

# HEAT PUMPS IN NORTH AMERICA 2011

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**Abstract:** This report provides a snapshot of the North American heat pump and air conditioning market in the context of a severely depressed U.S. housing and economic period, following a period of robust growth during the last decade. Nevertheless heat pumps show continuing growth as an efficient electric heating alternative to fossil fuel heating systems. Instabilities and higher prices for fossil fuels add impetus to this interest in heat pump systems. Statistical data are presented to illustrate the growing number of heat pump systems in the U.S. and Canada. A positive prognosis is offered for further penetration of heat pump systems for both residential and commercial building heating and cooling in North America, providing motivation for continued efforts to improve products and applications

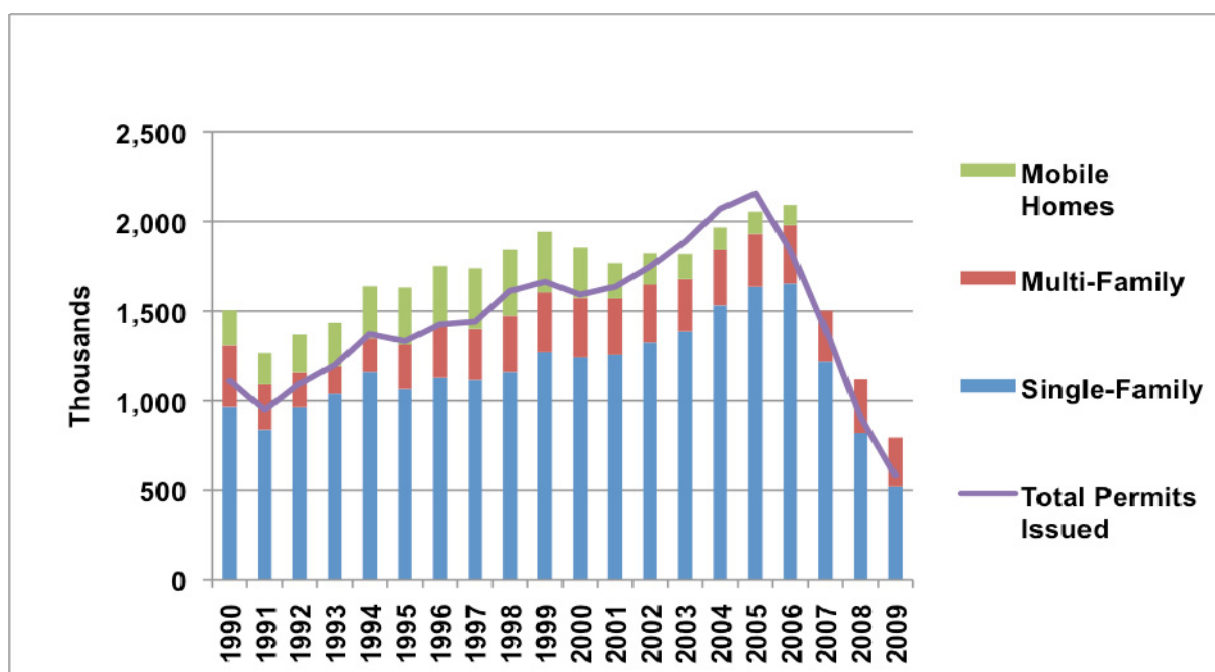
**Key Words:** heat pumps, building heating systems, energy efficiency

## 1 INTRODUCTION

The U.S. is slowly recovering from the worst housing market decline since 1989, which began in 2006 as a result of the sub-prime mortgage and banking crisis that triggered a major economic recession. As shown in Figure 1 (National Association of Home Builders 2011) the rate of new housing starts (seasonally-adjusted) dropped from 1.75 million in 2006 to below 500,000 in 2009. Although there was some improvement in 2010 new home sales have continued to languish despite low interest rates and government incentives for first-time homebuyers.



**Figure 1 U.S. New Home Starts - Seasonally Adjusted**



**Figure 2 U.S. Home Completions 1990 = 2009**

In Figure 2 (Lapsa and Khowalied 2011) the actual single- and multi-family home completions are shown, along with new mobile home completions. Housing permit activity is superimposed on this chart.

