Recent Progress in the Residential U.S. Heat Pump Market

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Abstract: 13.5 million homes in the United States rely on heat pumps (HPs) for their primary heating equipment, about 80% of which are concentrated in the Southern United States. HPs are a technology of choice in the South not only due to the relatively moderate winter weather, but also because of the relatively greater affordability of electricity compared to natural gas in that region. Historical data analysis showed a strong correlation between growth in HP shipments and a drop in electricity prices relative to natural gas. HPs also showed growth in the new housing market: 38% of homes completed in 2012 included a HP, up from 25% in 1978. However, more than 74% of HP shipments are absorbed by the replacement and add-on markets. Even though HP technology experienced growth in the last decades, the future may be even more promising. The market transformation and research societies are working toward validating HPs in the cold climate region. This, together with other potential favorable market conditions, could even exceed the 2014 Annual Energy Outlook (AEO) estimates of tripling HP stock by 2040.

Key Words: heat pump, U.S. market, efficiency, residential

1 THE EXISTING RESIDENTIAL BUILDING STOCK

HP technology is increasing in popularity in the U.S. residential sector. As of 2011, 13.5 million, or 12%, of homes occupied in the United States relied on HPs for their primary heating needs (American Housing Survey (AHS) for the United States: 2011 (Table C-03-AH)). About 13% of single-family homes and 10% of multifamily units use HPs for their primary heating equipment. However, HP deployment in the United States is very concentrated in warmer climate zones. For example, 11 million, or 80%, of all homes relying on HPs are located in the Southern United States, and about 11% of homes using HPs are in the West. HPs are popular in the South due to the moderate winter weather, making HPs a great candidate to satisfy households cooling and heating needs. The South is also the most populous region in the United States with 37% of households concentrated in that region as of 2009. Between 2005 and 2010, the South was the only region to report a significant population net gain of 1.1 million (Faber, 2012). This seems to be a historical trend. Since the 1980s the South has shown a positive population net gain of more than 1.4 million every 5 years. The Northeast and the Midwest have consistently shown a population net loss since 1965. The West has experienced only minor net gains for the last 15 years. In the 2005 to 2010 timeframe, the West experienced a net gain of only 71,000 residents.[1]

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Figure indicates that in 2009 the total heating load of all occupied housing units in the United States was 4.226 quadrillion BTUs or Quads (4.46 EJ). Due to the cold weather, the Northeast and the Midwest have the highest average site energy consumption for heating, close to 60 Mbtu (63.3 GJ) per household. The average in the South stands at 22 Mbtu (23.2 GJ), while the average in the West is 27 Mbtu (28.5 GJ) (2009 RECS Survey Data (table CE3.1)). Even though 37% of the occupied housing units are located in the South they only represent 21% of the total U.S. residential buildings heating load. The HP deployment trends throughout the United States have had a major impact on HP's share of the national heating load. Because HPs are mainly prevalent in moderate climate conditions with low per household heating loads, they are only responsible for only 0.3 Quads (0.32 EJ) or 8.2% of total heating load.

