

2019 Efficiency Programs: Promoting High-Efficiency Residential Air Conditioners and Heat Pumps

High-efficiency residential central air conditioners (ACs) and heat pumps (HPs) represent a small fraction of units sold in the market, while the vast majority are low-to-medium efficiency. An analysis of available models shows that nearly 80% of heat pumps and nearly 50% of air conditioners just meet or are slightly above the most recently agreed upon minimum efficiency standards that will take effect in a few years (DOE 2016).¹ However, there are new air conditioners and heat pumps using advanced technologies that achieve higher efficiency ratings, which can save consumers substantial money on their energy bills while reducing energy use and peak demand. Efficiency programs are in a position to help propel these high-efficiency units into the mainstream and help transform the residential AC and HP market.

Energy efficiency program administrators should provide the greatest incentive for the highest-tier energy-efficient equipment (i.e., SEER 18 and greater); generally, these use variable speed controls. In addition, program administrators should evaluate their local markets to determine the best program approach (e.g., downstream vs. midstream, whether to address quality installation).

High-Efficiency Equipment

MECHANICAL EFFICIENCY

As part of their *Residential Heating and Cooling Systems Initiative*, program administrator members of the Consortium for Energy Efficiency (CEE) work together to specify efficiency performance tiers for residential air conditioners and heat pumps, including both split systems and packaged systems (CEE 2015). Each member then decides whether to incorporate one or more of these tiers in their programs. For residential HVAC equipment, CEE developed four tiers (0, 1, 2, and 3) for split ACs and

HPs, and two tiers (1 and 2) for packaged ACs and HPs. This document focuses on the Tier 3 specification for split-system ACs and HPs, which corresponds to 18 SEER and greater (CEE 2015).² The Environmental Protection Agency (EPA) adopted these criteria for the 2018 ENERGY STAR[®] Most Efficient air conditioner and air-source heat pump program.

ADVANCED CONTROLS AND FEATURES

Consumers have access to different types of programmable and smart thermostats to help them control their HVAC load and reduce home energy costs. The highest efficiency units are typically equipped with variable frequency drives, which take advantage of advanced thermostat controls by reducing motor speed when full speed is not required, also known as operating in part-load condition. In addition, many residential air conditioners and heat pumps are equipped with new technologies like grid-connectivity, on-board diagnostics, and self-commissioning, all of which can help reduce energy consumption and/or demand. Some types of equipment may be more appealing in certain residential applications. For instance, in homes that use electric resistance heating, heat pumps can cut home electricity use by as much as 50% (Nadel and Kallakuri 2016).

Residential Air Conditioner and Heat Pump Market

Of the different types of residential systems, the Department of Energy (DOE) projected that 2018 shipments would consist of 58% split-system central air conditioners,³ 33% split-system heat pumps, 5% packaged air conditioners, and 4% packaged heat pumps (DOE 2016). An analysis of the two largest categories—split-system air conditioners and heat pumps—reveals that high-efficiency products, defined here as 18 SEER or

- 1 This analysis is based on 14 SEER for split-system air conditioners and 15 SEER for split-system heat pumps. Models included in the analysis fall in the 13–14.99 SEER bin for air conditioners and 14–15.99 SEER for heat pumps.
- 2 Tier 2 for packaged ACs and HPs represents 16 SEER and greater. Packaged equipment is not the focus of this paper since it has a much smaller market share than split systems, as well as fewer options for high-efficiency equipment.
- 3 Shipments of split-system air conditioners consist of about 60% coil-only and 40% blower-coil units. Blower coil units consist of both a fan and a cooling coil, while the coil-only units consist of just a cooling coil. Coil-only units generally use the blower in an existing furnace.

greater, represent less than 3% of the market. Figures 1 and 2 show DOE's analysis for equipment available in the marketplace.

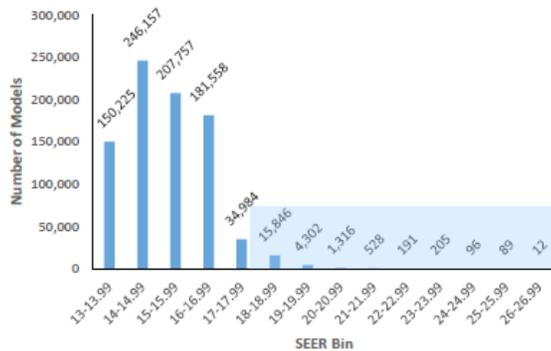


Figure 1. Distribution of SEER ratings for residential split-system air conditioners. The blue window identifies the 3% of equipment that falls within the highest CEE tiers (and ENERGY STAR's Most Efficient) at SEER 18 and above. Source: DOE 2016, based on the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance.

A review of equipment listed on the EPA's ENERGY STAR Most Efficient 2018 web page on March 19, 2018, found several equipment examples meeting the specifications, as shown in table 1.

