THE EVOLUTION OF THE U.S. HEAT PUMP MARKET[1]

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Abstract:The heating and cooling equipment market in the United States (U.S.) evolved in the last two decades affected by the housing market and external market conditions. The average home size increased by 25% since 1999, contributing to increased average equipment size of heat pumps (HPs) and air conditioners (ACs).The home size increase did not correlate with higher residential energy used. The last decade is recognized for improved home insulation and equipment efficiency in addition to the U.S. population shift toward warmer climates, which has made up for the larger home size and still yielded relatively lower residential energy use. The lower energy use coincides with more homes using HPs. HP growth was supported by the price stability and affordability of electricity. The heating and cooling equipment market also seems to be rebounding faster than the housing market after the economic crises. In 2009 only 22% of HPs were sold to new homes, reflecting increased heat pump sales for add-on and replacement applications. HPsare growing in popularity and becoming an established economic technology.

Key Words: heat pump, U.S. market, efficiency, air conditioners

1 THE HOUSING MARKET IN THE U.S.

The applications of heating and cooling equipment are strongly affected by changes in the housing market. The number, the geographic distribution, andthe size of homes, in addition to improvements in existing homes shape the application of the heating and cooling equipment.

The Number of Homes:
Figure 1 shows the number of new homes constructed in the last 30 years and the total permits issued for new, privately owned housing units. The timeline analysed presents wide variation in terms of the total number of new homes built annually. Declines in new homes being built in 2001 and 2007 coincided with U.S. economic downturns, although the shock that the U.S. new home market experienced in 2001 was less severe than that of 2007. The U.S. home construction market recovered promptly in 2002, reaching the pre-crisis growth level. In 2006, the home construction market peaked to reach almost 2 million newly constructed homes. Shortly afterwards, the housing bubble that triggered the 2007 economic recession in the U.S.burst, and the new home construction market was negatively impacted through 2009 when the total new home construction was only 0.8 million homes. Although complete data for 2010 is not yet available, the total permits issued suggest a slight increase for 2010in comparison to 2009.

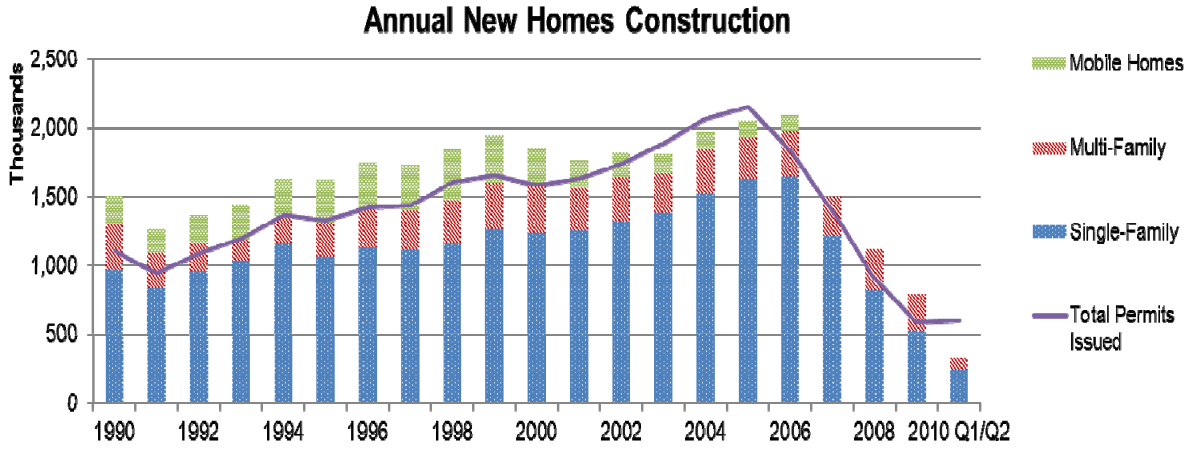

Figure 1: Annual New Homes Construction and Total Permits Issued (Building Energy Data Book, 2009; U.S. Census Bureau, 2010)

The Geographic Distribution of Homes:

The U.S. geographical population shift toward warmer climates is expected to continue through 2030 to the extent that the number of U.S. cooling degree days in the Annual Energy Outlook (AEO) 2008 reference case is about 10 percent greater than the National Oceanic and Atmospheric Administration (NOAA - benchmark for normal weather) 30-year average with fixed population weights, and the number of heating degree days is 8 percent less. Accordingly, electricity providers are projected to see more peak summer demand and a decline in heating energy use through 2030 (EIA, 2008).

More homes are being built in warmer climates than in colder ones, in response to the significant geographical population. Since HPs are more economical and widely used in warmer climates compared to colder ones, the U.S. population shift would contribute toward a faster HPs market penetration.

The Size of Homes:

It is commonly thought that the average single-family home size impacts the residential heating energy use. Figure 2 shows the average single-family home size in relation to the total residential energy used and the heating residential energy used. The figure shows an increase in the average single-family home size from 1998 to 2008, with a surprising, generally flat overall trend in the heating residential energy consumed. This time period also saw significantimprovements in home insulation and equipment efficiency, in addition to the population shift to warmer climates starting in 1971 (EIA, 2008) these improvementsseem to have partially made up for larger home sizes resulting in a lower level of general residential energy consumed.

