, the team determined that ResStock can be used to generate both the baseline and retrofit residential models since it includes a variety of residential building types and a wide range of energy efficiency packages (including various levels of envelope and electrification measures). However, in Task 2, the team explored how the model *distributions* compare to the current Bay Area building stock as characterized in the main body of the Task 2 report.

In Task 2, the baseline residential energy and emissions were quantified using three main sources (more details on this methodology are available in the main body of the Task 2 report):

- Parcel data (Regrid and county data)
    - Used for determining building type and vintage of each parcel, where possible
- U.S. Census data (2018-2022 American Community Survey)
    - Used for filling in gaps in building type and vintage by location where parcel data was unavailable
- NREL's ResStock tool
    - Used for estimating energy performance for a given building type, vintage, and location

The parcel data and the newest U.S. Census contain more recent data than the latest version of ResStock, which uses the 2015-2019 American Community Survey and the 2020 Residential Energy Consumption Survey from the Energy Information Administration (EIA). To provide an accurate representation of the current Bay Area building stock, the team wanted to include the most recent data available. There are two main options to incorporate this newer data into the energy modeling results: 1. Reweight and rerun the ResStock dataset or 2. Use the ResStock dataset as-is and apply post-processed weights to accurately represent the building counts and sizes of each category of buildings.

The RR team discussed these approaches with NREL staff and decided to move forward with the second option. Rerunning the ResStock dataset is very computationally intensive, while applying post-processed weights would still provide the level of detail necessary for the Tableau tool.

This analysis provided guidance on how to develop the post-processed weighting methodology (described in the main body of the report). It compares the distribution of critical housing characteristics (location, typology, vintage, and heating fuel) in the parcel data, most recent census, and ResStock.

Data Summary: This analysis showed any discrepancies between the building stock data sources and the ResStock building distributions to help confirm the use of parcel and census data for determining a representative, up-to-date building stock. ResStock will only be used to provide an average energy use intensity (EUI) for each building category (each combination of vintage, type, location). EUI will be converted to emissions using emission factors for each fuel type.

ResStock Release Versions

The ResStock building types are: single family (attached or detached), multifamily including those with 2-4 units, 5+ units spanning 1-3 stories, and 5+ units spanning 4+ stories, and mobile homes. Each of these are further divided by vintage, which is available by decade from pre-1940s to post-2010s. ResStock also includes rooftop photovoltaic systems in some of the baseline detached single-family models (varying in system size and orientation based on an LBNL survey of rooftop solar installations) and outputs the generation in kWh. Since ResStock includes a wide range of energy efficiency packages (including various levels of envelope and electrification measures) it can be used to generate both the baseline and retrofit energy use and emission results. ResStock default distributions for building type, location, and vintage are primarily determined from samples such as the Residential Energy Consumption Survey (RECS) and the U.S. Census.

As a first step, the team needed to determine which version of ResStock to use. The following table shows the differences between inputs and outputs in the four releases of ResStock. 2024.1 and 2024.2 are the most recent releases, but the earlier releases are also included for reference.

Table 1. ResStock Release Versions.

Data Source		ResStock Release				Most Recent Version of Data Source
		2021.1	2022.1	2024.1	2024.2	
RECS Version		2009	2009	2020	2020	2020
ACS Version		2012-2016	2015-2019	2015-2019	2015-2019	2018-2022
PUMS Version		2017	2019	2019	2019	2022
Time granularity	15-min	Y	Y	---	Y	---
	Annual	Y	Y	Y	Y	---
Weather files	TMY3	Y	Y	Y	Y	---
	AMY2012	---	Y	---	---	---
	AMY2018	Y	Y	---	Y	---
# of Measure packages		None	10	260*	15	---
Variable speed HP/GSHP available?		---	---	---	Y	---
# of real units represented by each model**		~242	~242	~63	~252	---

* The 260 measure packages include 55 distinct measures falling into 15 categories.
**A smaller number of units represented by each model means the dataset is more granular.

Model Granularity

A key difference between the releases is that ResStock 2024.1 has a higher number of models (2.2 million dwelling units), but only provides annual results. In comparison, ResStock 2024.2 provides hourly timeseries data, but has fewer models (550,000). Said another way, there is one 2024.1 model for every 63 homes that exist in the US, while each 2024.2 model represents 252 homes.

ResStock documentation says "a general guideline is to use at least 1,000 samples to maintain approximately 15% or less sampling discrepancy for common quantities of interest….dataset subsets corresponding to sparsely populated areas or uncommon dwelling unit characteristics, or subsets with multiple filter criteria applied to the housing stock characteristics, may have relatively few samples available. In these cases, samples from similar locations can be grouped to increase the sample size until the needs of the particular analysis being performed are met."[1]

All nine Bay Area counties meet this 1,000-sample threshold with 2024.1, but only four do in 2024.2, as shown in Figure 1 below. The most granular ResStock region is PUMA, which is shown in Figure 3 below. Less than

[1] Present, E., et al. "ResStock Dataset 2024.1 Documentation." February 2024. NREL. https://www.nrel.gov/docs/fy24osti/88109.pdf.

half of the Bay Area PUMA regions meet the threshold when using 2024.1 and none of them do when using 2024.2. To minimize errors, the team recommends assuming that buildings with the same type and vintage have the same average EUI across a county, rather than trying to distinguish differences in average EUI at the jurisdiction level.