Table 1. ENERGY STAR Most Efficient air conditioners and heat pumps

Manufacturer	Cooling capacity (kBtu/hr)
AirEase/ Armstrong	Split AC: 24,000, 34,400, 46,000, 57,000 Split HP: 23,000, 34,000, 48,000, 56,500
Amana	Split AC: 22,800, 34,400, 45,000, 53,000 Split HP: 23,400, 35,400, 52,500
Bryant/ Carrier	Split HP: 24,200, 33,200, 33,600, 46,500, 56,000
Daikin	Split AC: 22,800, 34,400, 45,000, 53,000 Split HP: 23,400, 35,400, 46,500, 52,500 Mini-split HP: 9,000, 10,900, 15,000, 18,000, 21,400
Johnson Controls	Split AC: 23,400, 35,000, 45,500, 52,500 Split HP: 23,600, 34,600, 45,000, 53,000
Trane	Split AC: 22,400, 23,000, 26,200, 33,400, 35,000, 35,800, 46,500, 48,000, 54,500 Split HP: 23,600, 24,000, 25,000, 35,000, 36,000, 37,000
Lennox	Split AC: 23,000, 24,000, 25,800, 34,400, 35,000, 35,600, 46,000, 48,500, 49,500, 56,500, 57,000 Mini-split HP: 23,200, 22,800, 34,400, 36,400, 34,600, 48,000, 56,500, 58,000

Manufacturer	Cooling capacity (kBtu/hr)
LG	Mini-split HP: 9,000, 11,000, 11,200, 12,000, 15,000, 18,200, 22,000
Mitsubishi	Mini-split HP: 6,000, 9,000, 12,000, 14,000, 15,000, 17,000, 17,200, 18,000, 22,400, 24,000, 36,000

Johnson Controls includes Champion, Coleman, Fraser-Johnston, Luxaire, and York product lines. Trane units listed meet CEE Tier 3 criteria; however they do not have the ability to self-configure, part of the criteria for ENERGY STAR Most Efficient. Mini-split heat pumps are typically ductless systems; however some can be ducted. Source: EPA 2018; CEE Directory of Efficient Equipment (accessed April 20, 2018).

Energy Savings

The Consortium for Energy Efficiency estimates 23% energy savings from its highest tier equipment relative to minimally compliant split central air conditioners and 35% savings for split air source heat pumps (CEE 2015). On a national scale, DOE estimated that a Level 4 efficiency standard, which most closely aligns with CEE's top efficiency tier, would save more than 13 quads of source energy over a 30-year period (DOE 2016). Table 2 lists estimated energy savings for split-system air conditioners and heat pumps on a national and regional scale.

Table 2. Average annual site energy savings from CEE Tier 3 over minimum compliance product (kWh/unit)

	National	North	Southwest	Southeast
Split-system air conditioners	656 kWh	419 kWh	536 kWh	846 kWh
Split-system heat pumps	715 kWh	607 kWh	609 kWh	742 kWh

We used efficiency Level 9 for split-system heat pumps, i.e., 18.1 SEER, close to CEE's 18 SEER. Source: DOE 2016.

Cost and Cost Effectiveness

The Department of Energy's analysis from the 2015–17 rulemaking to determine energy efficiency standards for central air conditioners and heat pumps shows an average incremental installed cost of roughly \$1,200 per average-sized unit (3-tons) for the highest-tier air-conditioning and heat pump equipment, when compared to minimally compliant products (DOE 2016).

Using DOE estimates of costs and savings, the average cost per kWh saved can be calculated from the program administrator perspective. Table 3 summarizes results for split-system air conditioners.

Table 3. Representative annual site energy savings and costs per kWh saved from CEE Tier 3 (3-ton AC units)

	National	North	Southwest	Southeast
Average annual energy savings (kWh)	660	420	540	850
Incremental installed costs (2017\$)	\$1,160	\$1,160	\$1,260	\$1,140
Equipment life (years)	21.2	24.1	24.9	18
Levelized cost from program administrator perspective if program pays 50% of incremental costs	\$0.08	\$0.12	\$0.10	\$0.07

Incremental energy savings and measure life are from DOE rulemaking. We calculated the levelized cost from the program administrator perspective by annualizing costs using the loan payment function in Microsoft Excel (PMT) and dividing by annual kWh saved. Assumptions include: half the incremental cost paid by program administrator, program administration costs are 20% of incentive costs, a 5% real discount rate, DOE cost estimates adjusted to 2017\$ using the Federal Reserve Implicit Price Deflator. ACEEE calculations based on data from DOE 2016.

Table 4 summarizes national split-system heat pump results.

Table 4. Annual national site energy savings and costs per kWh saved from CEE Tier 3 (3-ton HP units)

Metric	Data
Average annual energy savings (kWh)	715
Incremental installed costs (2017\$)	\$1,030
Equipment life (years)	15.3
Levelized cost from program administrator perspective if program pays 50% of incremental costs	\$0.07

See notes to table 3.

