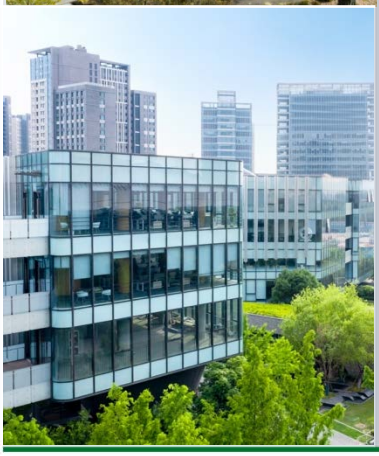
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY



Understanding Building Energy Use in Rural North and South Carolina Counties:

Basic Building Stock Characterization

August 2023

Disclaimer

This work was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, its contractors or subcontractors.

Authors

The authors of this report are:

Ry Horsey, Andrew Parker, Chris Caradonna, Matthew Dahlhausen, Lauren Klun, Amy LeBar, and Marlena Praprost, National Renewable Energy Laboratory

The technical managers of this report are:

Harry Bergmann, U.S. Department of Energy

Amir Roth, U.S. Department of Energy

Acknowledgments

The authors would like to acknowledge the valuable guidance and input provided during this report. The authors are grateful to the following list of contributors. Their feedback, guidance, and review is greatly appreciated by the authors.

Pacific Northwest National Laboratory: Bing Liu

Lawrence Berkeley National Laboratory: Paul Mathew, Cindy Regnier

U.S. Department of Energy: Ian Blanding, Billierae Engelman, and Ram Narayanamurthy

This report was prepared by the National Renewable Energy Laboratory for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office.

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 map of the buildings covered in this report. Appendix A lists the counties and county equivalents included in the map.

