Preliminary Market Assessment for

Cold Climate Heat Pumps

By

Gannate Khowailed, Karen Sikes, and Omar Abdelaziz.

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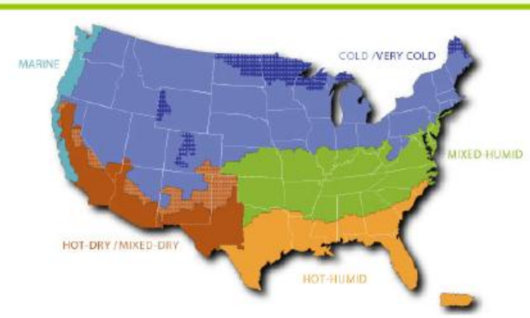

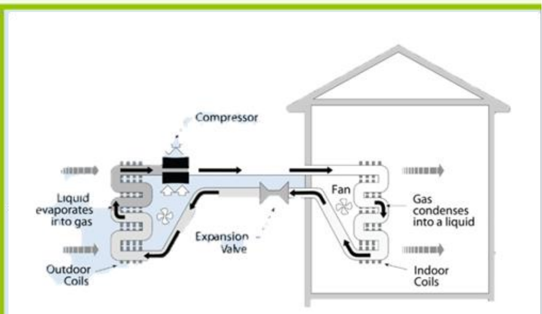

ORNL Building Equipment Research Group

Preliminary Market Assessment for Cold Climate Heat Pumps

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Abbreviations

AFUE	annual fuel utilization efficiency
AHRI	Air Conditioning, Heating, and Refrigeration Institute
BA	Building America
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
HDD	heating degree day
HE	heating equipment
HP	heat pump
HSPF	heating seasonal performance factor
HVAC	heating, ventilation, and air-conditioning
MSRP	manufacturer’s suggested retail price
RECS	*Residential Energy Consumption Survey*

Executive Summary

Cold climate heat pump (HP) technology is relevant to a substantial portion of the U.S. population, especially with more than one-third of U.S. housing stock concentrated in colder regions of the country and another 31% in the mixed-humid climate region. Specifically, it is estimated that in 2010 almost 1.37 million heating equipment units were shipped to the cold/very cold climate regions and that 1.41 million were shipped to the nation's mixed-humid region.

On a national level, the trend in the last decade has indicated that shipments of gas furnaces have grown at a slower rate than HPs.[1] This indicates a potential opportunity for the cold climate HP, a technology that may be initially slow to penetrate its potential market because of the less expensive operating and first costs of gas furnaces. Anticipated implementation of regional standards could also negatively affect gas furnace shipments, especially with the higher initial cost for more efficient gas furnaces. However, as of 2011, the fact that there are more than 500 gas furnace product models that already achieve the expected efficiency standard indicates that satisfying the regional standard will be a challenge but not an obstacle.

A look at the heating fuel and equipment currently being used in the housing stock provides an insight into the competing equipment that cold climate HPs hope to replace. The primary target market for the cold climate HP is the 2.6 million U.S. homes using electric furnaces and HPs in the cold/very cold region. It is estimated that 4.75% of these homeowners either replace or buy new heating equipment in a given year. Accordingly, the project team could infer that the cold climate HP primary market is composed of 123,500 replacements of electric furnaces and conventional air-to-air HPs annually. A secondary housing market for the cold climate HP comprises homes in the mixed-humid region of the country that are using electric furnaces. Homes using gas furnaces across both the cold/very cold and mixed-humid regions represent another secondary market for the cold climate HP. The cold climate HP could also target as a secondary market homes across both the cold/very cold and mixed-humid regions that use propane and fuel oil as their primary heating fuel. The combined total of homes in these three secondary markets is 46 million, and we can also infer that about 2.2 million of these systems are replaced annually.

When comparing heating equipment stock in 2001, 2005, and 2009 in the cold/very cold region of the country, it appears that gas furnaces are slowly losing market share and that electric furnaces and HPs are making gains. The fact that electricity-dependent heating equipment is rising in preference among homeowners in the colder regions of the country shows that future penetration of the cold climate HP holds promise. Accordingly, cold climate HP technology could achieve an attractive position, given certain favorable market conditions such as reaching a competitive cost point, strong federal incentives, a consistent level of reliable performance, and a product rollout by a credible market leader.

[1] Air Conditioning, Heating, and Refrigeration Institute. (n.d.). Historical Data. Retrieved August 11, 2011, from Air Conditioning, Heating, and Refrigeration Institute (AHRI): http://www.ahrinet.org/historical+data.aspx.

The project team relied on payback analysis to estimate the potential market penetration for the cold climate HP in each of its primary and secondary markets. In this analysis, we assumed a $250 price premium for the cold climate HP over the baseline HP. Electricity and gas prices and emissions were based on the 2010 *Buildings Energy Data Book*.[2] The average heating load was calculated as 25.2 MMBTU per year in the cold/very cold and mixed-humid regions of the United States. Typical installed costs were obtained from the technical document supporting the U.S. Department of Energy rulemaking. The analysis showed that the cold climate HP will have a 2.2 year payback period when replacing an existing electric HP in the colder regions of the nation. The cold climate HP will have a 6 year payback period when replacing gas furnaces in the same climate regions. Accordingly, we estimated that the cold climate HP will have a penetration ratio ranging between 5% and 35% in its potential primary and secondary markets, resulting in a total annual estimated shipment of 298,000 units to both targeted regions of the nation. Once the cold climate HP technology meets its potential market penetration, it would contribute to annual site energy savings of 3,664,405 MMBTU and a CO_2 emission reduction of 470,000 Ton.

[2] Buildings Energy Data Book - Heating, Cooling and Ventilation Equipment. (n.d.). Retrieved August 11, 2011, from U.S. Department of Energy - Energy Efficiency and Renewable Energy: http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.3.2.

I. Introduction

The majority of residential dwellings in the colder climate region of the country rely on gas furnaces as their main heating equipment (HE). The market foresees regional standards that will cause an increase in the minimum efficiency for gas furnaces to an annual fuel utilization efficiency (AFUE) rating of 90% in the cold/very cold (northern) part of the country [1]. This is expected to transform the cold/very cold region's HE market. Gas furnaces with an AFUE higher than 90% are likely to have a much higher initial cost than conventional gas furnaces. Hence, this will provide a window of opportunity for market entry for other energy-efficient HE that has higher first cost as well. The cold climate heat pump (HP) is a candidate to compete with gas furnaces in some major U.S. markets. While the cold climate HP technology is still at its research and development phase, it does promise substantial technological improvement. The purpose of this report is to provide a preliminary assessment for the market entry opportunity for the cold climate HP technology and to assess the potential geographical market, the competition, and the current residential HE stock. The foreseen regional standard on HE and its potential impact will also be summarized. Finally, the report will estimate the potential market penetration, energy savings, and carbon emission reduction for the cold climate HP technology.

