Interim results from rooftop unit characterization study

Packaged rooftop units (RTUs) are ubiquitous on commercial buildings because of their low capital cost, reliability, and well-developed service and distribution network (Figure 1). Anecdotally, these systems are reported to operate inefficiently and sub-optimally. In order to characterize both existing RTUs and the new/replacement market for RTUs, Seventhwave, in collaboration with the Center for Energy and Environment, is executing a CARD grant to characterize RTUs in Minnesota. Results from this effort will help inform the improvement or development of utility conservation improvement programs whose goal is to reduce the energy consumption of new and existing RTUs.

Figure 1: Typical rooftop unit (photo courtesy of Wikimedia Commons)

In the first part of the study, Seventhwave estimated the number, types, and capacities of RTUs in Minnesota, as well as the features of the buildings in which they are located and the attributes of the occupants and owners of those buildings. Results from this part of the study are now available.

The analysis concludes that there are currently 20,700 buildings with RTUs in the state, and an estimated 80% of the area of these buildings is served by RTUs. Buildings under 50,000 square feet dominate the total number of buildings with RTUs, comprising 78% of the buildings. However, buildings greater than 50,000 square feet dominate the total area of buildings, comprising 70% by area. The majority of buildings that have RTUs do not have significant secondary HVAC systems, but

are served entirely by RTUs. Over half (57%) of buildings served by RTUs are in the Twin Cities or surrounding seven-county metro area.

The building types with the highest population of RTUs are office, food service, food sales, and public order and safety. Combined, these building types comprise over half (51%) of the buildings with RTUs in Minnesota.

Other interesting characteristics of the Minnesota commercial buildings served by RTUs include:

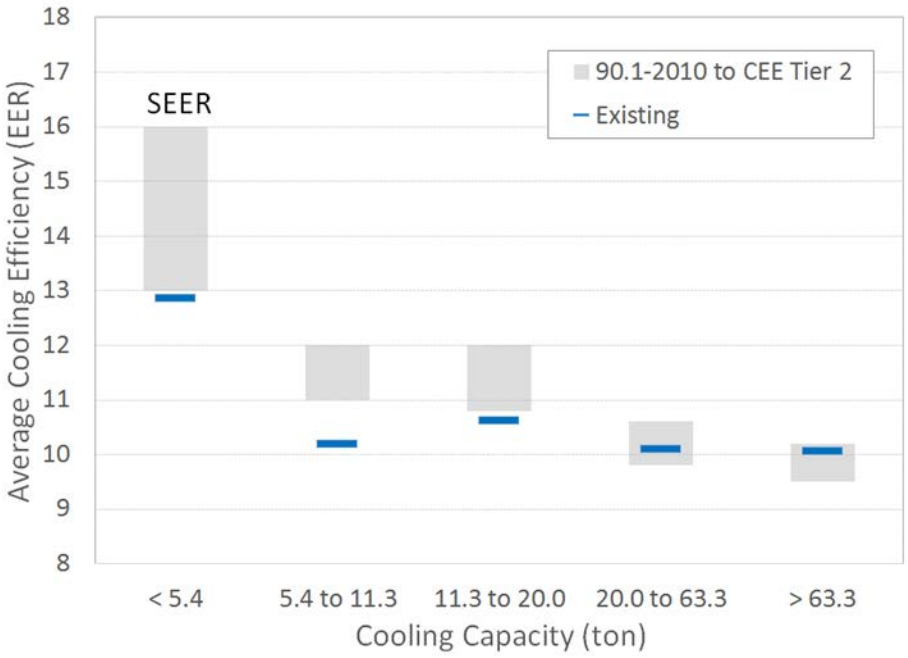
- Over four-fifths (83%) are owner occupied or public.
- Over two-thirds (68%) have a single tenant. The remainder tended to be malls, strip malls or multi-tenant office buildings.
- Approximately two-thirds (67%) had occupied hours exceeding what would be considered a standard work week.
- Over half (53%) use contracted vendors for maintenance purposes.
- Over one-third (36%) experience comfort complaints; two-thirds of these complaints were based on RTU performance, while one-third were dependent on an occupant's personal preferences.

The analysis indicates that there is a total of 136,000 existing RTUs in the state. On average, there are between 6 and 7 RTUs per commercial building served by RTUs. Three manufacturers (Carrier, Lennox and Trane) account for approximately three-quarters (75%) of the RTUs in Minnesota and over half (52%) of the installed capacity. ***The average age of an existing RTU in Minnesota is 13.1 years.*** Newer RTUs—those that are less than 5 years old—comprise 11% of existing RTUs.