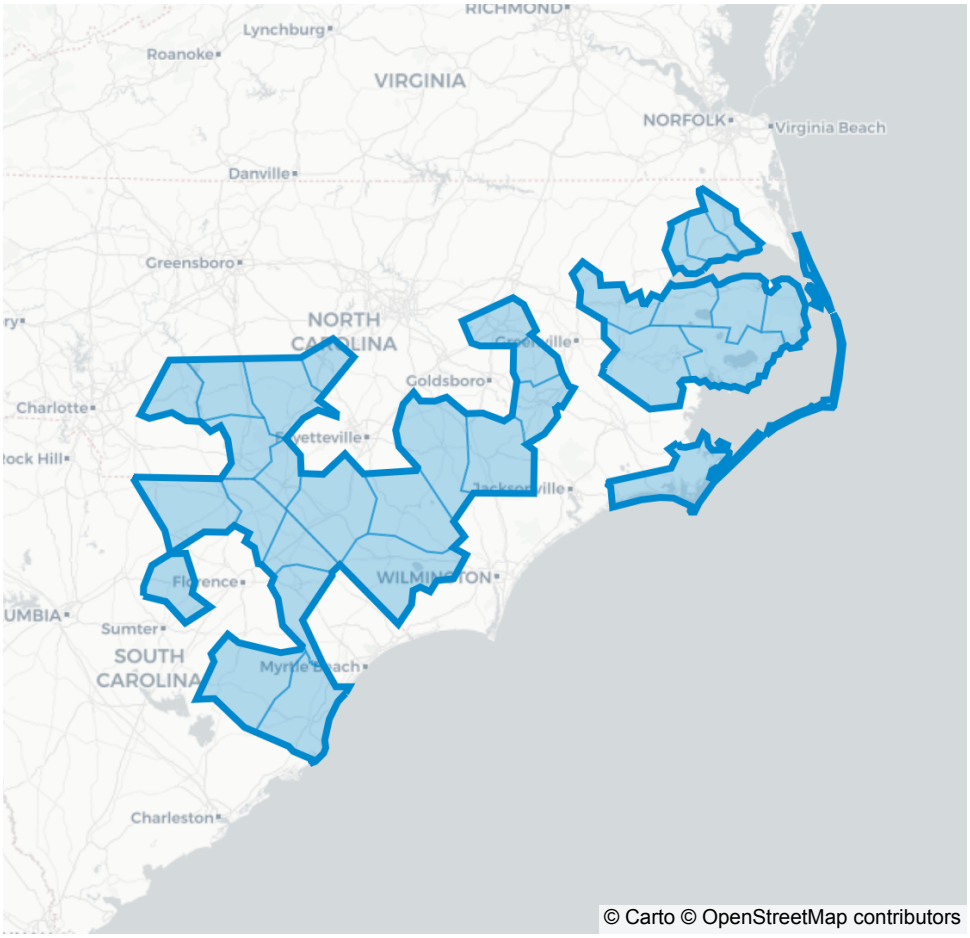


Figure 1. Map showing the cluster of counties analyzed in this report

3 Stock Segmentation by Size

Figure 2 shows building stock characteristics by building size. Table 2 in Appendix B 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 90% of buildings, but only 46% of area, 49% of site energy consumption, and 55% of emissions. Buildings over 50,000 square feet represent just 10% of buildings, but 51% of energy use and 45% of emissions. Thus, policies that target large buildings can address most emissions while impacting few buildings (10% vs 90%).

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 B provides these data in a tabular format. Among buildings over 50,000 square feet, Education buildings account for 48% of the energy used, followed by Healthcare buildings at 21% and Warehouse and Storage buildings at 12%. Other building types account for the remaining 19%. Among buildings over 25,000 square feet, Education buildings account for 38% of the energy used, followed by Mercantile buildings at 23% and Healthcare buildings at 18%. Other building types account for the remaining 21%.

