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Heat Pumps in North America – 2017 Regional Report

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Abstract

This report provides a snapshot of the North American heat pump and air conditioning market in the context of a recovering economy and housing market, following the U.S. economic crisis of 2006. Heat pumps show continuing growth as a standalone, complimentary, and efficient electric heating alternative to fossil fuel heating systems, particularly in the warmer areas of North America where there is strong population migration. Market growth of solar energy especially in the residential sector is creating favorable market conditions for heat pump technologies. Relatively new heat pump applications such as heat pump water heater and geothermal heat pumps are gaining market traction in some niche markets but struggling to overcome critical market barriers in others. Statistical data will be presented to illustrate the growing number of heat pump systems in the U.S. and Canada and to highlight the future outlook for increased potential penetration of heat pump systems for both residential and commercial building heating and cooling markets in North America, providing motivation for continued efforts to improve the technology and its applications.

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1. Introduction

The United States continues to experience a slow but steady recovery from the housing crisis that began in 2007. As a result, housing completions went from peaking in 2006 with close to 2 million new single and multi-family housing units to only 470,000 new units in 2011. Figure 1 shows the recovering trend with U.S. housing completions growing at an average of 13% annually since 2011. In 2015, approximately 1 million U.S. housing units were completed, which is 50% less than at the peak of the market in 2006. However, if the market continues to experience the same growth trend it could return to the 2006 completion level by 2021. It is also interesting to note that the U.S. multi-family market seems to be recovering at a faster rate, accounting for roughly one-third of the total housing market in 2015 relative to only 15% in 2005 [1].

Unlike the United States, Canada's housing market did not experience the same drastic changes in the housing completion trend likely due its more tightly regulated banking system. Figure 1 shows that in 2015, the total housing completions in Canada were already back to the same level they were 25 years ago with about

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180,000 units completed. However, similar to the U.S., the distribution between multi-family and single-family has changed. According to the figure, 67% of new completions are multi-family, up from 48% in 1990 [2].

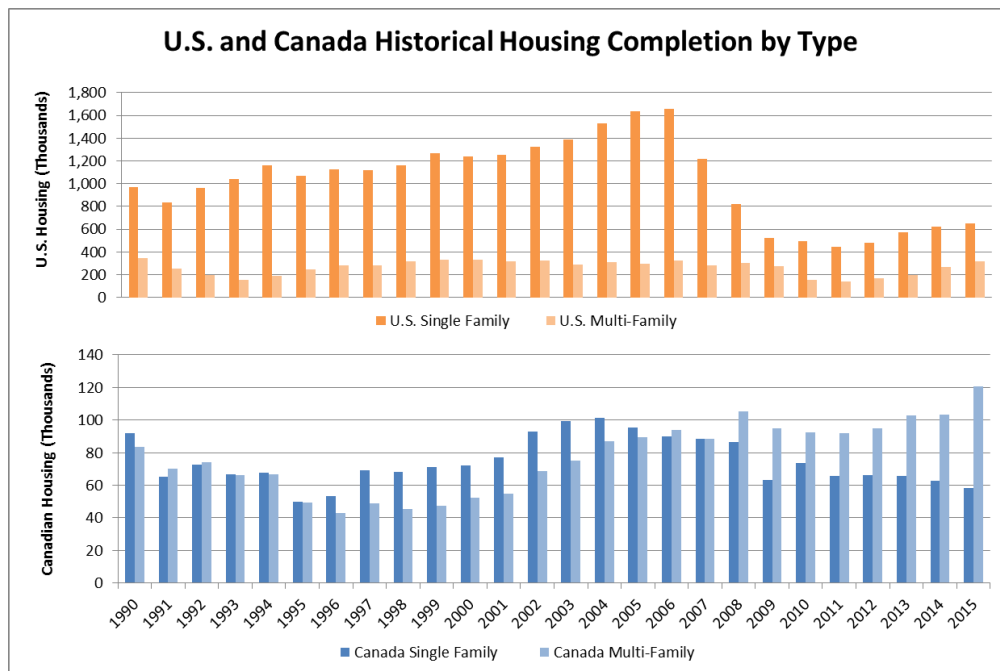


Fig. 1. U.S. and Canadian housing completions by type [1-2]

The housing market is an important driver of the heating, ventilation, and air conditioning (HVAC) market, which includes heat pumps (HP). Without new housing starts, HVAC manufacturers are limited to the add-on and replacement market (roughly 80% of total market) [3]. The impact of the housing market will be investigated in this paper, along with other important market influencers.

