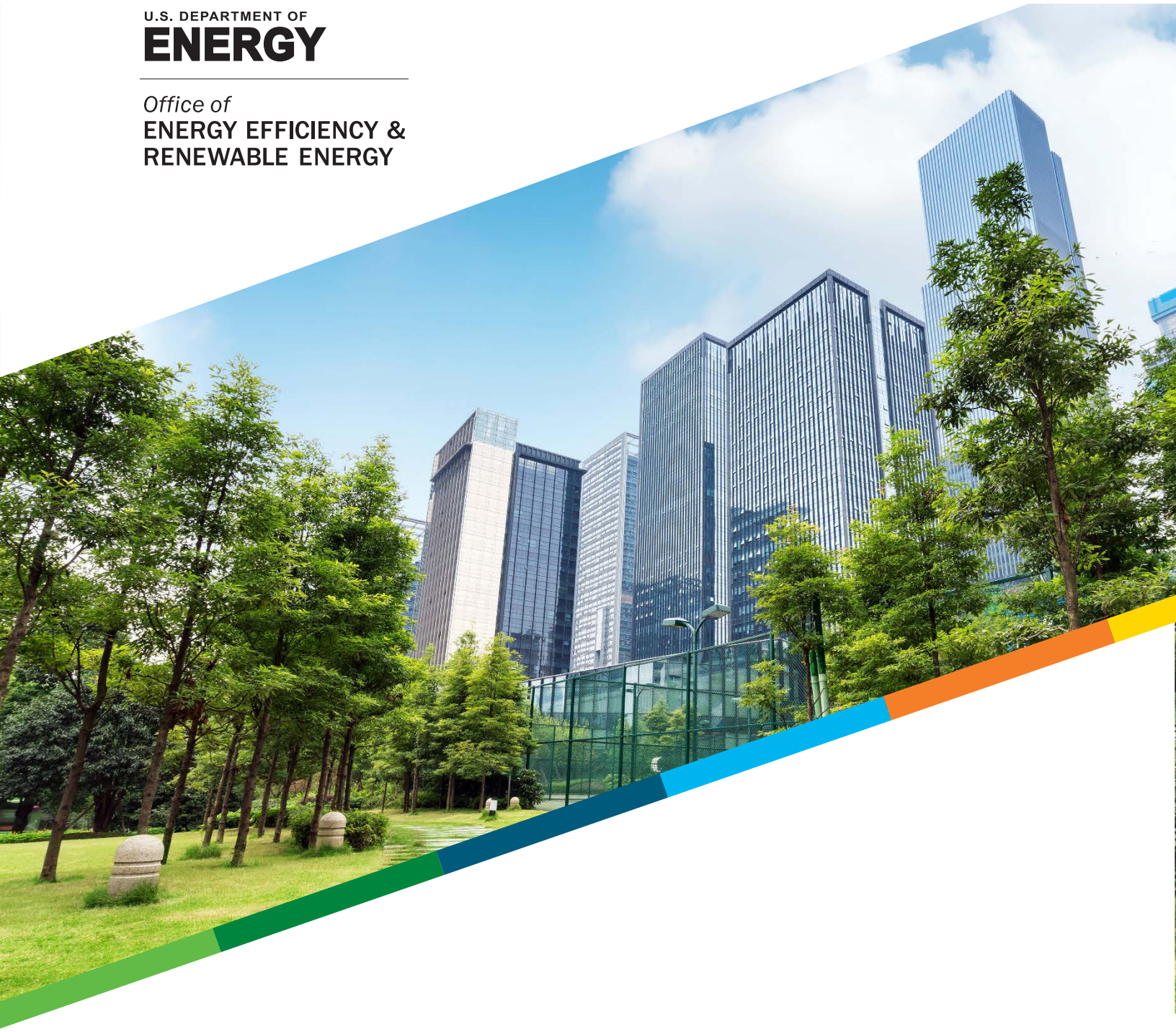
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY



Commercial Building Stock Segmentation for Decarbonization Planning

Technical Reference Document

May 2024

Disclaimer

Authors

The authors of this report are:

Andrew Parker, Matthew Dahlhausen, and Eric J. H. Wilson, National Renewable Energy Laboratory

Acknowledgments

The authors would like to acknowledge the valuable guidance and input provided during the development of this report. The authors thank the following list of contributors for their invaluable feedback, guidance, and review:

Sydney Applegate, U.S. Department of Energy (DOE)

Billierae Engelman, DOE

Sam Petty, DOE

Monica Neukomm, DOE

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.

Cover image from iStock # 875564252.

List of Acronyms

CAV	constant air volume
CBECS	commercial buildings energy consumption survey
DOAS	dedicated outdoor air system
DX	direct expansion
HVAC	heating, ventilating, and air conditioning
VAV	variable air volume

Executive Summary

This document discusses the development of a segmentation approach for the U.S. commercial building stock that focuses on identifying similarities that align with common decarbonization strategies. The resulting nine-segment approach primarily uses similarities in heating, ventilating, and air-conditioning systems, service water heating systems, and the presence of cooking equipment to separate buildings into categories.

Table of Contents

List of Figures

1 Goal of the Segmentation

The goal of the segmentation for decarbonization planning is to identify similarities across the commercial building stock that align with common decarbonization strategies.

There are a handful of prominent analyses on the U.S. commercial building stock. They include works such as:

- Commercial Buildings Energy Consumption Survey (CBECS), conducted by the U.S. Energy Information Administration (EIA).
- Documentation of the National Energy Modeling System (NEMS) Modules, also by the U.S. EIA.
- U.S. Department of Energy Commercial Reference Building Models of the National Building Stock (Deru et al. 2011).
- DEER Database: 2011 Update Documentation (Lai, Peter, and San Francisco 2011).

The primary goal of these works is to communicate where and how energy is consumed. The analyses segment the building stock according to building type, vintage, and floor area. This segmentation is logical because buildings of similar types and sizes tend to share other characteristics, such as operating schedules, ownership structures, etc. It is effective to look at the building stock this way because people with a nontechnical background can understand the differences between segments. For example, most people can differentiate a large office building from a small quick-service restaurant.

In contrast, our segmentation for decarbonization planning does not focus on traditional segmentation. This report will define this new segmentation and discuss the similarities in building characteristics that comprise each segment.

2 Understanding Building Stock Decarbonization

The general approach to decarbonizing operational emissions in the U.S. buildings sector is to transition the electricity generation system from emission-heavy to low/zero-emission sources and to switch the end uses that generate emissions on-site to provide the same services using low/zero-emission electricity.

