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Understanding Building Energy Use in California Climate Zone 13:

Basic Building Stock Characterization

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Disclaimer

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1 Overview

This report is part of a publication series that focuses on approximately 100 different local geographies, or "clusters." Each report provides commercial and multifamily building characteristic and energy data for a local geography, with the intention of helping policymakers at the city, county and state levels better understand building energy use. Specifically, this report breaks down the building stock in the counties shown in Figure 1 by building type, size, energy consumption, and emissions.

Buildings emit greenhouse gases due to on-site fossil fuel use and offsite electricity generation. Addressing climate change requires improving building efficiency and reducing on-site fossil fuel combustion. Policymakers who want to reduce emissions will benefit from understanding the building stock because different types of policy interventions will be more applicable to certain types and sizes of buildings than others. Several questions are critical to ask and answer: What types of buildings use the most energy? How do emissions change with building size? How do emissions change by location?

Commercial building energy data are provided by the United States Energy Information Agency (EIA) for the nine U.S. census divisions, each of which covers multiple states (CBECS 2014). The EIA provides similar residential building data by state (RECS 2022). However, city, county, and state policymakers often need finer resolution to understand the building stock and guide decision-making. This report presents commercial and multifamily building energy data for the counties shown in Figure 1. The energy data in this report are broken out by building type and size.

1.1 What Types of Questions Can This Help Me Answer for My City, County, or Region?

- How many buildings exist, by type and size?
- Which buildings are responsible for the most emissions today, by type and size?
- How many buildings or what fraction of emissions are covered by a policy's size threshold?
- How might a policy's building size threshold impact equity?

1.2 What Types of Questions Will This Report *Not* Help Me Answer?

- What will the building stock, energy use, and emissions look like in the future?
- What metric and target levels are best for building energy policy?
- How should a policy acknowledge variation in use within a given building type?
- How will zoning and development changes impact building energy use?

1.3 How Were the Geographic Clusters Developed?

Clusters are formed on a county basis and depend on building type, age, and climate. Adjacent counties with similar commercial densities, types, and age distributions form a cluster. Clusters form regional groups if they belong to the same American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) climate zone. See Horsey, Rozenfeld, and Bergmann 2023 for more detail on the clustering method.

1.4 What Building Types Are Covered?

This report includes multifamily buildings over 10,000 square feet and the commercial buildings listed in Table 1. The commercial building types considered in this analysis represent two-thirds of annual commercial building site energy consumption across the entire United States.

This report excludes a number of building types not currently included in the underlying data. The omitted building types with the highest national energy use include colleges, laboratories, grocery stores, entertainment venues, recreation centers, religious buildings, and vehicle repair shops. Some of these may be added in the future. Information on omitted building types, such as counts, energy use, and floor area can be found in CBECS 2014.

Table 1. Building Stock Segments Covered in This Document

Sector	Building Type Group	Building Type
Commercial	Food Service	Full Service Restaurant
		Quick Service Restaurant
	Mercantile	Retail Strip Mall
		Retail Standalone
	Office	Small Office
		Medium Office
		Large Office
	Education	Primary School
		Secondary School
	Healthcare	Outpatient
		Hospital
	Lodging	Small Hotel
		Large Hotel
	Warehouse and Storage	Warehouse
Residential	Multifamily	Multifamily

1.5 Vintage

The analysis in this report is not segmented by vintage (year constructed). The data do not support the common perception that older commercial buildings have a higher energy use per square foot. For example, commercial buildings constructed between 2000 and 2018 have roughly 10% higher energy use per square foot than buildings constructed before 2000. There do not appear to be other energy use per square foot trends in the data (EIA 2022).

2 Geographies Covered In This Report

Figure 1 shows the California Energy Commission's Climate Zone 13 represented by this report. For additional information on these California specific climate zones please refer to CEC Climate Zones, n.d. Building information has had to be approximated because the geography shown is not a U.S. Census geography. Currently only U.S. Census geographies are directly supported so approximations are required.