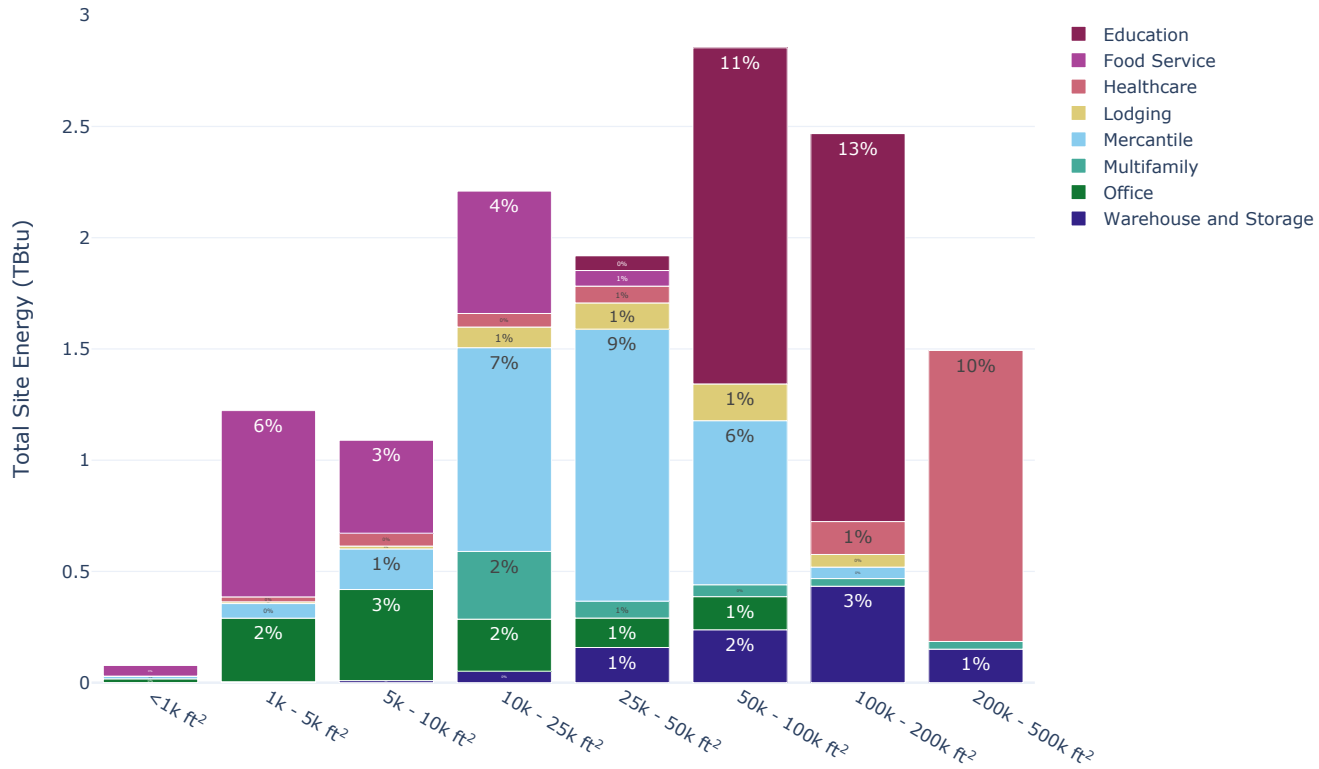


Figure 3. Site energy broken down by building type and size

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.