II. Geographical Market

The cold climate HP generates the most energy savings and efficiency improvements when used in colder regions of the country. The U.S. Department of Energy (DOE) Building America (BA) program's classification for climate regions is very popular and was used by the U.S. Energy Information Administration (EIA) in its most recent *Residential Energy Consumption Survey* (RECS) [2]. BA has defined the cold region in the country as that having approximately 5,400 heating-degree days (HDDs) or more (65°F basis) but less than about 9,000 HDDs (65°F basis). The very cold region has been defined as having about 9,000 HDDs or more (65°F basis) but fewer than approximately 12,600 HDDs (65°F basis) [3]. According to BA, the cold/very cold regions comprise entirely or partially the following 35 states: Alaska, Arizona, California, Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Dakota, Utah, Vermont, Washington, West Virginia, Wisconsin, and Wyoming. A graphical representation of the cold/very cold regions is shown in Figure 1. In this report, the project team focuses on the cold/very cold climate as the primary geographical market for the cold climate HP.

More than one-third (34.14%) of the U.S. housing stock resides in the cold climate region, which includes almost 39 million homes. However, only 30% of new housing projects during the 2008–2009 time frame were built in the cold climate region, which accounts for approximately 3.2 million homes in the cold/very cold climate regions [4]. This is consistent with the commonly discussed population shift away from the cold/very cold regions of the country toward warmer climates.

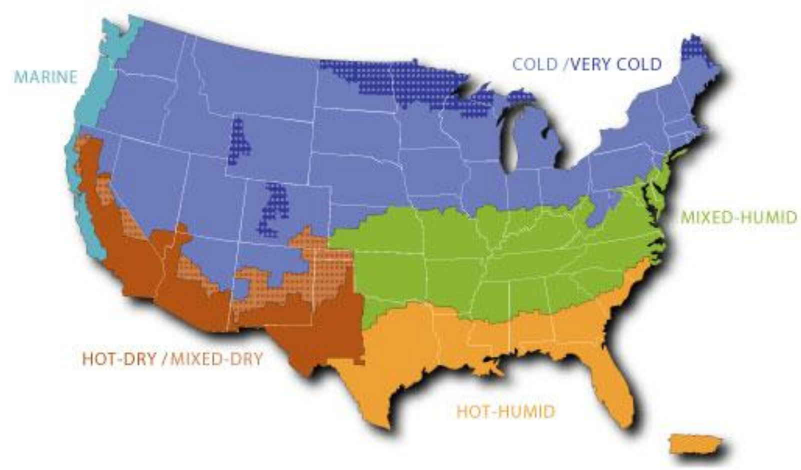

Figure 1. Building America Climate Regions Adopted in RECS2009 (U.S. Energy Information Administration) [4]

The mixed-humid climate area of the country represents a potential secondary market for the cold climate HP. According to BA, the mixed-humid climate is defined as a region that receives more than 20 inches (50 centimeters) of annual precipitation, has approximately 5,400 HDDs or fewer (65°F basis), and experiences an average monthly outdoor temperature drop below 45°F (7°C) during the winter months [3]. The mixed-humid region is highlighted in green in Figure 1. As of 2009, 31% of the U.S. housing stock was located in the mixed-humid climate [4].

III. Competition

Historical Heating Equipment Shipments by Climate Region

HE shipment data on a national level are provided by various organizations. However, the publicly available data are not broken down by climate region. The project team estimated the distribution of HE shipment by climate region in order to provide a clearer idea of the total market share for which the cold climate HP could compete. Total HE shipments for 2006 through 2010 are shown in Figure 2 [5]. The bar graph includes shipments for HPs, gas and oil boilers, and gas and oil furnaces. The most recent boiler shipment data were provided by the Air Conditioning, Heating, and Refrigeration Institute (AHRI)[5] in 2008. Since total boilers sales in 2008 represent only 3% of total shipments sales, the project team assumed that boiler sales would stay constant through 2010.

The most recent RECS [2] provided information on the age of the main HE—categorized by age brackets of less than 2 years, 2 to 4 years, 5 to 9 years, and so forth—by climate region. The 2009 survey indicated that 10.6 million U.S. homes installed HE within the 2008–2009 time frame. The cold/very cold and mixed-humid climates account for 30% and 31%, respectively, of total HE units installed between 2008 and 2009 [2].

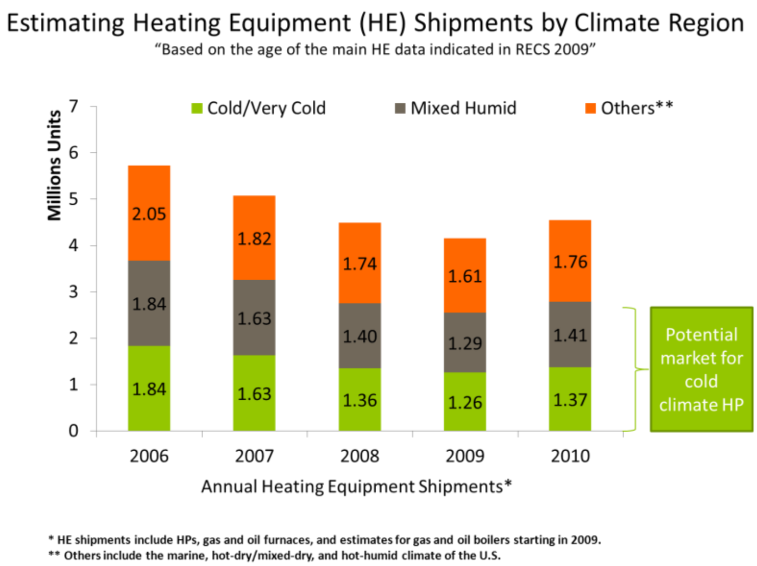

Figure 2. Estimated Heating Equipment Shipments by Climate Region

The project team infers that since 30% of HE installed within the 2008–2009 time frame was installed in the cold/very cold climate, then 30% of HE shipments in 2008 and 2009, on average, were destined for the cold/very cold region. The same assumption will apply to the mixed-humid region and throughout the analysis of 2006 through 2009. Also, the project team assumes that the 2009 ratio will stay almost constant for 2010. Estimates for the total HE shipments by climate region in Figure 2 were based on the previously explained methodology.