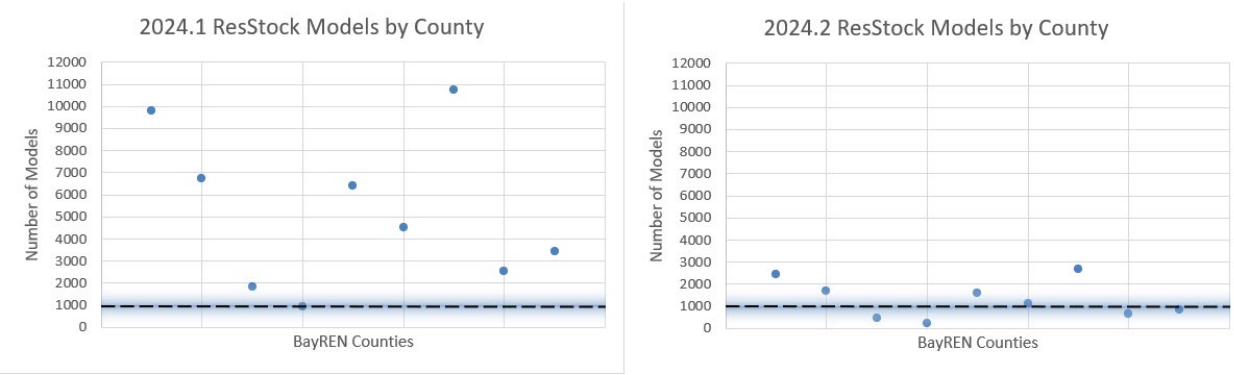

Figure 1. Number of Models by County for 2024.1 vs. 2024.2 Compared to 1,000-Sample Threshold

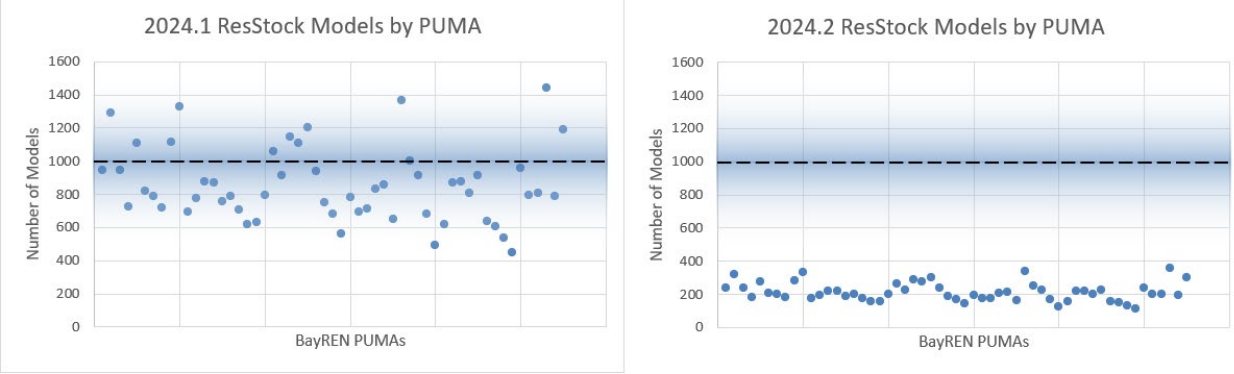

Figure 2. Number of Models by PUMA for 2024.1 vs. 2024.2 Compared to 1,000-Sample Threshold

Measure Packages

ResStock 2024.1 has 260 decarbonization measure packages while ResStock 2024.2 only has 15, so the team could better tailor decarbonization results to measures recommended by the team in Tasks 3 and 4 with ResStock 2024.1.

However, two drawbacks of 2024.1 are the lack of hourly data and the lack of variable-speed and ground source heat pumps. The team can leverage the strengths of both versions by using 2024.2 for the "explainer cases" to look at hourly impacts of select decarbonization options on select home types.

In parallel, the team can compare the annual impact of variable speed and ground source heat pumps available in 2024.2 to the heat pump types available in 2024.1. If either advanced heat pump type is recommended as a decarbonization solution for Bay Area homes, the team could post-process the difference in energy use. However, given the Bay Area's relatively mild climate, the difference in performance may be small. At a minimum, the team can document the difference in performance of each heat pump type on an hourly and annual basis and note possible applications in the final reporting.

ResStock release recommendation: The team recommends using the 2024.1 ResStock release for the primary EUI analysis, but supplement with 2024.2 as needed to highlight differences in heat pump technologies and hourly performance.

Comparison of Parcel and Recent Census Data

The study will use available parcel data as the main source of building characteristic information and distributions. As needed, this data will be supplemented with data from the newest U.S. Census (the 2018-2022 5-year average for Bay Area housing units) and ResStock. To identify potential gaps in the parcel data, the team first compared the distributions in the parcel data to the newest census data.

One challenge is that the census data records dwelling units, while parcel data usually reports buildings.[2] Translating dwelling units to a whole building requires estimating the number of units in the building, which may not correspond to the real distribution of multifamily building size. Instead, the team opted to compare floor area (rather than total buildings or total estimated units) as a metric for comparison. However, the census did not have granular floor areas by building type or vintage, so the team used average floor sizes by grouping from ResStock, which draws from the US EIA's Residential Energy Consumption Survey (RECS) for floor area distributions.

Additionally, some residential building types and vintages in the real parcel data are unknown and listed as "null." Rather than comparing absolute total floor area, the team compared the percent of total floor area by county, removing the "null" fields, to better compare the distribution of building types and vintages.

This section includes the team's recommendation on where to supplement gaps in the parcel data with census data.

Building Typology

There were some known sources of uncertainty when comparing building typology in the parcel and census datasets. In some cases, post-processing the parcel data was necessary to map the parcel building types to the five building types used to categorize residential buildings for this project. Specific types of multifamily buildings such as condominiums and duplexes are more challenging to identify from parcel data than single family buildings. Additionally, some multifamily buildings may be classified with other commercial types in parcel data in mixed use buildings, or they may even not be classified with any specific building type; neither of these would show up in the residential parcel data. The Arup team has attempted to adjust for these issues where possible, but in general the distribution of available parcel data may not fully represent the distribution of residential building types for all units.

Figure 1 shows the comparison of building types by county. In all nine counties, the percent of total floor area of the single family detached buildings is higher in the parcel data as compared to the census. In every county except Sonoma, this difference for single family detached is more than 10% (ranging from 12-23%). However, for the reasons described above–multifamily buildings categorized as commercial or "null" types; units that the census would classify as multifamily or single family attached getting classified as single family detached in the parcel data–it seems feasible that the known parcel data may overestimate single family detached distribution within all residential units. It is most clear in Marin that multifamily buildings are not appropriately included in the parcel data, as 100% of buildings by area are single family detached.