As shown in Figure 1, 60% of the on-site energy consumed in commercial buildings is electricity. For the purposes of this segmentation effort, the assumption is that the electricity grid transition to zero-emission sources will happen, facilitated in part by managing electric demand from buildings through the deployment of efficiency and grid-edge resource management. Therefore, the focus of the decarbonization segmentation is on strategies that reduce emissions in the remaining 40% of on-site energy

consumption, which includes natural gas, district heating, and other fuels such as propane and fuel oil.

Over time, as the electric grid transitions, on-site electricity consumption will have increasingly lower associated emissions, as shown in Figure 2.

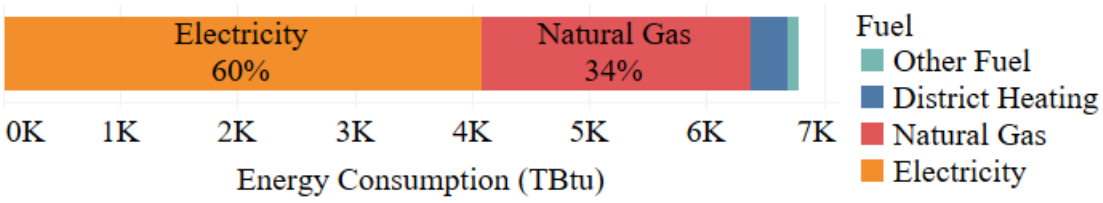


Figure 1. Annual U.S. commercial building energy consumption by fuel, 2018

Source: CBECS (2018)

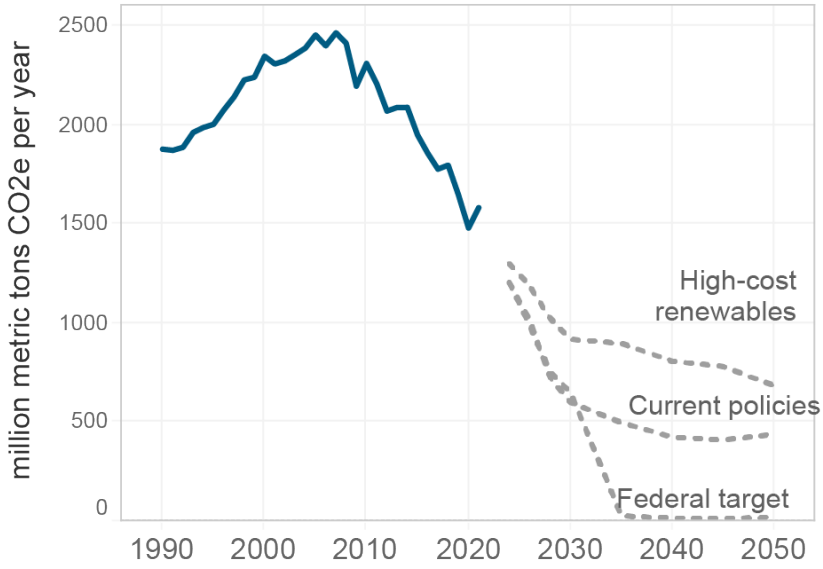


Figure 2. Historical and projected power emissions for a range of future grid scenarios.

Source: EPA (2023); NREL (2023)

3 Characteristics Used for Segmentation

The focus of the segmentation for decarbonization is strategies that reduce on-site consumption of natural gas, district heating, propane, and fuel oil. The first step was to evaluate the end uses served by these fuels. As shown in Figure 3, according to the CBECS, most of these fuels are used for heating, interior equipment (primarily cooking), and water heating.

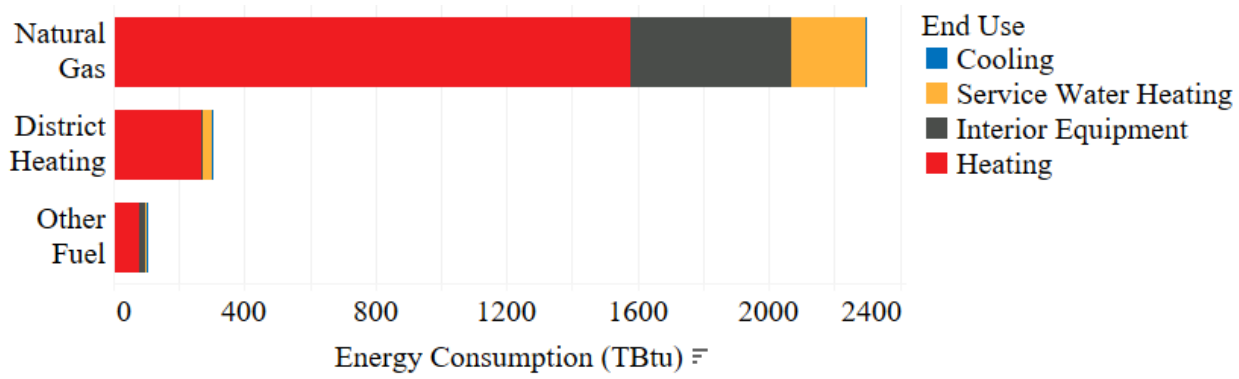


Figure 3. Annual U.S. commercial building energy consumption of non-electricity fuels by end use, 2018

Source: CBECS 2018

3.1 Heating End Use

Heating is the first end use of focus because it is the largest on-site fuel consumer, as shown in Figure 3. For this end use, a key factor in understanding decarbonization strategies is the type of heating, ventilating, and air-conditioning (HVAC) equipment that serves the building.

Although it is possible to replace the entire HVAC system, in many cases it is preferrable to reuse some pieces of the existing system. For this reason, the HVAC systems in the building stock were divided into the following five categories. Each of these categories has common HVAC system components that may be reused. Examples include hydronic piping and pumping components, ductwork, and mechanical chases.

- **Multizone constant air volume (CAV)/variable air volume (VAV)**: a forced air system that simultaneously serves multiple thermal zones in the building, each of which has different heating/cooling needs. Typically, these are either pieces of large rooftop equipment or an engineered system designed for that building.
- **Residential-style central systems**: small systems like a residential central heating and air-conditioning system, typically with a fan, gas heating coil, and direct expansion (DX) condenser coil inside the building and a DX evaporator coil outside the building connected by refrigerant lines. These systems often do not provide ventilation and have 5 tons or less of cooling capacity.
- **Small packaged unit:** a factory-built unit that typically contains a fan, gas heating coil, DX condenser and evaporator coils, and an outdoor air intake. These are often rooftop mounted and sometimes called “gas packs.” They typically have less than 10 tons of cooling capacity.
- **Zone-by-zone:** a heating and cooling system that uses small, individual pieces of equipment to heat or cool each zone in the building. These are often through-the-wall packaged terminal air conditioners or fan coil units found in hotels, but

they also include less common systems like zone-level water-to-air heat pumps. Ventilated air may be conditioned and supplied to the zone by a separate system or not provided at all in some cases.