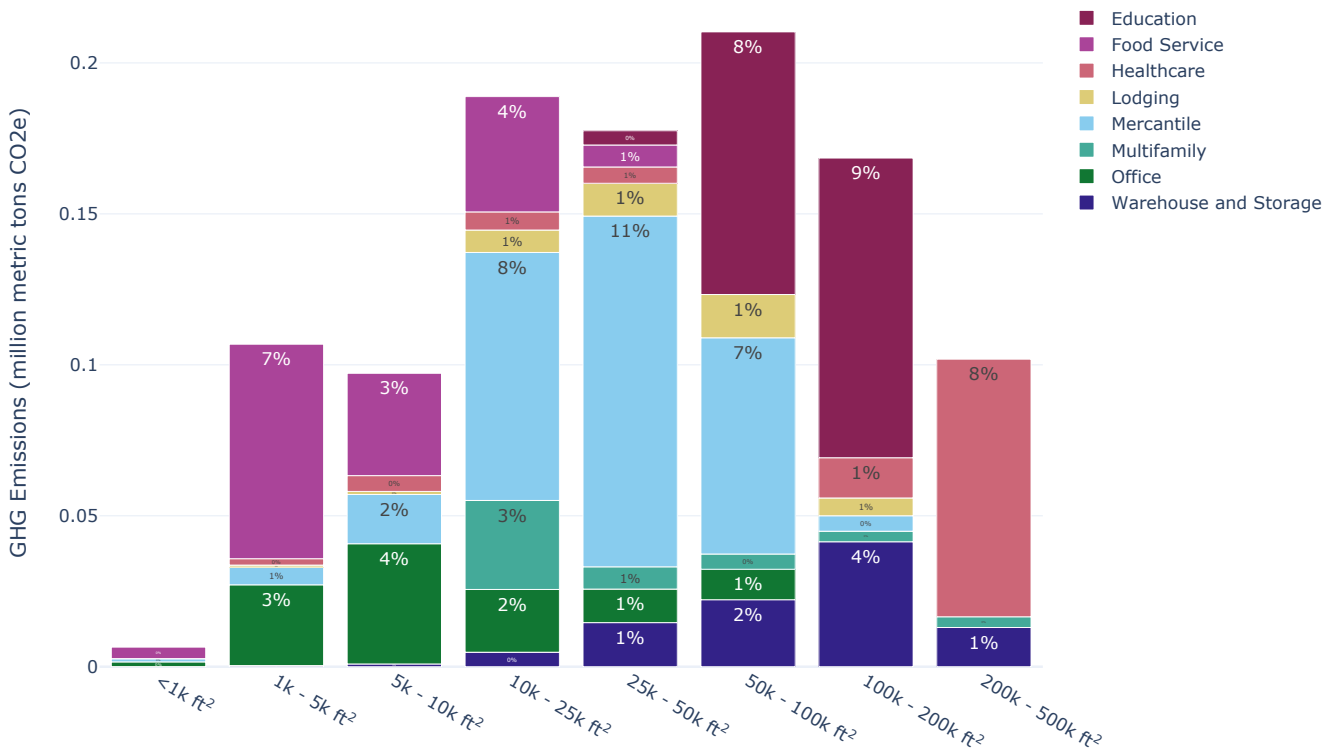


Figure 4. Greenhouse gas (GHG) emissions by building type and size

Figure 4 shows emissions by building type and size. Table 4 in Appendix B provides these data in a tabular format. Among buildings over 50,000 square feet, Education buildings account for 39% of emissions, followed by Healthcare buildings at 21% and Mercantile buildings at 16%. Other building types account for the remaining 25%. Among buildings over 25,000 square feet, Mercantile buildings account for 29% of emissions, followed by Education buildings at 29% and Healthcare buildings at 16%. Other building types account for the remaining 26%.

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, 6, and 7 compare building characteristics in disadvantaged communities to those in other areas. Tables 5, 6, and 7 in Appendix B 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.

