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The U.S. Residential Heat Pump Market, a Decade after "The Crisis"

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Abstract

The U.S. Heat Pump (HP) and Air Conditioning (AC) market is impacted by shifts in population patterns, fuel prices, housing characteristics, consumer preferences, regulatory and economic conditions - all catalyzed by rapid technological innovation and deployment efforts. This paper evaluates impacts of these factors on current HP and AC market trends and future outlook. Particular attention is paid to the major housing market crisis, which resulted in total HP and AC shipments falling from 8.6 million units in 2005 to 5 million units in 2010. It has recovered to reach almost 7 million shipments in 2015. HP and AC shipments in 2015 are now respectively 6% higher and 30% lower relative to 2005. Also, the new 2015 DOE minimum efficiency regulations had a significant impact on shipment trends. For instance, new split-system HPs must now have a minimum Seasonal Coefficient of Performance for cooling (SCOPc) of 4.1 and a minimum SCOP for heating (SCOPh) of 2.4 (compared to the previous 3.8 SCOPc and 2.25 SCOPh). The last quarter of 2014 showed historically high HP shipment growth of 18% relative to 2013, largely due to manufacturers shipping inventory before the enforcement of the new regulation. Finally, HPs are gaining market share outside of the South. 8-20% of new single-family homes outside the southern U.S. are using HPs. Research and deployment efforts by DOE, National Laboratories, Northeast Energy Efficiency Partnership (NEEP) among others shows promising future for HP technologies throughout the U.S.

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1. Heat Pump Market Overview

1.1. Market landscape

Shipments of heating and cooling equipment in the United States are continuing to show healthy growth following a dramatic decline as a result of the housing crisis that started in 2006 (Figure 1). In 2015, total air conditioning (AC), heat pump (HP), and warm air furnace shipments reached 10 million units, about 20% less than the 2005 peak of approximately 12 million and a 30% growth relative to the lowest level of 2009. Compared to its primary competitors, HP technologies bounced back the quickest by reaching 2.3 million units in 2015, showing a 6% growth relative to the peak year of 2005 and a 40% growth relative to the lowest level of 2009.

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It is also interesting to note that in the first half of 2016, HP and furnace shipments are almost equal. This is a significant change since HP shipments were only 40% of total furnace shipments in 2000. A similar, but less significant, pattern is noticeable in the cooling market, where HP shipments today are about 50% of total central AC shipments vs. 25% in 2000.

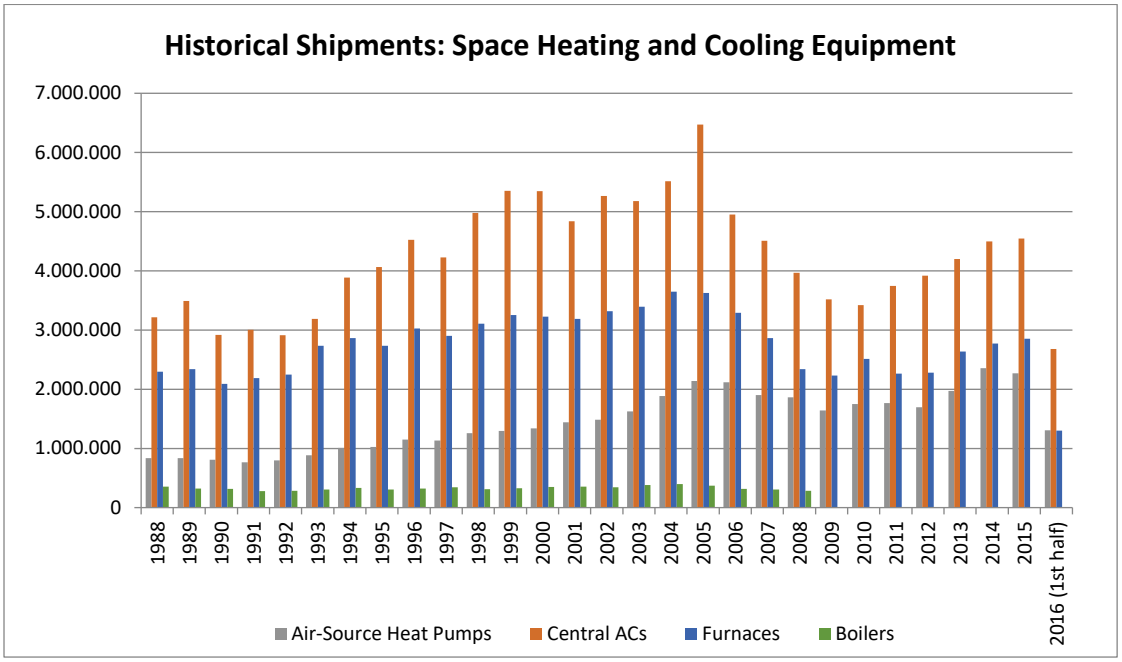

Fig. 1. Historical Shipments for Heating and Cooling Equipment [1]

From Figure 1, it is evident that the health of the housing market has a major impact on the shipments of heating and cooling equipment. In the subsequent sections of this paper, the authors investigate the magnitude of this relationship as well as other significant drivers such as the economy, fuel prices, standards, incentives, and new technological advances.