Heating Equipment Shipments in 2008 (Focus on Leading Heating Equipment)

Annual HE shipments continuously shape the installed HE stock. Figure 3 sheds light on the overall HE market in 2008, which, at that time, was predominately led by the gas furnaces with 51% of the market share, or 2.3 million units, followed by HPs with 42% of the market, or 1.9 million units [5]. A closer look at the historical shipments for gas furnaces and HPs in the last decade is also shown in Figure 3. Both HP and gas furnace shipments dropped from 2006 to 2009 in correspondence with the economic downturn, yet it is noticeable that HP shipments appear to be recovering faster than gas furnace shipments. Also, the surge in HP shipments in 2005 could partly be justified by the new efficiency regulation of HPs that took effect in January 2006. Many manufacturers shipped all their inventory of equipment that would not meet the 2006 standard in 2005.

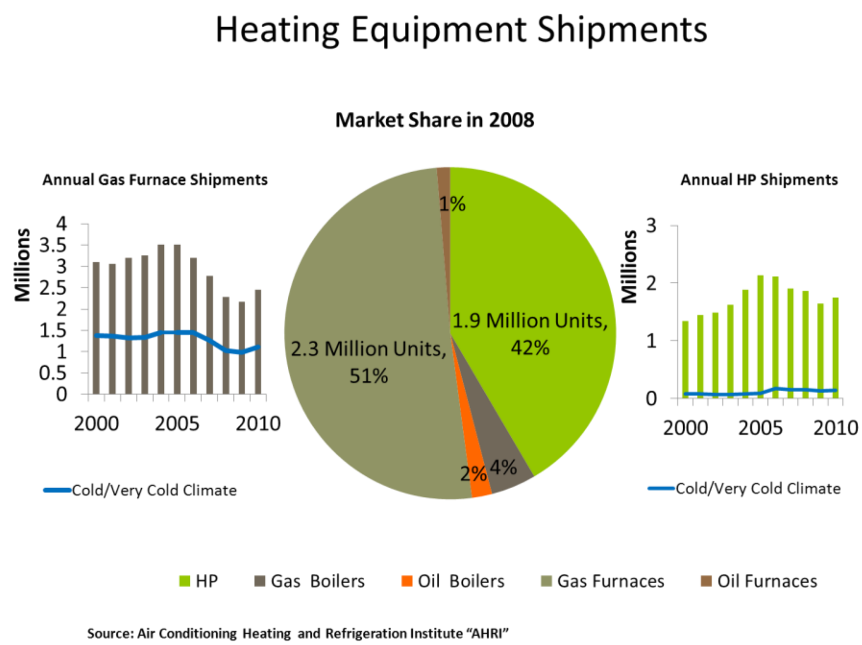

Figure 3. Heating Equipment Shipments

It was also interesting to note the proportion of shipments that is estimated to be directed toward the cold/very cold climate region of the country, which is also shown in Figure 3. RECS 2009 indicates that 44.3 million homes use gas furnaces as of 2009, and 45% of those homes are located in the cold/very cold region of the country [2]. Hence, the project team assumed that on average 45% of the gas furnace shipment between 2006 and 2010 was directed toward the cold/very cold climate regions of the United States. Data provided by RECS [6] was also used to estimate the gas furnace shipments to the cold/very cold climate regions between 2002 and 2005. The 2000 and 2001 estimates were based on the 2001 RECS [7]. Estimates for HPs followed the same assumption based on data from RECS 2009, 2005, and 2001 [2, 6, 7].

Evolution of the Main Heating Equipment Used in the Cold/Very Cold Climate Region

Figure 4 presents a contrast between the main HE used in the housing stock of the cold/very cold region as of 2001, 2005, and 2009. This figure also reflects some of the previously discussed trends in HE shipments. Although gas furnaces are still the leading HE used, they appear to be slowly losing market share in colder regions.

The gas furnace market share dropped from 52.9% in 2001 to 49.7% in 2005, followed by a slight rebound to 51.9% in 2009. This rebound may be due in part to the economic recession that hit the United States. Hence, consumers were buying the HE with the lowest first cost, and that tends to be conventional gas furnaces. The electric furnace has interestingly showed consistent growth with its share rising from 2.9% in 2001 to 4.3% in 2005, and to 4.7% in 2009. The electric HP has also shown a minor overall growth from 2001 to 2009 with its share rising from 1.6% to 2.1%.

The loss of market share of gas furnaces to other HE such as the electric furnace in the cold/very cold climate region suggests that the potential market entry for the cold climate HP could be very promising.

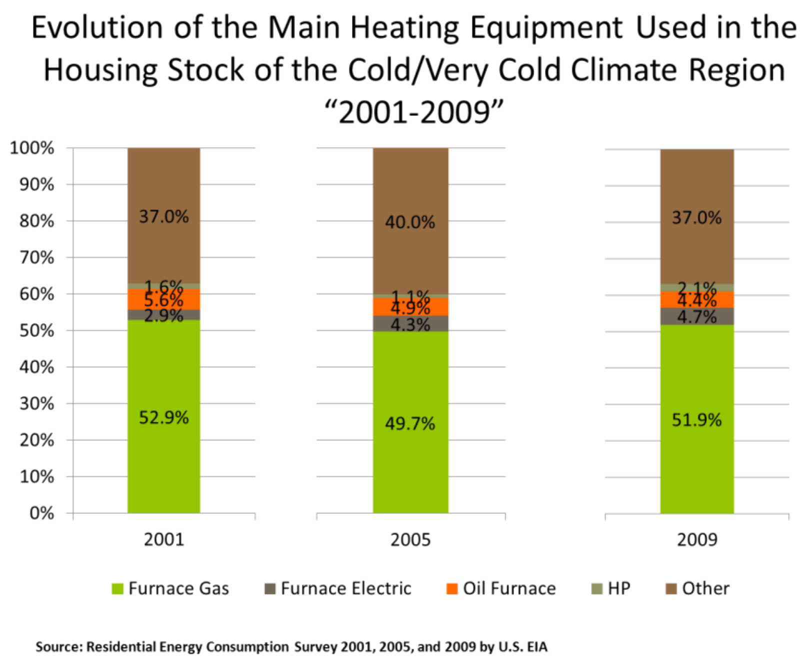

Figure 4. Evolution of the Main Heating Equipment Used in the Cold/Very Cold Climate Region

It is important to note a minor caveat in this analysis. In RECS 2009 [2], the cold/very cold climate region was defined as areas with HDDs of more than 5,400. However, in RECS 2001 and 2005 [7, 6], the closest benchmark for the cold/very cold climate is defined with more than 5,500 HDDs. In comparing the 2001, 2005, and 2009 data, note that 2009 does consider an additional portion of the country with climate regions between 5,400 and 5,500 HDDs. The warmer region tends to use more HPs and fewer gas furnaces than colder regions. The fact that the 2009 survey included an additional warmer portion of the country could have contributed slightly to the previously discussed trend of growing HPs in the market and the loss of share for gas furnaces; however, it does not completely justify it. In particular, the trend of gas furnaces losing market share and electric furnaces gaining market share was obvious in 2005 and consistent through 2009.