2. Background

Reports similar in nature have been presented at the past several International Energy Agency Heat Pump Conferences [cf., 4-5]. Like its predecessors, this report will focus primarily on the changes undergone by the market since the last one. For decades, HPs have been proving to be a viable alternative or complementary technology to traditional heating appliances like fossil fuel furnaces and boilers, direct electric heating, etc.; they also provide consumers a more efficient alternative to electric air conditioners. Because HPs offer both heating and cooling or air conditioning (AC) functions, they have proved to be most popular in climate regions where AC is primarily needed throughout the year as well as some heating, like the southern half of the United States. Coincidentally, these regions tend to have the largest potential for solar photovoltaic system penetration, and homeowners can use the electricity generated by the systems to help operate HPs and other electric appliances. This is not an option with fossil fuel-fired furnaces.

Heat pumps have so far failed to gain strong market in northern regions where heating accounts for the primary need and less expensive alternatives are present. The principal exception to this rule is areas with limited access to natural gas. Recent research efforts have focused on improving the technology performance and increasing the cost effectiveness of HPs in cold climates.

In addition to new home construction rates, which have boosted annual HP sales to more than 2 million units, the add-on and replacement market has also appeared to be a sweet spot for heat pumps since new units offer increased efficiency over traditional furnaces as a result of technological advancements and federal minimum efficiency standards.

3. Market Trends

3.1. Unitary heat pumps

Shipments. Figure 2 shows how unitary HP shipments have compared to other major heating and cooling equipment—particularly central ACs and furnaces—in the United States since 1988. As shown, HPs have enjoyed a gradual increase in their share of the cooling market, from approximately 21% in 1988 to 33% in 2015. Similarly HPs have slowly gained an increasing share of the space heating market, from 24% in 1988 to approximately 40% in 2015. Of the technologies shown in Figure 2, HP shipments have increased by the highest percentage (171%) since 1988 [6].

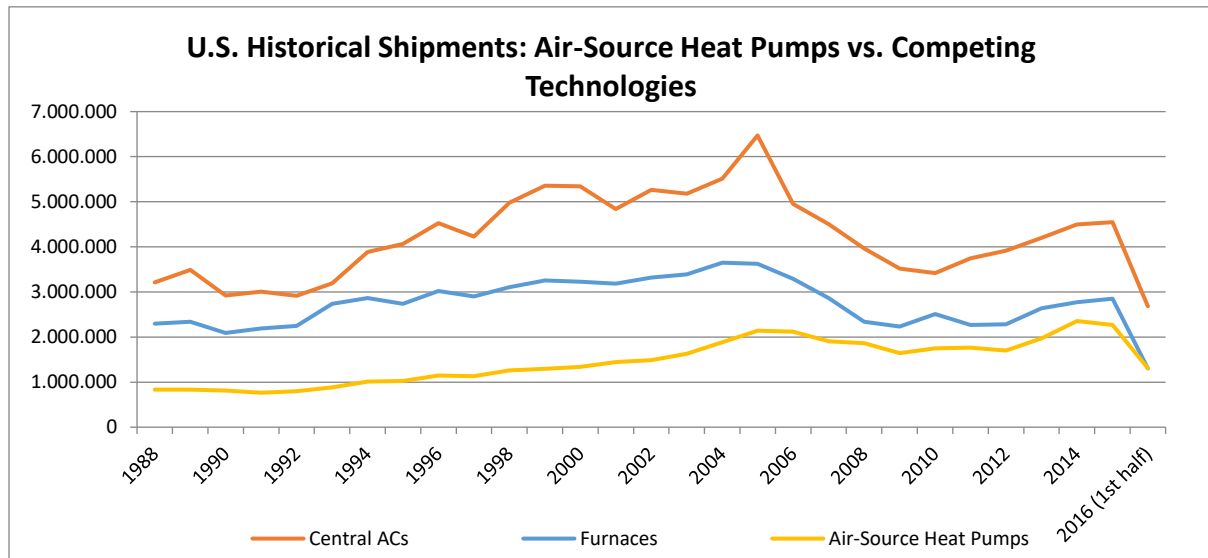


Fig. 2. U.S. heat pump shipments versus major competing technologies [6]

Among the most notable trends in Figure 2 is the sharp peak in AC shipments in 2005, followed by a deep slump in years immediately following. The peak is primarily a result of manufacturers building up and aggressively selling off older, low efficiency systems prior to an impending minimum efficiency standard increase from a seasonal energy efficiency ratio (SEER) of 10 to 13 that went into effect in 2006 (see section 4). While the dramatic decline in shipments of central ACs and gas warm air furnaces starting in 2006 was partially due to reduced market demand following the flood of shipments in 2005 and retooling of production lines in preparation for new models, it was also strongly linked to the nationwide housing crisis. The impact of the housing crisis on heat pump shipments was mitigated to some extent due to their strong appeal as add-on and replacement options during this time, accounting for 80% of their annual shipments [3].