These calculations show that the program administrator's cost per kWh saved varies from about 7 to 12 cents per kWh depending on the region. Note that DOE has a long history of overestimating costs (Nadel and deLaski 2013). These cost-of-saved-energy calculations are for all savings over a year; for residential air conditioners and heat pumps, much of these savings will occur during peak and mid-peak periods when the cost of power is higher than the average annual cost. Increasing the market share

of high-efficiency equipment could influence a future DOE minimum efficiency standard on this equipment; in some states, utilities receive credit for new efficiency standards if they contribute towards these new standards.

Barrier to Energy Savings: Installation Practices

A residential system can lose 20–40% of its energy efficiency from poor installation, which can negate energy savings from high-efficiency units (ASRAC 2016). To help standardize the process of installing HVAC systems, a group of industry professionals developed the ACCA Standard 5 HVAC Quality Installation Specification (ACCA 2015). While the specification is a start, the industry is still working on solving this problem. Participants in a recent stakeholder meeting convened by the DOE Building Technologies Office provided a number of recommendations. Energy efficiency-specific program administrator recommendations include developing programs that incorporate incentives for quality installation and conducting third-party evaluations of HVAC installations (Goetzler et al. 2016).

Successful Residential AC and HP Efficiency Programs

Most residential HVAC program offerings take the form of downstream incentives, in which the utility typically provides a rebate to the consumer for purchasing specified equipment. For instance, MidAmerican Energy provides Iowa residents with tiered rebates for central air conditioning and ductless mini-split systems depending on equipment efficiency. The customer receives \$50/ton for purchasing a SEER 15-15.9 unit, \$100/ton for a SEER 16-16.9 unit, and \$300/ton for a SEER 17 and above (MidAmerican Energy 2018).

However some program administrators are starting to use midstream programs for residential equipment. In midstream programs, the distributor receives an incentive and then passes some or all of the savings to the consumer, instead of giving the consumer a direct rebate. Program year 2017 was the first full year that Connecticut utilities Eversource, United Illuminating (UI), Connecticut Natural Gas, and Southern Connecticut Gas switched their Energize Connecticut (EnergizeCT) Ductless Heat Pump incentive program from downstream to midstream for residential HVAC. The program has since seen a 400% lift in participation for UI customers (L. Boba, program administrator, UIL Holdings Corporation, pers. comm., March 28, 2018). NYSERDA unveiled another type of midstream program in 2017; it bypasses the distributor and provides installers with \$500 for qualified air source heat pump installations (NYSERDA 2018).

Though midstream incentive programs have shown success in some types of residential HVAC equipment, it can be difficult to develop a qualified equipment list due to the nearly infinite combination of outdoor and indoor unit pairings. Instead, distributors will have to verify that a specific outdoor and indoor unit pair will qualify by using an online database of most possible pairs maintained by the Air Conditioning, Heating and Refrigeration Institute (AHRI). Jim Hanna, who helped pioneer midstream programs for Pacific Gas and Electric back in 1997, suggested that residential AC and HP program administrators considering implementing a midstream program should work together with distributors to develop a methodology to make this work for both parties. Hanna insisted, “Distributors are the experts. They know the industry better than anyone.” He also contended that if program administrators “provide enough incentive, the decision makers [distributors] can make it work” (J. Hanna, senior technical director, Energy Solutions, pers. comm., March 30, 2018).

Recommendations

Promoting high-efficiency residential HVAC equipment can take several forms. Some programs currently offer rebates directly to customers for high-efficiency equipment. Many of these downstream programs have had good program participation; however moving to a midstream model can increase program participation significantly by reducing the initial cost and eliminating the need to fill out a form (L. Boba, program administrator, UIL Holdings Corporation, pers. comm., April 2, 2018). However, some of these programs struggle with customer engagement, which is identified as one of the largest barriers to the success of downstream programs (Buege et al. 2014). As a result, a few programs are turning to midstream models by targeting incentives at either distributors or installers. Generally speaking, as the efficiency industry gains greater abilities to quantify results from market transformation initiatives, there has been a greater pursuit of midstream program applications for many residential equipment and product types (A. Rosenberg, senior program manager – residential sector, Consortium for Energy Efficiency, pers. comm., March 30, 2018). Residential HVAC may be the next big area of opportunity.

All residential AC and HP programs would benefit from placing a greater emphasis on high-efficiency variable speed equipment. However additional energy-saving features should be tailored to the specific region of the country. This will require program administrators to

conduct at least a moderate level of market research to determine sales trends in their service territories (Bickel et al. 2016). For instance, certain customer bases might be more open to programs targeting advanced thermostats or control features. Additionally, some climates would benefit from programs around greater humidity control or heat pumps over electric resistance heating.⁴ To ensure the program is holistic, administrators should also consider including provisions for quality installation practices. Developing and maintaining relationships with local trade allies helps program administrators gain a greater understanding of the local market, and connections with these stakeholders are important for the long-term success of the program.

⁴ Energize CT also has a direct install program to provide ductless heat pumps at a discount for customers who heat their homes with over 50% electric resistance (L. Boba, program administrator, UIL Holdings Corporation, pers. comm, March 28, 2018).

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