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Chillers, Refrigerant Compressors, and Heating Systems

Course Number: ME-02-242

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Module 1: Executive Summary

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the primary energy consumption breakdown between heating and cooling equipment in the U.S. commercial sector.
- **Evaluate** the impact of different equipment types and building categories on national HVAC energy use.
- **Analyze** how geographic climate and building floorspace distribution influence regional energy demands.

Executive Summary: HVAC systems in U.S. commercial buildings consume approximately 3.1 quads of primary energy for cooling (1.4 quads) and heating (1.7 quads). Packaged AC units are the most significant contributors to cooling energy due to their widespread use across 48% of cooled commercial floorspace.

Design Fundamentals and Study Objectives

This study provides a **bottom-up conservative estimate** of national energy consumption focused on equipment used to generate heating and cooling.

Primary Objectives

- Provide an accurate estimate of energy used by **primary cooling and heating equipment**.
- Establish a physical understanding of factors contributing to equipment energy use.
- Create a **baseline estimate** for calculating the impact of future energy-saving options based on calendar year 1995.

⚠ Safety Constraint: This volume focuses strictly on energy generation equipment such as boilers, furnaces, chillers, and compressors. Distribution energy—including fans and pumps—is addressed separately in Volume II to ensure clear distinction between generation and distribution.

📊 Calculation Note: Site electricity use is converted to primary energy using a heat rate of **11,005 Btu per kWh**, which accounts for transmission and distribution losses.

Summary of Design Findings: Cooling

Total cooling energy use accounts for approximately **1.4 quads** of primary energy annually.

- **Packaged AC Dominance:** Approximately **54%** of cooling energy is associated with Packaged AC units, primarily rooftop units.
- **Chiller Impact:** Centrifugal chillers account for **14%** of total cooling energy, while reciprocating chillers account for **12%**.



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- Efficiency Factors:** Reciprocating chillers are generally less efficient because they are typically air-cooled, whereas water-cooled centrifugal systems allow condensing temperatures to approach ambient wet bulb temperatures.