The total estimated cooling capacity of RTUs in Minnesota is approximately 1.3 million tons with an average cooling capacity of 10.7 tons per RTU. Slightly more than half (52%) of the individual RTUs have a cooling capacity of less than 5.4 tons. However, RTUs with cooling capacities over 20 tons comprise 45% of the cooling capacity of all RTUs.

Over half (56%) of RTUs had full load cooling efficiencies between 9 and 11 energy efficiency ratio (EER). ***The average full load cooling efficiency of RTUs in Minnesota is 10.6 EER***. For new construction or renovation projects, the Minnesota energy code requires a minimum level of cooling efficiency for RTUs. The requirement varies by cooling capacity range. It is therefore interesting to compare the average cooling efficiency within each of these cooling capacity ranges (Figure 2).

Figure 2: Average cooling efficiency by cooling capacity



The average existing RTU cooling efficiencies are plotted in Figure 2 as bars, while the range of cooling efficiency between the current Minnesota energy code[1] and the Consortium for Energy Efficiency's (CEE) Tier[2] recommendations are also plotted to illustrate the potential programmatic savings magnitude. For RTUs with cooling capacities below 20 tons, the average existing efficiency is below the code-minimum and well below the Tier 2 recommendation, suggesting that there is considerable opportunity for improved efficiency in smaller RTUs. For larger RTUs with cooling capacities between 20 and 63.3 tons, the average existing efficiency is between the code-minimum requirement and below the CEE's Tier 2 recommendation. This means there is a limited opportunity for increasing efficiency for RTUs in this capacity range, as their efficiency is already relatively high. For RTUs with cooling capacities above 63.3 tons, the average existing efficiency is near the CEE's Tier 2 recommendation leaving very little opportunity for increased efficiency.

The current trend in increasing RTU performance is with respect to part-load cooling efficiency, rather than full-load cooling efficiency. From this study, it is estimated that 35% of RTUs in Minnesota have some level of part-load efficiency. The proportion of RTUs with part-load efficiency has been growing steadily over the past 20 years. Half (50%) of RTUs with part-load cooling efficiencies had an integrated energy efficiency ratio (IEER) between 10 and 12. ***For existing RTUs in Minnesota with part-load cooling efficiencies, the average IEER is 11.2.*** Developing programs that incentivize improved part-load efficiency is therefore recommended.

The total estimated heating capacity of RTUs in Minnesota is approximately 23.8 million MBH with an average heating capacity of 205 MBH per RTU. Nearly three-fourths (72%) of individual RTUs have a heating capacity less than 225 MBH. However, RTUs with heating capacities over 225 MBH comprise 58% of the heating capacity of all RTUs. The average heating efficiency of natural gas fired RTUs in Minnesota is essentially the code-minimum required value across all capacities of approximately 80%. No high efficiency condensing RTUs were identified in this study, as they are a relatively new (but growing) technology.

Fan power is a large component of a RTU's energy consumption. ***The total estimated fan power of RTUs in Minnesota is approximately 389,000 horsepower with an average of 3.3 horsepower per RTU.*** Single speed fans are used on four-fifths (81%) of RTUs in Minnesota, representing 56% of total RTU fan power. A large and growing proportion of RTUs use variable speed fans, comprising 42% of fan power.

An estimated total of 6,400 new RTUs are shipped to commercial buildings in Minnesota annually. Of these, 40% (or 2,600) are for new construction projects, while 60% (or 3,800) are for existing retrofits or replacements. Of these, 3,500 shipments are for code-compliant RTUs, while 2,900 shipments are for high-performance RTUs.

Monitoring of the energy performance of 52 RTUs at nine sites is currently ongoing, concluding the fall of 2016. The data will be analyzed to draw conclusions regarding characteristics that lead to high and low RTU performance as well as typical consumption patterns for different building types. These results will help develop insights into best approaches to improve RTU efficiency. A final report and live, free video webinar will describe the project findings in February 2017.

The interim report, "Commercial Roof-top Units in Minnesota: Characteristics and Energy Performance" (pdf) provides details on the results so far. For further information, contact project manager Mark Garofano or CARD program administrator Mary Sue Lobenstein.

References

[1] ASHRAE 90.1-2010, Table 6.8.1A
[2] CEE 2016. High Efficiency Commercial Air-conditioning and Heat Pumps Initiative. Consortium for Energy Efficiency. 2016.