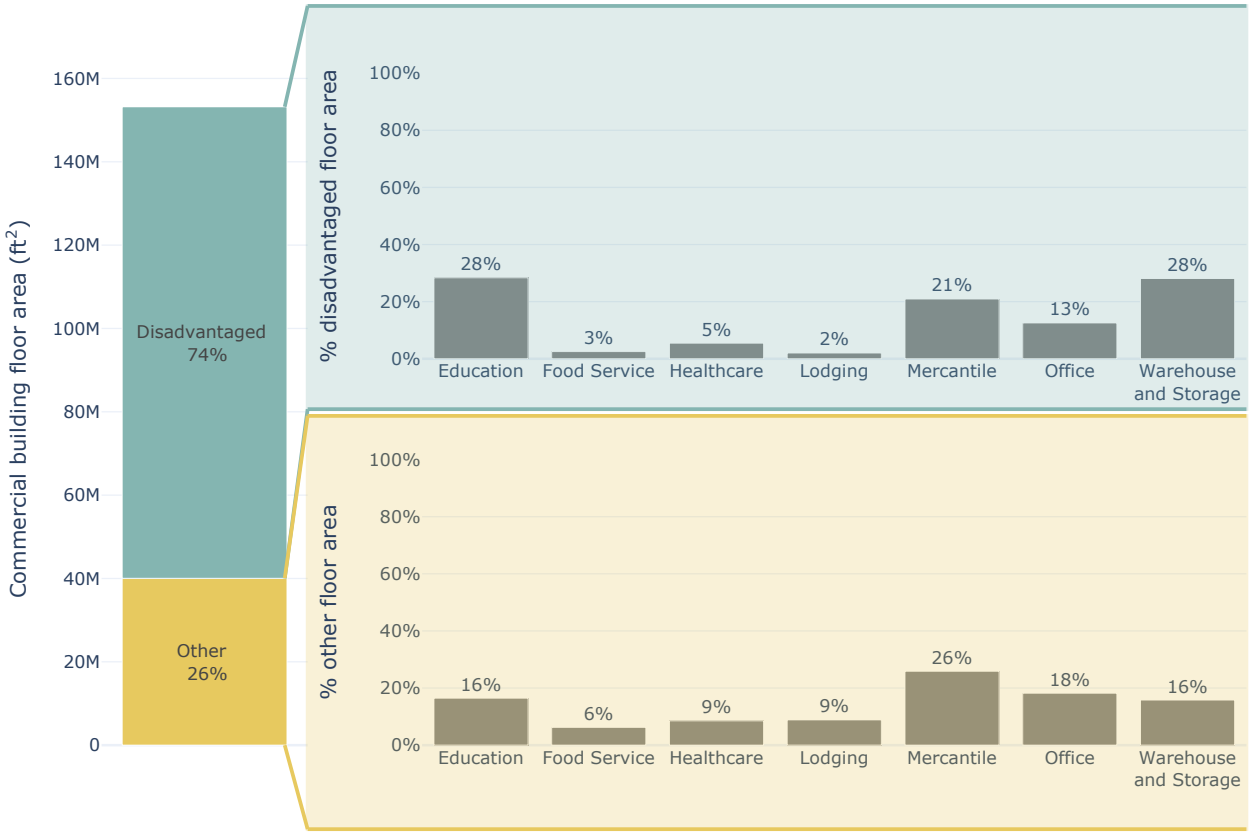


Figure 5. Segmentation of the commercial building stock by type, segmented into “disadvantaged” and “other” (as defined by CEJST)