Potential Impact of Pending Regional Standards on Heating Equipment

Nearly half of the gas furnaces shipped annually are sent to the cold/very cold climate region, the primary geographical market for the cold climate HP technology. Since gas furnaces are the most prevalent in the colder regions, it is important to shed light on upcoming regional standards for gas furnaces and other HE, which is expected to have a substantial impact. Current federal efficiency regulations that became effective in 1992 require gas furnaces to have a minimum AFUE of 78%. However, as of 2006, more than 35% of gas furnace shipments in 2006 had an AFUE greater than or equal to 88% [8].

The new suggested regional standard recommends dividing the country into three regions based on their HDDs as shown in Figure 5. The northern region of the country, which represents the potential primary market for the cold climate HP, reports greater than or equal to 5,000 HDDs. This closely corresponds with the cold/very cold climate region, which has more than 5,400 HDDs, according to BA. The regional standard would require the northern portion of the country to have a minimum of a 90% AFUE for gas furnaces, an 8.2 heating seasonal performance factor (HSPF) for split HPs, an 8.0 HSPF for packaged HPs, and an 83% AFUE for oil furnaces [9]. It would also require at least an 80% AFUE for gas furnaces in the South and the southeast regions. The regional standard is currently undergoing DOE's comment period, which will end October 17, 2011, for the direct final rule. If the regional standard is passed into law, it would take effect for gas furnaces on May 1, 2013 [10].

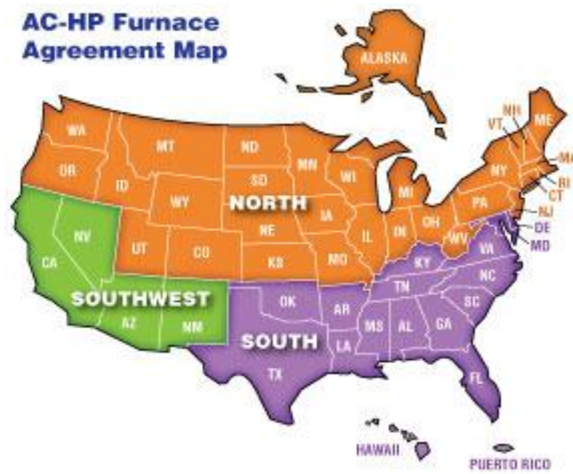

Figure 5. Regional Standard AC-HP Furnace Map [9]

Since gas furnaces are somewhat unusual in that the technology does not easily permit incremental change to the AFUE above 80%, achieving a 90% AFUE or higher requires the use of costly updates such as condensing technology, which yields a large efficiency gain but at a higher cost [11]. However, the HE industry is reasonably prepared for the regional standard. As of August 2011, more than 500 gas furnace product models are ENERGY STAR® certified, a designation that requires an AFUE higher than 90%. Many of the ENERGY STAR® gas furnaces have been introduced by the major manufacturers such as York, Trane, Rheem, NORDYNE, and Lennox as well as other smaller players [12]. If the standard became effective, these ENERGY STAR® gas furnaces would even comply with the efficiency standards for the northern United States.

The tax incentives in 2009 and 2010 for gas furnaces also had a major role in encouraging energy-efficient gas furnaces into the market. The federal incentives entailed a tax credit of 30% of the cost (including installation/labor costs) up to $1500 for any gas furnace that meets or exceeds an AFUE value of 90% in 2009 and 2010 [13].

IV. Potential Market for the Cold Climate HP

Heating Fuel and Equipment Used in the Housing Stock of the Cold/Very Cold and the Mixed-Humid Regions of the United States (2009)

This section discusses HE and fuel used by the current U.S. housing stock as of 2009 [2] in both potential geographical markets for the cold climate HP. Figure 6 illustrates that 25 million homes in the cold/very cold region (64% of homes in this region) use natural gas as their main heating fuel, and 14% of homes in the same region use electricity as their primary heating source. Since the cold climate HP will be using electricity to generate heat, it was important to shed light on other competing HE currently installed in homes that also use electricity. Figure 6 shows a breakdown of all electric-powered HE.

The electric central warm-air furnace is used as the main HE by 4.7% of U.S. homes in the cold/very cold climate whereas the electric HP is used by 2.1% of homes in this region. Most are conventional air-to-air HPs; some no doubt are innovative systems such as geothermal HPs, but their total number is a minor portion of the total stock. Cold climate HP units are expected to be more energy efficient and very competitive against other HE using electricity in the cold/very cold region. The cold climate HP technology will target the areas of the country where electric furnaces and conventional HPs are most prevalent. Accordingly, the project team concludes that the cold climate HP can easily target 6.8% (2.1% + 4.7%) of homes in the cold/very cold climate region, which translates to 2.6 million homes. "Built-in electric" refers to heating systems composed of individual-resistance electric heating units permanently installed in the floors, walls, ceilings, or baseboards and is part of the electrical installation of the building. (Electric space-heating devices that are plugged into an electric socket or outlet are not considered built-in.) Although built-in electric units represent 6.2% of homes in this region, the cold climate HP technology is not in a position to compete with them; these homes generally do not possess central air distribution networks.