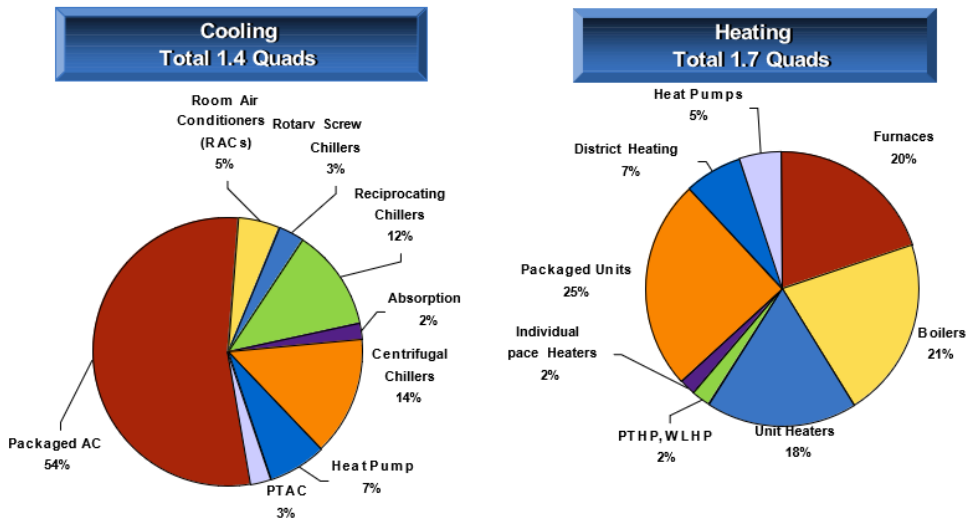


Figure 1-1: Primary Energy Use — Equipment Breakdown

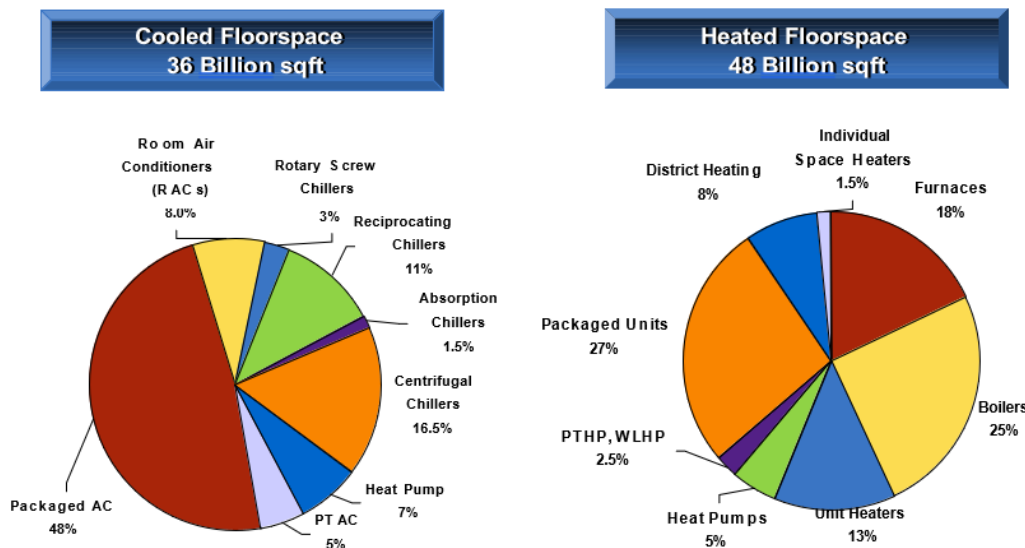


Figure 1-2: HVAC Equipment Distribution

Summary of Design Findings: Heating

Total heating energy use accounts for approximately **1.7 quads** of primary energy annually.

- Key Equipment Drivers:** Aside from packaged units (25%), the primary heating energy consumers are **boilers (21%), furnaces (20%), and unit heaters (18%)**.
- Energy Magnitude:** Furnaces, boilers, and unit heaters represent **0.34, 0.36, and 0.31 quads** respectively in commercial buildings.

Building and Regional Energy Trends

Building Category Impact

- **High-Volume Users: Offices, Mercantile & Service, and Public Buildings** are the largest energy consumers.
- **Floorspace Contribution:** These categories each represent at least 7 billion sq. ft. of floorspace and account for roughly 0.6 quads of space conditioning energy.
- **Energy Intensity:** Food service and health care categories are critical due to their **high energy use intensity**, particularly for cooling.

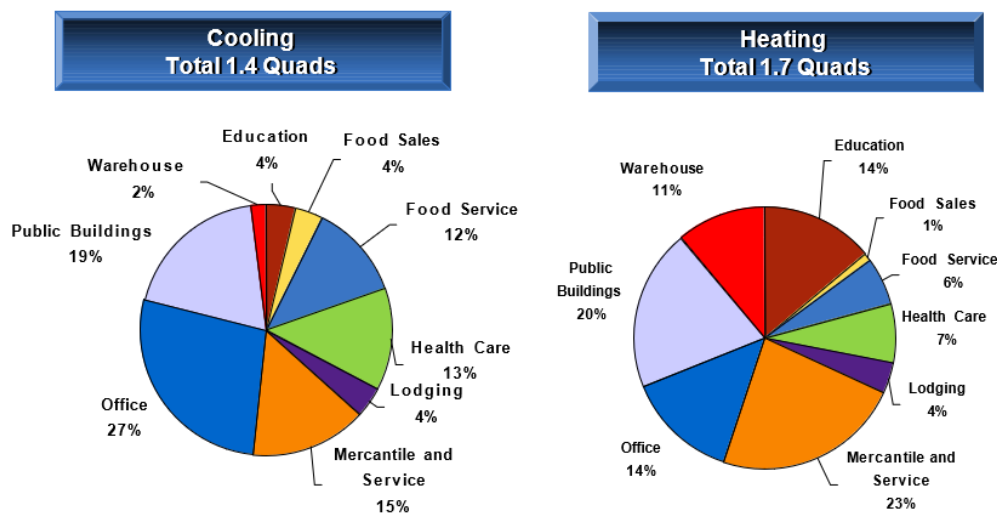


Figure 1-3: Primary Energy Use - Building Type Breakdown

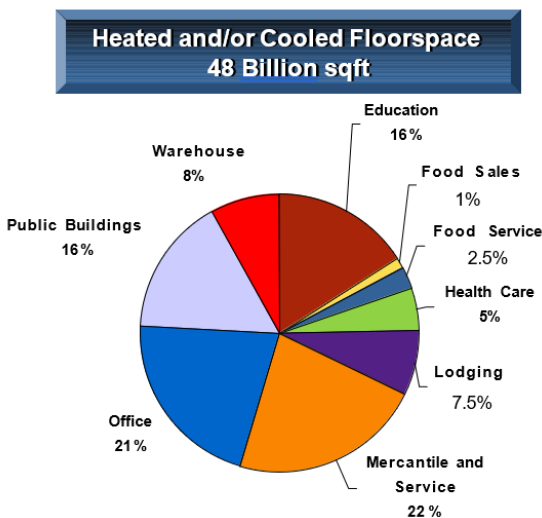


Figure 1-4: Heated and Cooled Commercial Building Floorspace

Regional Distribution

- **The South:** Represents the **highest energy usage for cooling** (61%) due to climate and large floorspace volume.
- **The Midwest:** Leads in **heating energy consumption** at 38%.
- **The Pacific:** Notable for having consistently **low energy use** for both heating and cooling.