- **Other HVAC:** Any system that does not fall into one of the other categories.

Figure 4 shows the breakdown of the total floor area for each HVAC system category covered by ComStock™. This was derived from CBECS data (U.S. EIA 2018). For more details on the derivation, see Parker et al. (2023). Although ComStock only represents two-thirds of the total commercial building floor area in the United States (see Figure 5), this breakdown gives a good sense of which system types are most common.

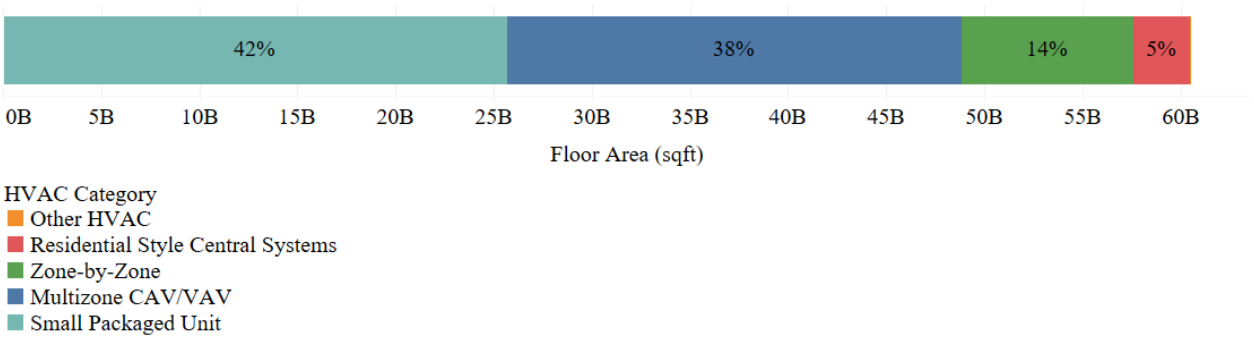


Figure 4. Floor area of building types included in ComStock by HVAC category

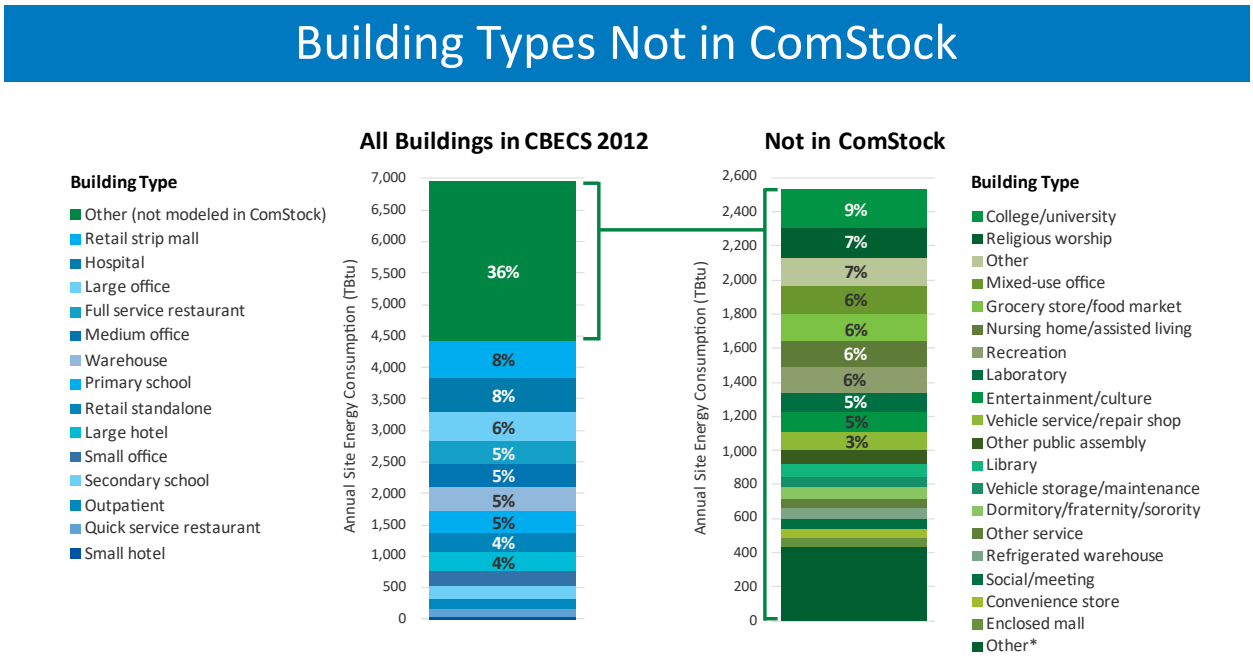


Figure 5. Overview of building types modeled and not modeled in ComStock, and comparison to CBECS annual site energy consumption

For the Multizone CAV/VAV category, further distinction is helpful to identify common HVAC equipment components that might be reused. This distinction was determined as follows:

- **Packaged multizone systems:** systems that burn fuel inside a heat exchanger, then pass air directly over the heat exchanger to heat the air.
- **Electric resistance multizone systems:** systems that pass air over electric resistance heating coils to heat the air directly.
- **Hydronically heated multizone systems:** systems that heat water, typically with a central boiler, and then circulate this water to air-to-water heating coils located throughout the building using pumps.

Figure 6 shows the breakdown of floor area for each type of system. Notably, the hydronic heating coils portion is the largest by far.

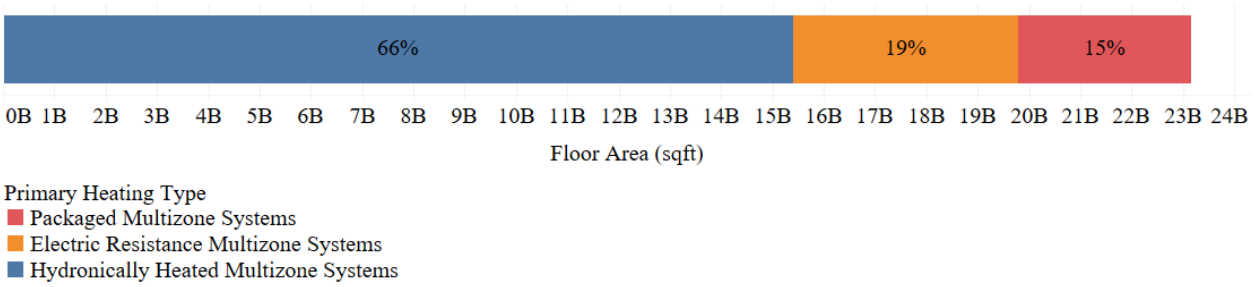


Figure 6. Floor area (billions sqft) of building types included in ComStock in the multizone CAV/VAV HVAC category by primary heating component type

3.2 Interior Equipment End Use

Looking back to Figure 3, interior equipment (primarily for cooking) is the second largest on-site fuel consumer. Unlike heating, this end use varies more extremely between building types. CBECS data presented in Figure 7 show order-of-magnitude differences in this end use between building types. Using this difference as part of the segmentation is logical, particularly because buildings with food service require a different approach to ventilation measures than buildings without food service.