Building typology recommendation: The team recommended using building typology parcel data for all counties except Marin. Census data was used to supplement the multifamily building counts in Marin.

[2] The parcel data most often reported buildings, however condos are sometimes classified as individual parcels when part of a larger building and some single parcels have multiple multifamily buildings or a single family home with an ADU.

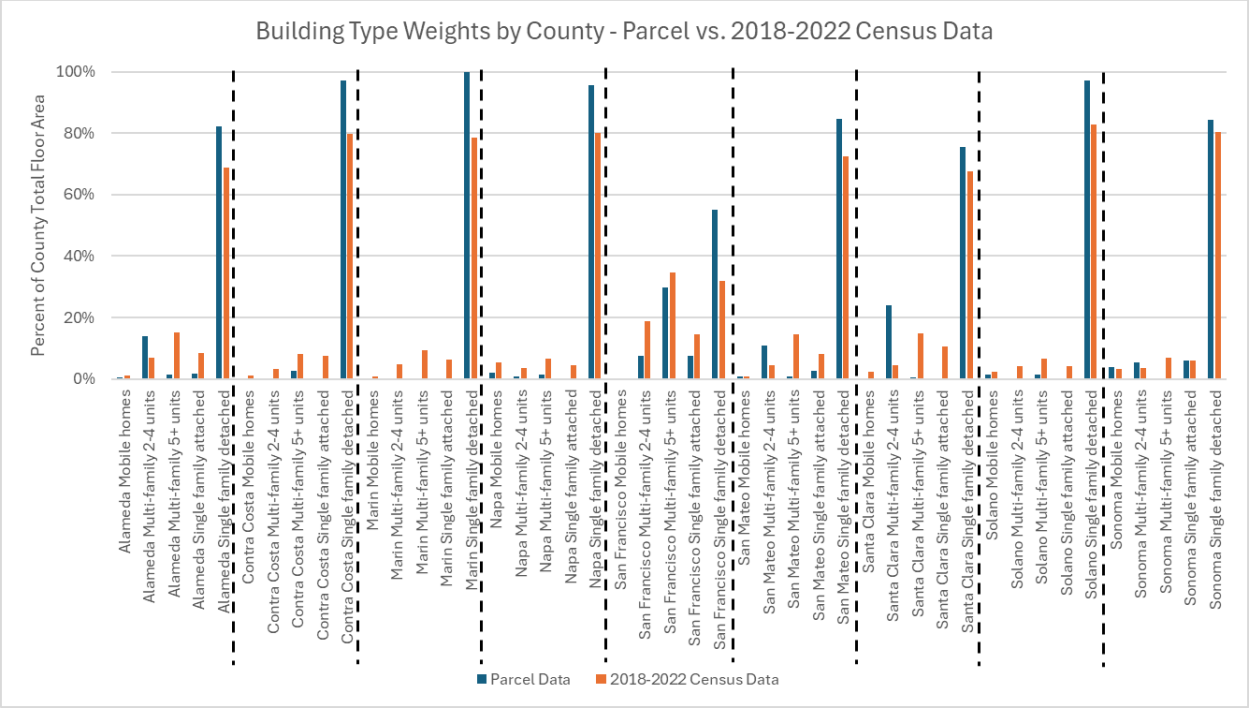

Figure 1. Parcel vs. 2018-2022 Census Building Typology Comparison

Figure 2 shows the comparison of data after the Arup team post-processed the null data. The distributions remain very similar, although there are changes in each county that are hard to visualize in the charts. For example, Marin now includes a small number of mobile homes and multifamily buildings.

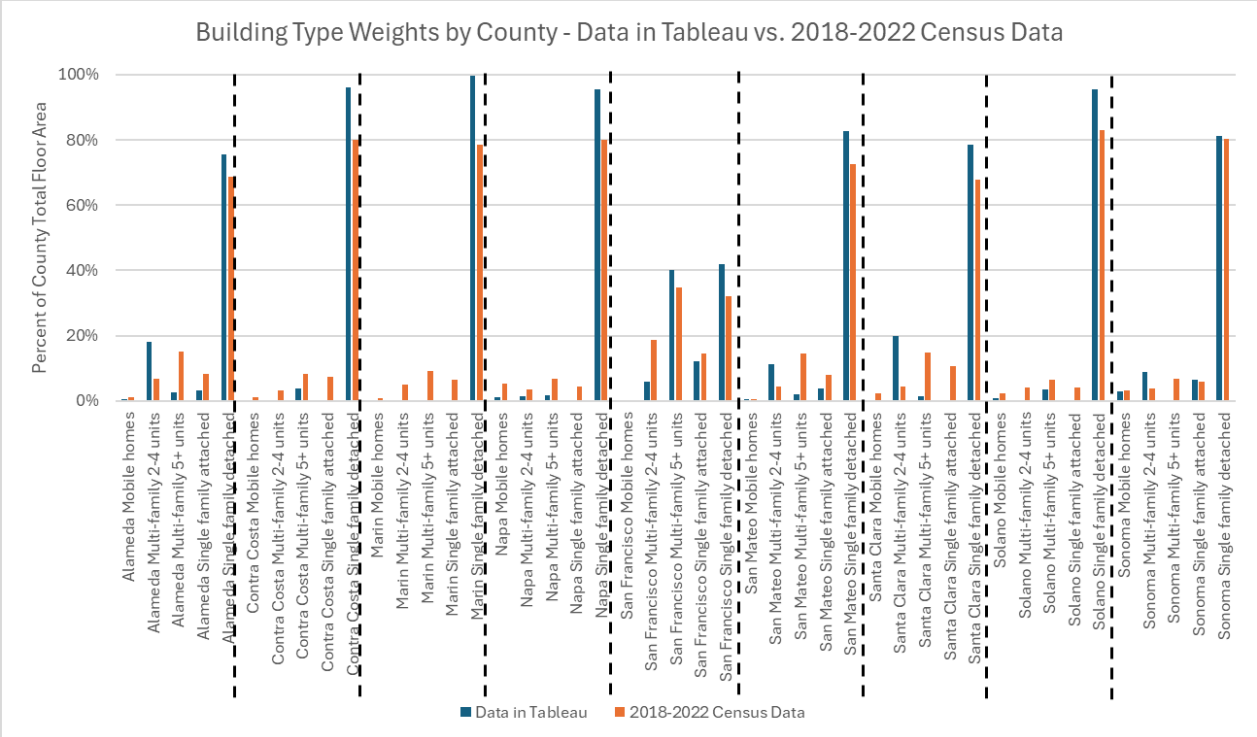

Figure 2. Post-Processed Data in Tableau Tool vs. 2018-2022 Census Building Typology Comparison

