

## HVAC: Packaged Rooftop Air Conditioners

Approximately half of all U.S. commercial floor space is cooled by self-contained, packaged air-conditioning units, most of which sit on rooftops (**Figure 1**). Also called unitary air conditioners or simply “packaged units,” these mass-produced machines include cooling equipment, air-handling fans, and sometimes gas or electric heating equipment. Rooftop units (RTUs) are available in sizes ranging from 1 ton to more than 100 tons of air-conditioning capacity (1 ton of cooling capacity will remove 12,000 Btu of heat per hour).

### Figure 1: Up on the roof

Rooftop units are the workhorses of commercial air conditioning and are used widely in industrial facilities as well.



Source: Platts

The three main power consumers in a rooftop unit—compressor, supply fan, and condenser fan—account for approximately 83, 10, and 7 percent, respectively, of the RTU’s peak power (**Figure 2**). However, because supply fans are often used to provide ventilation even when the compressor is not in use, the compressor’s annual energy usage can be as low as 55 percent of the total energy use, with fans accounting for the remaining 45 percent.

### What Are the Options?

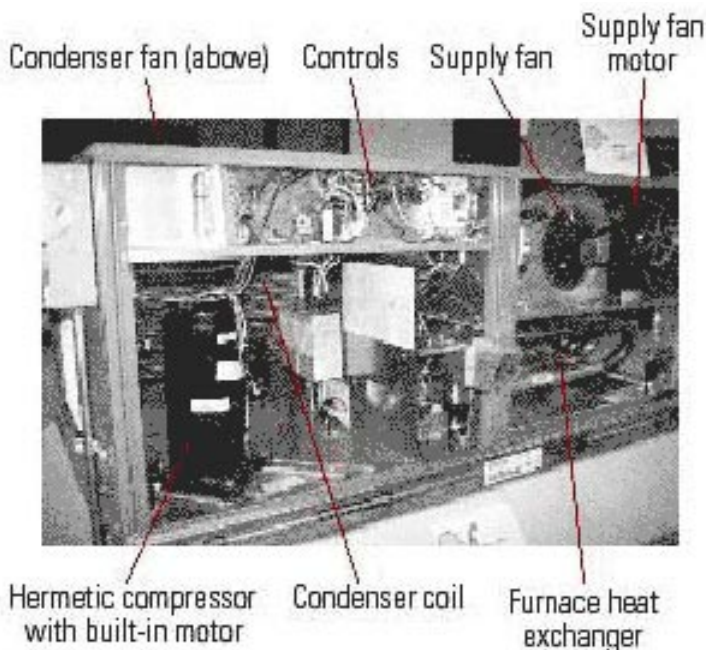
**Efficiency.** RTUs of the same capacity are usually available with a wide range of efficiencies. The Air-Conditioning and Refrigeration Institute (ARI) defines efficiency using several different terms:

- **EER (energy-efficiency ratio):** The ratio of the rate of cooling (Btu per hour, or Btu/h ) to the power input (watts) at full-load conditions. The power input includes all inputs to compressors, fan motors, and controls.
- **SEER (seasonal energy-efficiency ratio):** A seasonally adjusted rating based on representative residential loads. SEER applies only to RTUs with a cooling capacity of less than 65,000 Btu per hour.
- **IPLV (integrated part-load value):** A seasonal efficiency rating method based on representative annual commercial loads. It applies to RTUs with cooling capacities equal to or greater than 65,000 Btu per hour.

EER is the rating of choice when determining which RTU will operate most efficiently during full-load conditions. SEER and IPLV are better indicators of which RTU will use less energy over the course of an entire cooling season.

### Figure 2: Anatomy of a rooftop unit

The rooftop unit shown contains electric cooling and gas heating components.



Source: Platts

The cooling efficiencies of RTUs under 250,000 Btu per hour are certified according to standards published by ARI. (ARI standards also apply to RTUs of 250,000 Btu per hour and over, but ARI has no certification program and does not publish efficiency data for this size range.)

**Federal minimum standards.** The current U.S. federal standard, last updated in 1992, requires manufacturers to produce equipment at a minimum efficiency of 8.9 EER and 8.3 IPLV for units with a capacity of at least 65 but less than 135,000 Btu/h and at a minimum efficiency of 8.5 EER and 7.5 IPLV for units of at least 135,000 Btu/h but less than 240,000 Btu/h.

**Highest available efficiency.** Manufacturers of RTUs continue to offer higher-efficiency units. As of 2005, the highest-efficiency RTUs on the market in sizes ranging from 65,000 to 135,000 Btu/h have EER values as high as 13.5; units from 135,000 to 240,000 Btu/h have EER values as high as 13.1.

**Compressor.** Most RTUs use efficient reciprocating compressors that feature several control options. RTUs normally handle part-load conditions by staging multiple compressors that are automatically turned on and off as necessary. As an alternative to completely shutting off the compressor, some units offer multiple valve-operated cylinders within the compressor that can be shut off individually. Shutting off cylinders effectively creates a smaller cooling unit that is nevertheless operating with the original heat exchangers, and the result is a more efficient RTU. Another option is hot-gas bypass, which allows the compressor to provide reduced cooling at low loads. However, this choice reduces capacity without reducing energy consumption.