According to one study the U.S. population shift among the U.S metropolitan areas resulted in about 11% reduction in the combined energy demand per person for heating and cooling compared to what the energy demand would have been if the population shift had not changed between 1960 and 2006 (Sivak,2009).

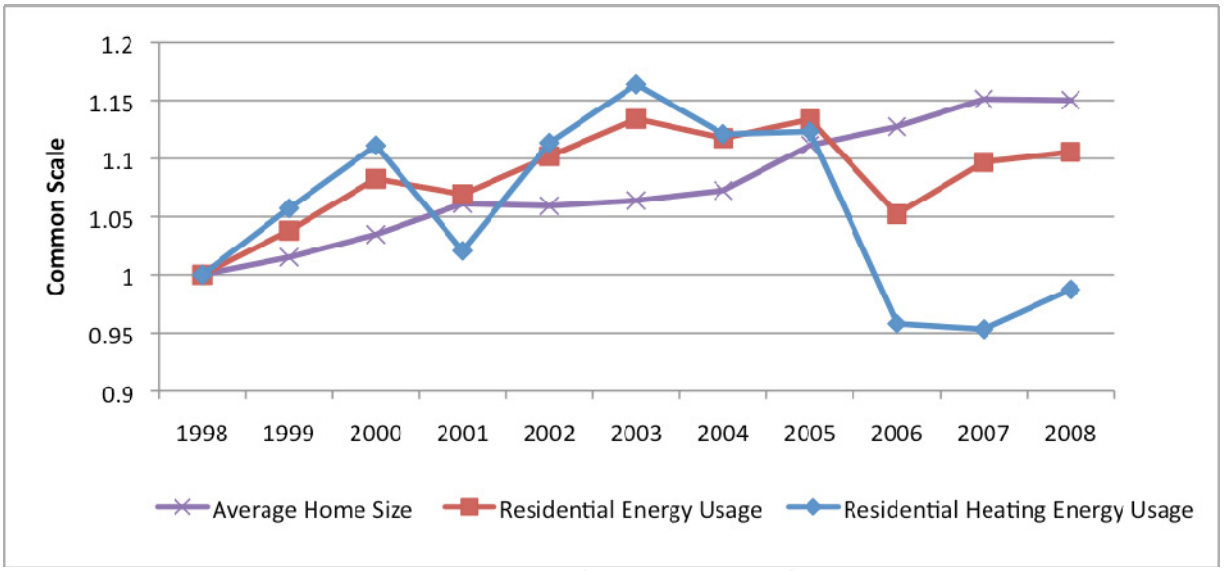

Figure 2: Investigating the Potential Impact of Average Home Sizeon Residential Energy Usage (US. Census Bureau, 2009; Buildings Energy Data Book, 1998-2008)

Impact on the ResidentialHeating Energy Used:

Starting in 2006, the residential heating energy used dropped relative to total residential energy used. The U.S. experienced a warmer than normal winter in 2006, which contributed to the lower heating residential energy use in 2006.Also, the 2007 economic downturn could have contributed to the lower heating energy use in 2007 and 2008 as consumers became more concerned with heating costs. 3) Finally, the drop in residential heating energy used also coincides with new government regulations to increase the minimum seasonal efficiency (SEER) for heating and cooling equipment that became effective in January 2006. Theimpact of thenew SEER regulation on energy consumption usually takes several years of sales of higher efficiency equipment for it to be significant as new efficient heating equipment replaces older less efficient heating equipment. But, minor reduction in the residential heating energy used starting in 2006 could be attributed to the new efficiency standards.

The overall growth in the residential energy used could also be partly justified by increased reliance on energy based equipment. For example the “other” residential energy category almost tripled from 2001 to 2006. The “other” residential energy category includes,but is not limited to, small electric devices, motors, swimming pool heaters, and outdoor grills.In addition, the 2006 residential energy used by consumer electronic equipment increased by 50% relative to 2001.

2 THE HEATING AND COOLING EQUIPMENT MARKET IN THE U.S.

The U.S. heating and cooling end-use market has gone through major changes in the last decade. Figure 3 shows annual shipments for heating and cooling equipment, as well as the annual completed housing. Although only the minority of heating and cooling equipment sales are for new construction, the trend of total heating and cooling equipment shipments still roughlyparallels the trend of new home construction since both markets are strongly affected by the general U.S. economic condition. But the overall heating and cooling equipment market is recovering faster than the housing market, due mostly to sales for the replacement and add-on markets. The replacements and add-on markets usually requires smaller financial commitment relative to the housing market which justifies the foreseen faster recovery.