1.2. Expansion into colder climates

To date commercial deployment of HPs has been mainly focused in moderate climates, especially in the southern part of the United States where homeowners rely on HP technologies for both cooling and moderate heating needs. However, HPs are slowly gaining traction in colder parts of the country. For instance, regions where homeowners currently rely on boilers for their heating needs and on ACs for cooling are great candidates for HPs when ACs need replacement, because HPs can be used for both cooling and as a secondary source of heating during the coldest months. Furthermore, homeowners would not have to rely on older and typically less efficient boilers for heating during the remainder of the year.

Another growing trend is with the increased deployment and outreach efforts of cold climate HPs (CCHP), especially in states such as Vermont and Maine. In Vermont, for example, up to $800 incentives are available for qualifying homeowners at time of purchase to scale up deployment of qualified CCHPs. To qualify as a CCHP under the Vermont program a HP must be a variable-speed mini-split or multi-split ductless HP with SCOPh $\geqslant$ 3.00 and SCOPc $\geqslant$5.86. As of December 2015, 1,296 qualified CCHPs were installed as part of Vermont's efforts, and it is anticipated that the total will reach ~1,800 by the end of 2016. The Vermont program targets homeowners that have open floor plans, currently use at least 2270 liters of oil or propane annually, and are interested in controlling future spikes in oil or natural gas prices. In areas where natural gas-fired furnaces are an option for homeowners, CCHPs are not promoted due to their generally higher energy cost. For example the

average cost per 1000 kWh of heat delivered to a space with a CCHP is ~$62.51 vs.~$50.05 with a condensing natural gas-fired furnace [2].‡

Similar to Vermont, Maine has deployed 20,000 high efficiency ductless HPs in Maine homes and businesses in the past 3 years. In Maine, $500 rebates are available toward installation of ductless HPs that provide a single or first zone of heating for a home. An additional rebate of $250 is available for ductless HP installations that provide a second zone of heating [3].

Although efforts in individual states are gaining traction, they are still niche efforts. However, it is promising to see that research institutes such as Oak Ridge National Laboratory are collaborating with manufacturers to design central ducted CCHPs HPs that can enhance the efficiency performance and bring down cost. These technologies are anticipated to hit the market around 2021.

2. Impact of Housing Market

2.1. Path to recovery

Following 15 years of a fairly steady increases in new housing completions, the United States experienced a major collapse of the housing market. After peaking in early 2006, housing prices underwent the largest price drop in history over the next two years, and the country entered the deep recession. The concern to the economy was so great that the U.S. government rolled out a limited bailout of the housing market to reverse the trend.

Among the many repercussions of the housing market collapse was the drastic slowdown in new home construction, dropping nearly 70% from 1.9 million completions in 2006 to 585,000 in 2011, as shown in Figure 2. New housing completions turned a corner in 2012 with the first year of growth since the recession; since then, they have rebounded by 66% in 2015 to approximately half of the number of houses completed in 2006. During this recovery period, new housing completions have been growing at an average rate of 13% annually. Assuming the housing market continues to grow at this pace, it is expected to reach 2006 levels by 2021.

Despite the overall direction of the housing market, HPs steadily increased their share of the new home market in the years leading up to, during, and following the recession, up to 41% in 2015 compared to only 25% in 1978. One reason for this is the higher rate of homebuilding in the South where HPs tend to be most cost effective and are therefore most prevalent. In the south, for example, 63% of homeowners rely on HPs for their space heating needs as of 2015. HPs are found in 19% and 13.5% of homes in the Midwest and West, respectively. Although researchers are making technological strides, HPs have traditionally lacked the ability to perform under cold climate conditions so they currently do not have a strong presence in the Northeast.

Another reason for increased HP penetration in new homes is the increased demand for space cooling, as shown in Figure 3. This trend stems from a combination of: a) increased home builds in the South, a warmer climate, and b) space cooling transitioning from a “luxury” item to a staple in many of today’s homes. When homeowners choose to install space cooling in their homes, they have two main system options: central air conditioning and HPs. More and more, homeowners appear to be opting for HPs due to the benefits described in section 1.

‡ Assumes a SCOPh for the heat pump of 2.4 and an annual heating efficiency of 93% for the condensing gas furnace.