**Condenser.** Nearly all RTUs under 20 tons have air-cooled condensers, which are about 20 percent less efficient than the evaporative condensers used in larger and more-efficient models. Because evaporating water can remove more condenser heat than a stream of ambient air, lower condenser temperature and pressure are attained, and the compressors can therefore run at lower power in water-cooled RTUs. For smaller units, however (below about 20 tons), the energy required for pumping and spraying the water can outweigh the compressor energy savings gained by evaporative cooling. Other potential drawbacks are that the savings from water cooling decrease in humid climates and that evaporative condensers require more maintenance than air-cooled condensers.

**Fans.** Fans are used to move air across both the condenser and the evaporator. The airflow across the latter is also the supply air for the building. While fan power use is a small fraction of compressor power use, fans can account for approximately 45 percent of the annual energy use because the fan operates for many more hours than the compressor. Most manufacturers also offer units with high-efficiency fans that increase both EER and IPLV as well as variable-speed fans that improve IPLV.

**Economizers.** An economizer is an additional dampered cabinet opening that draws air from the outside when outside air is cooler than the temperature inside the building, thereby providing “free” cooling. Many codes, standards, and utility programs already require the use of economizers, and most RTUs have this option. Economizers can reduce energy use by anywhere from 15 to 80 percent depending on conditions, and they are usually cost-effective given their minimal additional cost.

**Controls.** Programmable digital controls offer flexible settings that can be tailored to the application and are increasingly available as standard equipment. A good example is a seven-day time clock that consistently operates the RTU according to occupancy schedules and nighttime temperature setbacks. Digital controls are also easily tied into a central energy management system for monitoring and control as part of an overall building-control strategy. In addition, many new RTUs come ready to accept inputs from carbon dioxide sensors. These can be used to implement demand-controlled ventilation, an energy-saving strategy that adjusts building ventilation as occupancy changes rather than assuming that the building is always fully occupied.

---

**Cooling coils.** Smaller RTUs normally use direct-expansion evaporator coils, in which air is blown over a fin-and-tube heat exchanger that carries the evaporating refrigerant. Larger RTUs can use either direct-expansion or chilled-water coils. In the latter, the cooling water is piped to the RTU from a remote water-chilling unit. A key variable in coil design is the face area, which determines the air velocity over the coil. Most RTUs keep this face velocity below 600 feet per minute to prevent condensed water in the airstream from blowing off the coil and into the duct system.

## How to Make the Best Choice

**Select the right size.** An undersized unit won't be able to provide sufficient cooling, but if a unit is oversized (the more frequent occurrence), it not only costs more but will lead to higher costs for associated ductwork and other auxiliaries. Operating costs increase too, because oversized equipment spends more time at less-efficient part-load conditions. Specifiers and designers commonly overestimate loads because they fail to take into account the reduced air-conditioning loads that result from energy-efficient lighting, and they overestimate plug loads by using nameplate ratings of office equipment in the building.

It is also critical to use diversity factors when calculating internal loads. For example, consider a school: Peak load for the classrooms occurs when the classrooms are full, peak for the auditorium happens during an assembly, and peak for a gym occurs during a basketball game with the stands full. However, peak load for the school is not the sum of these loads, because they do not all occur simultaneously.

**Consider high-efficiency levels recommended by CEE and Energy Star.** The [Consortium for Energy Efficiency \(CEE\)](#) offers a program known as the High-Efficiency Commercial Air Conditioning & Heat Pumps Initiative. [The initiative's](#) goal is to encourage the use of high-efficiency unitary (single-packaged and split-system) central air-conditioning and heat pump equipment in commercial buildings. CEE currently suggests [efficiency levels](#) for commercial equipment that are approximately 22 percent greater than the current federal standard. The CEE specification is promoted by participating utilities through education and rebate programs.

[Energy Star](#) is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy (DOE) that establishes an efficiency specification above the federal standards. Equipment that meets these specifications is awarded the Energy Star label, which helps consumers and others readily identify high-efficiency products. The [current efficiency level](#) for Energy Star was set in 2002 and is the same as that of the CEE.

**Identify high-efficiency models.** ARI is the main source of information about energy-efficient RTU products. The organization maintains [directories](#) (available in both print and electronic formats) on its web site that include products from all ARI member-manufacturers.

CEE also maintains a [database of equipment efficiency data](#) that is easy to use.

**Evaluate high-efficiency models by performing a cost-effectiveness calculation.** The cost-effectiveness of a high-efficiency RTU depends on several factors, including cooling loads, operating hours, and the local cost of electricity. Use the calculation [tool](#) for preliminary screening of high-efficiency options. For more accurate predictions of performance, an analysis that accounts for local climate conditions and part-load equipment performance is necessary.