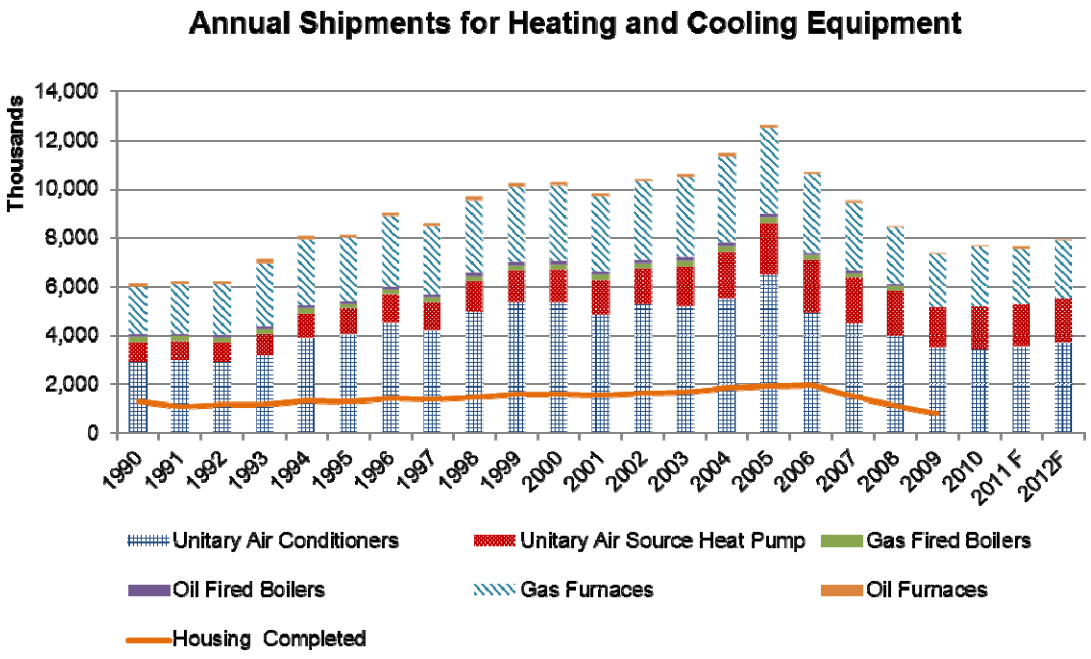

Figure 3: Annual Shipments for Heating and Cooling Equipment, short term forecasted shipment and Annual Housing Completed (AHRI, 2009a; Building Energy Data Book, 2009)

Due to the economic downturn, 2001 shows a slight fall in the total number of shipments. The new government regulations for SEER caused the spike in 2005 as manufacturers were attempting to clear out inventory before the new regulation became effective in January 2006. The drop in 2006 compared to 2004 could also be partly justified by this regulation - manufacturers reduced inventories, and some of the manufacturers could not produce at full capacity in 2006 while meeting the new government regulation. The sharp fall in total shipments starting in 2007 and continuing through 2009 is explained by the economic downturn.2010 shows a slight increase in total shipments which indicate prospects for slow recovery. The figure also shows the forecasted shipments for 2011 and 2012(Appliance Magazine.com, 2010). The heating and cooling equipment market is expected to slowly recover, bolstered in part by an upturn in the housing market.

Figure 4 shows the evolution of the annual heating equipment market from 1999 to 2008. It is worth noting that the unitary HP market share has been continuously growing for the last 10 years. 2008 shows a rise in the HP market share where HP shipments accounted for 42% of total annual heating equipment shipment, showing a growth from 27% in 1999, consistent with the population shift to warmer climates where HPs are more economical and widely used compared to colder climates.This demonstrates that the HP is growing in popularity and is an established economic technology.

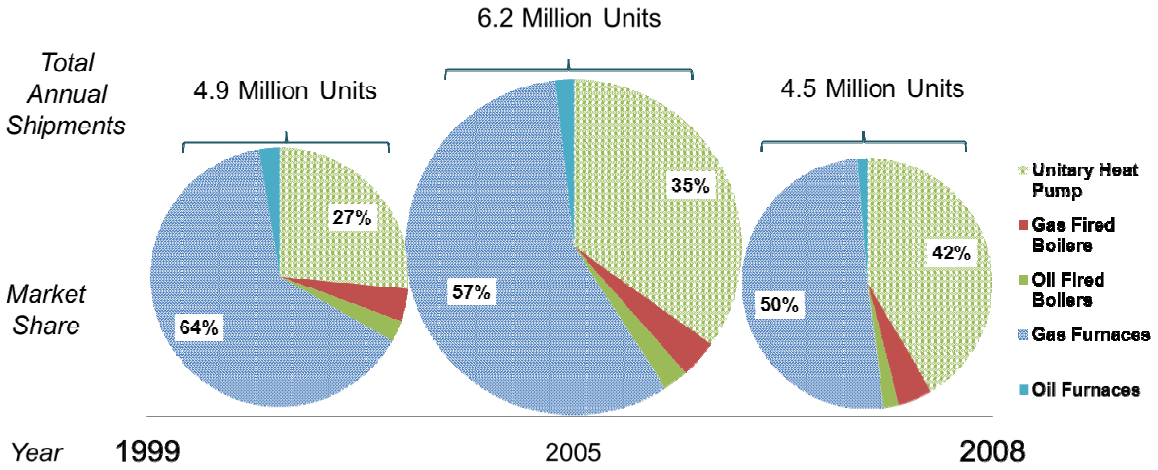

Figure 4: Evolution of the Residential Heating Equipment Market Annual Shipments (AHRI, 2009a)