Vintage

Figure 3 shows the comparison of vintages by county. Some counties (Alameda, Marin, and Napa) had no vintage data available in the parcel dataset, so those were removed from the comparison. The comparison shows some large discrepancies, which differ in makeup by county. Some counties show a higher percentage of older buildings in the parcel data than in the census data. This is possibly attributable to missing multifamily floor area in the parcel summary data, as noted above. The other counties show large spikes of data in specific decades, such as 1950s San Mateo. This could be due to some county or jurisdiction-specific reporting nuances that may not accurately capture buildings in older years or certain jurisdictions. The percent difference in total county floor area is less than 10% in all cases except <1940 San Francisco and 1950s San Mateo.

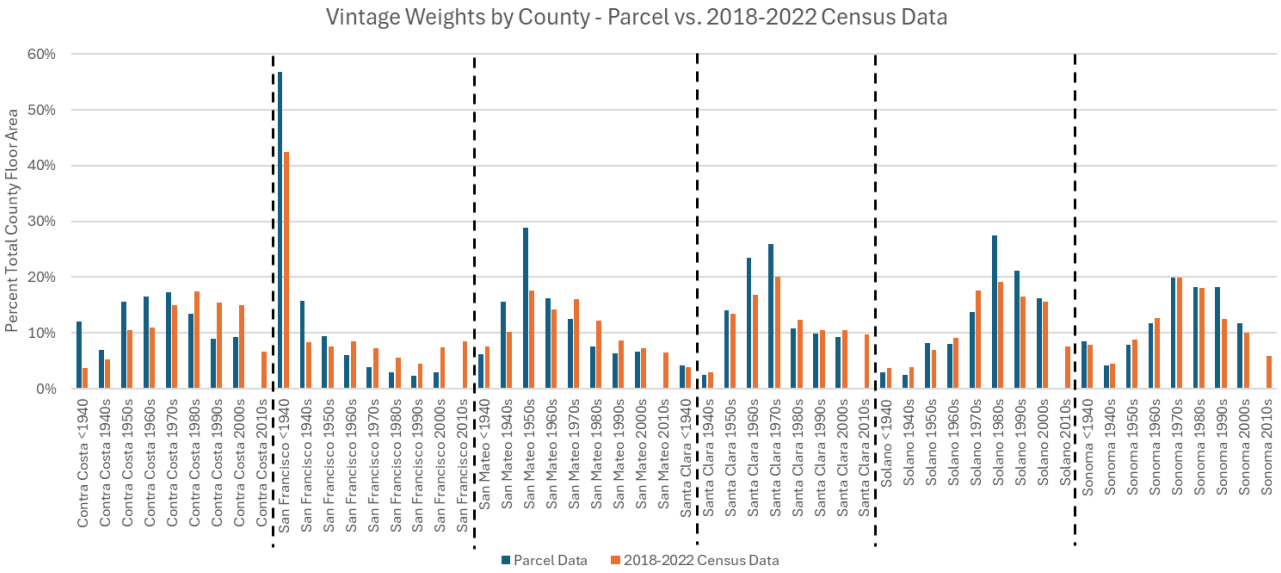

Figure 3. Parcel vs. 2018-2022 Census Vintage Comparison

Vintage recommendation: Where available, the team recommended using year built from the parcel data. Census data was used to provide vintage distributions in Alameda, Marin, and Napa and supplement gaps in all other counties.

Figure 4 and Figure 5 show the post-processed distributions of vintages by county that are used in the Tableau tool. All counties now have available vintage data and there are not quite as many outliers as in the previous comparison.