Federal minimum efficiency standards rose again in 2015, but a peak resembling that of 2006 was not observed since the jump from 13 SEER to 14 SEER was less technically challenging for manufacturers to achieve, plus cost increases driven by the change were much smaller. Furthermore, 13 SEER units can still be sold in the northern region of the United States due to new regional standards, providing manufacturers with some inventory flexibility. Federal minimum efficiency standards are discussed in more detail in section 4.

Figure 3 shows shipments for residential HPs, ACs, and furnaces in Canada since 2009. Unlike the United States, the total shipments in Canada have been relatively stable over the timeline analyzed (2009-2016), experiencing single digit growth or decline on an annual basis. Total shipments had the strongest growth in recent history with an 8% growth in 2015, relative to 2014. The first half of 2016 implies shipment levels similar to those of 2015 [7].

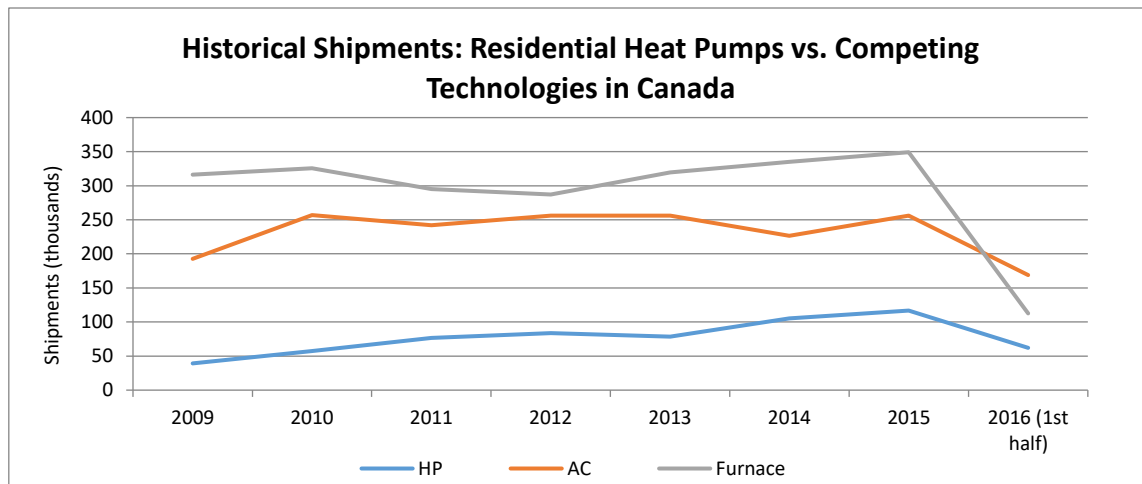


Fig. 3. Canadian residential heat pump shipments versus major competing technologies [7]

The market share for HPs has steadily increased in the Canadian residential market since 2009. In fact, HP shipments tripled in 2015 by almost 300% relative to 2009 shipments while AC and furnace shipments only grew by 30% and 10% in 2015 relative to 2009, respectively [7]. Driving this market traction for HPs is the diminishing price difference between HP and AC technologies. Furthermore, when homeowners are faced with a replacement situation, they find value in replacing their ACs with HPs since they can also act as their primary or secondary heating equipment depending on the heating needs.

Nominal Capacity. To better understand the nature of the cooling market inventory in the United States, Figure 4 breaks it down by capacity. Capacities up to 19.0 kW (65,000 Btu/h) are generally categorized as residential, while 19.0 kW and above are considered commercial. AHRI does not differentiate between central ACs and HPs in this data set, but approximately one-third of the shipments are estimated to be HPs.