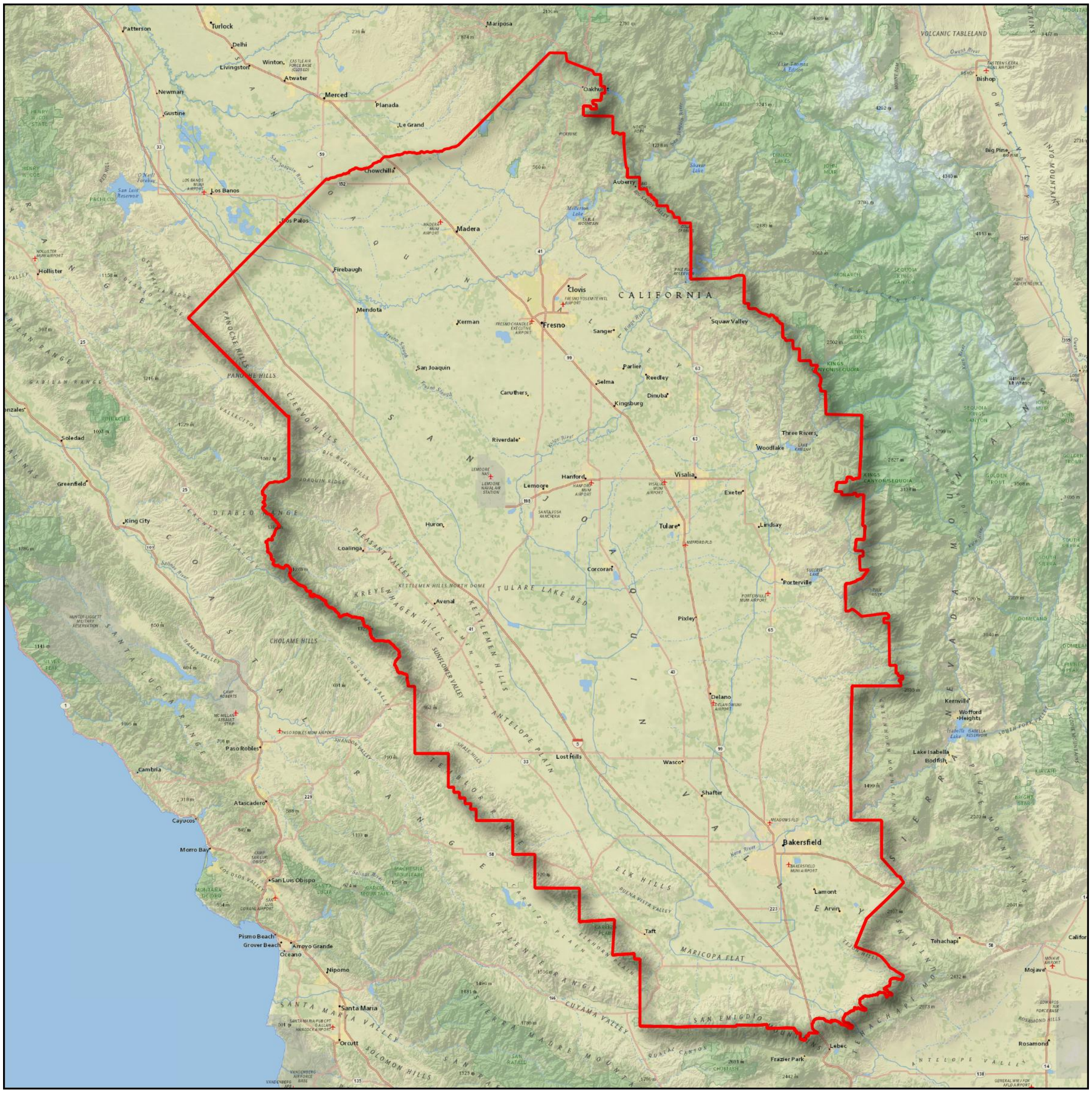

Figure 1. Map showing the California Energy Commission climate zone analyzed in this report. ***Illustration by Billy Roberts, NREL***

3 Stock Segmentation by Size

Figure 2 shows building stock characteristics by building size. Table 2 in Appendix A provides these data in a tabular format. Emissions include both direct and indirect greenhouse gas emissions. Direct emissions are from on-site fossil fuel combustion, and indirect emissions are from regional electricity generation. Direct emissions include both combustion and pre-combustion emissions (e.g., methane leakage for natural gas) and are based on RESNET/ANSI/ICC Standard 301 2018. Indirect emissions are calculated using state level data from the EPA for 2019 (eGRID, n.d.).

Building energy use and emissions depend on the total floor area, not the number of buildings. This is because lighting, heating, cooling, and ventilation scale with floor area.