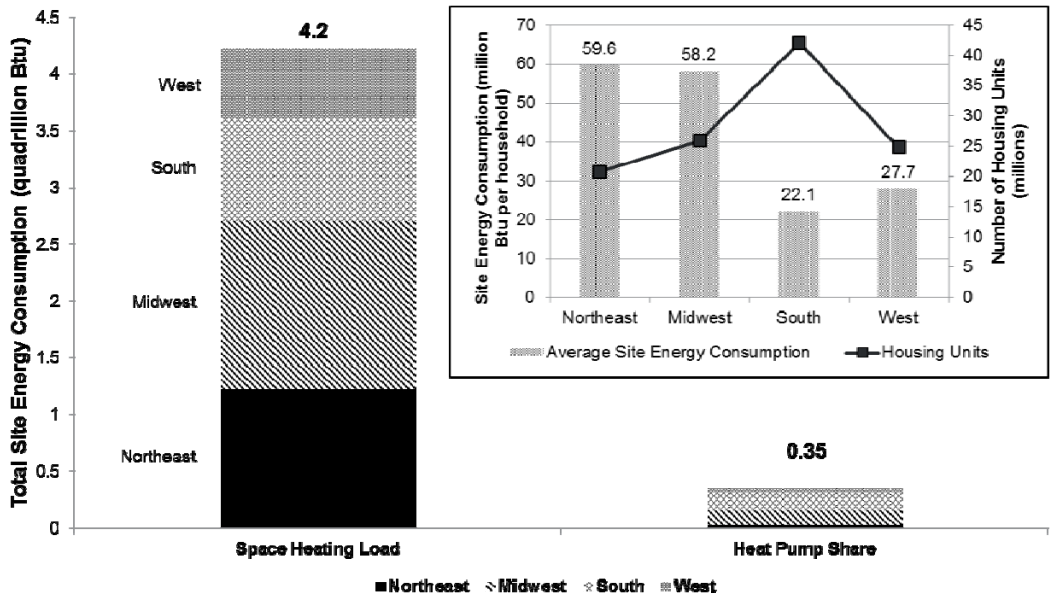


Figure : U. S. Residential Heating Load Characteristics; total and per household

2 NEW HOUSING MARKET

It takes decades of sustained growth in HP shipments to affect the existing housing stock, but the impact is more easily noticed in the new housing market. Figure highlights the continuous growth in HP installations in new homes. In 1979, 17% of completed multifamily units included a HP. By 2011 this had reached a historic high of 58% and stabilized back to 49% in 2012. Similarly, 25% of new, completed single-family homes included a HP in 1978, but grew to 38% in 2012.

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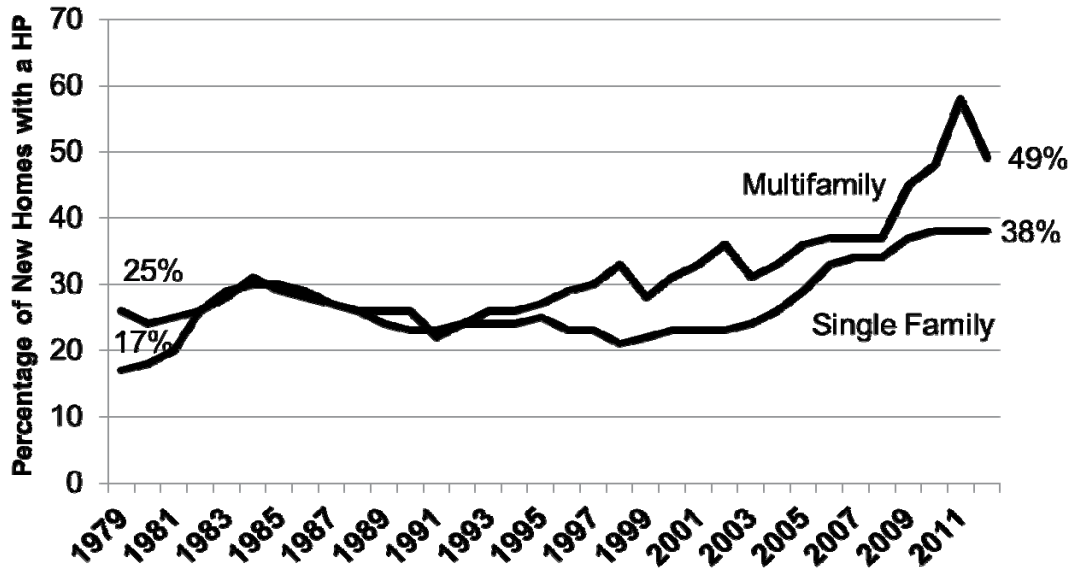


Figure : Percentage of New U.S. Homes with a HP

Figure shows the total annual HP shipments trend since 1979 (AHRI, 2014) for the replacement and add-on markets, new single-family market (Census.gov (Type of Heating System)), and multifamily market (Census.gov (Presence of Heat Pump)). The replacement market absorbed between 74% (assuming two HPs per single-family unit) and 85% (assuming one HP per housing unit) of total HP units shipped in 2012. As is evident in the figure, the U.S. new housing market is still struggling to recover from the housing crisis that began in 2007, halting many new home construction plans. In 2012 almost 500,000 new single-family homes were completed—down from the 1.6 million homes completed in 2006. However, total HP shipments remained relatively high and have begun to increase somewhat in response to demand from the replacement and the add-on markets. Before 2006 the replacement market was only responsible for 51% (assuming two HPs per housing unit) to 73% (assuming one HP per single-family unit) of total units shipped. The replacement market role will likely continue to grow as the new housing market recovers.