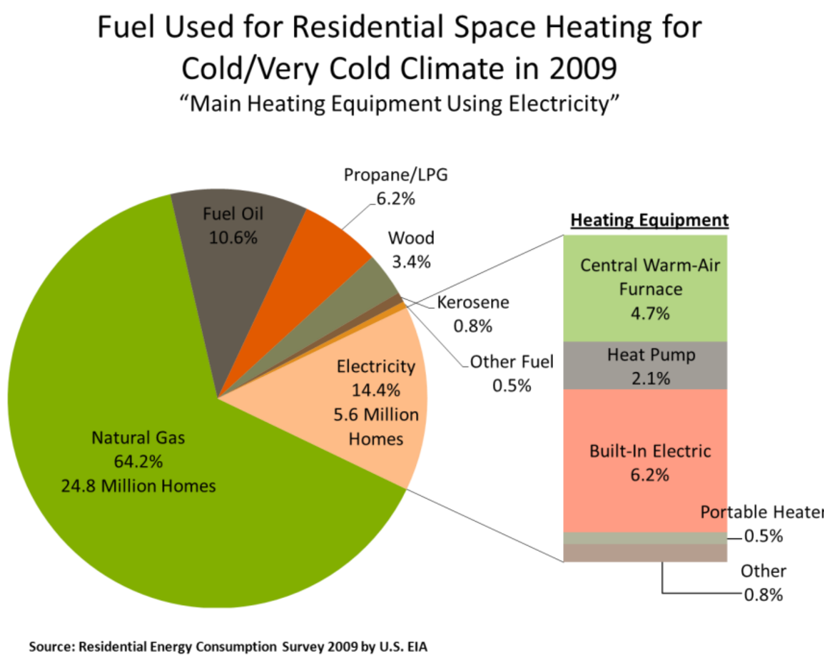

**Figure 6. Fuel Used for Residential Space Heating for Cold/Very Cold Climate in 2009—
Main Heating Equipment Using Electricity**

As noted earlier, the primary geographical market for the cold climate HP is the cold/very cold region of the country. However, the mixed-humid climate region represents an opportunity as a secondary geographical market for the cold climate HP. Figure 7 presents an overview of the fuel and the HE used in the mixed-humid climate. In this climate, residents rely more on electricity and less on natural gas for their heating purposes relative to the cold/very cold climate. Nearly 14 million homes (37%) in this region use electricity for their main heating purposes. As for the HE using electricity, central warm air furnace and HP options lead with respective shares of 18% and 13% of homes. The cold climate HP technology is expected to be more energy efficient and cost effective than the electric furnace. Due to the relatively smaller number of HDDs, conventional HPs are relatively efficient; hence the project team assumes lower market penetration in the HP replacements in this category. The 11.2 million U.S. homes or the 31% of homes in the mixed-humid climate that are using electric furnaces and HPs would be considered as a viable secondary market for the cold climate HP.

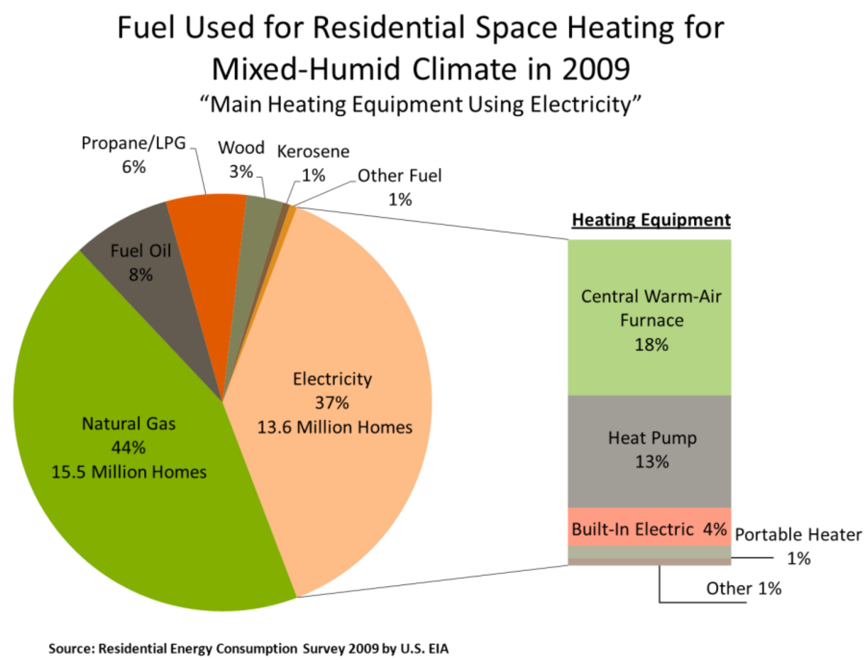

Figure 7. Fuel Used for Residential Space Heating for Mixed-Humid Climate in 2009—Main Heating Equipment Using Electricity

Figure 8 and Figure 9 show HE using natural gas, a primary competing heating fuel for electricity, in cold/very cold and mixed-humid climate regions, respectively. The gas furnace is the most common HE in the cold/very cold climate with 51.8% of homes (20.1 million) in the cold/very cold region using a gas furnace. The gas furnace is less prevalent in the mixed-humid climate region, with only 34% (11.9 million) of homes using them as their main HE option.

The impending regional efficiency standard discussed earlier will place the gas furnace technology at a competitive disadvantage due to the higher first cost needed to achieve the AFUE levels required. Combined with the recent slow decline in market share for gas HE, this indicates that there is a potential opportunity for a slow market share gain for the cold climate HP in the homes currently using gas furnaces. Accordingly, we can suggest that the homes using gas furnaces in both cold/very cold and mixed-humid climate regions represent another secondary market for the cold climate HP. This secondary market across both regions represents 32 million U.S. homes.

Yet another potential secondary market for the cold climate HP includes the homes that use propane or fuel oil as their main heating fuel in both the cold/very cold and the mixed-humid regions. This represents another 11.4 million homes across both regions that manufacturers of the cold climate HP technology could target.

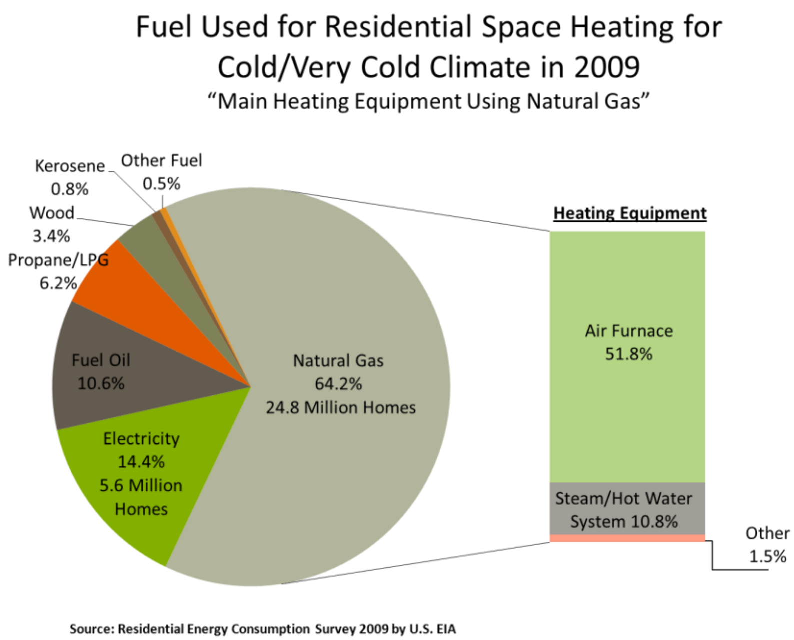

Figure 8. Fuel Used for Residential Space Heating for Cold/Very Cold Region in 2009—Main Heating Equipment Using Natural Gas