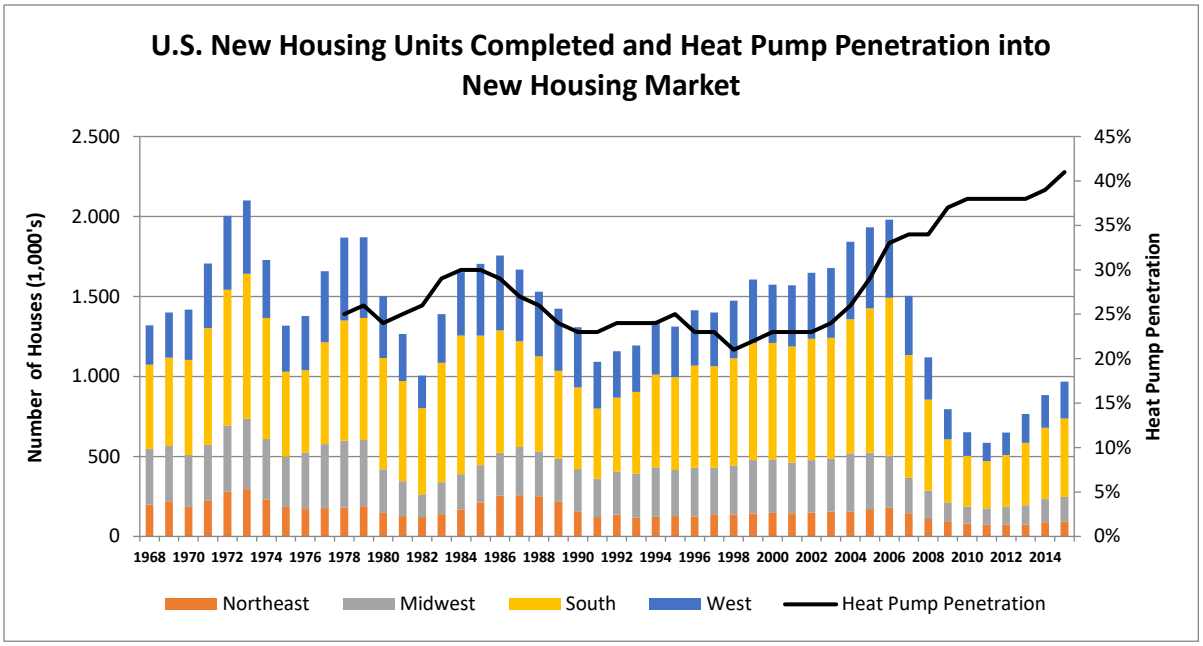

Fig. 2. HP market penetration into the new housing market rose before, during, and after housing crisis [1,4]

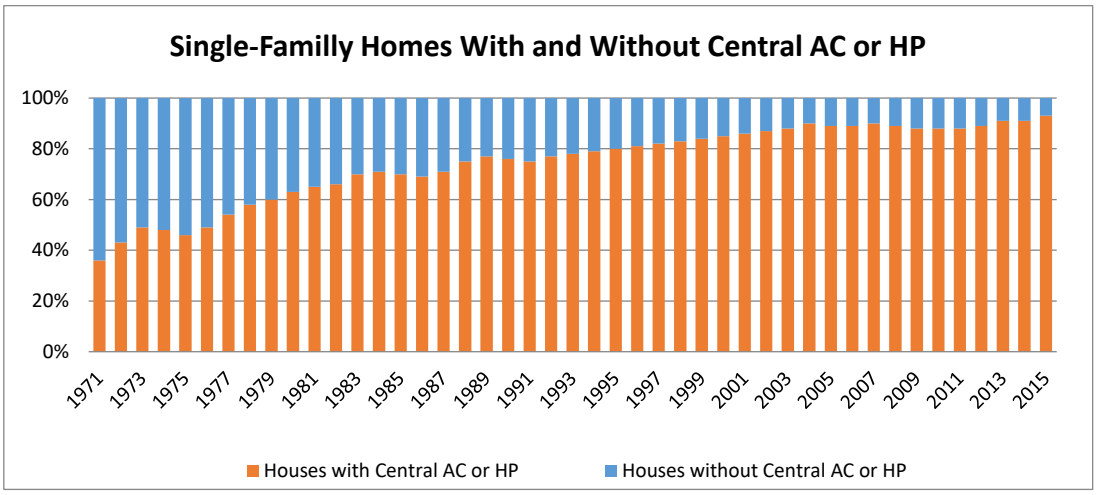

Fig. 3. Space cooling is no longer viewed as a luxury appliance in new homes [4]

2.2. Target market segments for HPs

New home builds. During the design phase of a new home, builders (and, sometimes, future homeowners) are not constrained to existing infrastructure and fuel supply and can weigh all available heating and cooling system options. Although regional factors (e.g., electricity to natural gas price ratio, climate zones, and fuel availability) will need to be considered, this scenario provides the builder an opportunity to consolidate heating and cooling appliances down to one. States most likely to seize this opportunity, based on available HP technology, are those with low electricity-to-natural gas ratios, and moderate climates with both heating and cooling needs throughout the year (although not extreme winters). Once CCHPs are market-ready and trusted by contractors and homeowners, they could become more viable choices in northern states.

In some southern states where space heating is not necessary, HPs would compete directly with ACs, which are both electric, for space cooling so the decision would come down to purchase price and operating cost savings. In some northern states where space cooling needs are small, HPs would compete directly with furnaces and boilers. While purchase price and operating cost savings play an important role in this decision, the concern

over whether a HP can perform under extremely cold conditions will factor in as well.