The Canadian housing market did not experience the dramatic changes seen in the U.S., likely due to the fact that Canadian banks refrained from wide-spread issue of sub-prime mortgages and credit to homebuyers who were unable to pay their mortgages once banks raised interest rates to normal levels.

The rapid changes in the U.S. housing market have resulted in some notable market changes for heating and cooling system sales. These changes are discussed in ensuing portions of this report.

## 2 BACKGROUND

The U.S. air conditioning and heat pump situation has been well documented in earlier presentations and this report will focus primarily on the changes that have occurred since 2008 when a similar report was presented at the 9<sup>th</sup> International Energy Agency Heat Pump Conference in Zurich, Switzerland (Groff, 2008). Heat pumps have been accepted as a viable option to fossil fuel furnaces and boilers or direct electric heating since the 1980s. Heat pump systems have been popular in the U.S. in the southern and southwestern parts of the country where the space-conditioning need is primarily for cooling but some heating is required. They have been less popular in parts of the country where heating is the primary need, except in special situations where electricity rates are low or natural gas and fuel oil are not readily available and electric heat or propane are the main alternatives. Heat pump installations in colder parts of the U.S. have shown quite successful performance and reliability results when careful attention has been paid to the sizing of the units and to installation. With greater new home construction rates in the south and southwest over the past twenty years heat pump annual sales grew to more than 2 million units. And with the

installed heat pump stock accumulated over the past 30 years, a significant portion of these sales has been for add-on and replacement. Replacement sales have been stimulated by the higher efficiencies of current air conditioners and heat pumps.

### 3 RESIDENTIAL HEAT PUMP SALES

#### 3.1 UNITARY HEAT PUMP AND AIR CONDITIONER SHIPMENTS

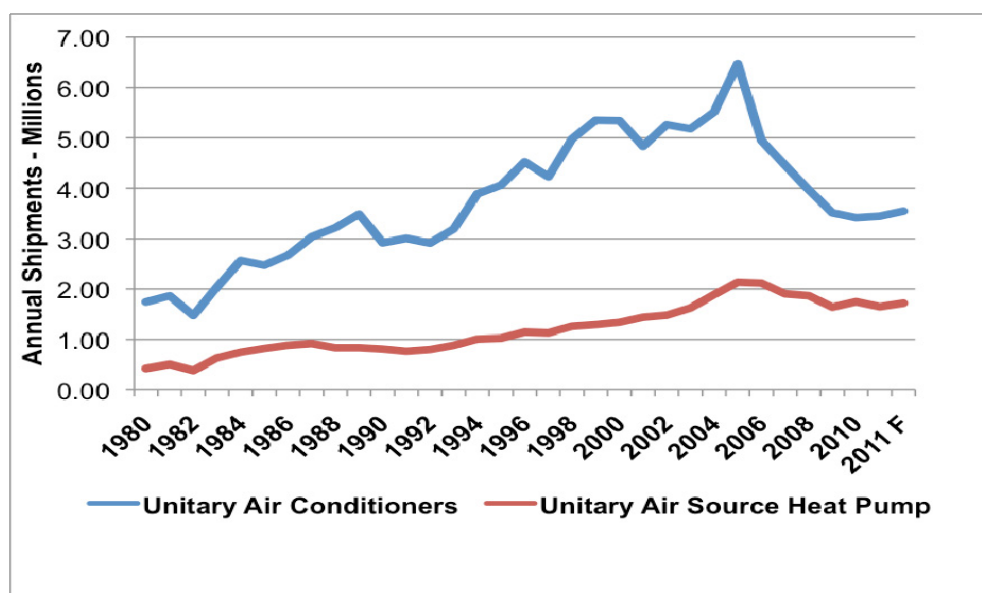
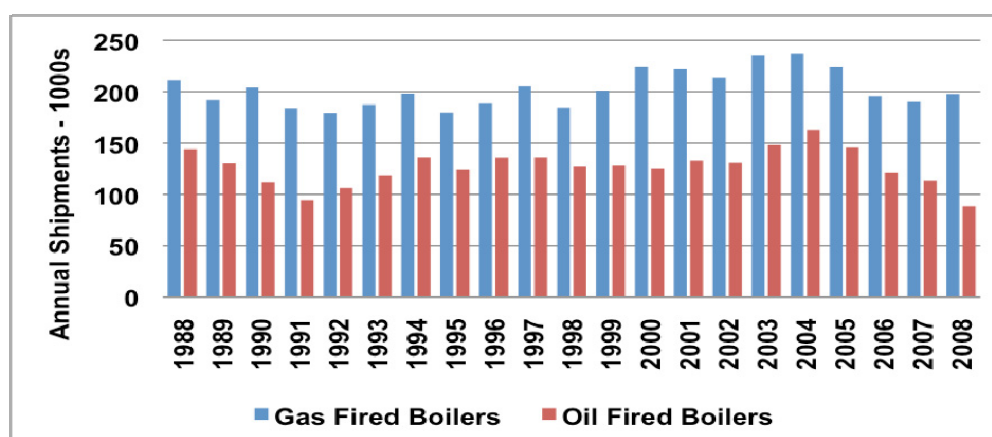