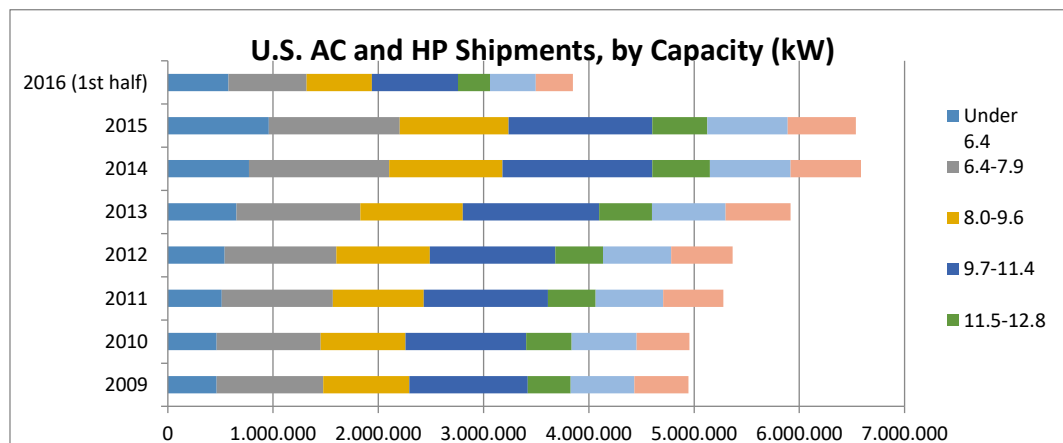


Fig. 4. U.S. annual shipments of residential HPs and ACs, by nominal capacity [6, 8]

Figure 5 presents a similar breakdown of Canada's residential cooling market. (Commercial data is not publicly available.) It should be noted that these shipments are estimated based on the number of relevant compressor bearing units shipped during this period. The data suggests that shipments of HPs with nominal capacity under 6.4kW are experiencing major growth. In 2009 that category was only responsible for 15% of total shipments, but has grown to 66% in 2015. Shipments for all the larger capacity segments lost market share relative to the smallest (<6.4 kW) segment.

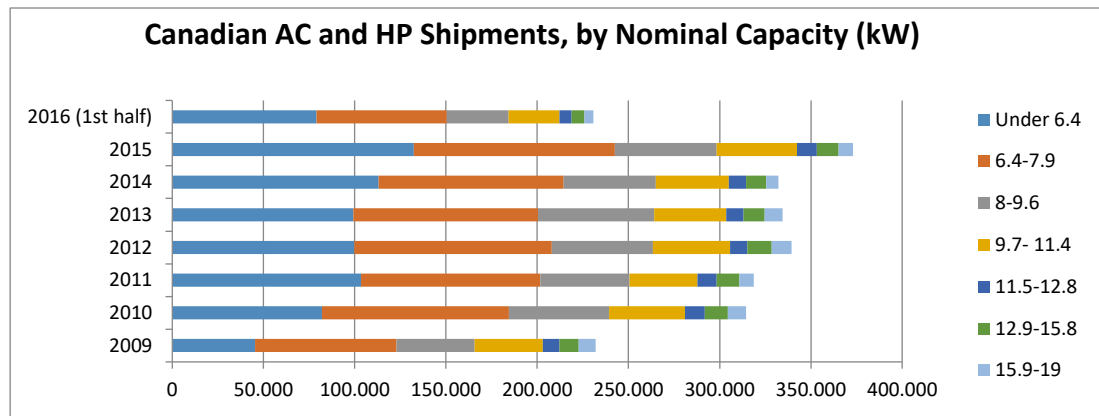


Fig. 5. Breakdown of Canadian residential HP shipments, by nominal capacity [7]

Residential vs. commercial market. Similar to the residential market, commercial AC and HP shipments (above 19.0 kW in capacity) in the United States have experienced some volatility over the past two decades due to economic conditions, fluctuating fuel prices, etc. The effect of the housing crisis was not as immediately felt in the commercial sector with shipments increasing through 2007. As mentioned previously, however, the flood of lower efficiency equipment in late 2005 likely expedited the downturn in residential shipments. Since the bottom of the market in 2009, total commercial HP and AC shipments have increased by 32% back up to a “normal” shipment level of approximately 277,000 units in 2015. As shown in Figure 6, commercial AC and HP shipments only account for 4% of the total market; this percentage has varied only slightly over the past 15 years, between 3 and 5%. It is important to note that residential units are often installed in commercial buildings, resulting in a smaller market percentage than expected. Plus, commercial units, which tend to be larger in capacity, can cool a much broader space so fewer are needed per unit area [6].

The commercial HP and AC market in Canada has been relatively stable since 2008 with total commercial HP and AC shipments averaging around 39,000 units each year. However, the residential market has been growing at a faster pace. About 20% of total residential and commercial shipments served commercial purposes in 2008. This percentage dropped to about 15% in 2015 and to only 10% in the first half of 2016 [9]. It is also interesting to note the difference in scale between U.S. and Canada’s cooling market due largely to the fact that Canada’s population is only about 10% of the U.S. population.