Replacements. Unlike with new home builds, homeowners tend to base their replacement decisions on what infrastructure (i.e. fuel type) is already established. Because of the additional time and cost required, a very compelling argument in favour of one particular appliance must exist for a homeowner to proactively switch fuel types, for example, from electricity to natural gas and vice versa.

To better understand the various replacement scenarios, Figure 4 provides a snapshot of residential space heating and cooling equipment installations in 2009 [5]. While this data is somewhat outdated, it lays out several key market opportunities for HPs as existing inventory is replaced. Using the logic above, HPs have a much better chance of replacing an electric furnace than a gas-fired furnace or boiler. For space cooling, HPs' main competition is central AC, so if it saves the consumer money in the long run, they may be inclined to purchase a HP. The appeal of HPs as a cooling replacement may increase in Northern states since they could use the more efficient HP for primary space heating, and their existing furnace or boiler for supplementary heating during extreme winter conditions.

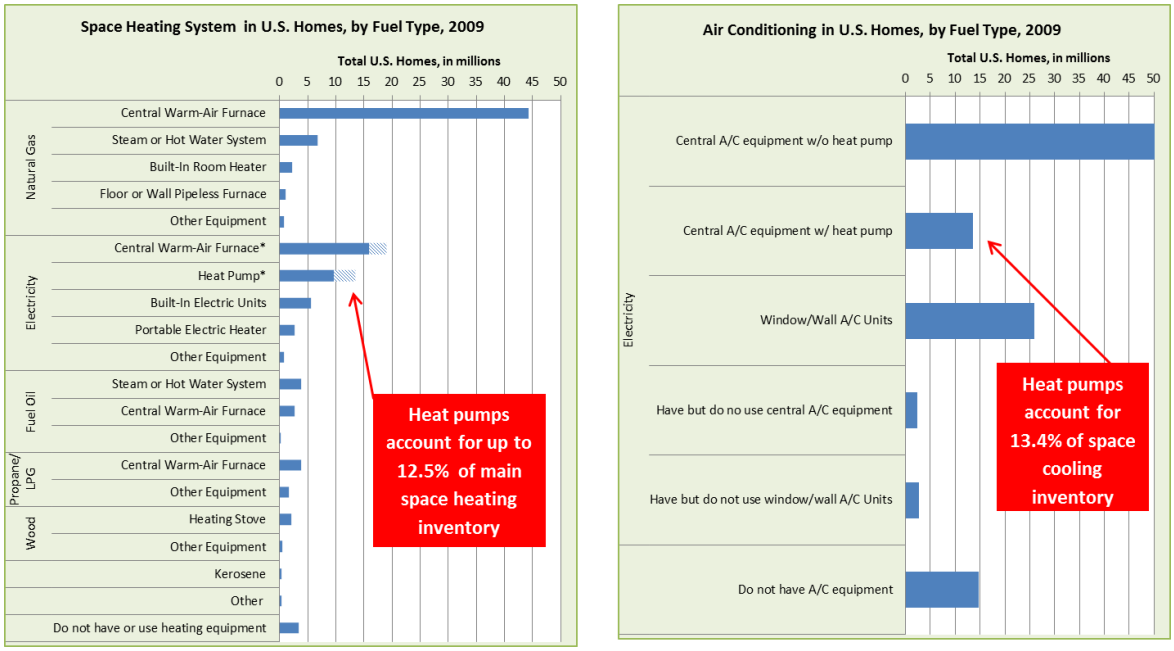

Fig. 4. Breakdown of space heating and cooling equipment in U.S. homes [5]

3. Impact of the Economy

The state of the economy directly influences the HP market through multiple aspects. First, as mentioned previously, new home construction rates fall when the economy is down, limiting the demand for HP shipments. Second, reduced HP shipments leads to lost revenue for manufacturers, which may adversely impact R&D budgets needed to explore new and improved HP technologies. Third, consumers have less expendable cash for remodeling and upgrading to more efficient technologies before they reach "end of life," and when they do, consumers may opt for the least expensive replacement.

To investigate how strongly the economy influences the HP market, the correlation between HP shipments and the Leading Indicator of Remodeling Activity (LIRA) from the beginning of 2012 through the third quarter of 2016 was calculated and is presented in Figure 5 [1,6]. The LIRA, published by the Joint Center for Housing Studies of Harvard University (JCHSHU), tracks home improvement spending through the current quarter, plus projections for the upcoming four quarters. It is measured in four-quarter moving rate of changes, and its resulting rates provide a short-term outlook for national home improvement and repair spending in owner-occupied homes and may help identify future inflection points in the home improvement market.