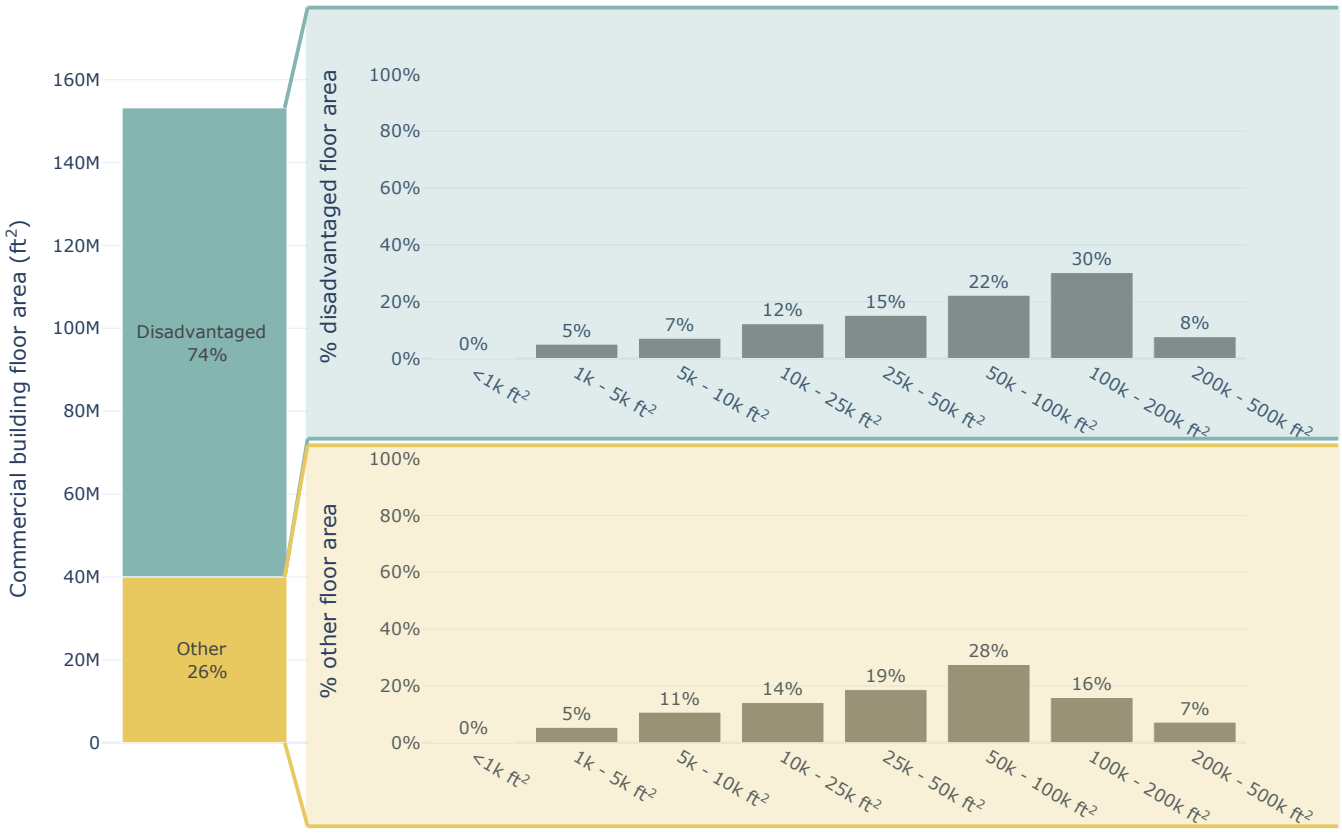


Figure 6. Segmentation of the commercial building stock by size, segmented into "disadvantaged" and "other" (as defined by CEJST)