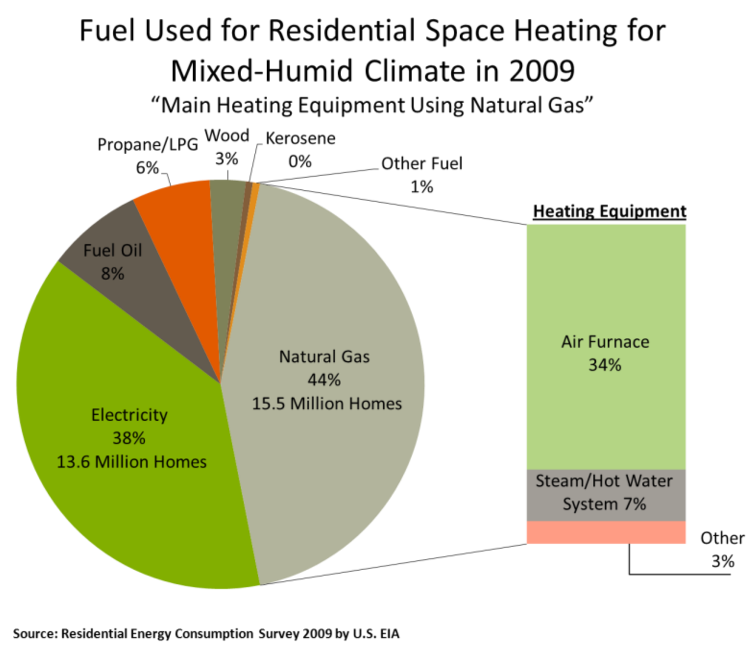

Figure 9. Fuel Used for Residential Space Heating for Mixed-Humid Climate in 2009—Main Heating Equipment Using Natural Gas

Estimates for the Cold Climate HP Primary and Secondary Target Market Size

The primary target market for cold climate HP technology is composed of U.S. homes using electric furnaces or HPs in the cold/very cold climate region, which accounts for 2.6 million homes. The cold climate HP represents a substantial economic and efficiency benefit in comparison to the conventional air-source HP and electric furnace in this colder region of the country.

RECS 2009 [2] provides data on the age of the main HE. With this information, the project team inferred an estimate of the replacement ratio of HE. According to the 2009 survey, 10.6 million homes were using HE installed within the 2008–2009 time frame [2]. These homes also represent a ratio of 9.6% of all U.S. homes using HE. Hence, the project team could determine that, as of 2009, 9.6% of the 10.6 million homes either replaced or bought new HE within the 2008 and 2009 time frame. Therefore, the biannual replacement ratio would be 9.6%.

According to RECS 2005 [6], the biannual replacement ratio was 10.7% of all homes that have and use HE. RECS 2001 [7] indicates a biannual replacement ratio of 8.2%. The replacement ratio was substantially lower in 2001 and 2009 in comparison to 2005, which can partly be accounted for by the economic downturn that the nation was facing. During 2009, strong federal incentives resulted in a higher replacement ratio than shown in 2001.

To estimate the replacement ratio, the project team averaged the biannual replacement ratio from RECS 2001, 2005, and 2009 [7, 6, 2], and then estimated a biannual replacement ratio of 9.5% for all housing units that have HE. On average, an estimated annual replacement ratio of 4.75% was calculated for all U.S. homes that have or use HE.

The primary target market for the cold climate HP accounts for about 2.6 million homes. Using the replacement ratio of 4.75% yields a potential for 123,500 unit shipments to replace existing electric HE in the cold region.

The secondary target market within the country for cold climate HP technology includes the following:

- Homes using electric furnaces or HPs in the mixed-humid region, representing 11 2 million homes. Following the same methodology for calculating the replacement ratio, the project team can conclude that there is an estimated annual shipment of 532,000 units of HE to this secondary market.
- Homes using gas furnaces as their main HE in the cold/very cold and the mixed-humid regions, both of which account for 32 million homes. Assuming the same replacement ratio of 4.75%, it is reasonable to assume an annual shipment of 1.52 million HE units to this secondary market.
- Homes using propane or fuel oil as their main heating fuel in both the cold/very cold and the mixed-humid regions account for another 11.4 million homes. Assuming the same replacement ratio, the project team can assume an annual shipment of 541,500 units of HE for this secondary market.

Figure 10 presents a summary of the primary and secondary potential target markets for the cold climate HP technology. It also shows the number of homes as of 2009 located in the cold climate HP target market; "Electric Furnace" refers to the cold climate HP secondary market of homes using electric furnaces in the mixed-humid regions, and "Gas Furnaces" refers to the secondary market of homes using gas furnaces in both the cold/very cold and the mixed-humid regions. "Propane and Fuel Oil" refers to the cold climate HP secondary market of homes using propane or fuel oil as their main heating fuels in both the cold/very cold and the mixed-humid regions of the United States

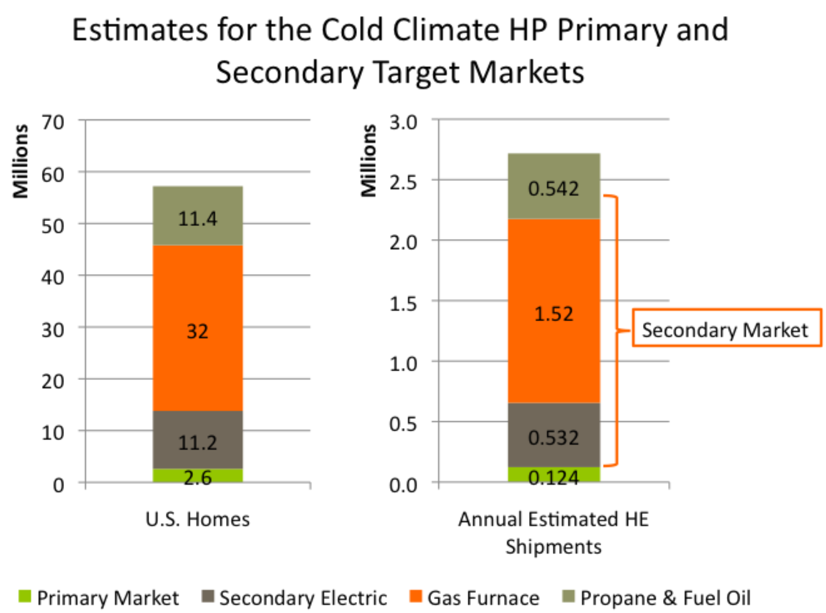

Figure 10. Estimates for the Cold Climate HP Primary and Secondary Target Markets