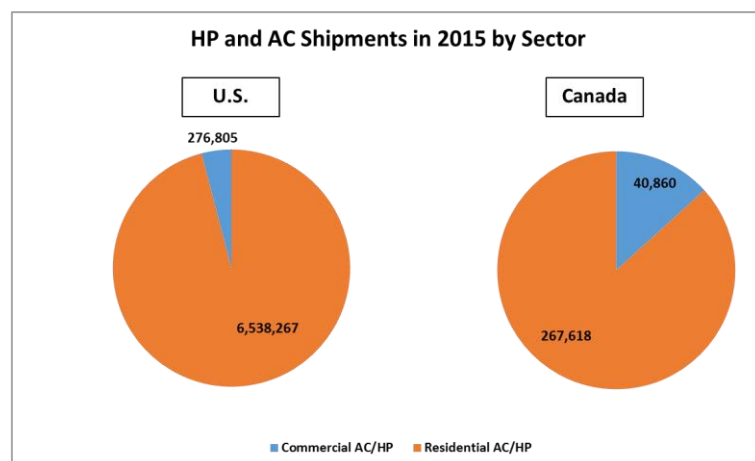


Fig. 6. A 2015 snapshot of the residential and commercial HP and AC markets in Canada and the United States [6,9]

3.2. Geothermal heat pumps

In the early 2000's, interest in geothermal heat pumps (GSHPs) was relatively low in both the United States and Canada. As shown in Figure 7, U.S. shipments appear to have steadily grown, picking up steam in the late 2000s. This shipment boost is partly due to a 30% federal tax credit has been available in the United States for GSHPs placed in service after 2008 and lasting through December 31, 2016. To qualify for this tax credit, GSHPs must meet federal ENERGY STAR criteria [10]. Once this credit expires, a dip in shipments may be expected. Canada shipment data is limited, but market trends seem to be consistent with the U.S. for the years available, albeit on a much smaller scale.

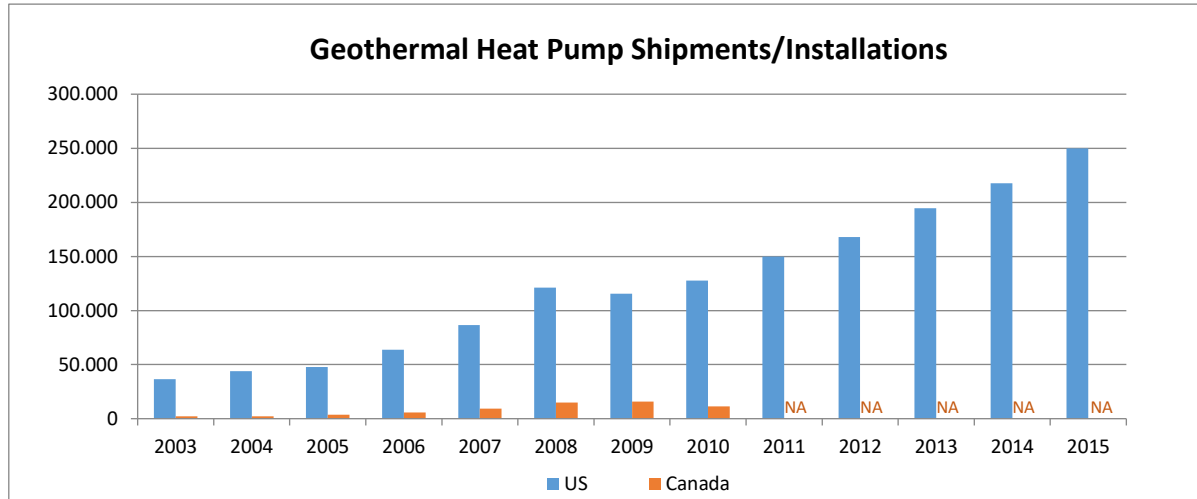


Fig. 7. North American geothermal heat pump shipments (U.S.) and installations (Canada). Note: U.S. shipments from 2010-2015 were estimated based on ENERGY STAR® Unit Shipment and Market Penetration Reports [11-13]. NA = Data not available.

3.3. Heat pump water heaters

Electric heat pump water heaters (HPWH) were introduced to the market in the 1970s throughout North America, starting with small entrepreneurial companies, then utilized by utility support programs in the Northeast region of the U.S., and eventually produced and sold by major manufacturers like General Electric. Expectations were high for HPWHs since their efficiency far exceeded that of traditional electric resistance water heaters. Because of this, consumers in states whose primary fuel source is electricity showed particularly high interest since HPWHs since it would help maximize their utility savings. Despite long-term savings, the up-front cost of these appliances as well as somewhat more complex installation requirements have combined to create a major barrier to wide scale adoption.