The source of the data in this report is the public release of *ComStock End Use Savings Shape 2023 Release 1 Baseline Dataset - 2018 Weather* 2023. For reference documentation please see Parker et al. 2023.

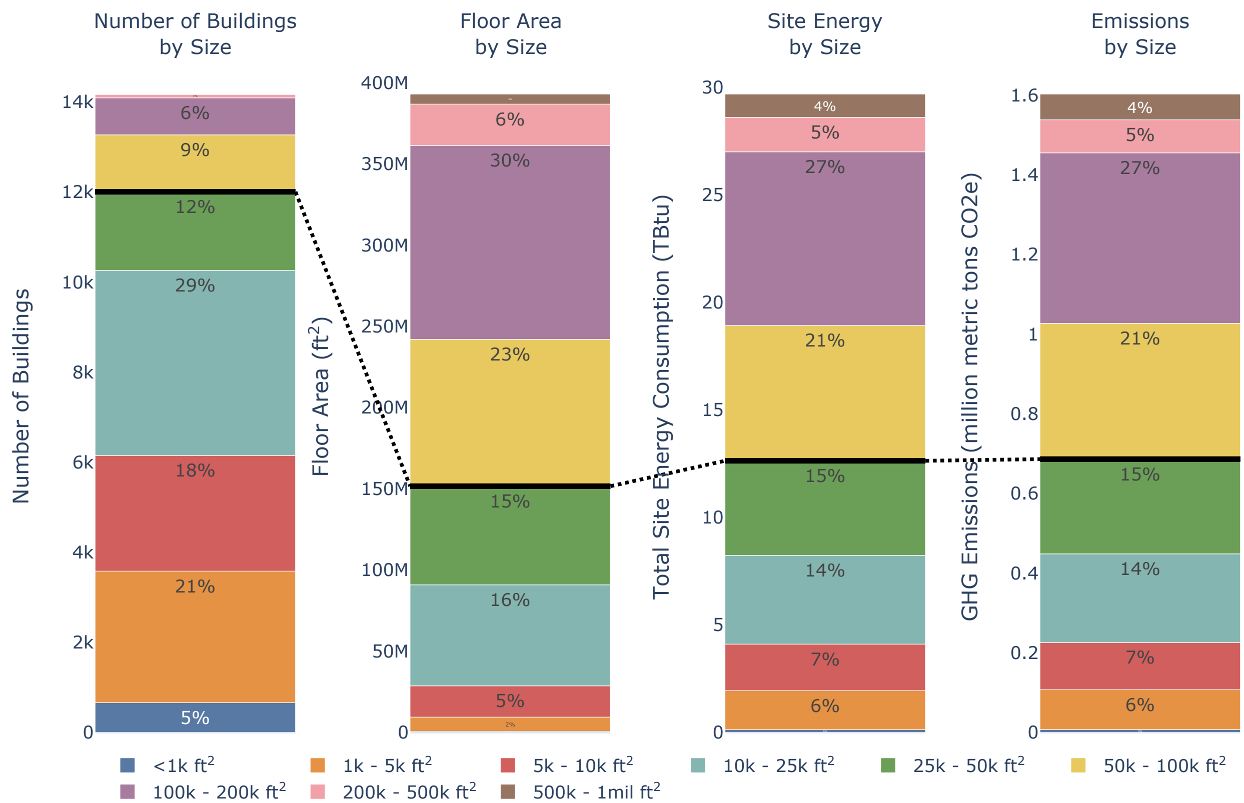

Figure 2. Building stock segmentation by building size. The black line indicates buildings above 50,000 square feet

The black line in Figure 2 traces buildings over 50,000 square feet across each column. Buildings less than 50,000 square feet make up 85% of buildings, but only 39% of area, 43% of site energy consumption, and 43% of emissions. Buildings over 50,000 square feet represent just 15% of buildings, but 57% of energy use and 57% of emissions. Thus, policies that target large buildings can address most emissions while impacting few buildings (15% vs 85%).

In this analysis only multifamily buildings over 10,000 square feet are presented. Due to limitations in the data used to develop this report, buildings over 500,000 square feet are underrepresented. If the analysis area shown in Figure 1 includes a significant number of skyscrapers, energy use in large buildings will be underrepresented.

4 Building Site Energy Use and Emissions Segmentation

The building types in this report have unique energy challenges and opportunities.