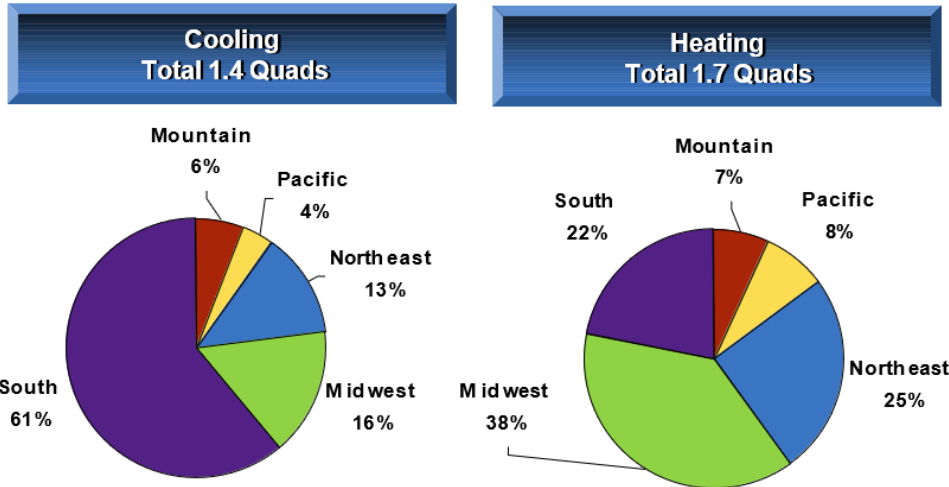


Figure 1-5: Primary Energy Use -- Regional Breakdown

Heated and/or Cooled Floorspace
Total 48 Billion sqft

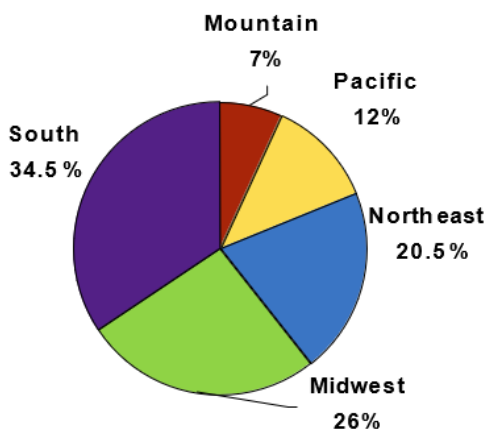


Figure 1-6: Commercial Building Floorspace — Regional Breakdown

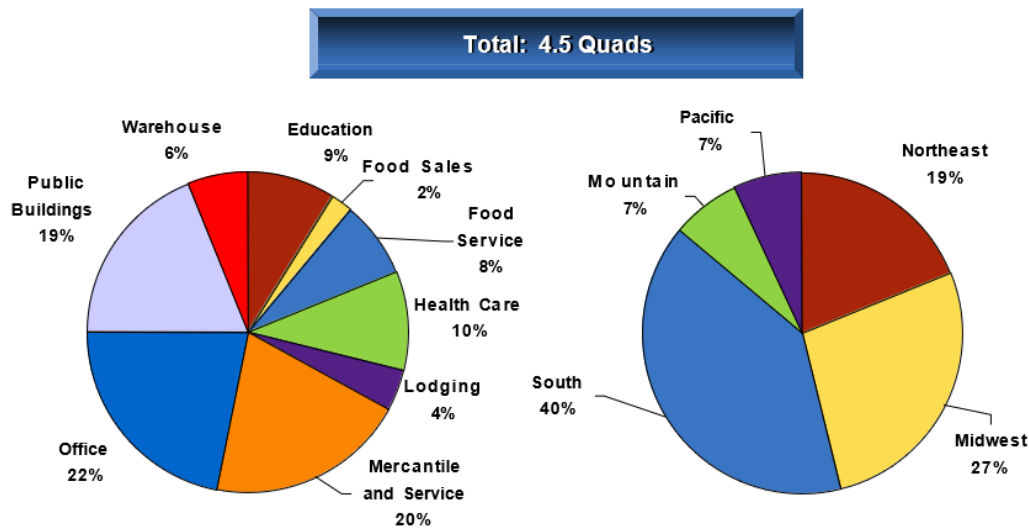



Figure 1-7: Total HVAC Primary Energy Use

 **Design Tip:** When evaluating regional impacts, consider that the South's heating impact is increased by the more prevalent use of **electric heat** compared to other regions.

Checkpoint Quiz

1. **Which equipment type is responsible for more than half of the total cooling energy use in the U.S. commercial sector?**
 - a) Centrifugal Chillers
 - b) Packaged AC Units
 - c) Reciprocating Chillers
 - d) Heat Pumps

Answer: (b). They account for 54% of cooling energy, largely because they are used in a majority of building types representing significant floorspace.

2. **Why are reciprocating chillers generally characterized as less efficient than centrifugal chillers in this study?**
 - a) They are exclusively used in smaller, poorly insulated buildings.
 - b) They utilize older refrigerant types that are now phased out.
 - c) Most are air-cooled rather than water-cooled, limiting heat rejection efficiency.
 - d) They have higher parasitic fan loads that are included in their primary rating.



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