Estimates for Potential Cold Climate HP Market Penetration, Energy Savings, and Emission Reduction

The previous section estimated the annual HE shipments for the total market that could be targeted by the cold climate HP. This section will take the analysis one step further and estimate the potential market penetration for the cold climate HP technology at each of the markets mentioned earlier. Accordingly, total energy and emissions savings due to the cold climate HP adoption could also be estimated.

Table 1 summarizes the process followed to estimate the Cold Climate HP market penetration. Columns A through D summarize the findings from earlier sections. Column E presents the estimated payback period of the cold climate HP technology relative to leading HE (gas furnace and electric HP). The project team relied on the following data and assumptions for their payback calculations:

- For gas furnaces, a base model of a 90% AFUE condensing design (assuming the regional standard will go into effect in 2013) with a 100 kBtu/h burner was selected. We assumed a manufacturer's suggested retail price (MSRP) for the base unit of $916, an annual energy use for heating of 28 MMBTU [14], and a gas price of $13.10 per MMBTU [8]. This yields a total annual energy cost for heating of $367 for the base unit for a conventional home in the colder region of the country.

- For the electric HP base alternative, a split HP with a seasonal energy efficiency ratio of 13 and an HSPF of 8 was selected. The base model has an MSRP including transportation of $1,481.60, an annual energy use for heating of 3154 kWh [14], and an electricity price of $0.1096 per kWh [8]. These assumptions lead to an annual energy heating cost of $345.60 for a conventional home in the colder region of the United States.
- The project team estimated that the MSRP of the cold climate HP would incur an additional $250 premium relative to the base electric HP, yielding a potential MSRP for the cold climate HP of $1731.60. The main price premium over current HP technology is due to the added cost of a vapor-injected compressor and the additional economizer. This price premium assumes ultimate technology adoption leading to mass production. The cold climate HP is expected to produce 35% energy savings relative to the base electric HP; thus the estimated annual energy cost is $230.40 for heating a conventional home in colder regions of the United States.
- Accordingly, the payback period of the cold climate HP relative to the base gas furnace and the base electric HP following the simple payback equation would be 6 and 2 years, respectively, as shown in column E in Table 1.

Table 1. Breakdown of the Cold Climate HP Estimated Market Penetration

A) Market	B) Region	C) Competing Technology	D) Annual Replacement Market (Units)	E) Payback (years)	F) Market Penetration (%)	G) Market Penetration (Units)
Primary	Cold/very cold	Electric furnace	85,500	2.8	25%	21,375
Primary	Cold/very cold	Electric HP	38,000	2.2	35%	13,300
Secondary	Mixed-humid	Electric furnace	308,750	2.8	25%	77,188
Secondary	Mixed-humid	Electric HP	223,250	2.2	15%	33,488
Secondary	Cold/very cold	Gas furnace	954,750	6	5%	47,738
Secondary	Mixed-humid	Gas furnace	565,250	6	5%	28,263
Secondary	Cold/very cold	Propane	114,000	-	10%	11,400
Secondary	Cold/very cold	Fuel oil	194,750	-	10%	19,475
Secondary	Mixed-humid	Propane	104,500	-	10%	10,450
Secondary	Mixed-humid	Fuel oil	128,250	-	10%	12,825
Total						275,500

The project team decided to estimate the market penetration for the cold climate HP based on payback analysis as suggested by the DOE Office of Energy Efficiency and Renewable Energy in their 2005 publication entitled *Guide for Evaluation of Energy Savings Potential* [15]. The project team realizes that this methodology for estimating market penetration has its limitations; however, it is sufficiently accurate for the purpose of this preliminary study. Figure 11 shows the suggested correlation between a technology's payback period and its estimated market penetration. The tentative market penetration for the cold climate HP relative to the leading HE (gas furnace and electric HP) presented in column (F) of Table 1 is estimated based on the correlation suggested in Figure 11. Other market penetration ratios were estimated based on the project team's understanding of market behavior. Column (G) presents estimated market shipment size of cold climate HPs for each of its potential secondary and primary markets. In total, the project team calculated an estimated annual shipment size of 221,500 units of cold climate HPs to its potential market.

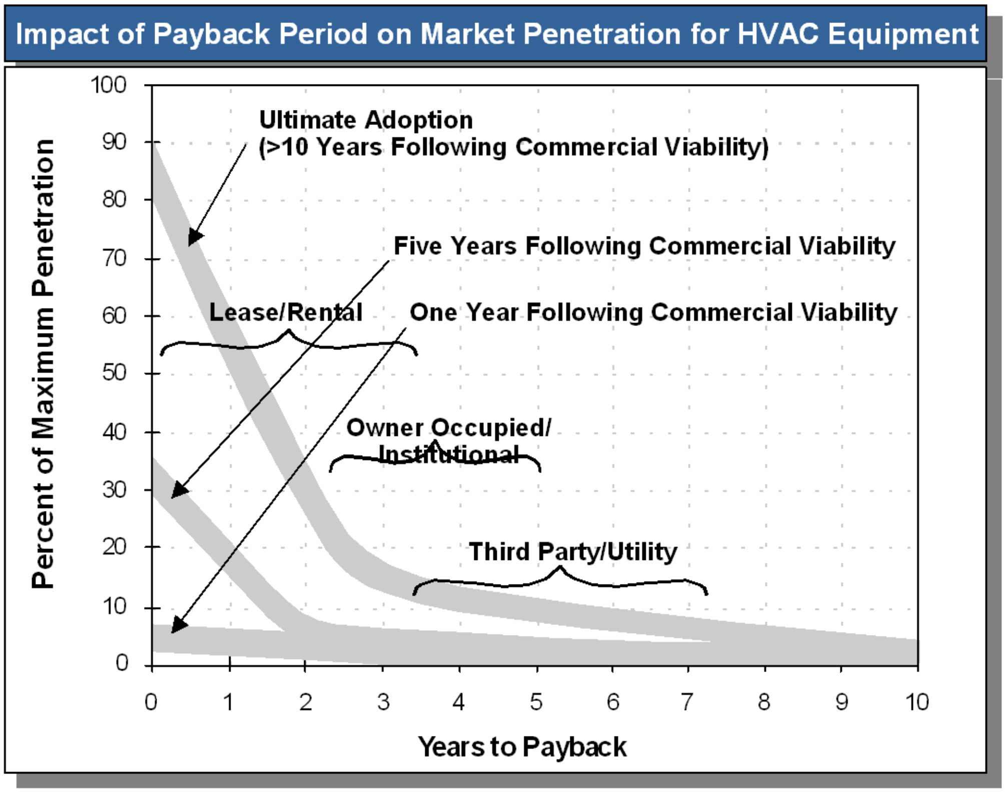

Figure 11. Impact of Payback Period on Market Penetration for HVAC Equipment [15]