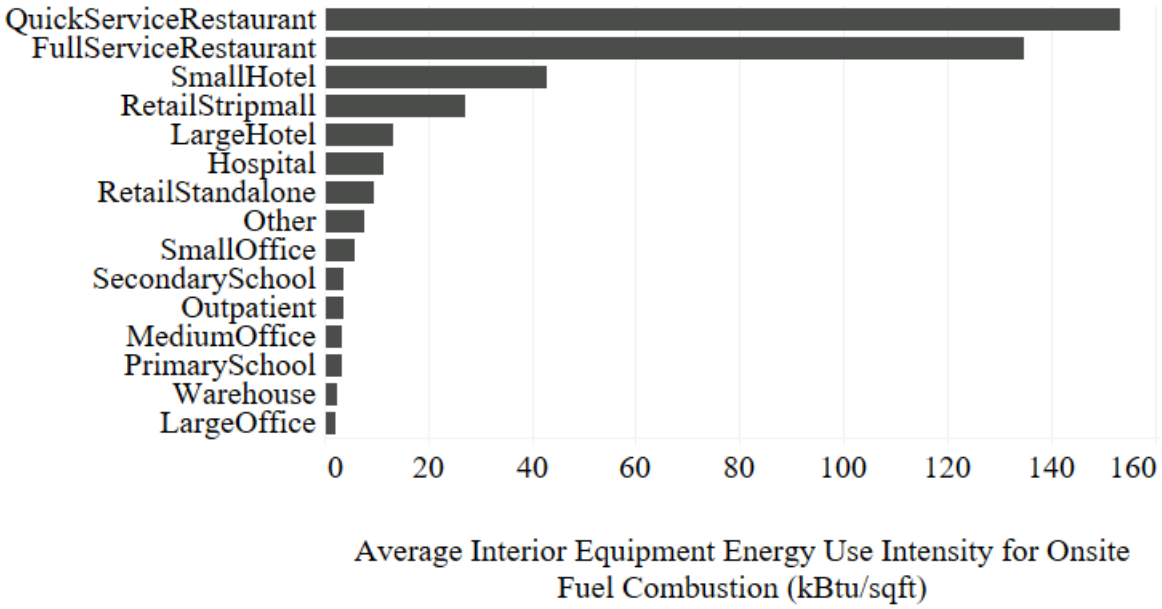


Figure 7. Average interior equipment energy use intensity for fuels combusted on-site by building type, 2018

3.3 Service Water Heating End Use

Service water heating is the third largest on-site fuel consumer as shown in Figure 3. Similar to interior equipment, the energy use intensity for the service water heating end use varies extremely between building types. CBECS data presented in Figure 8 show this difference. Using this difference as part of the segmentation is logical because buildings that use service water heating in different ways will need different strategies to decarbonize this end use. As shown in Figure 9, the vast majority of service water heating is provided using natural gas.

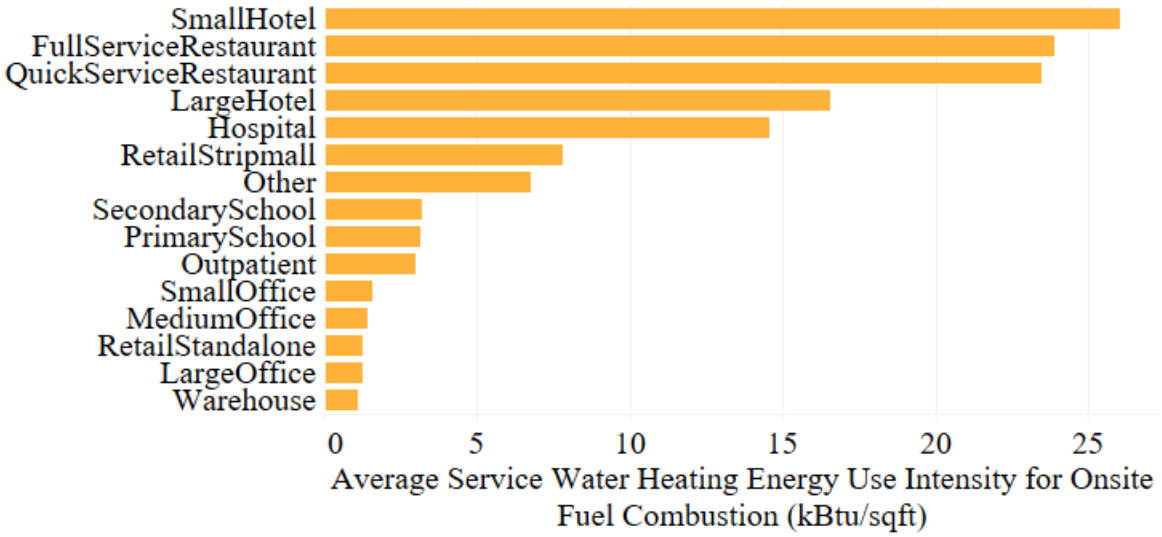


Figure 8. Average water heating energy use intensity for fuels combusted on-site by building type, 2018

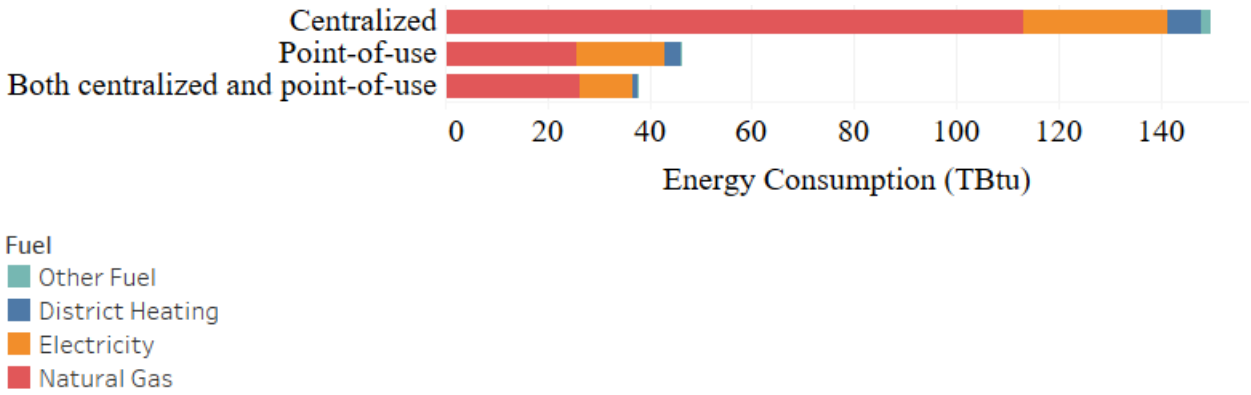


Figure 9. Water heating energy consumption by water heating equipment type and fuel, 2018

4 Segmentation for Decarbonization

Based on combinations of the characteristics previously described as meaningful to reducing on-site fuel consumption, the following commercial building stock segmentation for decarbonization planning was developed. Figure 10 shows the floor area of each segment in the ComStock baseline. The source data for this work is ComStock 2023 Release 2 and is publicly available via https://comstock.nrel.gov/page/datasets.