In the last decade, the HP was favoured with positive external market conditions relative to other heating equipment. Natural gas and heating oil average retail prices experienced major surges and almost doubled within the last decade (EIA, 2011). The market share of oil furnaces and oil boilers in the U.S. dropped throughout the last two decades, their combined market share falling to almost 3% in 2008 versus 10% in 1988. The gas furnace market share also dropped from 64% in 1999 to 50% in 2008. These figures are relative to annual shipments.

Average retail electricity prices did not experience a major surge (EIA, 2011) in contrary to natural gas and heating oil prices, which positioned heat pumps in a favourable position. Scholars suggest that the retail electricity prices will ultimately parallel the natural gas prices due to the increased reliance on natural gas for electricity generation purposes. However, recent statistics on average retail prices pattern of electricity versus natural gas still shows relative stability and affordability for electricity prices versus natural gas and heating oil.

In addition, the HP is an excellent solution for regions with milder weather due to its ability to provide both heating and cooling. Finally as mentioned earlier the U.S. population shift to warmer climates where HP are more popular was another enabling factor for increasing HP popularity. These combinations of factors propelled an increase in the HP market share.

Figure 5 shows the impact of heating equipment annual shipments over the past decade on the total installed residential stock of heating equipment. The heating equipment annual shipments slowly affect the total residential equipment stock. The number of residences using HPs as the primary heating equipment increased from 10.9% in 1999 to 12.3% in 2009. If the HP would continue its precedent growth with a minimum of 3% annual shipment growth, its heating equipment share of the total housing stock could reach almost 13.6% by 2020 as will be discussed below in the “Business as Usual” scenario at the future outlook section.

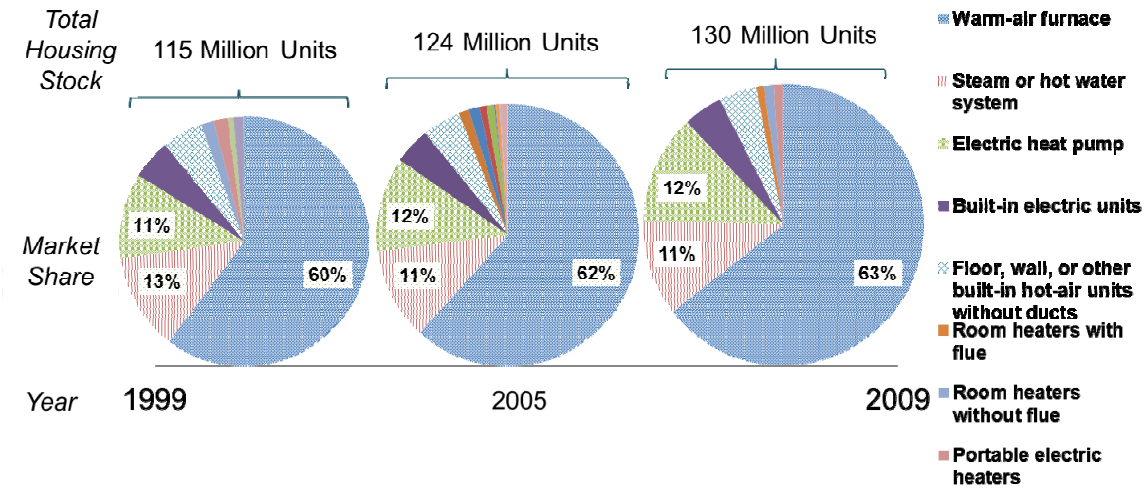

Figure 5: Evolution of Residential Primary Heating Equipment Stock (U.S. Census Bureau, 1997-2009)

3 THE CHARACTERISTICS OF THE HEATING AND COOLING MARKET IN THE U.S.

Theheating and cooling market in the U.S. was shaped by the efficiency improvements in heating and cooling equipment and the distribution of the heating and cooling equipment users. Since HPs, ACs, and gas furnaces constitute the majority of the heating and cooling equipment market, we will discuss the efficiency improvements of those three leading equipment types.

The SEER for unitary ACs and HPs has seen significant improvement in the last 2 decades as shown in Figure 6. The improvements were nurtured by technological advancements and driven by government efficiency regulations. A noticeable spike is obvious in 2006, reflecting the new government regulation for heating and cooling equipment to reach an averageshipment weighted SEER of ~13.2(3.86 cooling SPF) versus~11.5 (3.37 cooling SPF)in 2005.