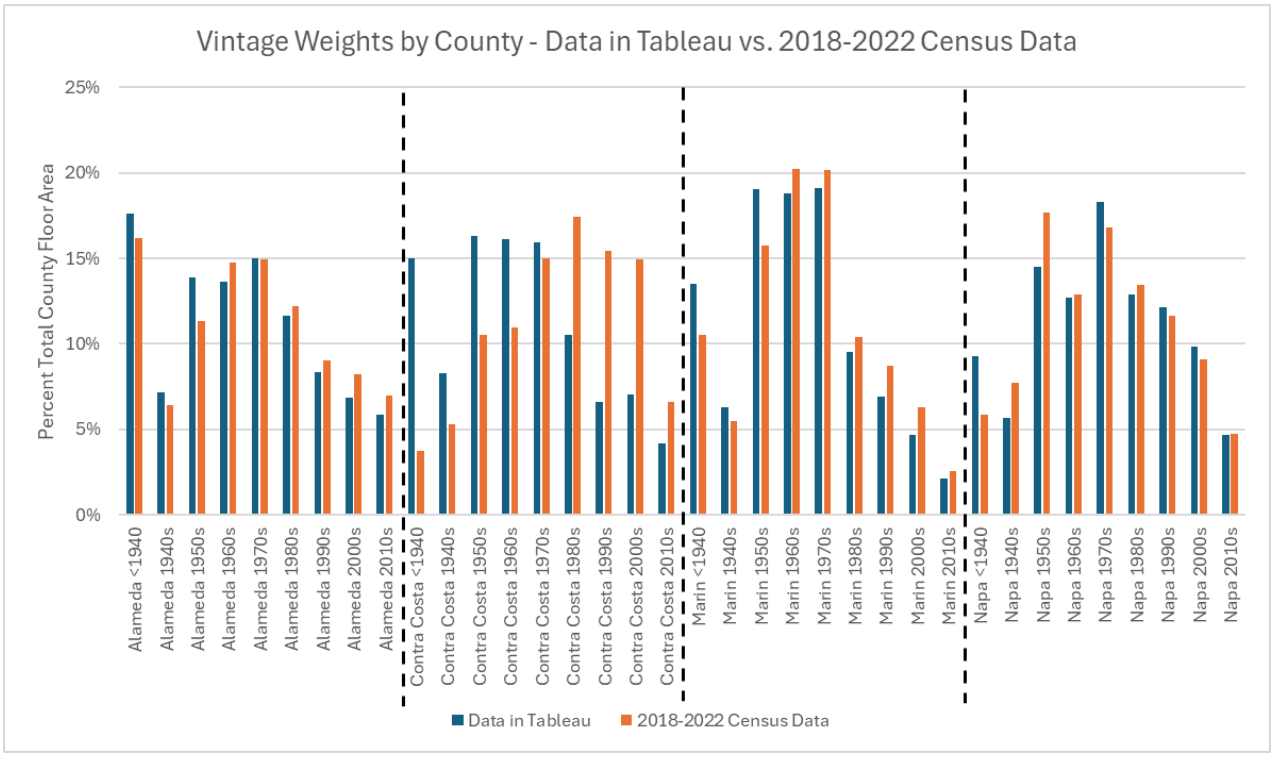

Figure 4. Post-Processed Data in Tableau Tool vs. 2018-2022 Census Vintage Comparison

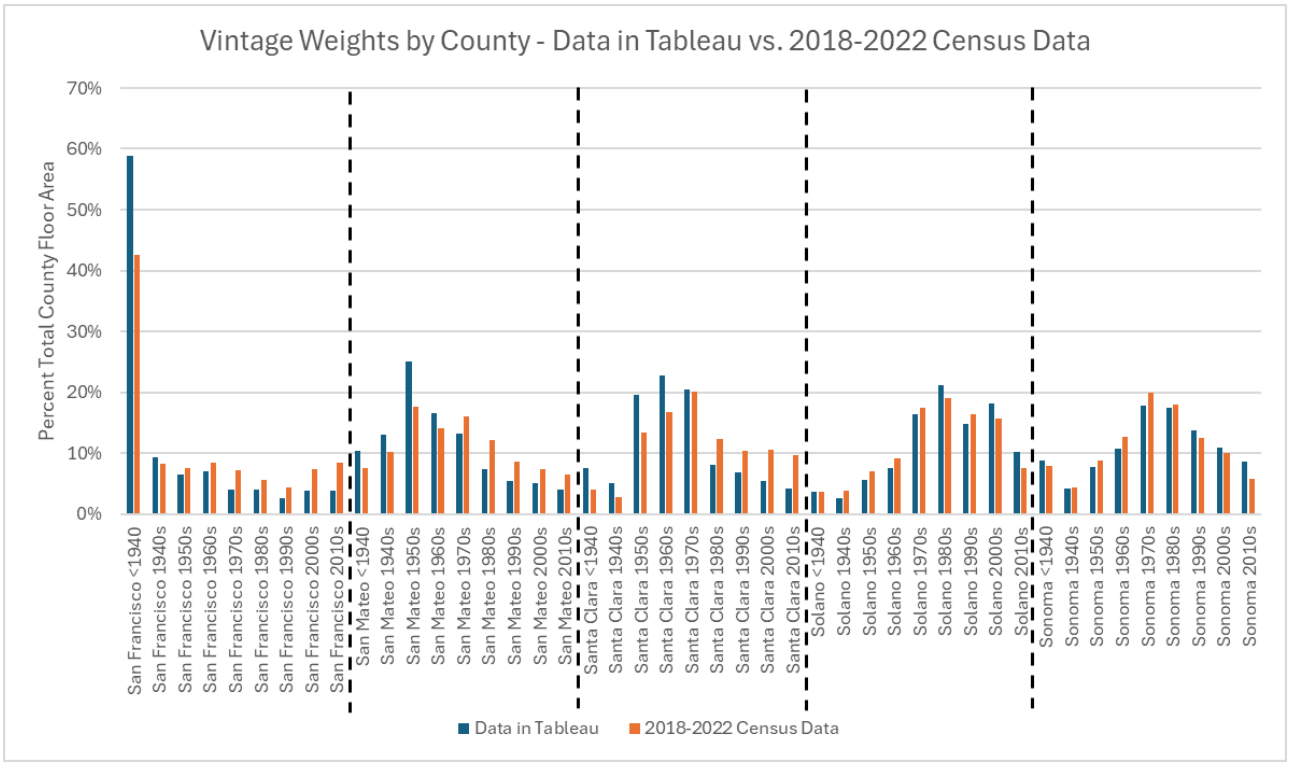

Figure 5. Post-Processed Data in Tableau Tool vs. 2018-2022 Census Vintage Comparison

Comparison of ResStock and Recent Census Data

ResStock 2024.1 uses the 2015-2019 American Community Survey (ACS) data, but the 2018-2022 data is the most recently available ACS. This section is for informational purposes only to illustrate the importance of using the most recent data available.

As expected,

- The new census data shows 2% more units in the Bay Area than ResStock 2024.1, indicating more construction of units than demolition in recent years (shown in Figure 6).
- ResStock 2024.1 building stock skews slightly older than the new census data (shown in Figure 7).