Despite federal tax credits and significant outreach efforts, HPWHs have struggled to gain market traction, accounting for 2% or less of the U.S. electric water heater market for the past six years [13]. At the close of 2016, only approximately 60,000 HPWHs are expected to be installed in the United States. Further indicating a market downturn, General Electric Appliances announced they will discontinue their line of HPWHs, including the GeoSpring® model, by the end of 2016 due to low demand and profitability [14]. Several other major manufacturers, like Rheem and Whirlpool, continue to offer HPWHs in their product line. Currently, consumers can receive a \$300 tax credit with the purchase of an ENERGY STAR certified HPWH. Currently, select major cities, Pacific Northwest National Laboratory, Oak Ridge National Laboratory, Northeast Energy Efficiency Alliance, and the U.S. Department of Energy (DOE), among others, are collaborating in the formation of national strategic plans to encourage deployment of HPWHs in upcoming years. According to ENERGY STAR's website, 183 and 69 ENERGY STAR certified HPWH models offered by various manufacturers are available for purchase in the U.S. and Canada, respectively.

4. Heat Pump Penetration in Existing Housing Stock

5. HPs have also been penetrating the existing housing stock as a cooling and heating technology. In the U.S., almost 9% of existing homes rely on HPs for heating purposes as of 2009; the distinction is not made for cooling purposes. Also, 75% of all HPs in existing housing stock are concentrated in the southern part of the U.S. Another 2% of homes rely on HPs for their secondary heating purposes [15].

6. In 2011, 3% of the homes in Canada relied on HPs for their heating needs, the distinction is not clear for cooling purposes. However, it's recorded that 5% of the existing homes in Canada have a HP. About 75% of these HPs are Air Source HPs with the remainder being GSHPs. It's also interesting to note, that 70% of all HPs deployed within the housing stock were installed in the last 5 years with the remainder being installed in the last decade [16].

7. Heat Pump Efficiency Standards

United States. In 1992, U.S. federally-mandated efficiency standards were instituted for unitary ACs and HPs as part of its effort to conserve energy nationwide. The seasonal energy efficiency ratio (SEER) was adopted as the efficiency metric for both ACs and HPs in the cooling mode, and the heating seasonal performance factor (HSPF) for HPs in the heating mode.[‡] Similar seasonal performance requirements were also set for gas and oil warm air furnaces and boilers.

As previously mentioned in Chapter 3, the residential AC and HP industry experienced its first major increase in efficiency standards in 2006, when the minimum SEER jumped by 30% from 10 to 13. In 2010, a consortium petitioned the U.S. Congress and DOE to establish regional standards to recognize climate differences and varying operational requirements. In response DOE established a new minimum efficiency regulation effective January 1, 2015, creating three distinct regions (see Figure 8) with different minimum efficiency standards for residential ACs and HPs. As a result, the minimum SEER for single package AC systems increased from 13 to 14 (SCOPc from 3.81 to 4.10) in all regions, and the minimum SEER for split AC systems remained at 13 in the North. The minimum SEER for HP increased from 13 to 14 for all regions. ACs shipped to the Southwest region are also required to meet minimum steady-state energy efficiency ratios (EER) at 95°F of 12.2 or 11.7 (cooling COP at 35°C of 3.58 or 3.43) depending on capacity.

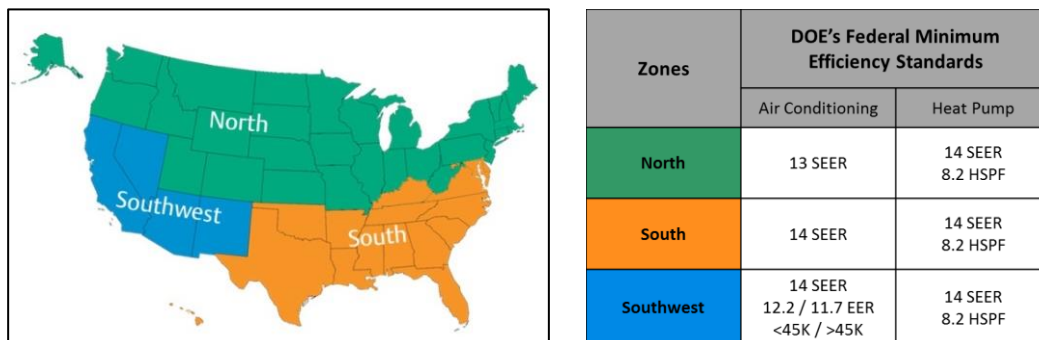


Fig. 8. Regional standard zones for DOE's Federal Minimum Standards as of January 1, 2015