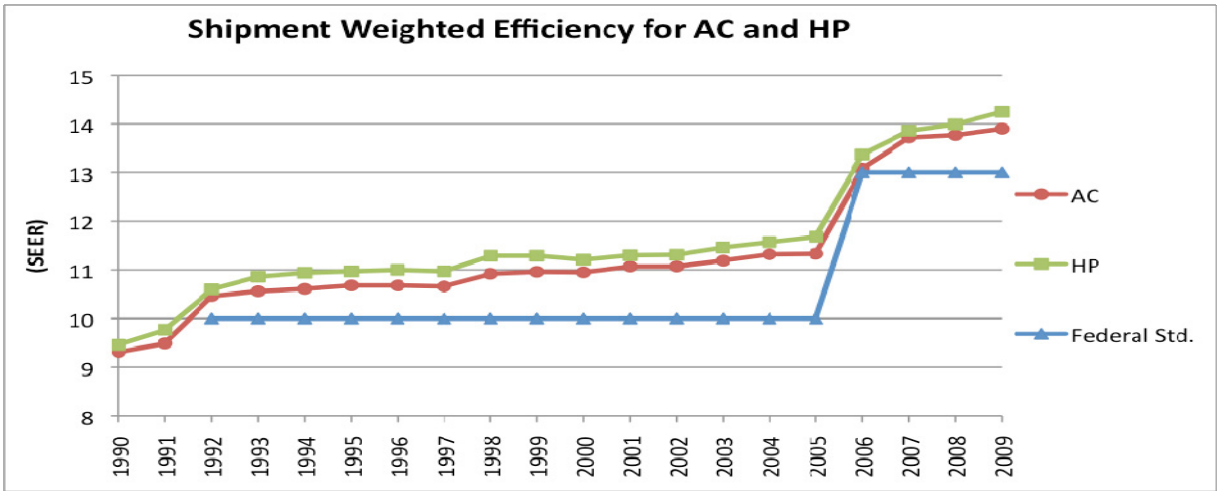

Figure 6: Shipment Weighted Efficiency for AC and HP (AHRI, 2009b)

Gas furnaces also experienced major efficiency improvements in the last decade. 2006 shows an increase in the efficiency of gas furnace shipments in comparison to shipments in 1985, reflecting the impact of federal minimum efficiency regulations on these products as well as heat pumps.In 1985, 58% of the shipments were below 71% Annual Fuel Utilization Efficiency (AFUE), while in 2006, 64% of were between 75% and 88% AFUE(Buildings Energy Data Book, 2008a). Also, looking at a longer timeframe, the best available gas furnace AFUE in 1981 was 85%; that progressed to a best available AFUE of 97% by 2007.

The distribution of heating and cooling equipment users has also evolved in the last decade. Figure 7 shows the percentage of heat pump sales to new homes (22% in 2009) versus replacement or add-on. In the mid-1980s, 50% of HP shipments were for new homes (Groff, 2008). Increased HP sales for replacement or add-on, as well as the aging of previously installed heat pumps, suggest that HPs are also growing in popularity for this market sector.

It is worth noting that from 1999-2007 the percentage of HP sales for new homes remained relatively constant at ~30-33%, with an exception in 2006. The year 2006 shows a spike where heat pump sales to new homes reached a high of 38% that also coincides with a spike in the new housing market sales. In 2008 and 2009 the share of sales to new homes decreased reflecting the drop in new home construction.

The project team calculated the percentages in Figure 7 based on data regarding completed single-family and multi-family homes using heat pumps(U.S. Census Bureau, 2009). Each of those houses uses at least one heat pump, and the project team assumed that large homes with floor areas of 3,000 ft^2 or more would be equipped with two heat pumps. Taking into account heat pumps sold to single-family and multi-family new homes, we could compute the total number of heat pumps to new homes. Knowing the total heat pump shipments we could generate the percentage of heat pump sales to new homes versus replacement or add-on as shown in Figure 7.