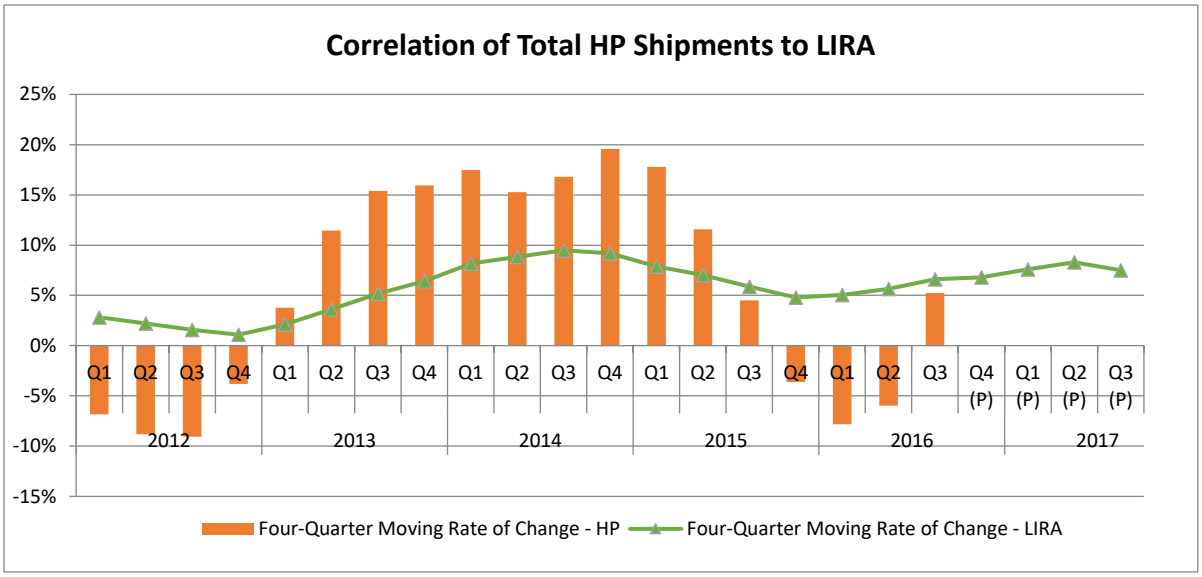

Fig. 5. A strong correlation exists between HP market growth and the LIRA [1,6]

Analysis yielded a coefficient correlation of 0.77 between HP shipments and the LIRA, indicating a strong relationship between U.S. economic health (via LIRA) and growth in the HP market as measured by shipments. With a strong relationship now established, continued growth in the HP market can be expected through the first half of 2017 since the LIRA projects growth in home improvement and repair expenditures to reach 8.0%, well above its historical average of 4.9%.

4. Impact of Fuel Prices

While the first cost or purchase price of heating and cooling equipment is very important to homeowners, fuel prices also play an important role in product selection since it largely impacts operating cost. In Figure 6, the national average for residential natural gas-to-electricity price ratio is presented along with HP shipments between 1990 and 2015. The forecasted ratio through 2040 is also presented. The national average ratio stood at about 0.27 in 2015, which means that the residential price of 1000 kWh of natural gas is 27% the price of 1000 kWh of electricity. Starting in 2004, the ratio started to drop, meaning that natural gas was becoming a cheaper operating fuel relative to electricity, and it is reasonable to assume that the drop in natural gas prices may be inhibiting HP market growth.

The overall coefficient of correlation for the 1990-2015 timeframe stands at about 0.7, indicating a strong relationship. However, when conducted for the 1990-2012 timeframe, the same exercise results in a coefficient of correlation of 0.94, a much stronger correlation when reducing the timeframe by three years, suggesting that up through 2012, HP shipments had a stronger reliance on fuel prices. However, this relationship has become weaker in recent years with HP shipments continuing to grow regardless of the drop in natural gas prices. This is promising for the future of HP technologies, especially since natural gas prices are expected to remain relatively low in comparison to electricity. According to the most recent Annual Energy Outlook [7], natural gas prices are expected to grow at about 0.8% annually while electricity prices will grow only at 0.2% annually.