While the new standards presented manufacturers with challenges of achieving necessary technology advances and more sophisticated testing regimens, the industry underwent dramatic improvements in operating efficiency – with more than a 50% increase in SEER over the past 22 years for both heat pumps and ACs – as a result (see Figure 9). The data in this figure only show the seasonal efficiencies in cooling operation, for both

[‡] SEER and HSPF are in units of Btu/Wh or kBtu/kWh; they may be converted to unit-less seasonal COP equivalents SCOPc and SCOPh, respectively, by dividing by 3.412.

cooling-only and heat pump units, but HSPF levels have experienced a similar trend over the same period. As shown in the figure, available data stopped short of the most recent minimum efficiency standards increase, but a strong upward trend is not expected since the shipment weighted efficiency already exceeds the new minimum standard requirements. Plus, dealers were given an 18-month “sell through” period (ending on June 30, 2016) to help deplete inventory at a reasonable pace [17].

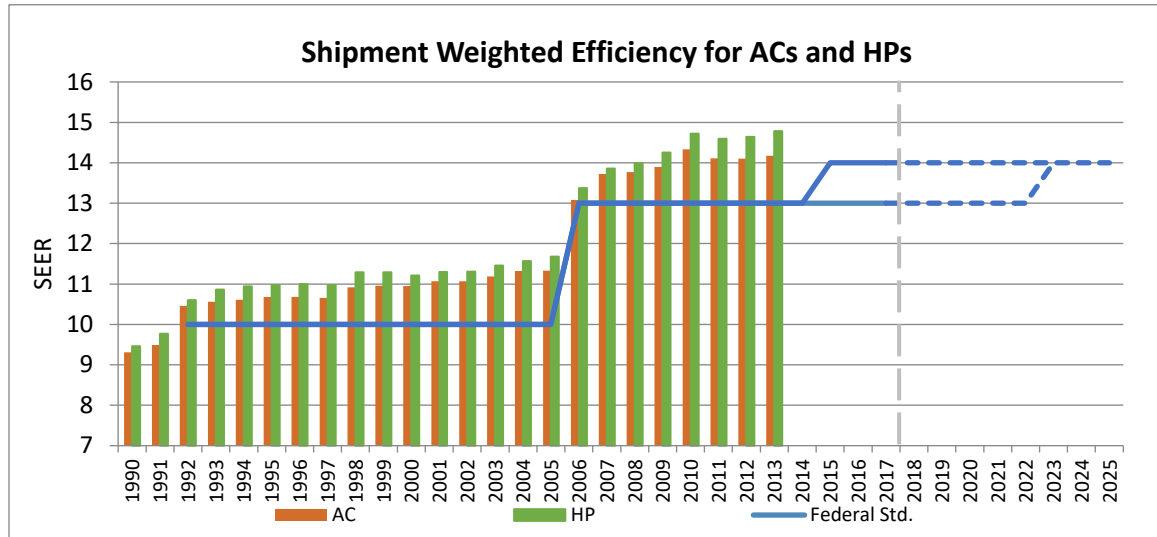


Fig. 9. U.S. shipment-weighted cooling efficiency vs. minimum efficiency standards

Canada. The current minimum efficiency standards in Canada for residential HPs and ACs (under 19kW (65,000Btu/h)) are as follows [18]:

- ACs and HPs – single package and split system, cooling: 13 SEER
- HPs – single package and split system, heating: 6.7 HSPF V
- ACs & HPs – through-the-wall and space-constrained, cooling: 12 SEER
- HPs – through-the-wall and space-constrained, heating: 6.4 HSPF V
- ACs & HPs – small duct, high velocity, cooling: 11 SEER
- HPs – small duct, high velocity, heating: 5.9 HSPF V

Figure 10 shows the distribution of SEERs for Canadian HP shipments from 2009 through the beginning of 2016. The data shows that since 2009, shipments have exceeded the efficiency standards. In 2009, only 4% of total shipments were in the “21.0+ SEER” category. In comparison, in the first half of 2016, that category has grown to account for nearly 50% of total shipments, which may be due to an increased penetration of very efficient ductless HPs with variable speed compressors that have gained significant market share over the last few years. In contrast, only about 20% of U.S. shipments in 2016 meet the 21+ SEER efficiency criteria, according to industry experts. A breakdown of Canadian HP shipments based on HSPF levels would be more relevant given the dominance of space heating loads for residences but this data was not available.