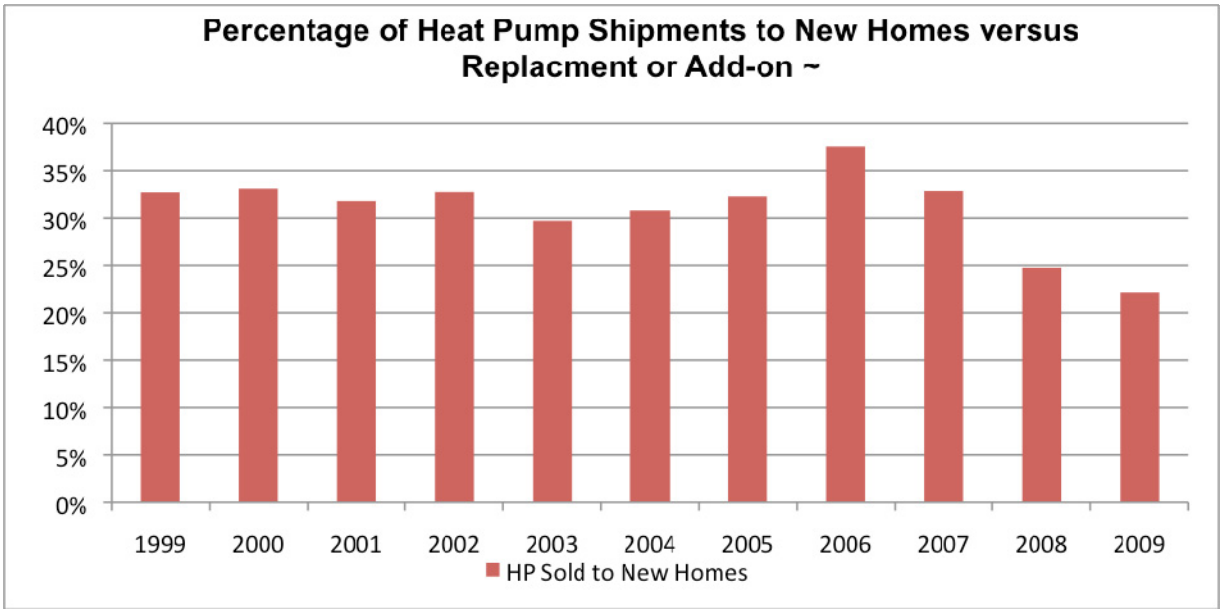

Figure 7: Percentage of Heat Pump Shipments to New Homes versus Replacement or Add-on

The distribution of heating and cooling equipment users is also affected by the percentage of equipment exported. The annual AC and HP unit exports are shown in Figure 8. The AC and HP market in the U.S. is mainly focused on the domestic market. At least 90% of total ACs and HPs produced between 1999 and 2005 were shipped domestically.

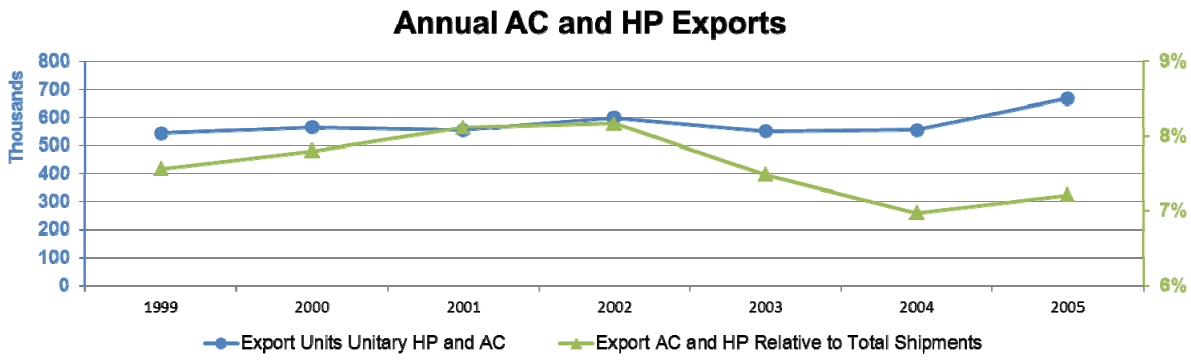

Figure 8: Annual AC and HP Exports(AHRI, 2009c)

Another important characteristic of the heating and cooling equipment market is the average unit size in the unitary AC and HP shipments. Figure 9 shows a breakdown of the annual unitary AC and HP shipments by size from 2006 through 2010. The market share of every size category went through only minor changes, within the timeframe analysed. The average equipment size for the timeframe analysed except for 2010 was consistent within the size category 11.4-12.9 kW(39-43.9 kBtu/h) as shown in the figure below. In 2006, the average equipment size was 12.25 kW(41.8 kBtu/h), and that increased to 13.3 kW(45.5kBtu/h) by 2010. There is a slow, upward trend in the average size of equipment which parallels the increasing size of new homes with the exception of 2009. The smallaverage unit size in 2009 coincides with the economic downturn when fewer larger homes were built.