Figure 7 segments households in multifamily buildings by building size, differentiating between "disadvantaged" and "other" communities (as defined by CEJST data on a census tract basis). This report only includes households in multifamily buildings over 10,000 square feet. Multifamily building characteristics come from a collation of county assessor databases (LightBox 2020). The figure illustrates how a policy's building size threshold might impact multifamily buildings in disadvantaged communities. A 50,000-square-foot threshold includes 21% of multifamily buildings in disadvantaged communities. A 25,000-square-foot threshold includes 46% of multifamily buildings in disadvantaged communities.

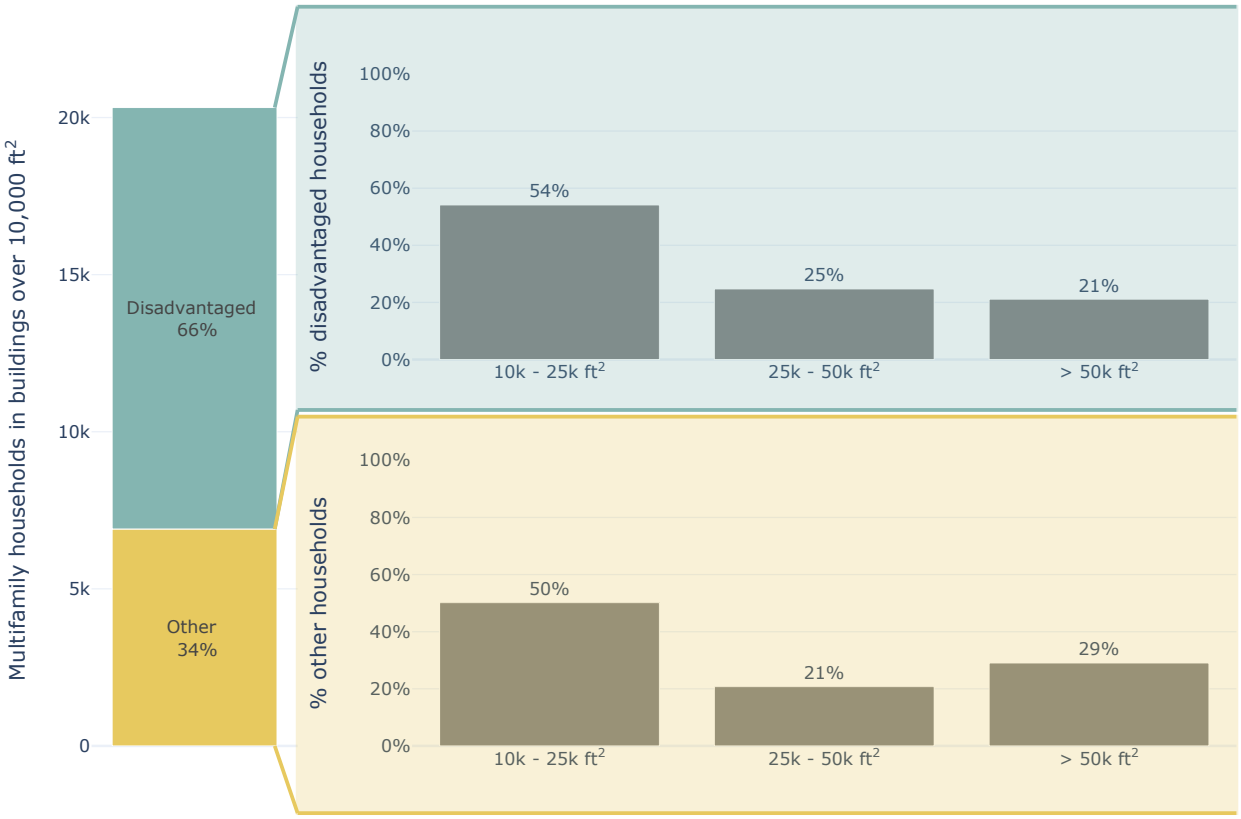


Figure 7. Households in multifamily buildings over 10,000 square feet, segmented into "disadvantaged" and "other" (as defined by CEJST)

A County and County Equivalents Included in the Analysis

The following counties (or equivalents thereof) in the listed states are included in this analysis:

North Carolina Beaufort County, Bladen County, Carteret County, Chowan County, Columbus County, Dare County, Duplin County, Greene County, Hyde County, Lee County, Lenoir County, Martin County, Montgomery County, Moore County, Pasquotank County, Perquimans County, Richmond County, Robeson County, Sampson County, Scotland County, Stanly County, Tyrrell County, Washington County and Wilson County.

South Carolina Chesterfield County, Dillon County, Georgetown County, Lee County, Marion County, Marlboro County and Williamsburg County.

B 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	428	428,000	0.0773	0.00648
1k – 5k ft^2	2,620	7,860,000	1.22	0.107
5k – 10k ft^2	1,650	12,300,000	1.09	0.0975
10k – 25k ft^2	2,140	30,100,000	2.21	0.189
25k – 50k ft^2	811	28,300,000	1.92	0.178
50k – 100k ft^2	530	38,300,000	2.85	0.21
100k – 200k ft^2	287	42,000,000	2.47	0.168
200k – 500k ft^2	40	13,300,000	1.49	0.102

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	0.0479	0.000521	0	0.0117	0	0.0168	0.000431
1k – 5k ft^2	0	0.837	0.0221	0.00786	0.0657	0	0.286	0.00423
5k – 10k ft^2	0.00331	0.419	0.0579	0.0129	0.182	0	0.409	0.0093
10k – 25k ft^2	0	0.55	0.0609	0.0927	0.916	0.305	0.234	0.0515
25k – 50k ft^2	0.0661	0.0702	0.0755	0.118	1.22	0.076	0.132	0.158
50k – 100k ft^2	1.51	0	0	0.165	0.737	0.0535	0.149	0.238
100k – 200k ft^2	1.74	0	0.148	0.0568	0.0515	0.0345	0	0.433
200k – 500k ft^2	0	0	1.31	0	0	0.0345	0	0.151

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	0.00379	5.39e-05	0	0.00105	0	0.00155	3.96e-05
1k – 5k ft^2	0	0.071	0.00212	0.000663	0.00587	0	0.0267	0.00038
5k – 10k ft^2	0.00022	0.034	0.00524	0.001	0.0163	0	0.0398	0.000906
10k – 25k ft^2	0	0.0382	0.00601	0.00742	0.0821	0.0295	0.0208	0.00479
25k – 50k ft^2	0.00473	0.00728	0.0054	0.0109	0.116	0.00738	0.0111	0.0146
50k – 100k ft^2	0.087	0	0	0.0143	0.0716	0.00505	0.0101	0.0222
100k – 200k ft^2	0.0993	0	0.0133	0.00589	0.00513	0.00349	0	0.0414
200k – 500k ft^2	0	0	0.0853	0	0	0.00356	0	0.013

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	32,100,000	6,590,000
Food Service	2,850,000	2,500,000
Healthcare	6,190,000	3,410,000
Lodging	2,300,000	3,550,000
Mercantile	23,700,000	10,400,000
Office	14,200,000	7,290,000
Warehouse and Storage	31,800,000	6,330,000