4.1 Size

Figure 3 shows energy use by building type and size. Table 3 in Appendix A provides these data in a tabular format. Among buildings over 50,000 square feet, Education buildings account for 50% of the energy used, followed by Warehouse and Storage buildings at 24% and Mercantile buildings at 11%. Other building types account for the remaining 15%. Among buildings over 25,000 square feet, Education buildings account for 40% of the energy used, followed by Warehouse and Storage buildings at 23% and Mercantile buildings at 20%. Other building types account for the remaining 17%.

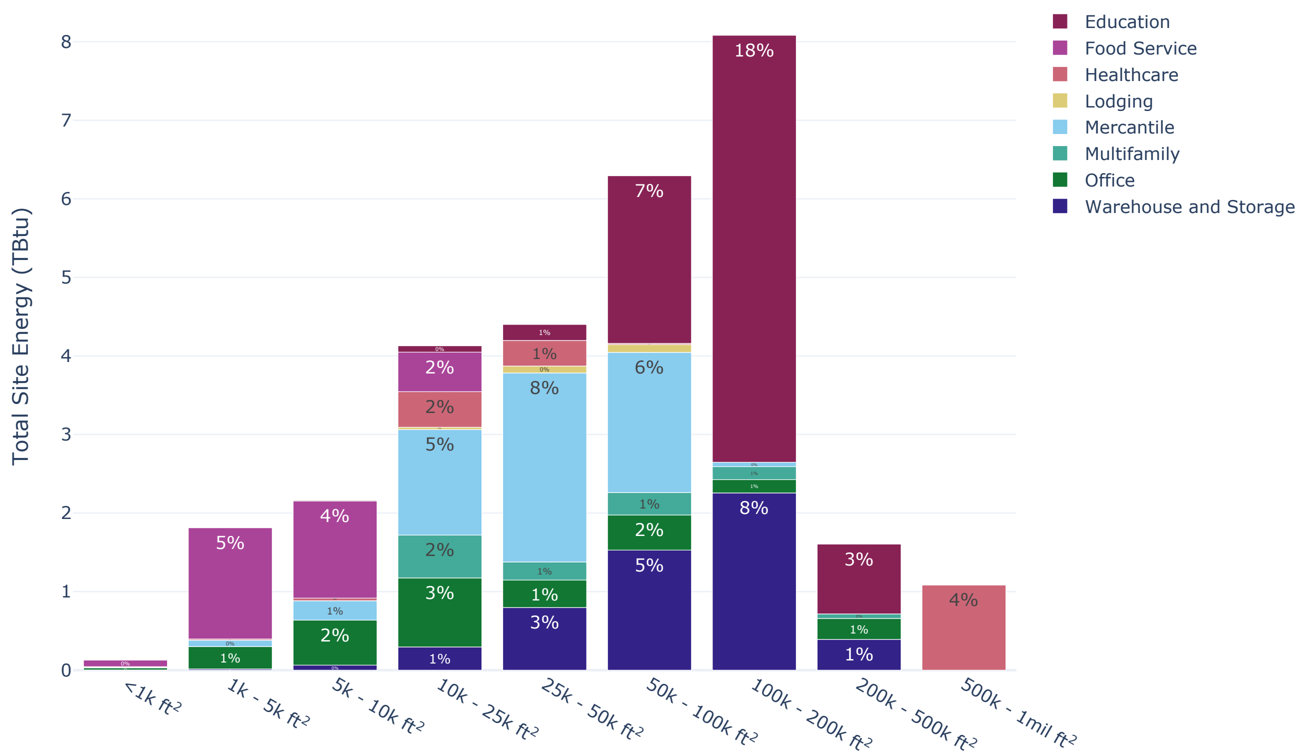

Figure 3. Site energy broken down by building type and size

Large buildings tend to have more complex heating, ventilation, and air conditioning (HVAC) systems and dedicated facility staff. They also have the resources to track and report energy use. In the context of large buildings, energy costs and efficiency matter enough for dedicated staff to focus on it. Large buildings may already have plans to improve energy efficiency.

Smaller buildings may have a part-time maintenance person at best. Energy costs and thus potential savings tend to be small, and it is often not worthwhile to hire a professional to recommend energy savings projects. Small commercial HVAC contractors serve these buildings with limited professional engineering design. Efficient equipment incentives, codes, and standards matter in these buildings.

Certain building types, like offices, span a range of building sizes. Others, like healthcare, are large, whereas restaurants are small. As shown throughout this analysis, a policy targeting larger building types can reduce a large fraction of emissions.