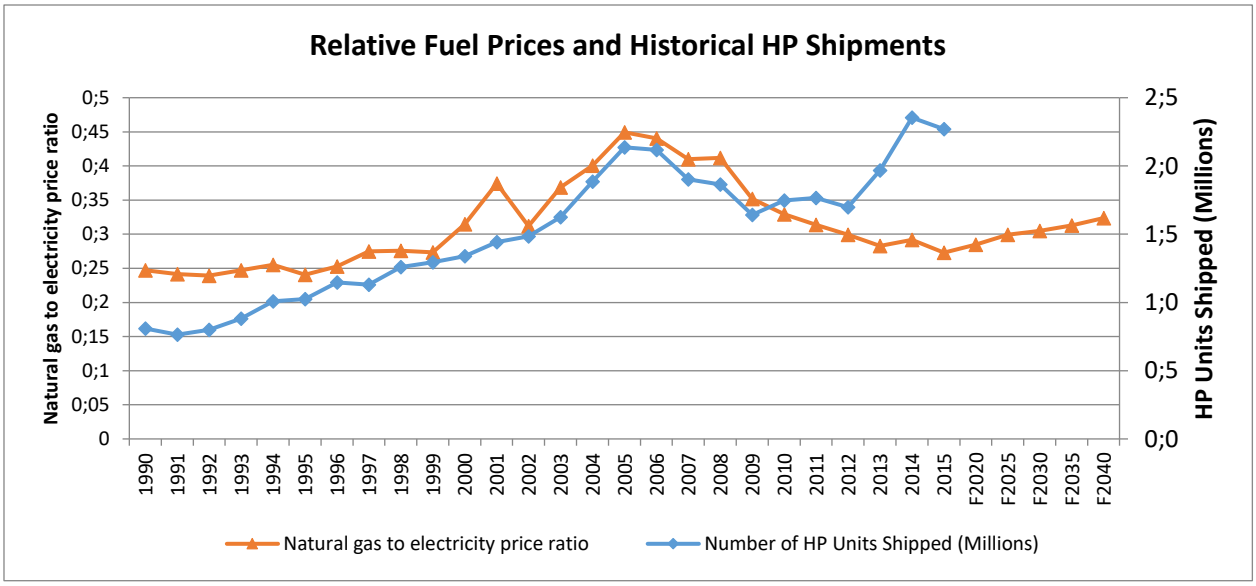

Fig. 6. Relative fuel prices and historical HP shipments [1,8-10]

5. Impact of Regulatory Actions

5.1. Minimum efficiency standards

Like most building equipment and appliances, residential HPs are subject to federally-mandated minimum efficiency standards designed to conserve energy and cut associated greenhouse gas emissions. Because they offer both heating and cooling functions, HPs must meet both minimum SCOPc and SCOPh levels. These standards have pushed manufacturers to design innovative and cost-effective technology capable of meeting these efficiencies, and overall they have successful delivered with each new round. In fact, shipment weighted cooling efficiency for HPs rose 56% in less than 25 year (from 2.77 SCOPc in 1990 to 4.33 SCOPc in 2013).

While the standards are in place to improve the quality of the space heating and cooling equipment, shipments often suffer immediately following their implementation. Such dips are evident in Figure 7, where year-over-year growth overlays HP shipments since 2000. In 2005, for example, minimum SCOPc increased from 2.93 to 3.81, and growth dropped significantly in the subsequent years. A similar response occurred in 2014 when minimum SCOPc increased from 3.81 to 4.10 in two of the three U.S. regions.

Two main reasons can potentially be linked to this trend:

- Offloading Non-Compliant Inventory: Manufacturers quickly offloaded larger-than-normal amounts of lower efficiency models in the months leading up to the new standard. This is especially noticeable in 2005 when the jump in minimum SCOPc was the highest ever. As a result, shipments dropped significantly in the early months of 2006 and 2015 since the market was flooded with inventory. Furthermore, manufacturers may have used this time for necessary retooling of their production lines for higher efficiency models.
- Higher Price for Higher Efficiency: Achieving a higher efficiency with traditional HP technologies usually comes with a higher price tag, at least in the near term. Plus, manufacturers may need time for economies of scale to take effect. This sticker shock may lead consumers to either a) opt for a less expensive alternative, b) wait until prices drop to previous levels, or c) attempt to repair existing cooling equipment. The latter may be most likely since compressor shipments surged in 2006.

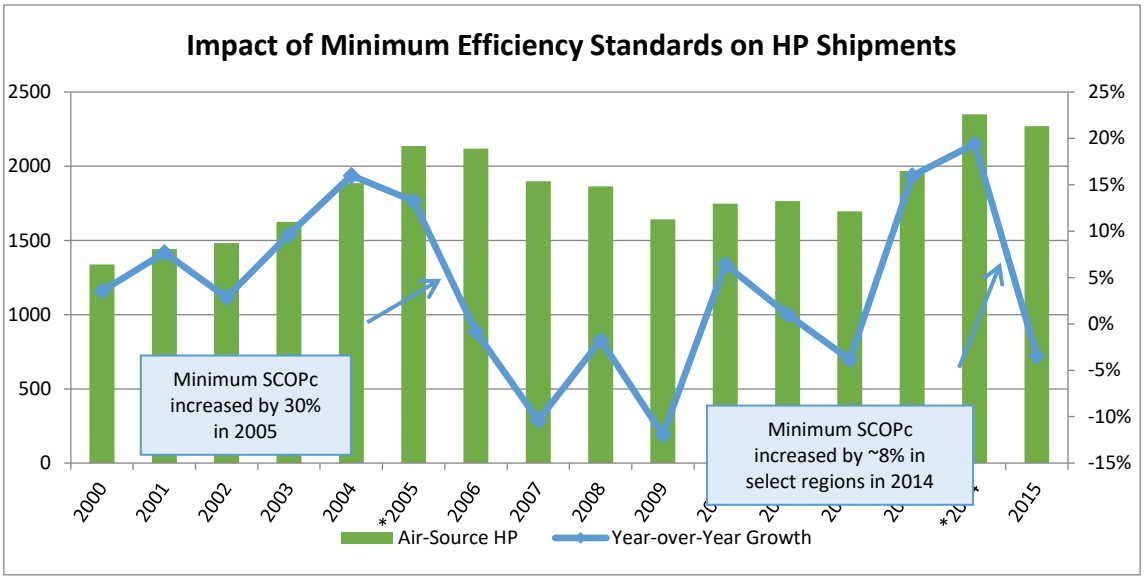

Fig. 7. Year-over-year growth significantly drops during years that new minimum efficiency standards go into effect [1]