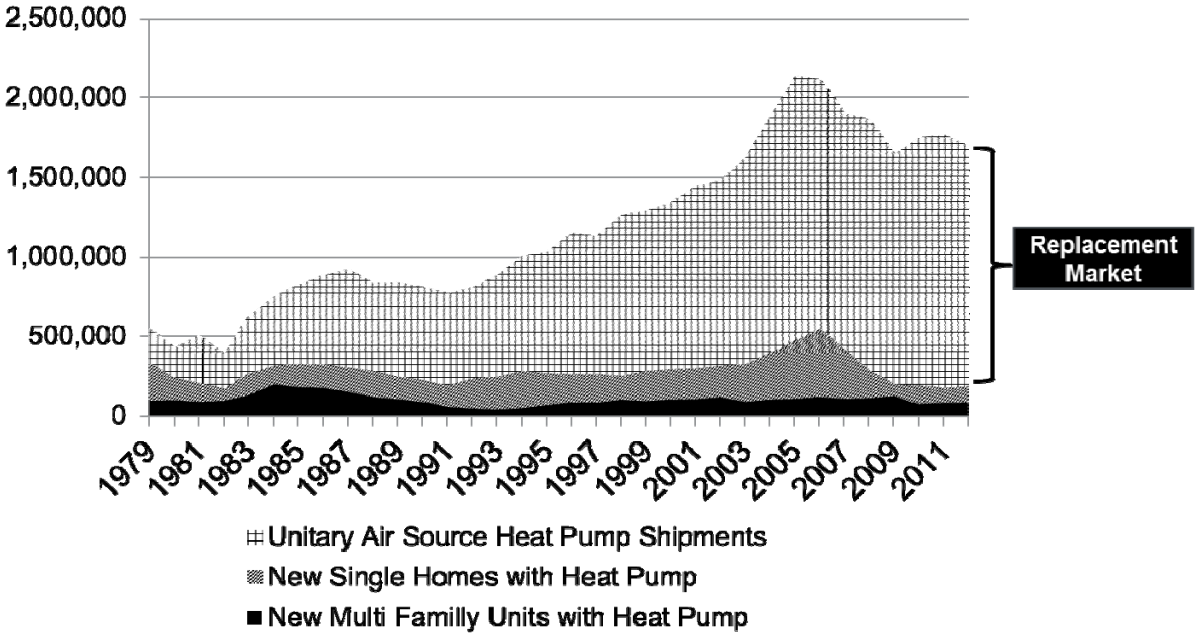


Figure : Total U.S. HP Shipments for Replacement and New Construction Markets

Figure **shows the number of new homes completed with air-conditioning (AC) systems, HPs, and warm-air furnaces (Census.gov (Type of Heating System)), (Census.gov (Presence of Central Air-Conditioning)). Note the sharp decline in new housing starts accompanying the economic recession that began in 2007 and how HPs gained market share during this time at the expense of furnaces. From the late 1970s through about 2006, homes completed with HPs represented only 25-30% of total homes completed while homes completed with a furnace represented 50-60% of total homes completed. In 2012, furnaces maintained a steady market share at ~58% of new homes completed while the share of new homes with a HP rose to 38%.**

The HP market share increase has been due mainly to phasing out of hot water, steam, electric baseboard, panel, radiant heat, space heater, floor or wall furnace, and other heating equipment types because of the superior efficiency and lower cost of HPs relative to other legacy technologies. This is promising for the future of HP technologies. The increase can also be explained in part by the population migration shift toward warmer climates where HPs are more prevalent. About 53% of newer homes are in the more temperate South, compared with only 35% of older homes (Energy Information Administration, 2013). It is also interesting to note that 89% of homes completed in 2012 are equipped with ACs, because it symbolizes the potential market for HP technologies. That is, as technological advances are made in cold climate HP technology, allowing for increased efficiency, HPs will become strong candidates to potentially replace ACs to meet the cooling and heating needs of households in these regions. This is especially true for air-source HPs (ASHP), the most prevalent type sold in the United States.