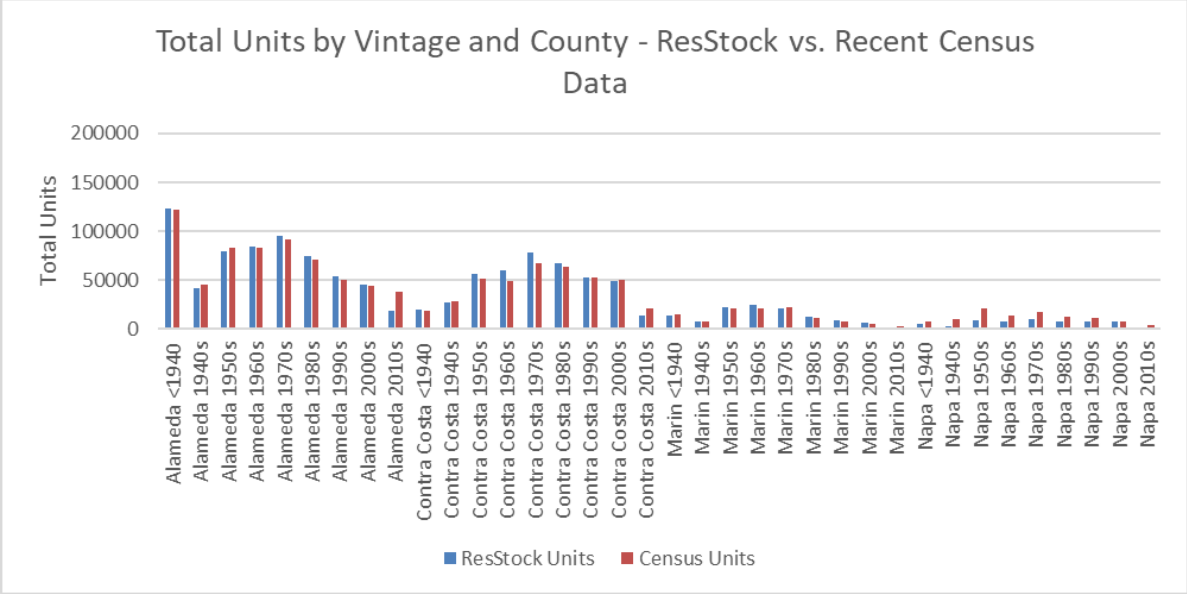

Figure 6. ResStock vs. Recent Census Data for Vintage, (1 of 2)

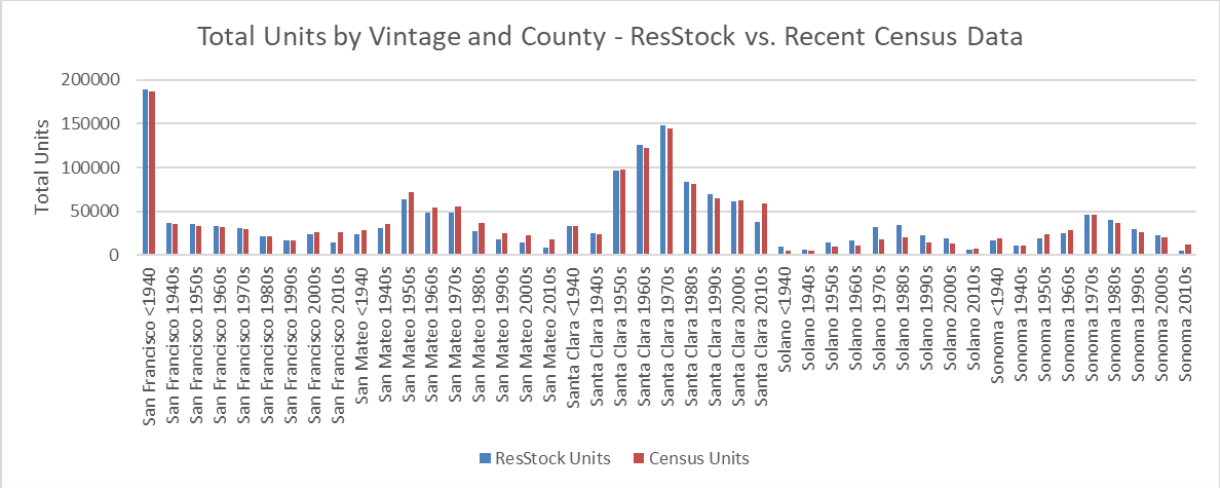

Figure 7. ResStock vs. Recent Census Data for Vintage, (2 of 2)

Heating Fuel

ResStock 2024.1 shows slightly more mixed fuel heating than the recent census data, as shown in Figure 8. This may be the result increased electrification retrofits and construction in recent years.

Heating fuel recommendation: The team recommends using the most recent census data for heating fuel.

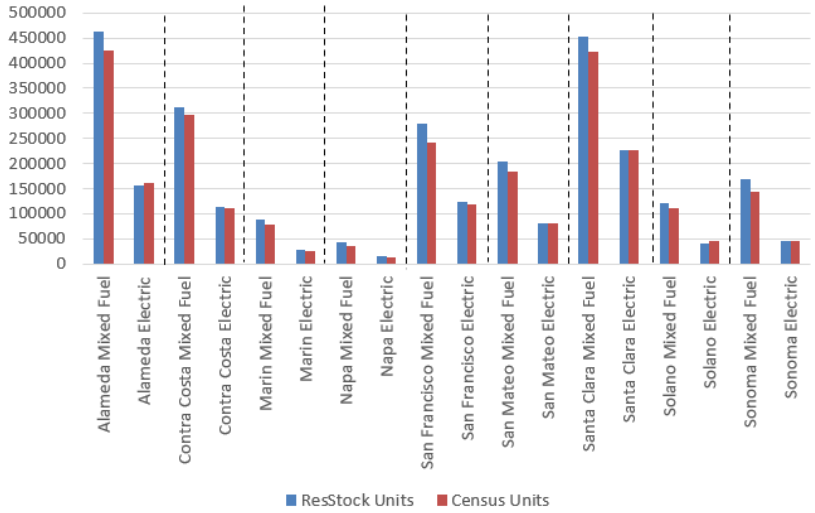

Figure 8. ResStock vs. Recent Census Data for Heating Fuel Type

Conclusion

To summarize, after comparing the data distributions from the parcel, census, and ResStock datasets, the team has the following recommendations that were incorporated into the Tableau tool:

- **Updated distributions:** Use the ResStock dataset as-is and apply post-processed weights (based on parcel and census data) to accurately represent the counts and areas for each category of buildings.
- **ResStock release:** Use the 2024.1 ResStock release for the primary EUI analysis, but supplement with 2024.2 as needed to highlight differences in heat pump technologies and hourly load shapes.
- **Building typology:** Use building typology parcel data for all counties except Marin. Census data will be used to supplement the multifamily building counts in Marin.
- **Vintage:** Where available, use year built from the parcel data. Census data will be used to supplement gaps in Alameda, Marin, Napa, San Mateo, and Santa Clara.
- **Heating fuel:** Use the most recent census data for heating fuel.