As expected, manufacturers have successfully achieved efficiency levels required to be compliant with the most recent standards increase in 2014, since manufacturers provide input and are heavily involved with the Department of Energy at each round of efficiency standard update. However, additional improvements may be required. DOE recently proposed important revisions to its test procedures for central ACs and HPs originally established in the Energy Policy and Conservation Act of 1975. The most notable changes to the test procedures are:

- 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 changes, DOE expects to see SCOPc and SCOPh ratings that are more representative of real-world conditions [11]. In turn, consumers will be presented with more realistic operating cost savings calculations that will allow them to make better informed purchasing decisions. The industry as a whole should benefit from these improvements. However, assuming the minimum efficiency levels do not change, it means that manufacturers must push product efficiency even further to abide by existing standards since rated cooling and heating seasonal efficiencies calculated based on the proposed revised test procedures could be as much as 5% and 15% less, respectively, than those calculated using the current test procedures.

5.2. Commitment to alternative refrigerants

Like many countries across the world, the United States is committed to transitioning to a new generation of refrigerants that have less negative impacts on the global climate. Specifically, the design, manufacture, and servicing of new products will need to align with the U.S.'s phase-out schedule for refrigerants outlined in the Montreal Protocol on Substances that Deplete the Ozone Layer. Currently, the most popular refrigerant used in ACs and HPs is the hydrofluorocarbon (HFC) R-410A. While this refrigerant has zero ozone depleting potential, its global warming potential (GWP) is relatively high, so the desire is to transition to a new generation of refrigerants that have much lower GWPs but maintain or improve upon the efficiency levels of R-410A-based equipment. Experts anticipate future refrigerants to include lower-GWP HFCs (e.g., R-32), hydrofluoroolefins (HFOs, e.g., R-1234yf), hydrocarbons, carbon dioxide, and blends of two or more of these.

The additional efficiency and environmental improvements demanded from manufacturers may prove to be very difficult to achieve with today's technologies. Newer and more unconventional concepts under

investigation include advanced vapor compression systems, non-vapor compression systems, and the integration of cooling equipment with other building systems [12].

6. Impact of Key Stakeholders

6.1. Role of incentives by utilities and states

Figure 8 shows a sample of the HP incentives currently offered by utilities and state programs across the United States [13-14]. While the map is not comprehensive, it shows that incentives are becoming widely spread. The incentives structures are largely driven by utilities' cost-effectiveness test and other policies that vary from a program to another. As shown, some programs opt for financing programs while others prefer monetary incentives to homeowners or directly to mid-stream market actors such as retailers. Financing programs include either on-bill financing (where utilities offer loans to customers so they can pay for energy efficiency improvements through regular monthly payments) or a subsidized interest rate. Monetary incentives, in comparison, seem to be more widely deployed. The majority of the HP incentives range between $250 and $500. Some programs, such as MASSAVE in Massachusetts, set aggressive efficiency targets where a homeowner qualifies for the $500 incentives if the HP has a SCOPc rating ≥5.86. Other programs, such as that of PP&L in Pennsylvania, assign a sliding range of incentives based on the efficiency and cooling capacity of the unit.

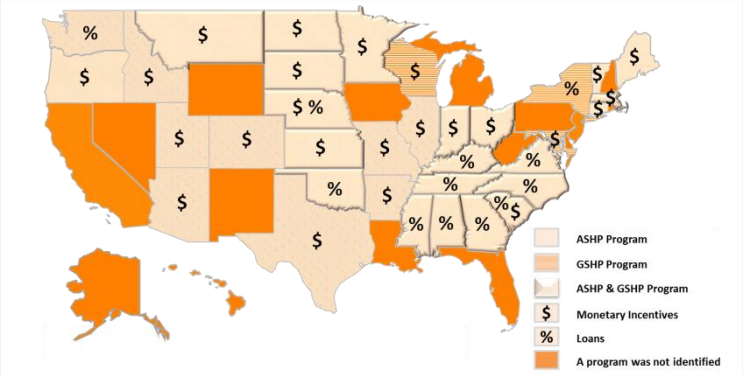

Fig. 8. Sample of Financial Incentives and Loans availability for HP and GSHP in the United States

Incentives for HPs extend beyond air-source models. Ground-source, or geothermal, HPs (GSHP) are also eligible for incentives to encourage their widespread deployment. The U.S. federal government has a tax credit in place for GSHPs that covers up to 30% of the cost including installation [14]. The tax credit was introduced in 2009 and is set to expire at end of 2016. In addition, many states, utilities, and local programs are providing loans, state tax credits, or financial incentives as shown in Figure 8 for both residential and commercial purposes. Incentives seem to range from $3,000 to $10,000 for residential programs.

