U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America Case Study
Efficient Solutions for New and Existing Homes

Residential Mechanical Precooling

Roseville, California

PROJECT INFORMATION

Project Name: Residential Mechanical Precooling Best Practices

Partner: Alliance for Residential Building Innovation (ARBI)

Building Component: Space Cooling

Application: New and/or retrofit; Single family and/or multifamily; Efficient building envelopes

Year Tested: 2014

Applicable Climate Zone(s): Hot Climates, IECC CZ 1-5 (excluding Marine)

PERFORMANCE DATA

Cost of Energy-Efficiency Measure (including labor): $0

Projected Energy Savings: Up to 10% annual space cooling energy savings

Projected Coincident Peak Demand Savings: Up to 100% A/C savings

Projected Energy Cost Savings: Up to 32% annual space cooling utility dollar savings (varies with utility rates)

Building America U.S. Department of Energy

Air conditioners are present in nearly all newly built production homes throughout the United States, and some form of mechanical air-conditioning equipment is found in 87% of all homes, based on the 2009 Residential Energy Consumption Survey (RECS). According to the RECS data, cooling represents about 6% of annual residential site energy consumption nationally; however, the impact on utility coincident peak demand is much more significant. This is especially true in hot-dry climates in the western United States where residential cooling loads are much more concentrated around the hottest hours of the day. For example, California residential air conditioning represents about 15% of the state's peak coincident electrical demand but only 2% of annual electrical consumption. During peak hours, growing coincident peak demand forces utilities to rely on lower efficiency "peaker" plants, which strains the transmission and distribution system and can lead to brownouts. Finding solutions that save energy and reduce electrical demands on the electrical grid is an important national objective and supports key Building America goals.

Precooling is an operational strategy with potentially no up-front cost that cools occupied spaces earlier in the day to minimize or avoid afternoon air conditioner operation. In its simplest form, precooling can be implemented by scheduling air conditioner operation to reduce thermostat setpoints 2°–6°F below typical comfort settings in advance of the on-peak time period. Performance benefits stem from reduced compressor cycling degradation, as well as shifting condensing unit operation to earlier periods of the day when outdoor temperatures are more favorable to operational efficiency. Precooling can also be combined with nighttime outdoor air ventilation cooling, providing even greater energy savings. It should be noted that buildings respond differently to precooling depending on interior thermal mass, envelope thermal performance, internal gains, and infiltration rates.

This research, conducted by the Alliance for Residential Building Innovation team, evaluated mechanical air conditioner precooling strategies in homes throughout the United States. EnergyPlus™ modeling evaluated two homes with different performance characteristics in seven climates. Results are applicable to new homes and most existing homes built in the last 10 years, as well as fairly efficient retrofit homes.

Results of EnergyPlus Modeling

Energy savings are difficult to achieve with precooling alone. In most cases, particularly on hotter summer days, there was no precooling strategy (without a subsequent setup during the peak hours) that resulted in cooling energy savings.

Projected coincident peak demand reductions were found to be greater in high-performance homes. A home with greater envelope integrity provides better storage capability, increasing the effectiveness of precooling.

Precooling, combined with a 2°F setup during peak hours, eliminated air conditioning coincident peak demand in the high-performance home in all scenarios, except in Phoenix (climate zone 2B) on days with average outdoor air temperatures above 80°F. Alternatively, results with the 78°F peak setup demonstrated 100% demand savings for the benchmark in only two climates.

A strategy focused on minimizing coincident peak demand had a nontrivial impact on energy consumption. In the high-performance home, energy use increased by 2%–8%, or up to 105 kWh, with precooling that targeted demand savings. Depending on the stakeholder's viewpoint, this conclusion may be interpreted differently.

For more information, see the Building America report, *Residential Mechanical Precooling*, at *www.eere.energy.gov/buildings/publications/pdfs/building_america/residential-mechanical-precooling.pdf*.

Image credit: All images were created by the ARBI Team

Case	Description
Base Case	• Constant setpoint of 76°F
Morning Precooling	• Vary setback from 74°–70°F in 1°F increments • Time windows evaluated: 4 a.m. to 8 a.m., 5 a.m. to 8 a.m., 6 a.m. to 8 a.m. • Evaluate setup to 78°F from 3 p.m. to 8 p.m.
Part Peak Precooling	• Vary setback from 74°–70°F in 1°F increments • Time windows evaluated: 12 p.m. to 4: p.m., 1 p.m. to 4 p.m., 2 p.m. to 4 p.m. • Evaluate setup to 78°F from 4 p.m. to 8 p.m.

The setpoint control strategies evaluated in the energy model

Lessons Learned

- Mechanical precooling is effective at reducing or eliminating air conditioner coincident on-peak demand. However, energy savings are difficult to achieve without allowing the interior temperature to float above setpoint a few degrees during the peak hours. Allowing the temperature to float may have comfort implications, especially in more humid climates.
- Cost savings are dependent on utility rates and the on-peak time period.
- Individual houses respond very differently to precooling. Efficient envelopes and good glazing are key prerequisites; however, occupancy patterns and internal gains can have a significant impact.
- Approaches that customize precooling to individual houses result in the greatest impact.

Looking Ahead

With increased interest from utilities and improved sophistication in controls and appliance connectivity, the future of precooling is already becoming more tailored to a specific house, the day's predicted weather, occupancy patterns, and the utilities' predicted demands. Smart controls learn how the building and occupants respond and also utilize next-day forecasted outdoor temperatures to determine optimal precooling targets. Several advanced thermostat manufacturers and cloud-based systems implementing strategies like this have been demonstrated with major utilities in the southwestern United States in the past few years.

A successful off-peak air conditioning strategy offers the potential for increased efficiency, assured occupant comfort, and a more reliable and robust electrical grid. The advent of demand-response capabilities and further integration with photovoltaic time-of-use generation patterns provides for additional opportunities to flatten loads and optimize grid impacts.

DOE/GO-102017-4572 • May 2017