The figures within each segment's section show pictures of example buildings for that segment. Unlike traditional segmentation approaches, not all buildings in the segment look similar. The pictures are intended to provide non-technical readers with a notion of what buildings in a segment may look like.

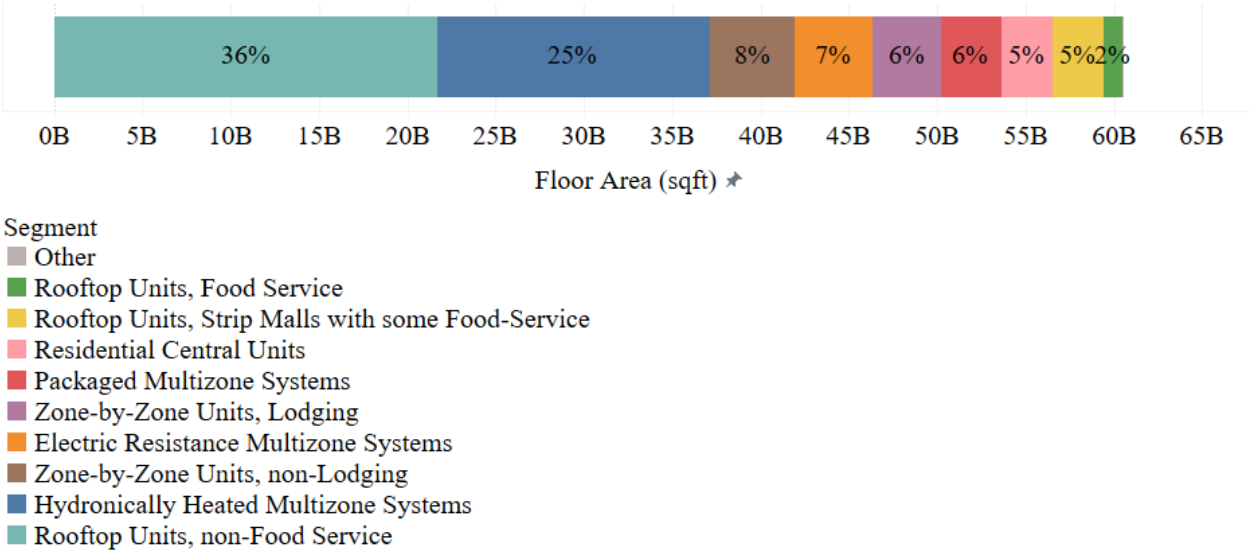


Figure 10. Floor area (billions sqft) of building types included in ComStock by segment

Rooftop Units, Non-Food Service

- Common examples include one- to two-story strip malls, retail buildings, warehouses, offices (Figure 11).
- Heating and cooling outside air for ventilation drives the HVAC energy consumption, peak demand, and system sizing.
- Leased space will cause split incentive challenges for approximately 50% of the segment.

Figure 11. Example of buildings in the Rooftop Units, Non-Food Service segment

Photos from Getty #172191793, top, and NREL #32773, bottom

Rooftop Units, Food Service

- Common examples include freestanding restaurants (Figure 12).
- Many small, high-energy-intensity buildings.
- Heating and cooling outside air for ventilation drives the HVAC energy consumption, peak demand, and system sizing.
- High ventilation because of cooking air exhaust hoods.
- High service water heating needs, including high-temperature water for dishwashing, primarily using water heaters with tanks, split between electricity and natural gas.
- High process loads for cooking, primarily natural gas.

Figure 12. Example of buildings in the Rooftop Units, Food Service segment

Photos from Getty #1155188071, top, and NREL #32773, bottom

Rooftop Units, Strip Malls with Some Food Service

- Common examples include strip malls with restaurants (Figure 13).
- Many small, high-energy-intensity buildings.
- Heating and cooling outside air drives the HVAC energy consumption.
- In restaurant portions, high ventilation because of cooking air exhaust hoods, high service water heating needs, including high-temperature water for dishwashing, and high process loads for cooking, primarily natural gas.
- Leased space will cause split incentive challenges for most of the segment, but cooking and dishwashing equipment may be tenant-supplied.

Figure 13. Example of buildings in the Rooftop Units, Strip Malls with Some Food Service segment

Photos from Getty #172188540, top, and #183318283, bottom

Zone-by-Zone Units, Non-Lodging

- Buildings with zone-by-zone systems are typically over 25,000 square feet but can include small buildings. This type of system is often based on the need for individual zone-level control without complex central plant equipment. (Figure 14).
- Most are heated with electric resistance.

Figure 14. Example of buildings in the Zone-by-Zone Units, Non-Lodging segment

Photos from Getty #173935126, top, and #1217120532, bottom

Zone-by-Zone Units, Lodging

- Common examples include motels and hotels, typically part of large chains (Figure 15).
- Most are heated with electric resistance.
- Significant service water heating demand for showering and sometimes laundry, primarily natural gas.

Figure 15. Example of buildings in the Zone-by-Zone Units, Lodging segment

Photos from Getty #136802528, top, and #1600997598, bottom

Residential Central Units

- Common examples include small buildings converted from residential uses (small offices such as dentist, accountant, lawyer, etc.) (Figure 16).
- Commonly called “central forced air” in the residential context.
- Typically, do not have mechanical ventilation.

