Better Buildings
U.S. DEPARTMENT OF ENERGY

Fact Sheet: Rooftop Unit Sizing Guidance

BETTER BUILDINGS ALLIANCE

Overview

Correctly mapping building loads to rooftop unit (RTU) capacity can minimize both capital investment and ongoing operational costs while maximizing thermal comfort. Depending on unit functionality, incorrectly sized RTUs can consume more energy or provide less comfortable space conditions (or both) than right-sized equivalents. Common sizing mistakes (with respect to cooling tonnage and supply fan horsepower) can be controlled with these recommended processes to help project teams avoid those mistakes and ensure effective RTU replacement investments.

Oversizing

RTUs are often oversized due to the application of excessive safety factors or because loads were calculated incorrectly. Or they may have been correctly sized for building loads that have since been decreased through efficiency improvements such as a lighting retrofit. Replacement provides an opportunity to identify and eliminate oversizing due to typical like-for-like replacements (e.g., a 10-ton unit is replaced with a similar 10-ton unit without reevaluating building loads).The impact of oversizing depends heavily on the operation and functionality of the unit. In general, oversizing can have the following consequences:

- Constant-speed fans consume more energy than right-sized or variable-speed fan equivalents, particularly in low load scenarios such as "ventilation only" modes.
- Oversized fixed capacity compressors cycle more frequently, which can increase the frequency of service calls and reduce the overall compressor lifetime.
- Compressor cycling and excessive fan flow rates lead to less efficient operation and reduced latent cooling capacity, resulting in poor humidity control and a reduction in space comfort.
- Variable capacity RTUs may run more efficiently at part load when oversized; however, the marginal efficiency gains are unlikely to offset the higher capital cost of a larger unit.
- High-efficiency units usually weigh more than standard efficiency units, and a same size replacement may necessitate expensive roof reinforcements. Right-sizing may allow a smaller high-efficiency unit replacement that does not require structural reinforcement.
- Higher capacity units may require larger ducts or higher capacity electrical circuits. In a replacement scenario, this more expensive infrastructure may already be in place; if not, however, right-sizing provides an opportunity to reduce the cost of such infrastructure.

Right-sizing requires thorough understanding of the building program and loading conditions, but can significantly reduce both upfront and ongoing operational costs. Photo by Michael Deru, NREL 30455

Undersizing

RTUs may have been undersized from the outset because loads were not calculated correctly, or, more likely because space uses have changed (e.g., a storage space is converted to an office space). Because undersizing typically affects space comfort, it is less likely to be overlooked in a replacement scenario.

In general, undersizing can have the following consequences:

- It is most likely to result in an inability to maintain sensible cooling set points.
- It will reduce the value of variable-speed and variable-capacity functionality, which provides benefit only during part load operation.

Right-Sizing

Ensure proper sizing by hiring an engineer or contractor that follows the load calculation methods listed in the side bar. The following steps will help to ensure that an RTU replacement remedies any current operational issues that may have resulted from the oversized or undersized units:

1. **Characterize building and space requirements.** Accurate external load calculations must be based on a correct assessment of building construction details (envelope construction types, insulation levels, building orientation, fenestration design, etc.). Internal loads are difficult to predict without understanding how the building and its spaces will be used. What types of spaces (office, food service, storage, etc.) will the unit serve? What are the expected occupancy density and activity level? During what hours will the space be occupied and require conditioning? What will be the thermostat set points? Will the unit provide ventilation? Will the unit need to dehumidify? What are the expected future uses of the spaces? These types of questions will need to be answered before heating and cooling loads can be predicted and mapped to the appropriate unit type.

2. **Calculate loads and corresponding capacity and airflow requirements at design conditions.** Once the basic unit requirements have been captured, the engineer or contractor should determine capacity and airflow requirements using steady-state peak load calculation methods or dynamic whole-building energy simulations. Whatever the method, the design should reflect the full range of loading conditions. Typical sizing practices may consider only the maximum sensible load scenario (e.g., 1% cooling dry-bulb design point). However, other key loading conditions (maximum latent load, maximum solar gain, etc.) may influence sizing requirements, and the loads should be evaluated for all relevant design conditions. Unit capacity should be specified according to the minimum requirements established by the relevant design conditions. The total static pressure of the system should be estimated before supply fan horsepower is specified; an incorrectly sized supply fan motor can render an otherwise accurate tonnage assessment less effective. The purpose of the rigorous building characterization and design load calculation exercise is to capture the conditioning requirements as accurately as possible and avoid the need for excessive safety factors.

The Fundamentals of Design Load Calculation

A wide array of available resources automates design load calculation to varying degrees. Resources vary in complexity but share the same set of fundamental physical principles. The following resources provide insight into those underlying principles:

- ANSI/ASHRAE/ACCA Standard 183-2007 - Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings
- ACCA Manual N - Commercial Load Calculation
- ASHRAE Fundamentals Handbook - chapter on Nonresidential Cooling and Heating Load Calculations.

Sizing Resources

Numerous resources are available to guide system designers through the sizing process. Various mobile applications and software tools have been designed to simplify load calculation; such tools are quick and easy to use, but often compromise on calculation fidelity, which may lead to improper sizing. On the other end of the spectrum, energy simulation (using programs such as EnergyPlus, Trane TRACE, Carrier HAP, etc.) facilitates the most accurate and comprehensive load calculations, but is more expensive and requires specific expertise. Various spreadsheet tools bridge the gap between simple, less accurate mobile applications and detailed, highly accurate whole-building energy simulation engines. A February 2004 ASHRAE Journal article by Glenn Hourahan, titled, "How to Properly Size Unitary Equipment," provides additional guidance about RTU right-sizing.

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