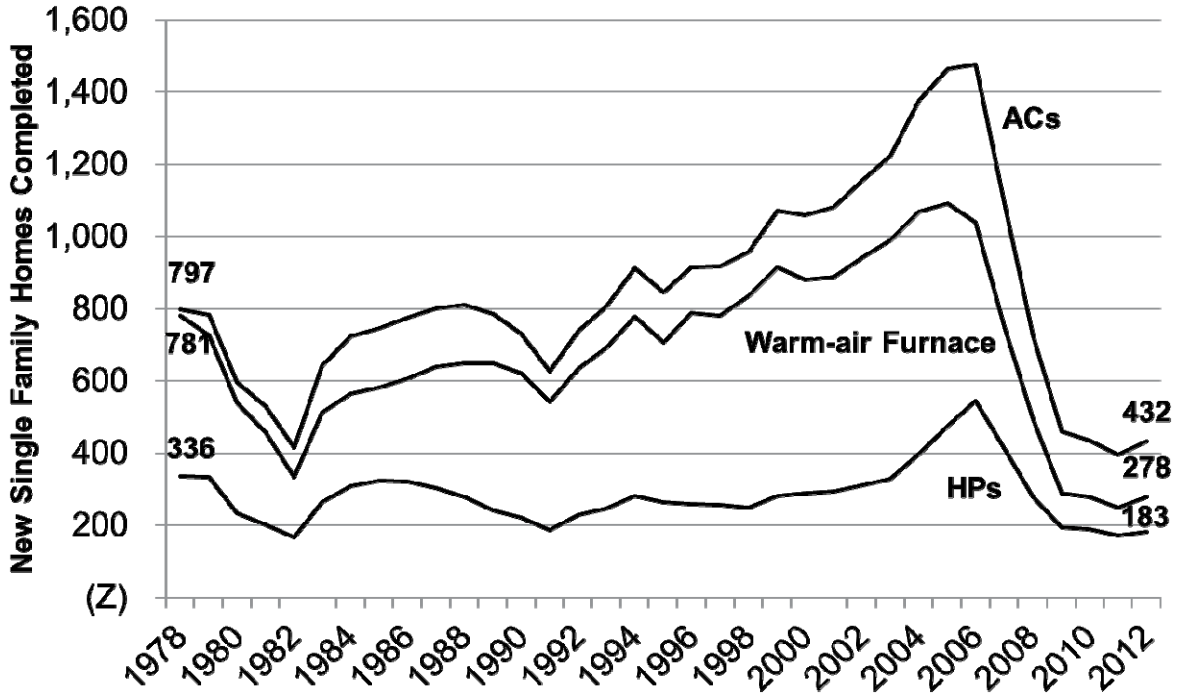


Figure : New Homes Completed with AC Systems, Warm Air Furnaces, and HPs

Not only are HPs more popular in the Southern United States, they are also substantially more popular outside metropolitan statistical areas (MSAs) (Census.gov (Presence of Heat Pump)). 51% of new homes built outside MSAs have a HP, relative to only 36% of new homes completed inside MSAs. That probably is due to the fact that HPs are more readily available to residential customers outside MSAs. About 99.8% of homes outside MSAs have electricity available, relative to only 43% that have access to and use natural gas (American Housing Survey (AHS) for the United States: 2011 (Table C-03-AH)), which gives HP technologies a competitive edge over furnaces in these areas.

3 HEATING EQUIPMENT SHIPMENTS

The HP market is recovering from the economic crisis that began in 2006 faster than other heating technologies as seen Figure , which shows unit shipments for the most popular heating equipment: ASHPs, gas furnaces, and oil furnaces (AHRI, 2014). The 1.7 million HP units shipped in 2012 is equal to ~80% of HP shipments made in 2005, while the 2.2 million gas furnace units shipped in 2012 is equal to only ~63% of gas furnace shipments made in 2005.

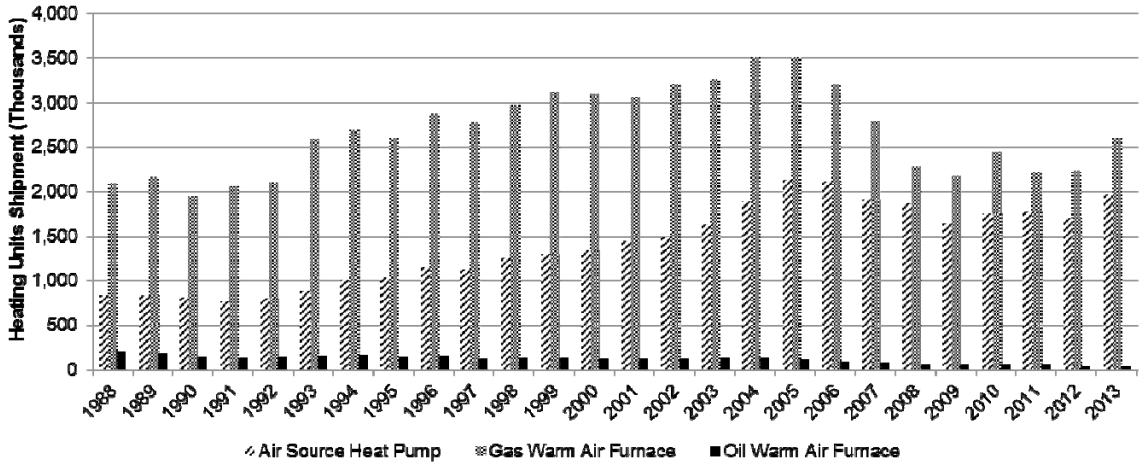


Figure : ASHP, Gas Warm Air Furnace, and Oil Warm Air Furnace Historical Shipments

HP efficiency has also increased substantially over the last two decades. In 1990, prior to the initiation of federal minimum energy efficiency standards, the average shipment-weighted cooling seasonal energy efficiency ratio (SEER) was less than 10 Btu/Wh (2.93 W/W). The federal standards and associated technological advancements effectively led to steady increases in shipment-weighted SEER. In 2005, the average HP and AC SEERs were 11.3 and 11.6 Btu/Wh (3.3 and 3.4 W/W), respectively. In January 2006, the minimum required SEER for new ACs and HPs was increased to 13 Btu/Wh (3.8 W/W). In January 2015, new federal minimums standards for SEER and Heating Seasonal Performance Factor (HSPF) will be required to be at least 14 and 8.3 Btu/Wh (4.1 and 2.4 W/W) for HPs and ACs respectively, and space-constrained HPs will be required to meet a minimum efficiency of 12 SEER (3.5 W/W). The shipment-weighted average SEERs for split HPs and split ACs in 2013 (through November) already exceed the new 2015 minimum requirement - 14.78 (4.3 W/W) and 14.17 (4.2 W/W), respectively.