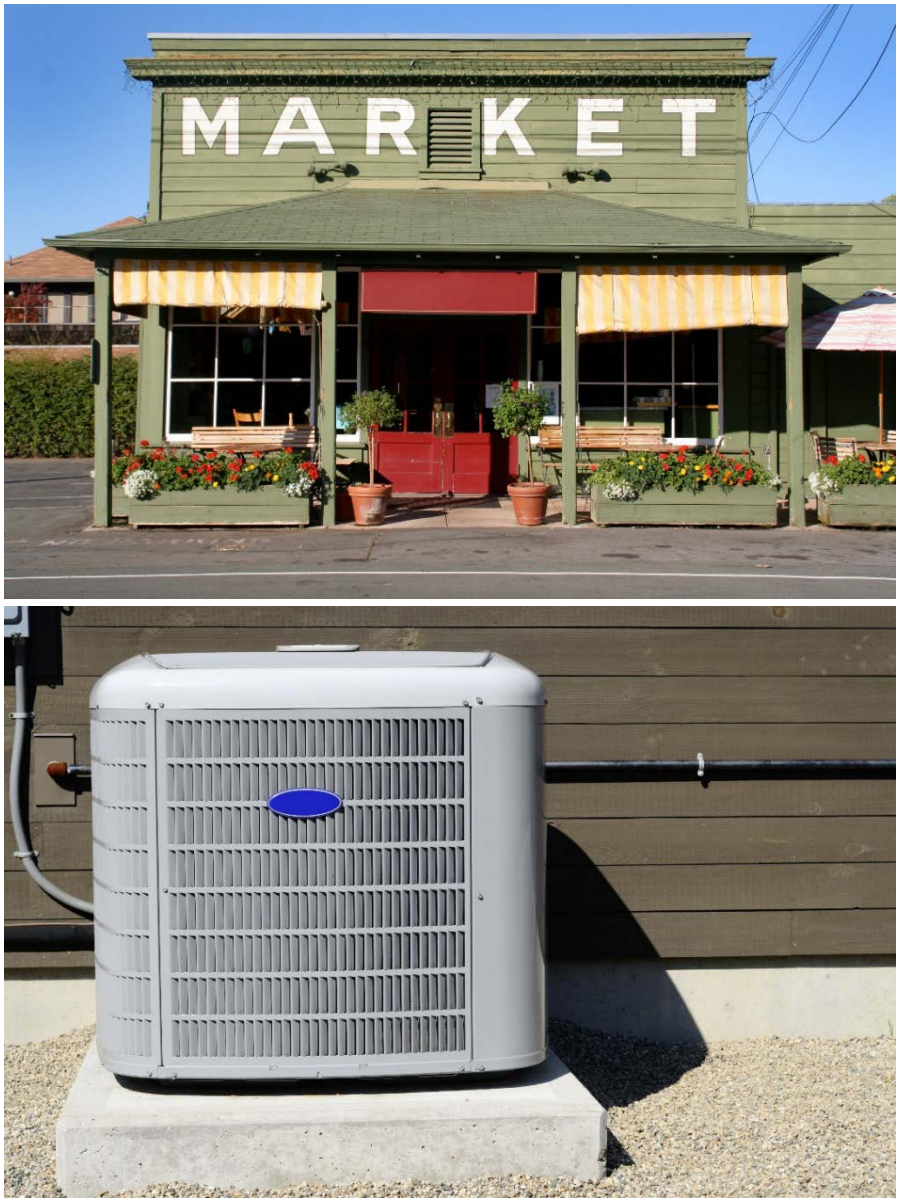


Figure 16. Example of buildings in the Residential Central Units segment

Photos from Getty #184979106, top, and #173021768, bottom

Packaged Multizone Systems

- Common examples include small to medium offices and schools (Figure 17).
- Combustion of natural gas in heat exchanger to directly heat air.
- Systems located inside or on rooftops.

Figure 17. Example of buildings in the Packaged Multizone Systems segment

Photos from Getty Images #157187378, top, and #1819098634, bottom

Hydronically Heated Multizone Systems

- Common examples include large buildings with boilers (schools, large offices, healthcare facilities) (Figure 18).
- Heating and cooling outside air drives the HVAC energy consumption.
- Typically complex, custom-engineered HVAC systems.
- Split incentive is less likely to be a barrier in institutional or healthcare, but still an issue in large offices.
- More likely to be served by a district heating or cooling system.

Figure 18. Example of buildings in the Hydronically Heated Multizone Systems segment

Photos from Getty #157738406, top, and NREL #38463, bottom

Electric Resistance Multizone Systems

- Common examples include medium to large offices and healthcare facilities (Figure 19).
- Often use electric reheat or electric resistance heat in the perimeter zones for construction cost reasons.