Finally, some programs are further encouraging consumers to purchase HPs over ACs. For example, Connecticut's Energize CT program provides a $500 incentive for HPs compared to only a $250 incentive for ACs. Such scenarios are making the cost differential between HP and ACs negligible.

6.2. Addressing consumer hesitations

As with most new technologies, a natural resistance to change is observed in most consumers (e.g., homeowners and contractors), in this case from traditional ACs and furnaces to HPs. As noted in the previous section, states, utilities, and even federal entities understand the benefits of HPs and have invested heavily in building the market for HP technologies. Their efforts appear to be paying off. Just in the last decade over 30 million HP units were shipped and installed [1].

According to industry experts [15], homeowners started the decade with concerns and doubt regarding the performance of HP technologies. However, with time homeowners are gaining confidence as they experience the performance firsthand. There seems to be an adjustment of expectation to match reality, where homeowners know what to expect from HP technologies and are left satisfied with the performance of these technologies.

HVAC contractors also play a huge role in encouraging or discouraging homeowners to invest in HP technologies. Contractors are very comfortable with the technology performance in milder climates; however, hesitation seems to persist in colder climates. A common fear of HVAC contractor is that an abnormally cold winter will hit, and homeowners with HPs will experience abnormally high electric bills. As a result, they will lose confidence in the contractor and will be calling service companies in the dead of winter. Because of that concern, HVAC contractors may not recommend HPs for primary heating purposes. To sufficiently address this concern, additional education is needed in terms of aligning the expectation of the unit performance with contractor expectation.

7. Summary and Future Outlook

HP technologies are continuing to gain stronger traction as a primary heating and cooling equipment in mild climates and secondary heating equipment in colder climates. We anticipate the trend to continue supported by monetary incentives, consumer loyalty, a recovering housing market, and a steady economy. As shown in the last few years, relatively lower natural gas prices becoming somewhat less of a strong deterrent to HP growth. As the federal incentives for GSHP technology is expiring in 2016, we anticipate a surge in shipments in 2016, followed by a drop in 2017. The full impact of federal incentives in creating a stable market for GSHP is yet to be seen.

HP deployment is showing significant growth in Southern region in the U.S., we expect this regional market to mature in the next few decades. For the HP deployment growth trend to continue, aggressive penetration in colder climates is necessary. HP manufacturers are currently focused on preparing to comply with new testing procedures and the shift toward alternative refrigerants. In the short term, it seems challenging for manufacturers to shift their attention and investment toward new HP design that could better match the requirements for high efficiency heating in colder climates. We expect the testing procedures and the alternative refrigerant issues to come to rest by 2024 and hence allowing manufacturers to focus on CCHPs as this represent a significant opportunity for HP growth.

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References

[1] Air-Conditioning, Heating, and Refrigeration Institute (AHRI), 2016. “Historical Data: Central Air Conditioners and Air-Source Heat Pumps.”
[2] Vermont Public Service Department, 2015. “Heat Pump Report: A review of heat pumps and applicable standards in Vermont, As called for in Act 56 of 2015 Sec. 21a. 30 V.S.A. § 8001(b).”
[3] Efficiency Maine, 2016. “High Efficiency Heat Pumps.”
[4] U.S. Census Bureau, 2016. “Presence of Air-Conditioning in New Single-Family Houses Completed.”
[5] U.S. Energy Information Administration, 2009. “Residential Energy Consumption Survey Data, Tables HC6.1 and HC7.1”
[6] JCHSHU, 2016. “Growth in Remodeling Spending Projected to Peak in 2017.” October 20, 2016. Harvard University.
[7] U.S. Energy Information Administration, 2016. “Annual Energy Outlook 2016 with projections to 2040.”
[8] U.S. Energy Information Administration, 2016. “Short-Term Energy and Winter Fuels Outlook, Tables 5b and 7c.”

[9] U.S. Energy Information Administration, 2016. “Natural Gas: U.S. Price of Natural Gas Delivered to Residential Consumers.”

[10] U.S. Energy Information Administration, 2012. “Total Energy: Annual Energy Review.” September 2012.

[11] Energy Conservation Program: Test Procedures for Central Air Conditioners and Heat Pumps; Proposed Rule. Fed. Reg. Vol. 81, No. 164. (August 24, 2016). 10 CFR Parts 429 and 430.

[12] Goetzler, W., Guernsey, M., Young, J., Fuhrman, J., & Abdelaziz, O., 2016. “The Future of Air Conditioning for Buildings.” U.S. Department of Energy.

[13] Northeast Energy Efficiency Partnerships, 2016. “2016 Heat Pump Incentive Summary.”

[14] Database of Incentives for Renewables & Efficiency, 2016. Database of Incentives for Renewables & Efficiency. North Carolina Clean Energy Technology Center.

[15] Phone interviews with industry experts.