In addition, the Pacific Northwest National Laboratory offers a free life-cycle cost estimation tool that can be used to compare high-efficiency units with standard ones. This [tool](#) is more detailed and has the added benefit of displaying results graphically.

### Packaged RTU Efficiency Screening Tool

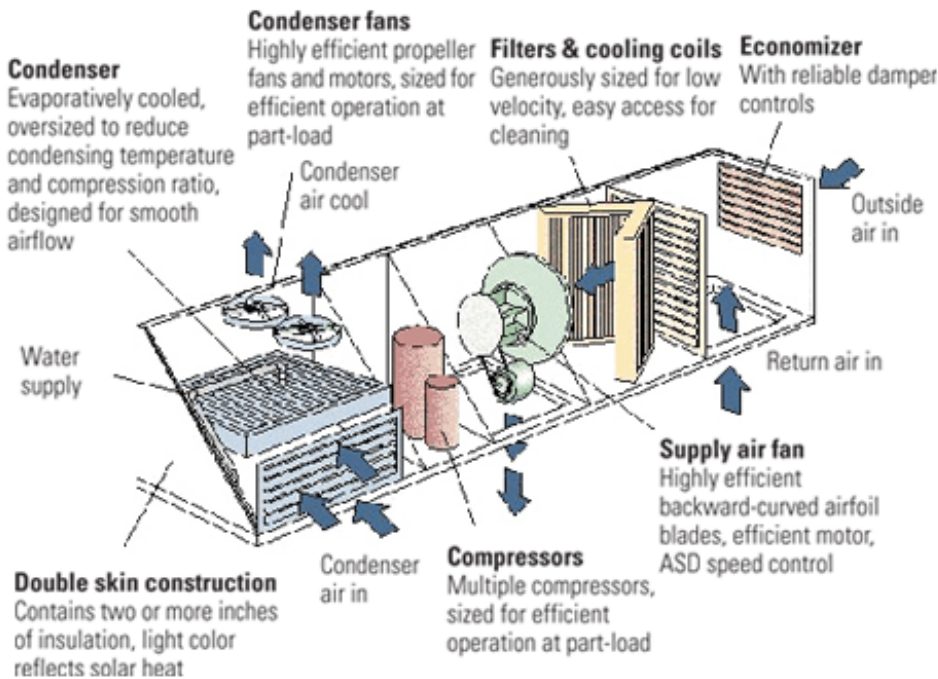
Other values required by this calculation tool should be available from utility bills and manufacturers' equipment data.

Case description	<input type="text"/>
Baseline unit:	<input type="text"/> versus High-efficiency unit: <input type="text"/>
Cooling load (tons at full load)	<input type="text"/>
Equivalent months of full cooling demand (EMFCD)	<input type="text"/> months
Equivalent full load hours/year	<input type="text"/> AEFLH/year
Utilities sales tax	<input type="text"/> %
Summer peak electric demand price	<input type="text"/> \$/kW
Summer peak electric energy price	<input type="text"/> \$/kWh
Base-case electric cooling efficiency (EER) at full load	<input type="text"/>
High-efficiency electric cooling efficiency (EER) at full load	<input type="text"/>
Installed cost premium for high-efficiency system	<input type="text"/> \$/ton
<input type="button" value="Calculate"/> <input type="button" value="Start over"/>	
Demand reduction	<input type="text"/> kW
Energy savings	<input type="text"/> \$/yr
Demand savings	<input type="text"/> \$/yr
Total savings	<input type="text"/> \$/yr
High-efficiency system net cost premium	<input type="text"/> \$
Simple payback	<input type="text"/> years

**Pay attention to design, commissioning, and maintenance.** No matter what equipment you choose, it's also important to make sure that the overall system is designed to be efficient (see [Figure 3](#)), that it's commissioned to operate as planned, and that it is properly maintained. A low-static-pressure duct system will reduce control problems, noise, and the fan power required. Comprehensive testing, adjusting, and balancing of the installed unit and its controls will maximize installed efficiency and comfort. Conducting regular tune-ups, correcting refrigerant charge, cleaning and adjusting the system to correct airflow and improve heat transfer, and repairing major duct leaks can yield surprising energy savings at low cost. CEE offers [installation guidelines](#) for commercial air-conditioning equipment.

### Figure 3: Rooftop unit components designed for energy efficiency

We designed this ideal packaged rooftop unit to maximize energy efficiency. Some available systems are built just like this, but many are not, or they have some but not all of these energy features. The RTU shown contains electric cooling and gas heating components.



Source: Platts

## What's on the Horizon?

The Energy Policy Act of 1992 mandates that whenever ASHRAE (the American Society of Heating, Refrigeration and Air Conditioning Engineers) updates the voluntary standard 90.1, which applies to commercial units, the DOE must update the federal standards within two years. ASHRAE approved a new version of 90.1 in 1999, thus initiating this process. Federal standards were passed for water-cooled and other equipment in 2001; however, the standards for commercial air-cooled equipment have not been updated yet. Proposed levels can be found at the [DOE's web site](#). A final rule on the new standard is expected by March 2006, with the standards taking effect on January 1, 2010.