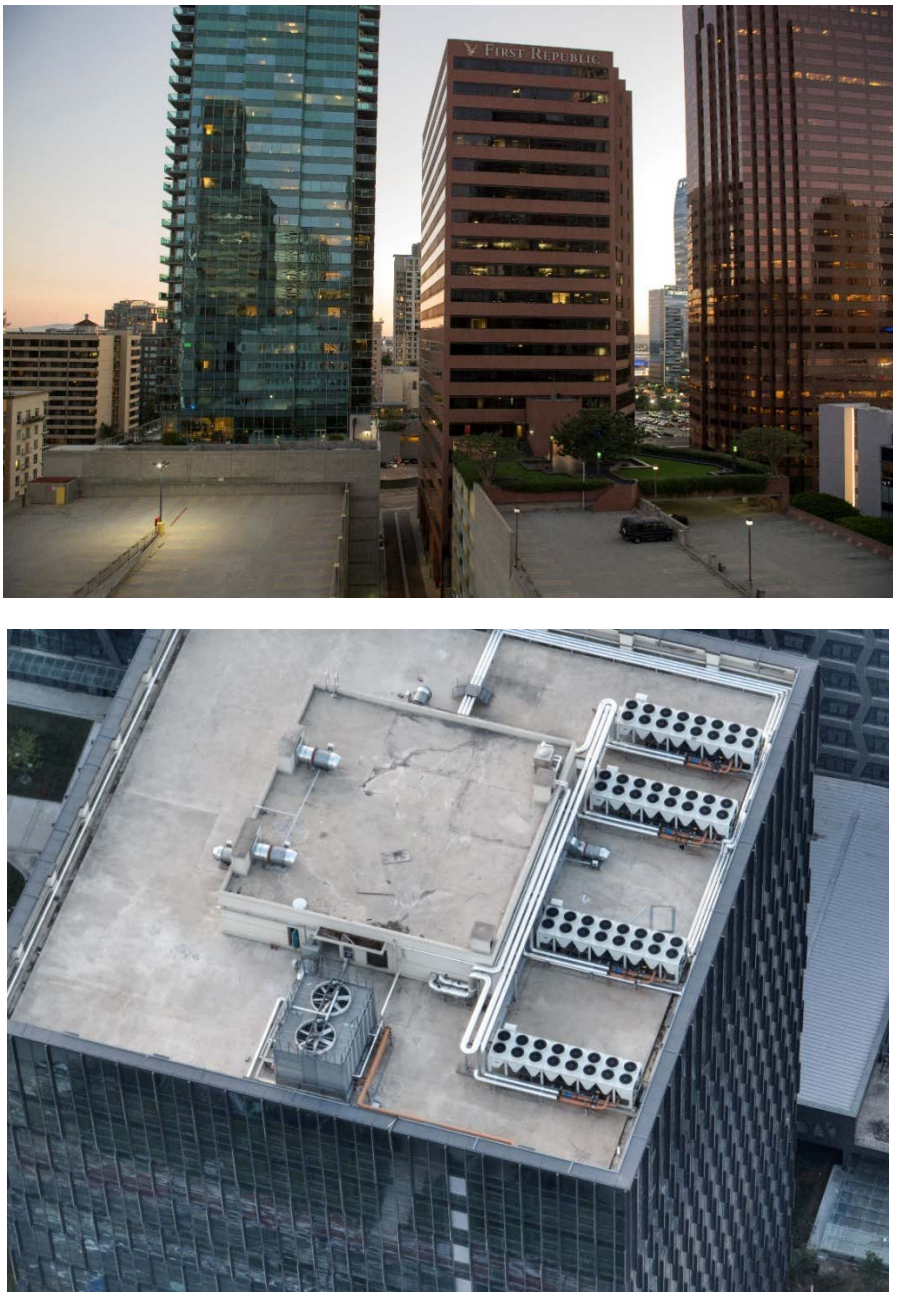


Figure 19. Example of buildings in the Electric Resistance Multizone Systems segment

Images from Getty Images #836167120, top, and #1353040767, bottom

Appendix

Table 1. Segments for Decarbonization Planning with ComStock HVAC System Type and Definition

Segment	in.hvac_combined_type	Definition
A: Non Food-Service Buildings with Small Packaged Units	**Central Single-zone RTU_ASHP_ASHP**	HVAC system type using constant air volume single-zone air handling unit with air-source heat pump for heating and cooling, outside ventilation air supplied directly through system
	Central Single-zone RTU_Boiler_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and hot water heating from gas boiler, outside ventilation air supplied directly through system
	Central Single-zone RTU_District_DX	HVAC system type using single-zone rooftop unit with hot water heating from district hot water system and chilled water cooling from district cooling system, outside ventilation air supplied directly through system
	Central Single-zone RTU_Electric Resistance_District	HVAC system type using constant air volume single-zone air handling unit with cooling from district chilled water system and heating from electric resistance coil, outside ventilation air supplied directly through system
	Central Single-zone RTU_Electric Resistance_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and electric resistance heating, outside ventilation air supplied directly through system
	Central Single-zone RTU_Electric Resistance_Evaporative Cooling	HVAC system type using direct evaporative coolers for cooling and zone electric resistance baseboard heating, outside ventilation air supplied directly through system
	Central Single-zone RTU_Furnace_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and gas furnace heating, outside ventilation air supplied directly through system
	Central Single-zone RTU_Furnace_Evaporative Cooling	HVAC system type using direct evaporative coolers for cooling and forced air furnace heating, outside ventilation air supplied directly through system
B: Food-Service Buildings with Small Packaged Units	**Central Single-zone RTU_ASHP_ASHP**	HVAC system type using constant air volume single-zone air handling unit with air-source heat pump for heating and cooling, outside ventilation air supplied directly through system

Segment	in.hvac_combined_type	Definition
	Central Single-zone RTU_Boiler_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and hot water heating from gas boiler, outside ventilation air supplied directly through system
	Central Single-zone RTU_Electric Resistance_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and electric resistance heating, outside ventilation air supplied directly through system
	Central Single-zone RTU_Electric Resistance_Evaporative Cooling	HVAC system type using direct evaporative coolers for cooling and zone electric resistance baseboard heating, outside ventilation air supplied directly through system
	Central Single-zone RTU_Furnace_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and gas furnace heating, outside ventilation air supplied directly through system
	Central Single-zone RTU_Furnace_Evaporative Cooling	HVAC system type using direct evaporative coolers for cooling and forced air furnace heating, outside ventilation air supplied directly through system
C: Strip Malls with some Food-Service with Small Packaged Units	**Central Single-zone RTU_ASHP_ASHP**	HVAC system type using constant air volume single-zone air handling unit with air-source heat pump for heating and cooling, outside ventilation air supplied directly through system
	Central Single-zone RTU_Boiler_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and hot water heating from gas boiler, outside ventilation air supplied directly through system
	Central Single-zone RTU_Electric Resistance_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and electric resistance heating, outside ventilation air supplied directly through system
	Central Single-zone RTU_Furnace_DX	HVAC system type using constant air volume single-zone air handling unit with DX cooling and gas furnace heating, outside ventilation air supplied directly through system
D: Buildings with Hydronically Heated Multizone Systems	**Central Multi-zone VAV RTU_Boiler_ACC**	HVAC system type using variable air volume system with hot water heating/reheating from gas boiler and chilled water cooling from air cooled chiller, outside ventilation air supplied directly through system

Segment	in.hvac_combined_type	Definition
	Central Multi-zone VAV RTU_Boiler_District	HVAC system type using variable air volume system with hot water heating/reheating from gas boiler and chilled water cooling from district cooling system, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_Boiler_DX	HVAC system type using packaged variable air volume system with hot water heating/reheating from gas boiler and DX cooling, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_Boiler_WCC	HVAC system type using variable air volume system with hot water heating/reheating from gas boiler and chilled water cooling from water cooled chiller, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_District_ACC	HVAC system type using variable air volume system with hot water heating/reheating from district heating system and chilled water cooling from air cooled chiller, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_District_District	HVAC system type using variable air volume system with heating/reheating from district heating system and chilled water cooling from district chilled water system, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_District_DX	HVAC system type using variable air volume system with hot water heating/reheating from district hot water system and DX cooling, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_District_WCC	HVAC system type using variable air volume system with hot water heating/reheating from district heating system and chilled water cooling from water cooled chiller, outside ventilation air supplied directly through system
E: Lodging with Zone-by-Zone Systems	**DOAS+Zone terminal equipment_ASHP_ASHP**	HVAC system type using zone variable refrigerant flow air-source heat pumps for heating and cooling, outside ventilation air provided by dedicated outdoor air system (DOAS)
	DOAS+Zone terminal equipment_Boiler_ACC	HVAC system type using zone fan coil units for heating and cooling from gas boiler and air-cooled chiller, outside ventilation air provided by DOAS