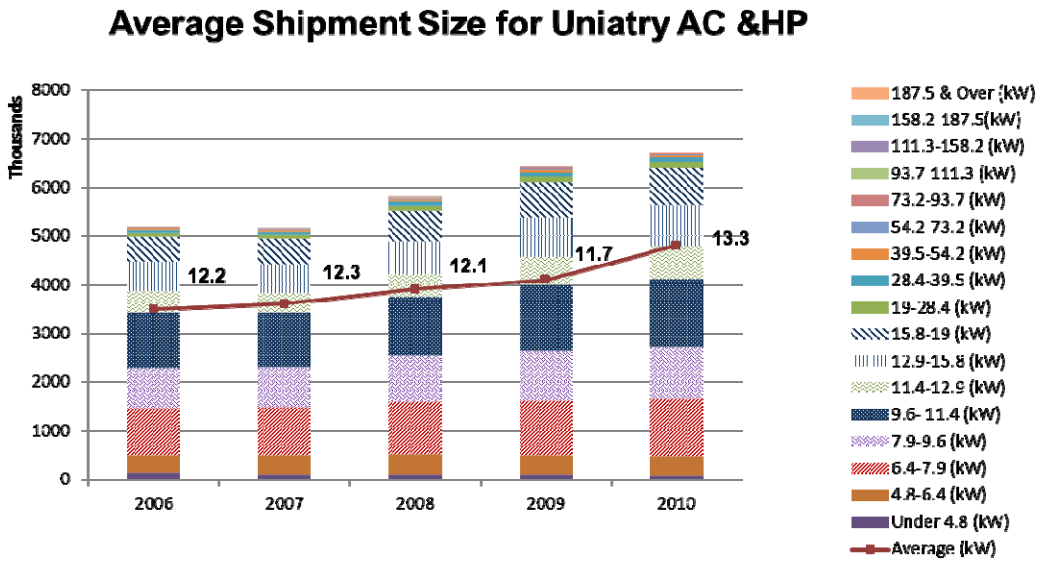

Figure 9: Breakdown for the Unitary Air Conditioners and Heat Pumps Shipments by Size (kW) (AHRI, 2009d)

4 FUTURE OUTLOOK

Heat pumps are recognized as energy-efficient heating equipment. As more homes begin using heat pumps as the main heating equipment, less energy should be consumed for residential heating on a national level. The energy used for residential heating is subject to other factors as well, such as the weather and the economic performance of the country.

Figure 10 is an attempt to correlate the relationship between the number of homes using heat pumps as the main heating equipment and the energy used for residential heating. The figure also includes the heating degree days as an indication of the weather and the residential heating carbon dioxide emissions. The number of homes using gas furnaces is also added to provide comparison for heat pumps.Finally, for the future outlook the project team included three potential scenarios for the total number of homes using HPs and the forecast for residential heating energy use according to the AEO 2010 (EIA, 2010). To simplify the graph, the project team used a common scale to display the development of the elements throughout the timeline analysed.

It is important to note that the change in the energy used for residential heating provides a parallel change in residential heating CO_2 emissions. Also, the change in energy used for residential heating is relatively consistent with the change in the heating degree days, but the degree of consistency varies throughout the timeline of the analysis (1997-2009). Finally, throughout the timeline analysed, the number of homes using gas furnaces has an almost constant, slow pattern of growth, and the gas furnace penetration declined due to the increase in average retail gas prices coupled with U.S. population shift to warmer climates. Accordingly, it's not likely to rationalize a drop in heating energy use due to gas furnaces.

Although the years 2000, 2003, 2008,and 2009 had almost the same number of heating degree days, the amount of energy used for heating purposes was very different. The jump in the energy consumed in 2003 relative to 2000 could partly be justified by the economic prosperity the U.S. was going through in 2003 relative to 2000. The energy consumed in 2008 and 2009 was very conservative in comparison to energy consumed in 2000. It's challenging to indicate with certainty the reason for such a drop in the use of heating energy. However, this period does coincide witha rise in the number of homes using a heat pump as the main heating equipment partly in response to U.S. population shift to warmer climates where HPs are more popular. It also coincides with an increase in the federal standard for heating equipment to 13 SEER (3.81 cooling SPF) instead of an earlier 10 SEER (2.93 cooling SPF), andsevere economic recession, and the fact that heat pumps retired during this period were being replaced by more efficient units. Finally, the last decade was also characterized with an improved home efficiency and insulation equipment.