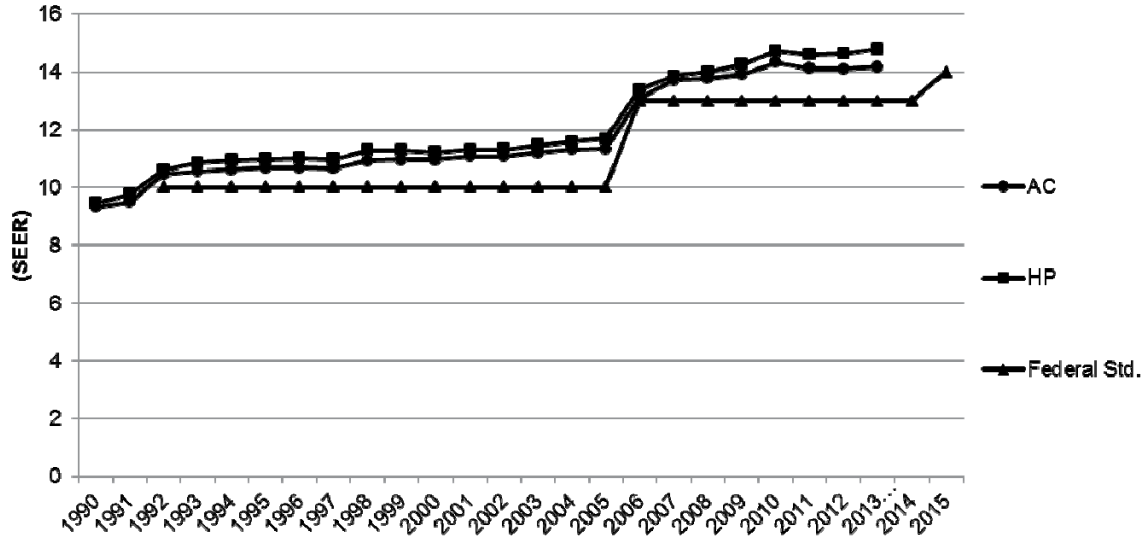


Figure : AC and ASHP Shipment-Weighted Average Seasonal Energy Efficiency Ratio (NOTE SEER in units of Btu/Wh; divide by 3.412 to get SEER in W/W units)

4 FUEL PRICES

4.1 State Level Analysis

Figure shows state-level data for the percentage of homes using HP (right axis of the chart) with only the publicly available data for 29 states shown (2009 RECS (tables HC3.8, HC 3.9, HC 3.10, HC 3.11)). As discussed earlier, HPs are more popular and prevail in the South; on average almost 20% of homes in the Southern United States rely on HPs as their primary heating equipment. Some Southern states, however, have a much higher penetration of HPs than some of their neighboring states. In Virginia (VA), for example, 37% of homes rely on HPs for their primary heating needs. In an attempt to better understand market drivers for HP penetration (besides moderate climate), the relationship between electricity ((Energy Information Administration (Average Retail Price of Electricity to Residential Sector)) and natural gas (EIA (Natural Gas Residential Prices)) residential prices per state were investigated. The left axis of Figure 7 displays the cost ratio between electricity and natural gas. For the state of VA, the cost ratio for 10^6 Btus (1.06 x 10^6 Joules) from natural gas to that from electricity is 1.7. That is, the price of electric energy to a residence is 1.7 times that of natural gas energy, which is relatively low compared to other states. In Alaska (AK), for instance, this cost ratio of 6, referring to the fact that an electric MMBtu is six times the price of a natural gas MMBtu. Figure 7 shows 12 states where more than 14% of homes use HPs as their primary heating equipment. In most of these states the electricity-to-gas fuel price ratio is less than 2.1. To conclude, the relative moderate climate and the relatively lower price of electricity compared to natural gas in these 12 states created a favorable market condition for HP technologies to penetrate the southern region of the United States.