Segment	in.hvac_combined_type	Definition
	DOAS+Zone terminal equipment_Boiler_District	HVAC system type using zone fan coil units for heating and cooling from gas boiler and district chilled water system, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_Boiler_WCC	HVAC system type using zone fan coil units for heating and cooling from gas boiler and water-cooled chiller, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_District_District	HVAC system type using zone fan coil units for heating and cooling from district hot water system and district chilled water system, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_District_WCC	HVAC system type using zone fan coil units for heating and cooling from district heating plant and water-cooled chiller, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_Electric Resistance_ACC	HVAC system type using zone fan coil units for cooling from air-cooled chiller, baseboard electric resistance for heating, and outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_Electric Resistance_District	HVAC system type using zone fan coil units for heating and cooling from electric baseboards and district chilled water system, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_Electric Resistance_WCC	HVAC system type using zone fan coil units for heating and cooling from electric baseboards and water-cooled chiller, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_GSHP_GSHP	HVAC system type using zone water-source heat pumps for heating and cooling with heat rejection served by ground loop, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_WSHP_WSHP	HVAC system type using zone water-source heat pumps for heating and cooling with heat rejection served by cooling tower and gas boiler, outside ventilation air provided by DOAS
	Zone terminal equipment_ASHP_ASHP	HVAC system type using zone packaged terminal heat pump with air-source heat pump for heating and cooling, outside ventilation air supplied directly through system

Segment	in.hvac_combined_type	Definition
	Zone terminal equipment_Boiler_DX	HVAC system type using zone packaged terminal air conditioners with DX cooling and hot water heating from gas boiler, outside ventilation air supplied directly through system
	Zone terminal equipment_Electric Resistance_DX	HVAC system type using zone packaged terminal air conditioners with DX cooling and electric resistance heating, outside ventilation air supplied directly through system
	Zone terminal equipment_Furnace_DX	HVAC system type using zone packaged terminal air conditioners with DX cooling and gas furnace heating, outside ventilation air supplied directly through system
F: Buildings with Electric Resistance Multizone Systems	**Central Multi-zone VAV RTU_Electric Resistance_ACC**	HVAC system type using variable air volume system with electric heating/reheating and chilled water cooling from air cooled chiller, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_Electric Resistance_District	HVAC system type using variable air volume system with electric heating/reheating and chilled water cooling from district cooling system, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_Electric Resistance_DX	HVAC system type using packaged variable air volume system with electric resistance heating/reheating and DX cooling, outside ventilation air supplied directly through system
	Central Multi-zone VAV RTU_Electric Resistance_WCC	HVAC system type using variable air volume system with electric heating/reheating and chilled water cooling from water cooled chiller, outside ventilation air supplied directly through system
G: Buildings with Furnace-Based Multizone Systems	**Central Multi-zone VAV RTU_Furnace_DX**	HVAC system type using variable air volume system with hot water heating from boiler, reheat from electric resistance coils, and DX cooling, outside ventilation air supplied directly through system
H: Buildings with Residential Style Central Systems	**Residential forced air_Furnace_DX**	HVAC system type using residential forced air system with DX cooling and gas furnace heating, no outside ventilation air
	Residential forced air_Furnace_None	HVAC system type using residential forced air system with gas furnace heating and no cooling, no outside ventilation air

Segment	in.hvac_combined_type	Definition
I: Non-Lodging Buildings with Zone-by-Zone Systems	**DOAS+Zone terminal equipment_ASHP_ASHP**	HVAC system type using zone variable refrigerant flow air-source heat pumps for heating and cooling, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_Boiler_ACC	HVAC system type using zone fan coil units for heating and cooling from gas boiler and air-cooled chiller, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_Boiler_WCC	HVAC system type using zone fan coil units for heating and cooling from gas boiler and water-cooled chiller, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_District_ACC	HVAC system type using zone fan coil units for heating and cooling from district hot water system and air-cooled chiller, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_District_District	HVAC system type using zone fan coil units for heating and cooling from district hot water system and district chilled water system, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_District_WCC	HVAC system type using zone fan coil units for heating and cooling from district heating plant and water-cooled chiller, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_Electric Resistance_District	HVAC system type using zone fan coil units for heating and cooling from electric baseboards and district chilled water system, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_Electric Resistance_WCC	HVAC system type using zone fan coil units for heating and cooling from electric baseboards and water-cooled chiller, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_GSHP_GSHP	HVAC system type using zone water-source heat pumps for heating and cooling with heat rejection served by ground loop, outside ventilation air provided by DOAS
	DOAS+Zone terminal equipment_WSHP_WSHP	HVAC system type using zone water-source heat pumps for heating and cooling with heat rejection served by cooling tower and gas boiler, outside ventilation air provided by DOAS

Segment	in.hvac_combined_type	Definition
	Zone terminal equipment_ASHP_ASHP	HVAC system type using zone packaged terminal heat pump with air-source heat pump for heating and cooling, outside ventilation air supplied directly through system
	Zone terminal equipment_Boiler_DX	HVAC system type using zone packaged terminal air conditioners with DX cooling and hot water heating from gas boiler, outside ventilation air supplied directly through system
	Zone terminal equipment_Electric Resistance_DX	HVAC system type using zone packaged terminal air conditioners with DX cooling and electric resistance heating, outside ventilation air supplied directly through system
	Zone terminal equipment_Furnace_DX	HVAC system type using zone packaged terminal air conditioners with DX cooling and gas furnace heating, outside ventilation air supplied directly through system
	Zone terminal equipment_Furnace_None	HVAC system type using zone gas unit heaters for heating and no cooling, no outside ventilation air
J: Other	**None_Electric Resistance_None**	HVAC system type using zone electric resistance baseboard heating and no cooling, no outside ventilation air

References

Deru, M., et al. *U.S. Department of Energy Commercial Reference Building Models of the National Building Stock*. NREL/TP-5500-46861, National Renewable Energy Laboratory, 2011, p. 118.

Lai, Peter, and San Francisco. *DEER Database: 2011 Update Documentation*. 2011, p. 147.

National Renewable Energy Laboratory (NREL). 2023. Cambium full data sets - Cambium 2022 release. https://www.nrel.gov/analysis/cambium.html; HighRECost, MidCase, and MidCase100by2035 scenarios and includes combustion emissions only.

Parker, Andrew, et al. *ComStock Reference Documentation (V.1)*. NREL/TP-5500-83819, National Renewable Energy Laboratory (NREL), Golden, CO (United States), 1 Mar. 2023. *www.osti.gov*, https://doi.org/10.2172/1967948.

U.S. EIA. *Commercial Buildings Energy Consumption Survey (CBECS)*. 2018, https://www.eia.gov/consumption/commercial/.

---. *Documentation of the National Energy Modeling System (NEMS) Modules*. U.S. EIA, 2023, https://www.eia.gov/outlooks/aeo/nems/documentation/.

U.S. Environmental Protection Agency (EPA). 2023. Inventory of U.S. GHG Emissions and Sinks: 1990-2021. (EPA 430-R-23-002) https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

For more information, visit: energy.gov/eere

DOE/GO-102024-6178 • May 2024