Task 2 focused on parcel, census, and ResStock datasets to identify primary building characteristics such as typology, vintage, and heating fuel. Task 3 will explore more detailed building characteristics using additional datasets such as Green Label, Bay Area Multifamily Building Enhancements (BAMBE) Program, and TECH Clean California.

Task 2 Appendix: Commercial Benchmarking

Table 7: Commercial typologies and EUI derivation methods / sources

Preliminary Alignment	EUI Derivation Method	ComStock Proxies for EUI derivation (if applicable)	EUI Scaling Benchmark Source	EUI Scaling Benchmark Typology
Agriculture - Crops	ComStock proxy(s)	Warehouse		
Agriculture - Greenhouse	ComStock proxy(s)	Warehouse		
Agriculture - Livestock	ComStock proxy(s)	Warehouse		
Agriculture - Preserve	ComStock proxy(s)	Warehouse		
Agriculture - Unspecified	ComStock proxy(s)	Warehouse		
Agriculture - Vineyard	ComStock proxy(s)	Warehouse		
Airport - General	ComStock proxy(s)	RetailStripMall LargeOffice QuickServiceRestaurant		
Airport - Small	ComStock proxy(s)	RetailStripMall SmallOffice QuickServiceRestaurant		
Auditorium & Stadium	ComStock proxy(s) + Benchmark Scaling	RetailStripMall LargeOffice QuickServiceRestaurant	SF Existing Building Energy Performance Ordinance Report	Stadium (Open)
Auto Sales	ComStock proxy(s) + Benchmark Scaling	RetailStandalone SmallOffice	LBL BPD	Retail - Vehicle dealership/showroom
Auto Service	ComStock proxy(s) + Benchmark Scaling	RetailStandalone Warehouse	LBL BPD	Service - Vehicle service/repair shop
Car Wash	ComStock proxy(s)	RetailStandalone SmallOffice		
Cemetery	ComStock proxy(s)	SecondarySchool SmallOffice		
Church	ComStock proxy(s) + Benchmark Scaling	SecondarySchool SmallOffice	LBL BPD	Religious worship
Commercial - Unspecified	ComStock proxy(s)	LargeOffice RetailStandalone Warehouse	2034 California CEUS (PG&E) / 2022 California CEUS (SCE)	All Commercial
Data Center	ComStock proxy(s) + Process Load	LargeOffice	LBL BPD	Data Center
Education - Early	ComStock proxy(s)	PrimarySchool		
Education - General	ComStock proxy(s)	PrimarySchool SecondarySchool		
Education - Secondary	ComStock proxy(s)	SecondarySchool		
Entertainment & Culture - General	ComStock proxy(s) + Benchmark Scaling	SecondarySchool SmallOffice	LBL BPD	Public Assembly - Entertainment/culture
Entertainment & Culture - Theater	ComStock proxy(s) + Benchmark Scaling	SecondarySchool SmallOffice	LBL BPD	Public Assembly - Movie Theater
Fire	ComStock proxy(s) + Benchmark Scaling	SmallOffice SmallHotel	LBL BPD	Public Safety - Fire or police station

Preliminary Alignment	EUI Derivation Method	ComStock Proxies for EUI derivation (if applicable)	EUI Scaling Benchmark Source	EUI Scaling Benchmark Typology
Food Service - Bar	ComStock proxy(s) + Benchmark Scaling	QuickServiceRestaurant	SF Existing Building Energy Performance Ordinance Report	Bar/Nightclub
Food Service - Quick	ComStock proxy(s)	QuickServiceRestaurant		
Food Service - Restaurant	ComStock proxy(s)	FullServiceRestaurant		
Food Service - Unspecified	ComStock proxy(s)	QuickServiceRestaurant FullServiceRestaurant		
Funeral & Mortuary	ComStock proxy(s) + Benchmark Scaling	SecondarySchool SmallOffice	LBL BPD	Public Assembly - Large Hall
Gas Station	ComStock proxy(s) + Benchmark Scaling	RetailStandalone QuickServiceRestaurant	LBL BPD	Convenience store with gas station
Group Housing - Assisted Living	ComStock proxy(s) + Benchmark Scaling	SmallHotel FullServiceRestaurant SmallOffice	SF Existing Building Energy Performance Ordinance Report	Senior Living Community
Group Housing - General	ComStock proxy(s)	SmallHotel LargeHotel SmallOffice		
Hotel - General	ComStock proxy(s)	LargeHotel SmallHotel		
Hotel - Large	ComStock proxy(s)	LargeHotel		
Hotel - Small	ComStock proxy(s)	SmallHotel		
Industrial/Manufacturing - Chemicals	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Factory	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Food Processing	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Heavy	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Light	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Lumber	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Mineral Processing	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Power Plant	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - R&D	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Timber	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Industrial/Manufacturing - Unspecified	ComStock proxy(s) + Process Load	Warehouse	SF Existing Building Energy Performance Ordinance Report	Manufacturing/Industrial Plant
Laboratory	ComStock proxy(s) + Process Load	LargeOffice	LBL BPD	Laboratory
Medical - Clinic	ComStock proxy(s) + Benchmark Scaling	Outpatient	LBL BPD	Health Care - Outpatient Clinic
Medical - Dental	ComStock proxy(s) + Benchmark Scaling	Outpatient	LBL BPD	Health Care - Outpatient Clinic
Medical - Hospital	ComStock proxy(s)	Hospital		