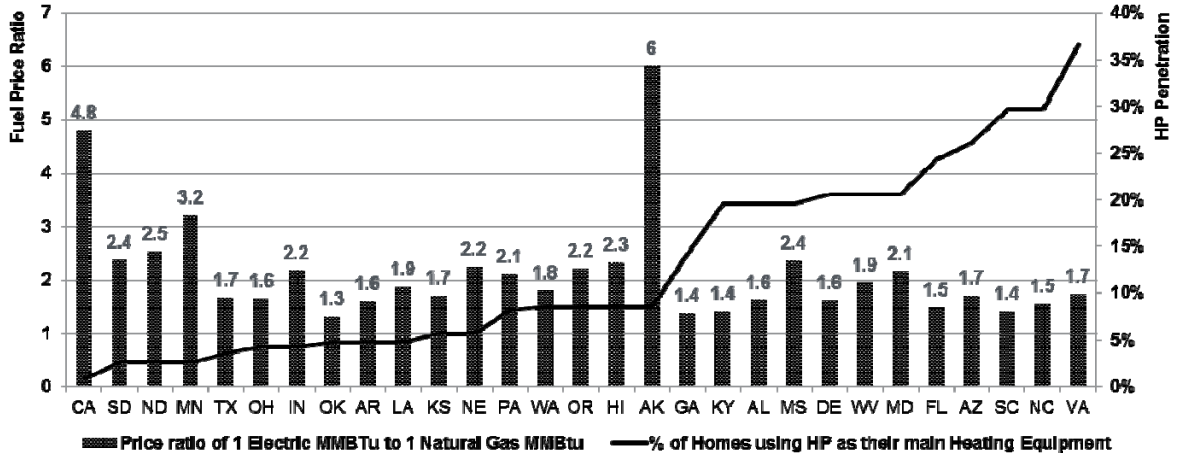


Figure : State Level Data on Relative Fuel Prices and Percentage of Homes Using HPs as Their Main Heating Equipment

4.2 Regional and Historical Analysis

gure shows the historical relationship between HP shipments (AHRI, 2014) and the national average residential gas-to-electricity price ratio (EIA (U.S. Price of Natural Gas to Residential Customers), 2014) and (EIA (Average retail price of electricity to ultimate customers by state, by provider, annual back) to 1990, 2013). Note that

in**gure** the fuel price ratio is inverted relative to Figure . The inverted fuel ratio is intended to ensure that the visual correlation between the two factors could be easily seen. The national average gas-to-electricity price ratio stands at about 0.3 for 2012, referring to the fact that 1 natural gas MMBtu is a third of the price of 1 electric MMBtu. The ratio has fluctuated between 0.25 and 0.45 between 1990 and 2012. HP shipment variations over the same period generally mirror the price ratio fluctuations with a correlation coefficient of 0.917. From 1990 to 2003 natural gas prices surged relative to electricity prices, giving an opportunity to the HP shipments to flourish. That trend broke in 2005, where HP shipments experienced a dropping trend partly driven by a surge in electricity prices relative to a more stable natural gas prices.

gure also shows a snapshot of the regional gas-to-electricity fuel price ratio for 2012 (EIA (Table 7c : U.S. Regional Electricity Prices)) and (EIA (Table 5b : U.S. Regional Natural Gas Prices)). Only four EIA regions have fuel price ratios higher than the average, that is, where natural gas is relatively more expensive than electricity. Three of these EIA regions (South Atlantic, East South Central, and West South Central) are located in the Southern United States, indicating that the South is generally characterized by lower electricity prices relative to natural gas prices. This trend highlights the role that relatively lower electricity prices play in promoting HP technologies and the role lower natural gas prices play as a barrier to HP penetration.