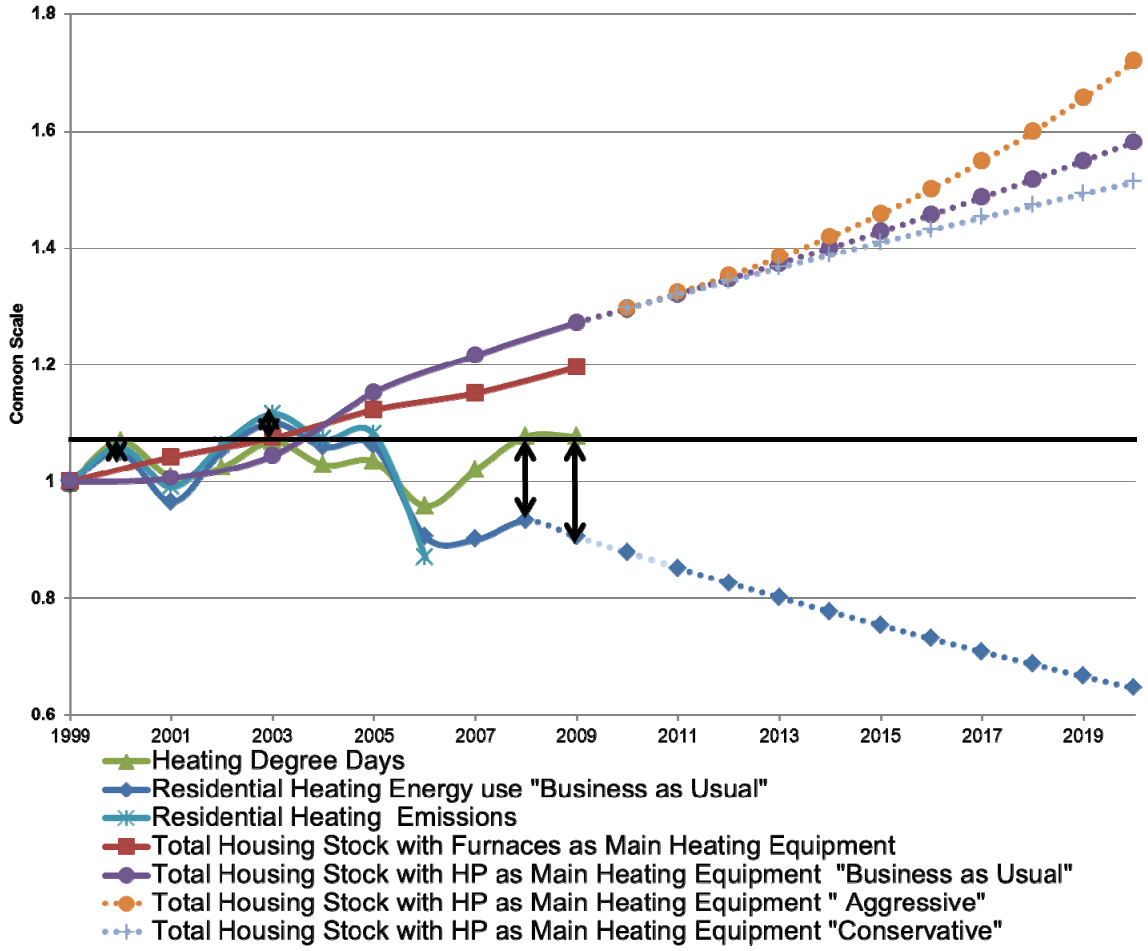

Figure 10:Correlating Houses using Heat Pump, Houses using Warm-Air Furnace, Heating Degree Days, Heating Residential Energy Used and Carbon Dioxide Emissions (Buildings Energy Data Book, 1998-2008, 2008b; U.S. Census Bureau, 1997-2009; EIA, 2009)

According to Figure 10, it is reasonable to assume that the high number of homes using a heat pump as the main heating equipment contributed to lowering the total residential energy used for heating purposes and carbon emissions. The increasing popularity and reliability of HPs suggests that HP shipments will continue to grow, especially with the expected upturn in the housing market and the population shift to warmer climates projected to continue through 2030.

In an attempt to draw on the future outlook of residential heating energy use and emissions, the project team investigated the potential future for HP shipments.
The project team assumed three potential scenarios for HP shipment growth relative to 2009 and through 2020; 1) the “Aggressive” scenario with HP shipment annual growth that reaches 10%, 2) the “Business as Usual” scenario with HP shipment annual growth that reached 3%, and 3) the “Conservative” scenario with HP shipment annual decline that reaches -2%. Each of those scenarios will impact the total residential heating equipment stock differently and consecutively impact the residential heating energy used and emissions. The project team assumed that the housing market will gradually rebound to reach 1.8 million units by 2015 and 2

million units by 2020 (EIA, 2010). The project team also assumed that only around 20% of HP annual shipments will be translated into new homes using HPs as the main heating equipment. The 20% ratio was close to that experienced in 2009, and although low, it does account for large homes and spaces that use more than one HP, HPs that are only used as secondary heating equipment, and HPs used to replace old HPs.

The “Aggressive” scenario would result in having HPs contribute to almost 15% of total housing stock by 2020, and, accordingly, the total number of homes using HPs could grow by almost 70% in comparison to 1999. The “Aggressive” scenario could have the strongest impact on lowering the residential energy used and emissions in contrast to the “Conservative” scenario where the total number of homes using HPs will only grow by 50% by 2020.

The “Business as Usual” scenario suggests that the total number of homes using HPs could grow by almost 60% by 2020 relative to 1999. This scenario will have the HP shipment grow by 3% annually which is the average growth for HP shipments in the last decade. It’s reasonable to assume that the “Business as Usual” scenario is likely. The potential future energy use for residential heating is also available(EIA, 2010) which assumes an annual decline of 3% for total emissions starting in 2009. The project team assumed that the “Business as Usual” scenario could probably lead to the Energy Information Administration’s (EIA’s) forecast for residential heating energy use.

The efficiency and insulation equipment of the housing stock is expected to continue improving. A group of organizations including the U.S.Department of Energy (DOE) are in the process of developing an update to the International Energy Conservation Code (IECC) 2012, which is expected to lead to 30% more energy efficient residences than IECC 2006 (NASEO, 2010). In addition, more government regulations are expected in the future to increase the required minimum SEER level which would lead to more efficient heating and cooling equipment.

The AEO (EIA 2010) forecastsalmost 40% reduction in residential heating energy use by 2020, which would be echoed strongly in carbon emissions reduction. Increasing the number of homes using HPs, more efficient homes, significant population shift to warmer climate, stricter equipment efficiency regulation, and higher efficiency heating and cooling equipment will contribute to lower residential energy used and lower CO_2 emissions in the future that could reach and potentially exceed the EIA’s forecast.

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