Table 2 shows total site energy savings and emission reductions that could be realized from the cold climate HP technology achieving its estimated market penetration. Annual CO_2 emission reduction calculations are based on a carbon emission factor of 185.07 kg/MMBTU for electricity and 53.06 kg/MMBTU for gas, which are calculated from data in the *Buildings Energy Data Book* (2010) [8] by dividing the space heating emissions (Table 1.4.2) by the corresponding total space heating loads (Table 1.1.4).

Table 2. Estimated Cold Climate HP Market Penetration, Site Annual Energy Savings, and Carbon Emissions Reduction

A) Market	B) Region	C) Competing Technology	D) Market Penetration (Units)	E) Energy Savings (MMBTU)	F) Carbon Emission Reductions (Kg)
Primary	Cold/very cold	Electric furnace	21,375	414,416	76,696,143
Primary	Cold/very cold	Electric HP	13,300	47,714	8,830,530
Secondary	Mixed-humid	Electric furnace	77,188	1,496,502	276,958,294
Secondary	Mixed-humid	Electric HP	33,488	120,138	22,234,014
Secondary	Cold/very cold	Gas furnace	47,738	995,976	52,851,001
Secondary	Mixed-humid	Gas furnace	28,263	589,658	31,289,896
Secondary	Cold/very cold	Propane	11,400	-	-
Secondary	Cold/very cold	Fuel oil	19,475	-	-
Secondary	Mixed-humid	Propane	10,450	-	-
Secondary	Mixed-humid	Fuel oil	12,825	-	-

As shown in Table 2, an annual shipment of 275,500 cold climate HP units to supplant electric furnaces, electric HPs, and gas furnaces could yield substantial energy savings and carbon emission reductions—an estimated annual national site energy savings of 3,664,405 MMBTU or 0.0037 quads of site energy. An estimated annual CO_2 emission reduction of 470,000 Ton is also anticipated with the technology realizing its anticipated market penetration. This analysis did not account for replacing propane and fuel oil because data for the comparison were not readily available.

V. Conclusion

With the cold climate HP showing technological promise, the likelihood of gradual market penetration across the cold/very cold and the mixed-humid regions of the United States has been shown. The fact that throughout the last decade gas furnaces have slowly started losing market share to other electric-powered HE is promising for the cold climate HP technology. Also, the foreseen tightening of regional standards for gas furnaces enhances the cold climate HP's chances of gaining market share. A preliminary payback calculation suggests that the cold climate HP technology should have a payback period of 2 and 6 years relative to the electric HP and gas furnaces, respectively. This suggests slow but favorable market penetration. The project team estimated the potential market penetration for the cold climate HP technology based on the payback analysis framework highlighted in the report. Accordingly, the cold climate HP technology is estimated to have an annual shipment of 275,500 units to supplant electric furnaces, electric HPs, and gas furnaces. Assuming that the cold climate HP technology fulfills this estimated market penetration, an estimated national site energy savings of 3,664,405 MMBTU or 0.0037 quads and a carbon emission reduction of 470,000 Ton are expected to be realized.

Figure 12 summarizes the estimated shipment size, energy savings, and carbon emission reduction per geographical market for the cold climate HP technology.

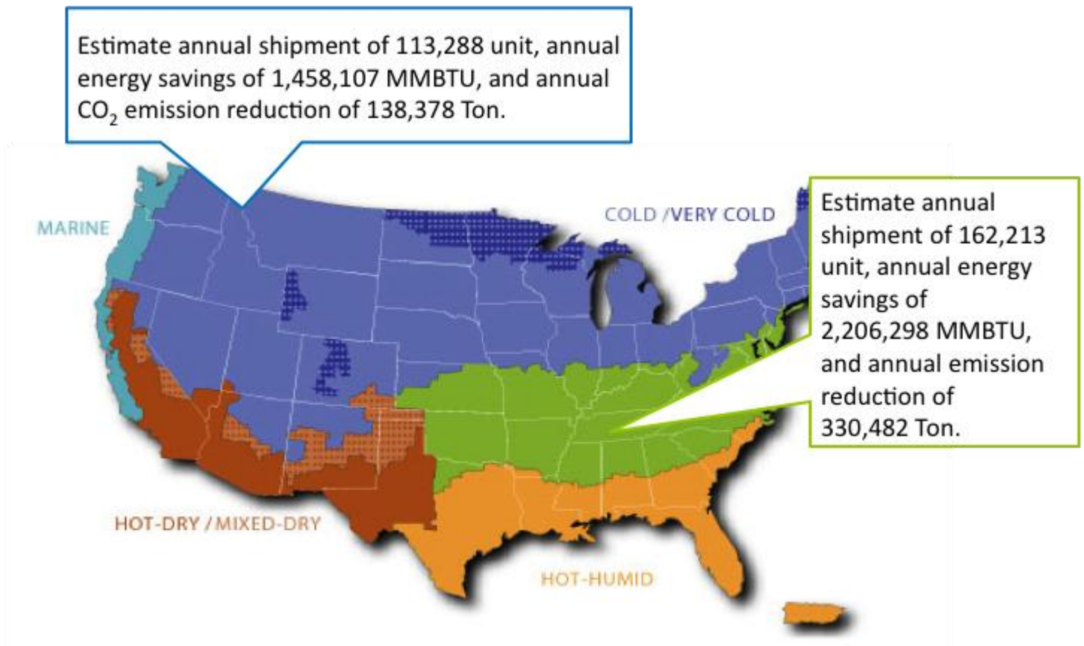

Figure 12. Estimates for the Cold Climate HP Shipment, Energy Savings, and Emission Reduction

VI. References

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