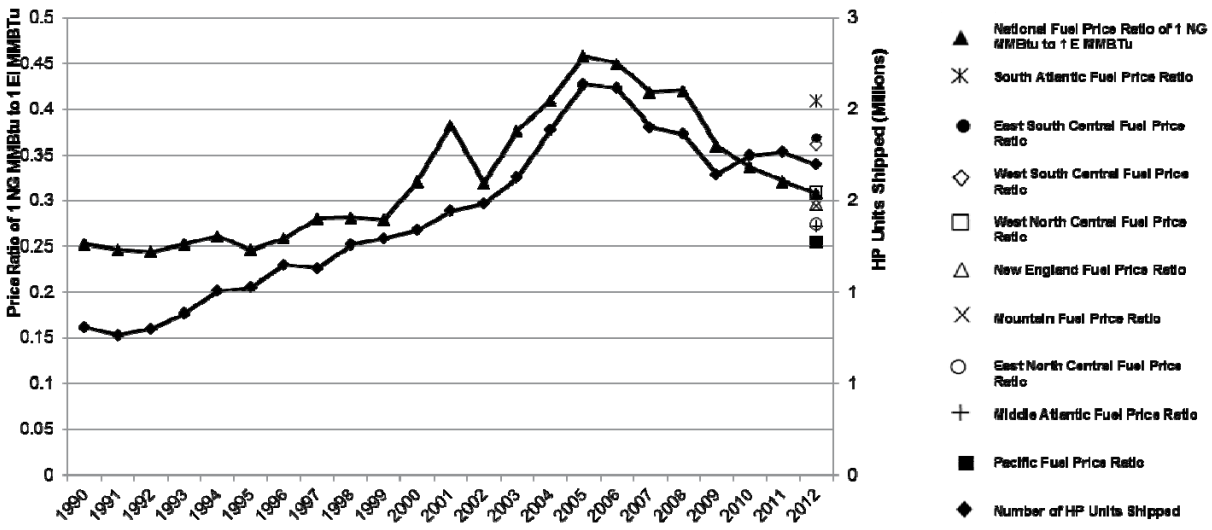


Figure : Relative Fuel Prices and the Number of HP Units Shipped

5 FUTURE OUTLOOK

Figure shows a forecast of the anticipated growth in residential heating equipment stocks from 2012 to 2040 (EIA (Annual Energy Outlook 2014 Early Release Overview)). The forecast takes into consideration electricity and natural gas prices and the important role they play in supporting or hindering the penetration of these heating technologies. An average growth rate for all electric HPs of 3.1% annually throughout the period is anticipated with stocks of geothermal heat pumps (GHP) projected to increase by 3.8% on average. In comparison, growth in natural gas heating equipment stock is projected at only 0.9% per year.

According to the AEO, 9.8 million homes were estimated to be using HPs as their main heating equipment in 2011 based on the latest data from the Residential Energy Consumption Survey (RECS). However, this number is believed to be underestimated since RECS respondents often have trouble identifying HPs. The general impression is that the number of electric central furnaces is overstated, and the number of HPs is understated. Comparing the HP numbers for heating versus AC seems to indicate this. Also, the RECS data indicate that 13.5 million households use HPs for space cooling while only 9.8 million use HPs for space heating. Another issue is that the RECS data is based on asking respondents to self-identify their main heating equipment. As HPs go into more and more homes, especially in warmer climates, respondents may think that other heating sources, such as space heaters, are their primary heating equipment because they do not use much heat. The number homes listing HPs as a secondary heating source did grow slightly from 1.2 million in 2005 to 1.3 million in 2009. Finally, RECS data only asked about homes that actually used heat in 2009. 2.4 million homes have heating equipment and did not use it. Since HPs are more common in warmer climates, it is possible that there are a significant number of homes with HPs that did not use heating at all.

To conclude, the combination of respondent misidentifications of heating equipment, respondent selection of main heating equipment type, and homes that do not use the heating equipment may have caused the 2012 value of HP equipment stock to be underestimated ((McNary) Personal Communication, 2014). In Figure , the dotted black line represents the estimated electric HP stock if the true HP equipment stock in 2012 was accounted for and assuming similar growth rate of 3.1%. The true HP equipment stock in 2011 is thus assumed to be 13.5 million. This number is consistent with the number estimated by the American Housing Survey (American Housing Survey (AHS) for the United States: 2011 (Table C-03-AH)) and by RECS for homes that use HPs for cooling purposes.

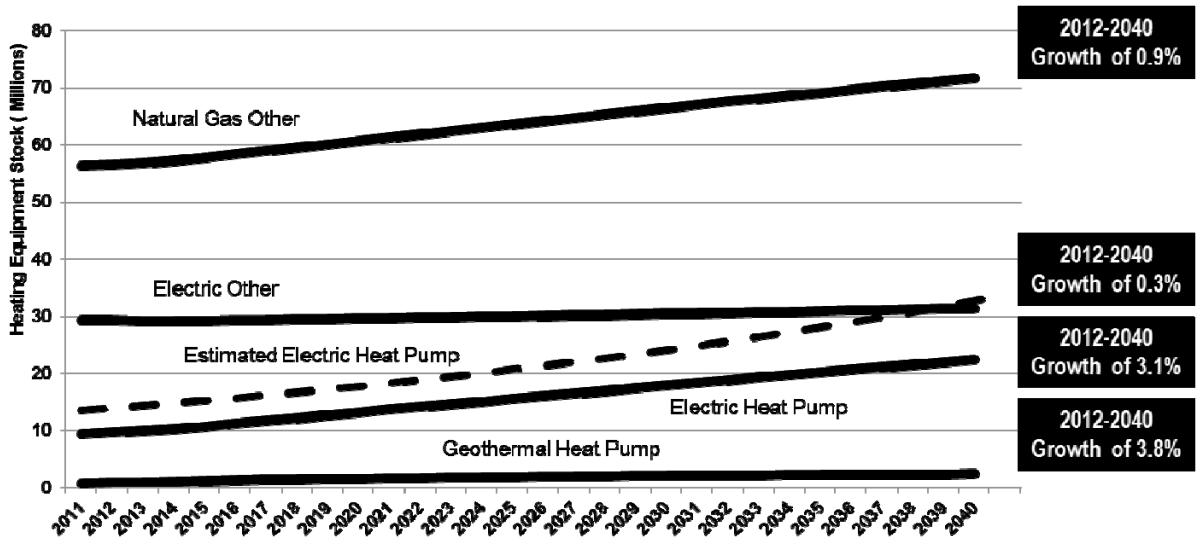


Figure : Forecast of Residential Heating Equipment Stock (2012-2040)

HP technologies have had a successful market penetration story to date. Their future potential continues to evolve as more stakeholders realize their unique applications

and potential energy savings as improvements to efficiency continue to be made. The AEO has estimated that residential HP stock to more than triple by 2040. A few promising highlights listed below suggest that HP technologies may even exceed the AEO estimates.