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	307,000	120,000
1k – 5k ft^2	5,690,000	2,170,000
5k – 10k ft^2	8,040,000	4,300,000
10k – 25k ft^2	13,800,000	5,660,000
25k – 50k ft^2	17,200,000	7,490,000
50k – 100k ft^2	25,200,000	11,000,000
100k – 200k ft^2	34,200,000	6,370,000
200k – 500k ft^2	8,690,000	2,900,000

0.6 Segmentation of Households in the Multifamily Building Stock Over 10,000 Square Feet

Table 7. Multifamily Households Segmented by CEJST Disadvantaged Definition and Size (all values are in number of households)

Building Size	Disadvantaged	Other
10k – 25k ft^2	7,260	3,460
25k – 50k ft^2	3,320	1,430
> 50k ft^2	2,840	2,010

References:

RESNET/ANSI/ICC Standard 301. *Standard for the Calculation and Labeling of the Energy Performance of Dwelling and Sleeping Units using an Energy Rating Index.* 2018.

CBECS. *Commercial Buildings Energy Consumption Survey 2012.* 2014. Technical report. U.S. Energy Information Administration 1000 Independence Ave., SW Washington, DC 20585: U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2012/.

CEQ. *Climate and Economic Justice Screening Tool.* 2023. Accessed Feb. 24, 2023 [Online]. Council on Environmental Quality, Council on Environmental Quality 730 Jackson Place NW Washington, D.C. 20506. https://screeningtool.geoplatform.gov/en.

ComStock End Use Savings Shape 2023 Release 1 Baseline Dataset - 2018 Weather. 2023. National Renewable Energy Laboratory. https://data.openei.org/s3_viewer?bucket=oedi-data-lake&prefix=nrel-pds-building-stock%2Fend-use-load-profiles-for-us-building-stock%2F2023%2Fcomstock_amy2018_release_1%2F.

CEJST: Technical Support Document. *Climate and Economic Justice Screening Tool: Technical Support Document - Version 1.0.* 2022. Council on Environmental Quality 730 Jackson Place NW Washington, D.C. 20506: Council on Environmental Quality, November. https://static-data-screeningtool.geoplatform.gov/data-versions/1.0/data/score/downloadable/1.0-cejst-technical-support-document.pdf.

eGRID. "Emissions and Generation Resource Integrated Database: 2019." n.d. U.S. Environmental Protection Agency. Accessed March 8, 2023. https://www.epa.gov/sites/default/files/2021-02/egrid2019_data.xlsx.

EIA. 2022. *Table C5: Consumption and gross energy intensity by census region for sum of major fuels.* Technical report. U.S. Energy Information Administration 1000 Independence Ave., SW Washington, DC 20585: U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/index.php?view=consumption.

Horsey, Henry R., Rozenfeld, Hernan, and Bergmann, Harry. 2023. *Stock Segmentation Cluster Development: Technical Reference Document.* NREL/NREL/TP-5500-84648. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy23osti/84648.pdf.

LightBox. 2020. *LightBox Property.* Technical report. LightBox LLC. https://www.lightboxre.com/data/property/.

OMB M-21-28. *Interim Implementation Guidance for the Justice40 Initiative.* 2021. OMB M-21-28. United States Office of Management and Budget, 725 Seventeenth Street NW., Washington, DC 20503. https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf.

Parker, Andrew, Horsey, Henry, Dahlhausen, Matthew, Praprost, Marlena, CaraDonna, Christopher, LeBar, Amy, and Klun, Lauren. 2023. *ComStock Reference Documentation: Version 1.* NREL/NREL/TP-5500-83819. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy23osti/83819.pdf.

RECS. *Residential Buildings Energy Consumption Survey 2020.* 2022. Technical report. U.S. Energy Information Administration 1000 Independence Ave., SW Washington, DC 20585: U.S. Energy Information Administration. https://www.eia.gov/consumption/residential/data/2020/.

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

For more information, visit:
energy.gov/eere/buildings

DOE/GO-102023-5980 • August 2023