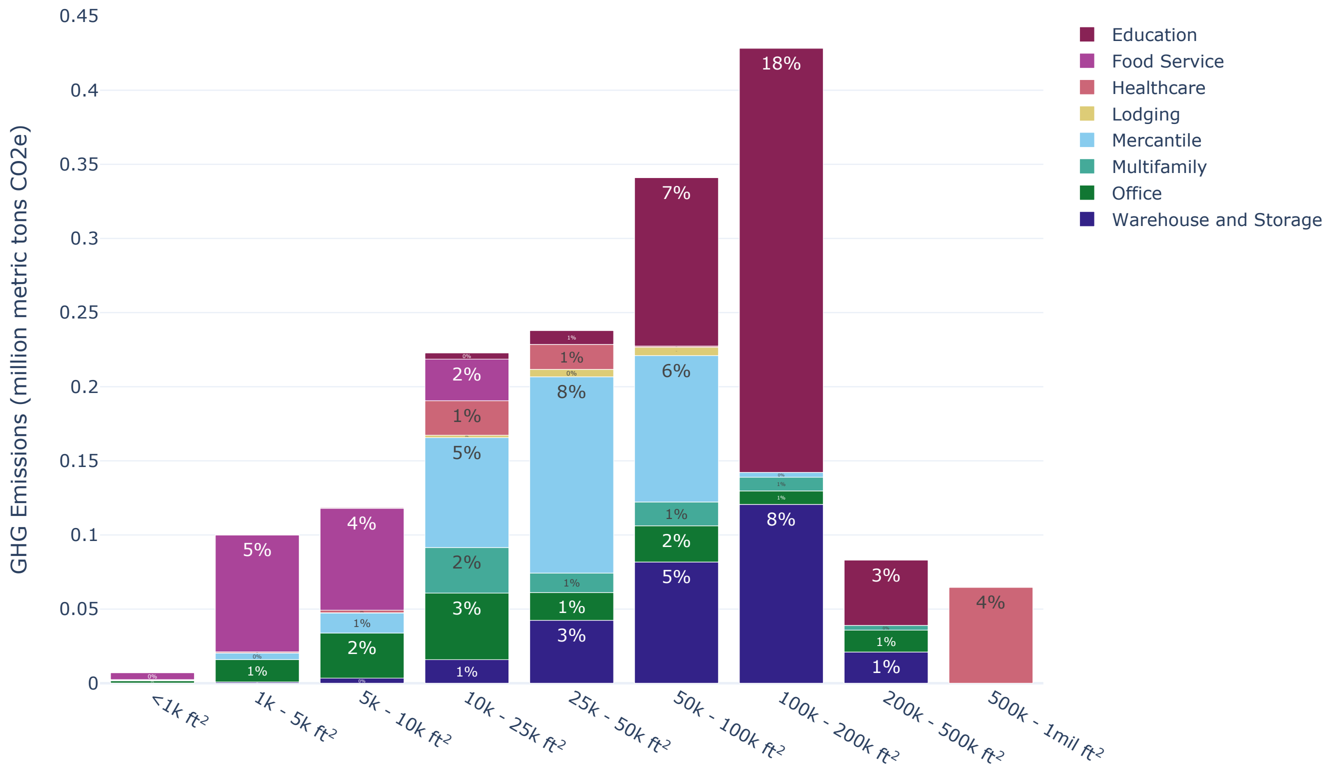

Figure 4. Greenhouse gas (GHG) emissions by building type and size

Figure 4 shows emissions by building type and size. Table 4 in Appendix A provides these data in a tabular format. Among buildings over 50,000 square feet, Education buildings account for 48% of emissions, followed by Warehouse and Storage buildings at 24% and Mercantile buildings at 11%. Other building types account for the remaining 16%. Among buildings over 25,000 square feet, Education buildings account for 39% of emissions, followed by Warehouse and Storage buildings at 23% and Mercantile buildings at 20%. Other building types account for the remaining 17%.

4.2 Energy End Uses

In this report series, "energy end use" is defined as the equipment that directly consumes energy in a building such as heating, cooling and ventilation, lighting, water heating, or refrigeration. The relative importance of each energy end use varies by building type. For example, lighting matters more in retail buildings than in warehouses. Restaurants are considered energy intensive because of their high cooking and water heating needs.