- Expansion into colder climates. As discussed earlier, HPs have always been a popular choice in the Southern United States. However, in the future, HP popularity may expand to reach other climate zones. Research and market transformation efforts are underway to substantiate HPs (particularly ASHPs) as legitimate heating equipment in colder climate regions. In the Northeast and the Mid-Atlantic region, the Northeast Energy Efficiency Partnership (NEEP) is coordinating the market transformation efforts. In a recent publication (Northeast Energy Efficiency Partnerships, 2014), NEEP has identified strategies that have the potential of transforming the heating equipment market in their region. The strategies range from creating a consumer and contractor awareness campaign to developing accurate modeling software for estimating energy and cost savings in cold climate regions. The report also indicates that the existing target market for HPs in the Northeast region would include: 10 million homes constructed prior to 1980, 9.5 million homes without central AC, and 4 million homes that use oil for heating. These population numbers are not additive, and the overlap is not known, but it is believed to be substantial. An excellent HP candidate home would be an older home that is getting an energy retrofit including a smaller and more energy-efficient heating system. If the home previously used electric resistance or oil for heating, the electric HP would offer energy cost savings. If the home did not have central AC, the HP would also provide a significant comfort improvement in the summertime.

HP technology in the Northeast region has also had a few modest deployment success stories, especially in Connecticut, Maine, and Vermont. In the one-year period starting in August 2012, Efficiency Maine was able to deploy 1,350 ductless split HP units as part of its weatherization program. In 2011 Connecticut's Home Energy Solutions Income Eligible program installed 3,576 ductless split HPs. In parallel with NEEP's market transformation efforts, the U.S. Department of Energy (DOE) and the International Energy Agency are coordinating efforts to address the key technical challenges facing ASHP technology in cold climate conditions, namely the reduction in heating capacity at low outdoor temperature (OD) temperatures and resultant increased usage of back-up electric resistance heating. The true challenge is achieving the higher low OD temperature heating capacity and higher HSPF will incur an installed cost premiums (Baxter, Van et al., 2014). The broadening of a market for ASHP technologies beyond the Southern United States to reach cold climate regions has the potential of drastically reshaping the HP market. Market transformation efforts driven by the technical and the marketing society hold much promise for substantial growth in the HP market.

- Role of Relative Equipment Efficiency. Relative equipment efficiency is one of the important factors that affect technology market penetration decisions. Long-term HP efficiency technological improvement promises are higher than its competing gas furnace technology. In addition, HPs allow for an opportunity to capitalize on renewable energy produced on site. However, the current difference in the efficiency performance of these two technologies has usually been balanced with the price difference of different fuel heating: natural gas

and electricity. If HP efficiency continues to improve and as long as fuel prices ratio stay almost constant, the market may tend to favor HP technologies.

- Potential New Markets for HPs. New end-use applications for HPs are gaining ground, particularly for water heating. For example, the stand-alone heat pump water heater (HPWH) is an exciting application with great potential. HPWHs experienced a significant boost in market presence in the United States beginning in 2009 when a number of manufacturers with considerable market presence and brand name awareness each introduced their HPWH models. However, HPWH (over 55 gallons) technologies will be challenged to grow from 1% of the market in 2012 to meet a federal standard that requires 100% penetration in April 16, 2015 (Northeast Energy Efficiency Partnerships, 2014). The efficiency requirement defined by the federal standard can today be only met by the HPWH technology. Multi-purpose heat pumps or integrated heat pumps (IHP) that combine space heating, space cooling, and water heating functions are another new HP technology with potential to achieve overall energy savings exceeding 50% compared to separate minimum efficiency systems (Baxter et al, 2013). Another promising technology, though not new, is the GHP. According to a new report from Pike Research (Navigant, 2011), GHP sales will experience strong growth rates in the next several years, with annual unit shipments in the United States increasing from just fewer than 150,000 in 2011 to more than 326,000 units in 2017. The potential for GHPs is high, but installations currently represent just 1% of the heating and cooling market. GHP and HPWH growth has the potential of educating consumers, contractors and cities in its entirety about HP technologies. This shared knowledge could set the stage for HPs to further penetrate the electric heating market.

In summary, the AEO projects the residential HP stock to more than triple by 2030. However, the applicability of newer ASHP technologies for cold climate regions, the potential of improved HPs efficiency relative to gas furnaces and increased application of HP technologies for domestic water heating (for water heating only or as part of an IHP system) could create a favorable environment for HP growth that may even exceed the AEO projections.

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