A new generation of central, ducted, variable-capacity heat pump systems has come on the market, promising very high cooling and heating efficiency. Rather than cycling on at full capacity and then cycling off when the thermostat is satisfied, cooling and heating outputs vary over a wide range (approximately 40% to 118% of nominal full capacity); thus, staying “on” for 60% to 100% more hours per day compared to fixed-capacity systems. It should be noted that two-stage systems were not evaluated in this research effort.

Although the variable-capacity system uses less total energy than the fixed-capacity system, the longer runtime of the variable-capacity system accounts for a greater energy increase percentage when going from an indoor to attic duct system. Preliminary research (comparing fixed-capacity and variable-capacity, three-ton heat pumps) identified that switching from an indoor duct system to an attic duct system caused a 13% increase in cooling energy use for the fixed-capacity system versus 21% for the variable-capacity system.

Further experiments examined the performance of two-ton and three-ton fixed- and variable-capacity systems and the impacts of system oversizing. Monitored energy consumption over 24 months at a highly instrumented lab house (Figure 1, page 2) found that oversizing a SEER 22 variable-capacity system yielded 8% cooling energy savings and 1.5% heating energy savings. Figure 3 (page 2) shows the variable capacity efficiency versus the cooling capacity delivered as a percentage of total available capacity. Figure 3 also shows higher efficiencies when the system operates at its lower capacities, and it also indicates that increases in cooling load result in a relative decreases in efficiency.

Current Phase 4 experiments show duct R-value enhancements benefit the overall operating efficiency of the variable-capacity system compared to the fixed-capacity system. The effective R-value of the attic duct system was increased from 6.1 to 11.6 by applying a foil-faced fiberglass insulation product (Figure 2, page 2). The relative energy performance of the fixed- and variable-capacity systems was examined with this higher efficiency attic duct system.
At a daily average of 82°F outside and 77°F inside, cooling energy savings from the duct insulation upgrade was 6.4% for the fixed-capacity SEER 13 system, 6.9% for the variable-capacity SEER 22 system (in standard control mode), and 8.2% for the variable-capacity SEER 22 system (in relative humidity (RH) control mode).

Lessons Learned

- If ducts cannot be moved indoors, energy can be saved by adding insulation to ducts in attic spaces; however, the labor cost would likely result in long payback periods greater than 15 years.

- Peak cooling demand savings from the duct insulation upgrade showed peak demand reductions of 2.9%, 15.3%, and 11.7% for the SEER 13, SEER 21, and SEER 22 system configurations, respectively, at 92°F outdoors and 77°F indoors. Peak cooling demand savings for the SEER 13 fixed-capacity system were understated because the two-ton fixed-capacity heat pump was unable to meet the full cooling load during a portion of peak hours at design conditions during the pre-retrofit period.

- Oversizing* a variable capacity system by about twice the design cooling load resulted in increased energy savings and acceptable indoor relative humidity.

Looking Ahead

A study of various sized dual-capacity heat pumps would help establish guidance on optimal sizing as well as energy impacts from going from indoor ducts to attic ducts.