5 Building Segmentation in Disadvantaged Communities

Figures 5 and 6 compare building characteristics in disadvantaged communities to those in other areas. Tables 5 and 6 in Appendix A provide the associated data in a tabular format. The definition of disadvantaged communities used in this report comes from Version 1.0 of the Climate and Economic Justice Screening Tool (CEJST), which is maintained by the White House Council on Environmental Quality (CEQ) (CEQ 2023). CEJST defines disadvantaged communities as "a census tract that is: (1) at or above the threshold for one or more environmental, climate, or other burdens, and (2) at or above the threshold for an associated socioeconomic burden." In addition, census tracts "within the boundaries of Federally Recognized Tribes are designated as disadvantaged" (CEJST: Technical Support Document 2022).

Not all disadvantaged individuals live in disadvantaged communities. The United States Office of Management and Budget (OMB) defines communities as “either a group of individuals living in geographic proximity to one another, or a geographically dispersed set of individuals (such as migrant workers or Native Americans), where either type of group experiences common conditions" (OMB M-21-28 2021). CEJST applies to geographically proximate communities. Thus, communities not labeled as disadvantaged may still contain many disadvantaged individuals.

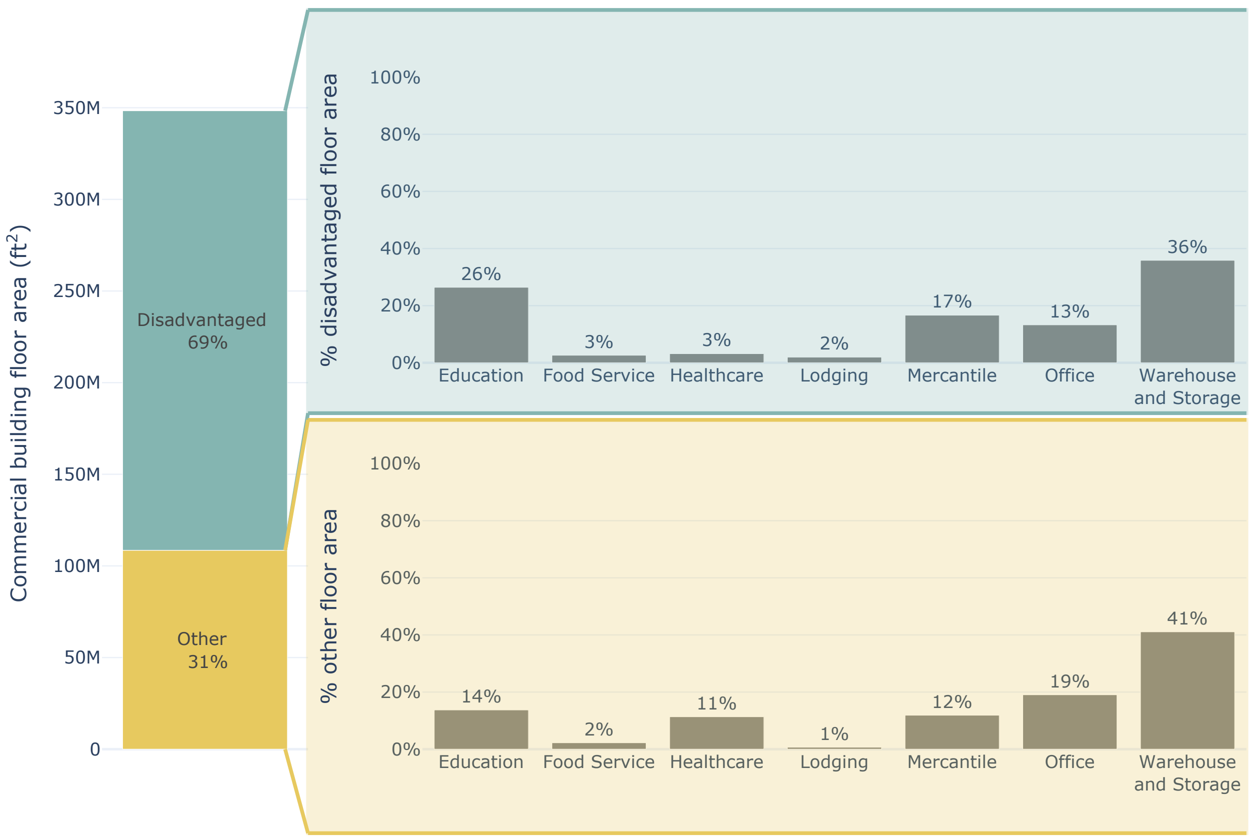

Figure 5. Segmentation of the commercial building stock by type, segmented into “disadvantaged” and “other” (as defined by CEJST)