At the time of this report, no revisions are underway for Canadian federal standards. Since there are no large-scale HVAC manufacturers based in Canada and most HPs are imported from the U.S., the U.S. minimum efficiency standards tend to impact the Canadian market as well.

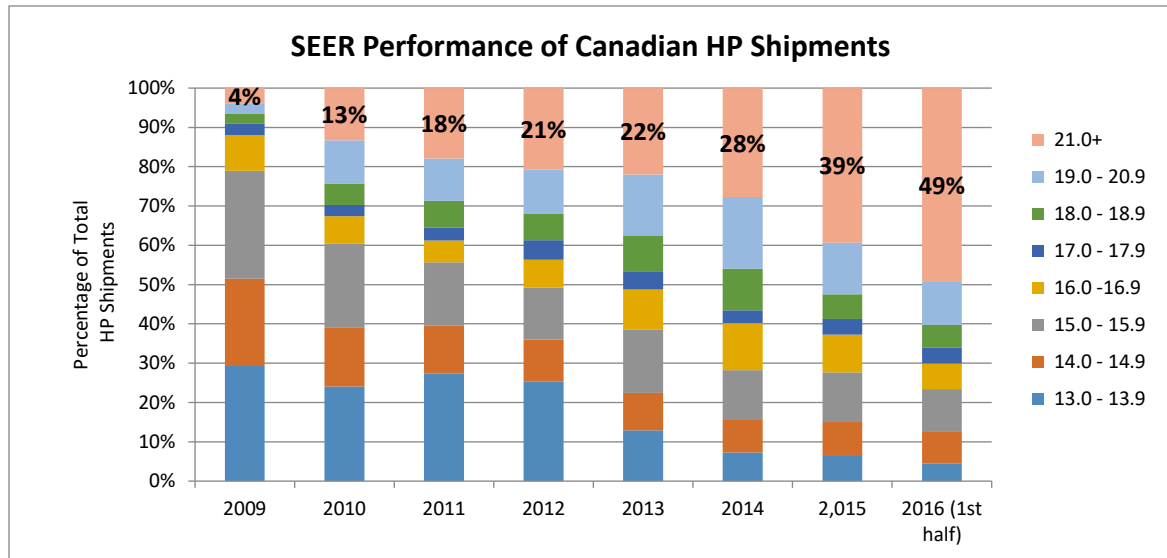


Fig. 10. Shipment-weighted cooling efficiency of Canadian HP shipments [7]

8. Summary and Outlook

Heat pumps have grown in popularity across North America in recent decades and have enjoyed steady gains in the space heating and cooling markets since they are able to offer increased efficiencies at reasonable costs relative to traditional equipment (e.g., central AC, furnaces), especially in moderate climates. Moving forward, key factors that will shape the North American heat pump market include:

- **Phase-out of climate-damaging refrigerants:** Both the United States and Canada are committed to the transition to more environmentally friendly refrigerants. Currently, most ACs and HPs in North America use refrigerant R-410A, which has zero ozone depleting potential but very high global warming potential. Future alternatives (e.g., lower global warming potential (GWP) hydrofluorocarbons, hydrofluoroolefins, hydrocarbons, carbon dioxide, and blends) may impact the way these appliances are designed, manufactured, and serviced.
- **Continued increases in minimum efficiency standards:** Federal minimum efficiency standards that aim to reduce energy consumption will continue support the growth of today's heat pump technology in near and mid-term. In the long term, however, these regulations will eventually reach a level of diminishing return. In other words, to continue achieving higher efficiencies with today's heat pump technologies, new innovations will be needed that reduce the end cost to consumers.
- **Proposed changes to test procedures:** DOE has proposed important revisions to its test procedures for central ACs and HPs originally established under the Energy Policy and Conservation Act. Key changes include new minimum external static pressure requirements, a revised heating load line equation, and a revised heating mode test procedure for units equipped with variable speed compressors. By incorporating these revisions, updated SEER and HSPF values (and resulting operating cost savings calculations) would become more accurate and representative of real world conditions [19]. While this is good news for consumers, manufacturers could end up with equipment stock that no longer meets efficiency standards since the SEER and HSPF values based on the proposed revised test procedures could be as much as 5% and 15% less, respectively, than current ones.

In preparation for these market challenges, the U.S. DOE, national labs, university researchers, and manufacturer researchers are actively evaluating more unconventional alternatives with advanced vapor compression systems, non-vapor compression systems, and the integration of cooling equipment with other building systems [20].

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