Preliminary Alignment	EUI Derivation Method	ComStock Proxies for EUI derivation (if applicable)	EUI Scaling Benchmark Source	EUI Scaling Benchmark Typology
Medical - Nursing	ComStock proxy(s) + Benchmark Scaling	Outpatient Hospital	LBL BPD	Health Care - Outpatient Clinic
Medical - Unspecified	ComStock proxy(s) + Benchmark Scaling	Outpatient Hospital LargeOffice	LBL BPD	Health Care - Outpatient Uncategorized
Medical - Veterinary	ComStock proxy(s) + Benchmark Scaling	Outpatient SmallOffice	SF Existing Building Energy Performance Ordinance Report	Veterinary Office
Mixed Use - General	ComStock proxy(s) + Benchmark Scaling	LargeOffice RetailStandalone QuickServiceRestaurant	SF Existing Building Energy Performance Ordinance Report	Mixed Use Property
Mixed Use - Hotel & Retail	ComStock proxy(s)	LargeOffice RetailStandalone		
Mixed Use - Office & Retail	ComStock proxy(s)	LargeOffice RetailStandalone		
Mixed Use - Residential & Office	ComStock proxy(s) + Benchmark Scaling	LargeOffice RetailStandalone		SF Existing Building Energy Performance Ordinance Report
Mixed Use - Residential & Retail	ComStock proxy(s) + Benchmark Scaling	LargeOffice RetailStandalone		SF Existing Building Energy Performance Ordinance Report
Municipal & Government - Military	ComStock proxy(s)	LargeOffice SmallOffice		
Municipal & Government - Office	ComStock proxy(s) + Benchmark Scaling	LargeOffice SmallOffice	LBL BPD	Office - Government
Municipal & Government - Unspecified	ComStock proxy(s) + Benchmark Scaling	LargeOffice SmallOffice	LBL BPD	Office - Government
Office - Financial & Bank	ComStock proxy(s) + Benchmark Scaling	LargeOffice SmallOffice	LBL BPD	Office - Bank or other financial
Office - General	ComStock proxy(s)	LargeOffice SmallOffice		
Office - Large	ComStock proxy(s)	LargeOffice		
Office - Small	ComStock proxy(s)	SmallOffice		
Open Space	Assume 0 energy			
Parking	Assume 0 energy			
Parkland	Assume 0 energy			
Post Office	ComStock proxy(s)	SmallOffice		
Public Assembly - General	ComStock proxy(s) + Benchmark Scaling	SecondarySchool	LBL BPD	Public Assembly - Large Hall
Recreation - Arcades	ComStock proxy(s) + Benchmark Scaling	SecondarySchool	LBL BPD	Public Assembly - Recreation
Recreation - Bowling	ComStock proxy(s) + Benchmark Scaling	SecondarySchool	LBL BPD	Public Assembly - Recreation
Recreation - Equestrian	ComStock proxy(s) + Benchmark Scaling	SecondarySchool	LBL BPD	Public Assembly - Recreation
Recreation - General	ComStock proxy(s) + Benchmark Scaling	SecondarySchool	LBL BPD	Public Assembly - Recreation
Recreation - Golf	ComStock proxy(s) + Benchmark Scaling	RetailStandalone	LBL BPD	Public Assembly - Recreation
Recreation - Indoor Sports	ComStock proxy(s) + Benchmark Scaling	SecondarySchool	LBL BPD	Public Assembly - Recreation
Recreation - Outdoor Activities	ComStock proxy(s) + Benchmark Scaling	SecondarySchool	LBL BPD	Public Assembly - Recreation

Preliminary Alignment	EUI Derivation Method	ComStock Proxies for EUI derivation (if applicable)	EUI Scaling Benchmark Source	EUI Scaling Benchmark Typology
Recreation - Swimming	ComStock proxy(s) + Benchmark Scaling	SecondarySchool	LBL BPD	Public Assembly - Recreation
Retail - Building Materials	ComStock proxy(s)	RetailStandalone		
Retail - Convenience Store	ComStock proxy(s) + Benchmark Scaling	RetailStandalone	LBL BPD	Convenience store
Retail - Department Store	ComStock proxy(s) + Benchmark Scaling	RetailStandalone	LBL BPD	Retail - Big Box (> 50K sf)
Retail - General	ComStock proxy(s)	RetailStandalone		
Retail - Grocery	ComStock proxy(s) + Benchmark Scaling	RetailStandalone	SF Existing Building Energy Performance Ordinance Report	Supermarket/Grocery Store
Retail - Machinery	ComStock proxy(s)	RetailStandalone		
Retail - Nursery	ComStock proxy(s)	RetailStandalone		
Retail - Shopping Center	ComStock proxy(s) + Benchmark Scaling	RetailStripmall	LBL BPD	Retail - Strip shopping mall
Retail - Wholesale	ComStock proxy(s) + Benchmark Scaling	RetailStandalone	LBL BPD	Retail - Big Box (> 50K sf)
Transportation - Boat Facility	ComStock proxy(s) + Benchmark Scaling	SmallOffice Warehouse RetailStandalone	LBL BPD	Transportation Terminal
Transportation - Highways/Streets	ComStock proxy(s) + Benchmark Scaling	SmallOffice Warehouse RetailStandalone	LBL BPD	Transportation Terminal
Transportation - Port	ComStock proxy(s) + Benchmark Scaling	SmallOffice Warehouse RetailStandalone	LBL BPD	Transportation Terminal
Transportation - Rail	ComStock proxy(s) + Benchmark Scaling	SmallOffice Warehouse RetailStandalone	LBL BPD	Transportation Terminal
Transportation - Road Terminal	ComStock proxy(s) + Benchmark Scaling	SmallOffice Warehouse RetailStandalone	LBL BPD	Transportation Terminal
Transportation - Unspecified	ComStock proxy(s) + Benchmark Scaling	SmallOffice Warehouse RetailStandalone	LBL BPD	Transportation Terminal
Utilities - Pipelines & Canals	ComStock proxy(s)	SmallOffice Warehouse		
Utilities - Steam	ComStock proxy(s)	SmallOffice Warehouse		
Utilities - Telecom	ComStock proxy(s)	SmallOffice Warehouse		
Utilities - Unspecified	ComStock proxy(s)	SmallOffice Warehouse		
Utilities - Water	ComStock proxy(s)	SmallOffice Warehouse		
Vacant	Assume 0 energy			
Warehouse - Nonrefrigerated	ComStock proxy(s)	Warehouse		
Warehouse - Refrigerated	ComStock proxy(s) + Process Load	Warehouse		
Water Bodies	Assume 0 energy			