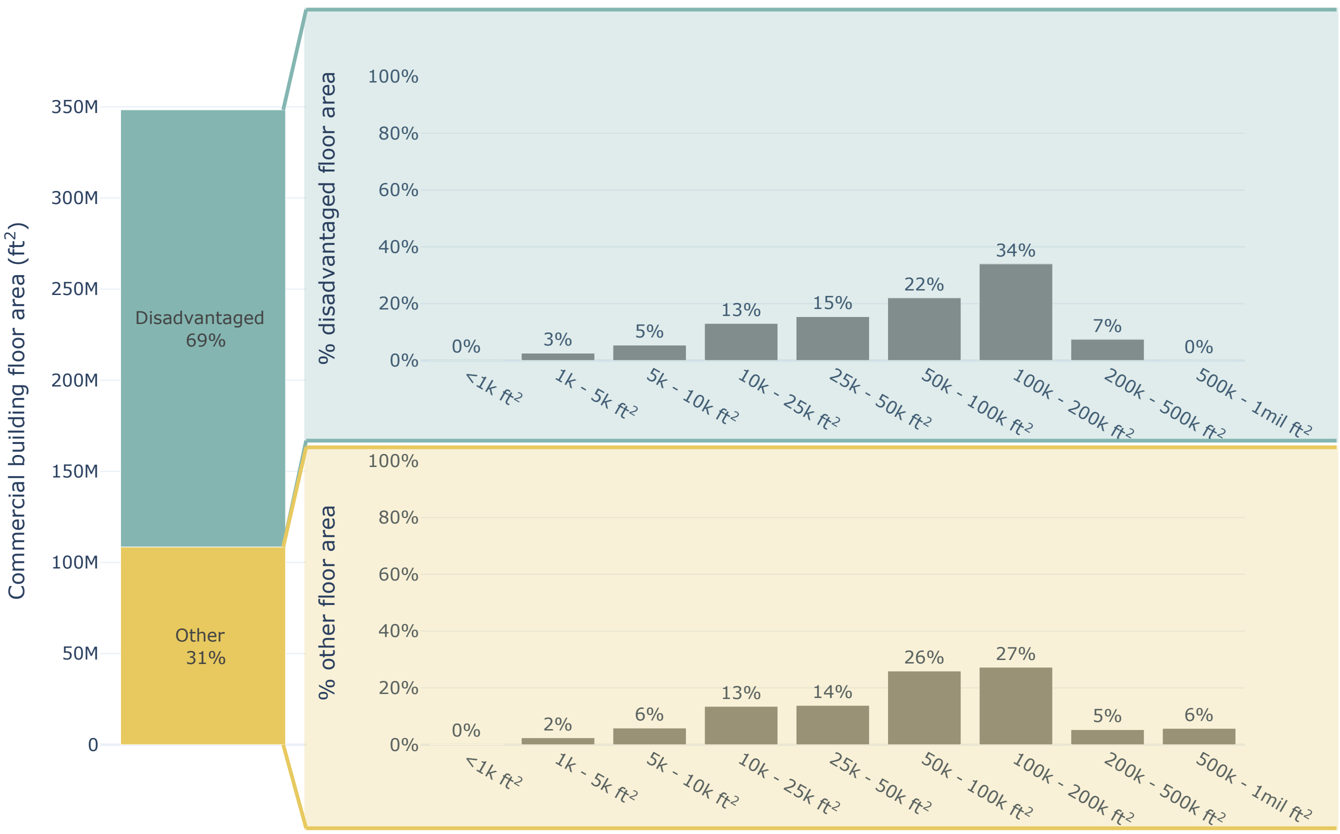

Figure 6. Segmentation of the commercial building stock by size, segmented into "disadvantaged" and "other" (as defined by CEJST)

A Tables of Figure Values

The following tables summarize the figures shown throughout the report.

0.1 Building Stock Segmentation by Building Size

Table 2. Segmentation of the Building Stock by Building Size (floor area is in square feet, site energy is in TBtu, and emissions are in million metric tons CO_2e)

Building Size	Number of Buildings by Size	Floor Area by Size	Site Energy by Size	Emissions by Size
<1k ft^2	661	661,000	0.127	0.00702
1k – 5k ft^2	2,920	8,770,000	1.82	0.1
5k – 10k ft^2	2,570	19,300,000	2.16	0.118
10k – 25k ft^2	4,110	62,200,000	4.13	0.223
25k – 50k ft^2	1,750	60,700,000	4.4	0.238
50k – 100k ft^2	1,260	90,400,000	6.29	0.341
100k – 200k ft^2	823	119,000,000	8.08	0.428
200k – 500k ft^2	76	25,400,000	1.6	0.083
500k – 1Mil ft^2	9	6,220,000	1.08	0.0646

0.2 Site Energy by Building Type and Size

Table 3. Building Stock Site Energy by Building Type and Size (all values are in TBtu)

Building Size	Education	Food Service	Healthcare	Lodging	Mercantile	Multifamily	Office	Warehouse and Storage
<1k ft^2	0	0.0827	0.00505	0.00203	0.00784	0	0.0275	0.00235
1k – 5k ft^2	0.00482	1.42	0.0153	0.00136	0.0802	0	0.284	0.0157
5k – 10k ft^2	0.00952	1.24	0.0325	0.00212	0.246	0	0.573	0.0636
10k – 25k ft^2	0.0808	0.503	0.453	0.0285	1.34	0.546	0.879	0.295
25k – 50k ft^2	0.204	0	0.326	0.0882	2.41	0.23	0.35	0.797
50k – 100k ft^2	2.13	0	0.0155	0.0996	1.78	0.287	0.446	1.53
100k – 200k ft^2	5.43	0	0	0	0.0568	0.165	0.169	2.26
200k – 500k ft^2	0.888	0	0	0	0	0.0579	0.266	0.392
500k – 1Mil ft^2	0	0	1.08	0	0	0	0	0

0.3 Emissions by Building Type and Size

Table 4. Building Stock Emissions by Building Type and Size (all values are in million metric tons CO_2e)

Building Size	Education	Food Service	Healthcare	Lodging	Mercantile	Multifamily	Office	Warehouse and Storage
<1k ft^2	0	0.00458	0.000275	0.000108	0.000425	0	0.0015	0.000127
1k – 5k ft^2	0.000251	0.0788	0.000802	7.61e-05	0.00438	0	0.0151	0.000843
5k – 10k ft^2	0.000493	0.0687	0.00171	0.000131	0.0136	0	0.0304	0.00343
10k – 25k ft^2	0.00418	0.028	0.0233	0.00163	0.0741	0.0307	0.0449	0.0159
25k – 50k ft^2	0.00932	0	0.0168	0.00503	0.132	0.0131	0.0187	0.0424
50k – 100k ft^2	0.114	0	0.000796	0.00563	0.0987	0.0161	0.0244	0.0817
100k – 200k ft^2	0.286	0	0	0	0.00326	0.00923	0.00909	0.121
200k – 500k ft^2	0.044	0	0	0	0	0.0032	0.0148	0.021
500k – 1Mil ft^2	0	0	0.0646	0	0	0	0	0

0.4 Segmentation of the Commercial Building Stock by Type and CEJST Disadvantaged Definition

Table 5. Commercial Building Stock Floor Area Segmented by CEJST Disadvantaged Definition and Type (all values are in square feet)

Building Type	Disadvantaged	Other
Education	63,400,000	14,900,000
Food Service	6,310,000	2,430,000
Healthcare	7,630,000	12,300,000
Lodging	4,720,000	740,000
Mercantile	40,000,000	12,900,000
Office	31,800,000	20,700,000
Warehouse and Storage	86,000,000	44,600,000

0.5 Segmentation of the Commercial Building Stock by Size and CEJST Disadvantaged Definition

Table 6. Commercial Building Stock Floor Area Segmented by CEJST Disadvantaged Definition and Size (all values are in square feet)

Building Size	Disadvantaged	Other
<1k ft^2	466,000	195,000
1k – 5k ft^2	6,130,000	2,640,000
5k – 10k ft^2	12,900,000	6,350,000
10k – 25k ft^2	31,200,000	14,600,000
25k – 50k ft^2	37,000,000	15,000,000
50k – 100k ft^2	52,800,000	28,100,000
100k – 200k ft^2	81,500,000	29,600,000
200k – 500k ft^2	17,800,000	5,750,000
500k – 1Mil ft^2	0	6,220,000

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