Figure 3 U.S. Annual Shipments of Heat Pumps and Air Conditioners

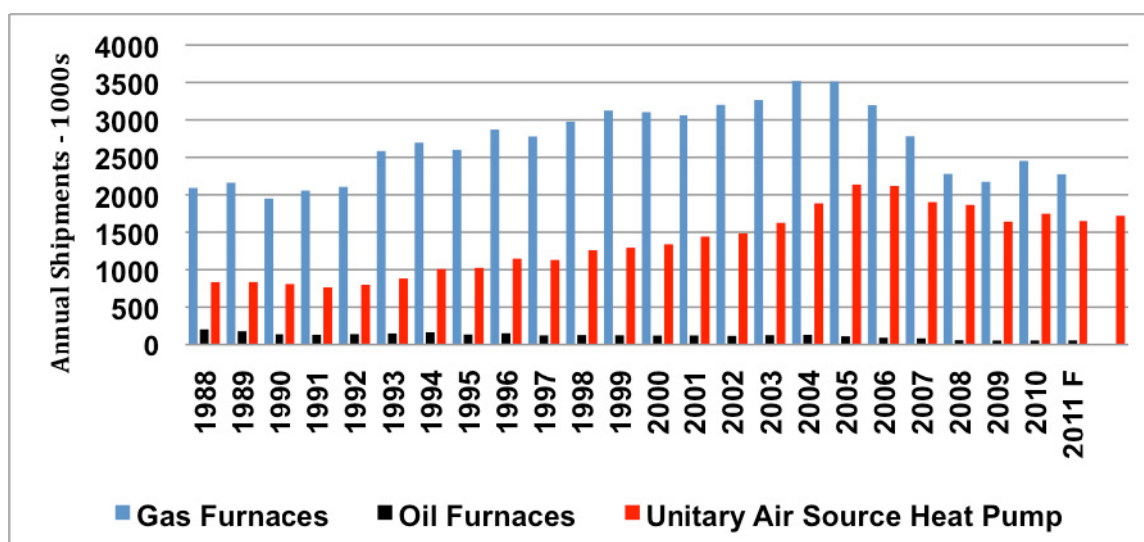
Figure 3 presents the unitary air conditioner and heat pump shipment statistics since 1980 (AHRI - Air Conditioning, Heating and Refrigeration Institute 2011). The drop in shipments starting in 2006 follows the housing market decline. To some extent this impact has been moderated by increased add-on and replacement sales, which have grown to be nearly 80% of annual shipments of heat pumps. Homeowners trying to sell their homes and those adding-on to existing homes, rather than moving to new homes, have given impetus to this sales growth. As can be seen in this graph, heat pump sales were not as adversely affected by the housing market decline, as were residential air conditioners. Annual heat pump sales are roughly one-third of the cooling-only unit sales.

#### 3.2 RESIDENTIAL FOSSIL FUEL FURNACE AND BOILER SHIPMENTS



**Figure 4 U.S. Annual Shipments of Residential Boilers**

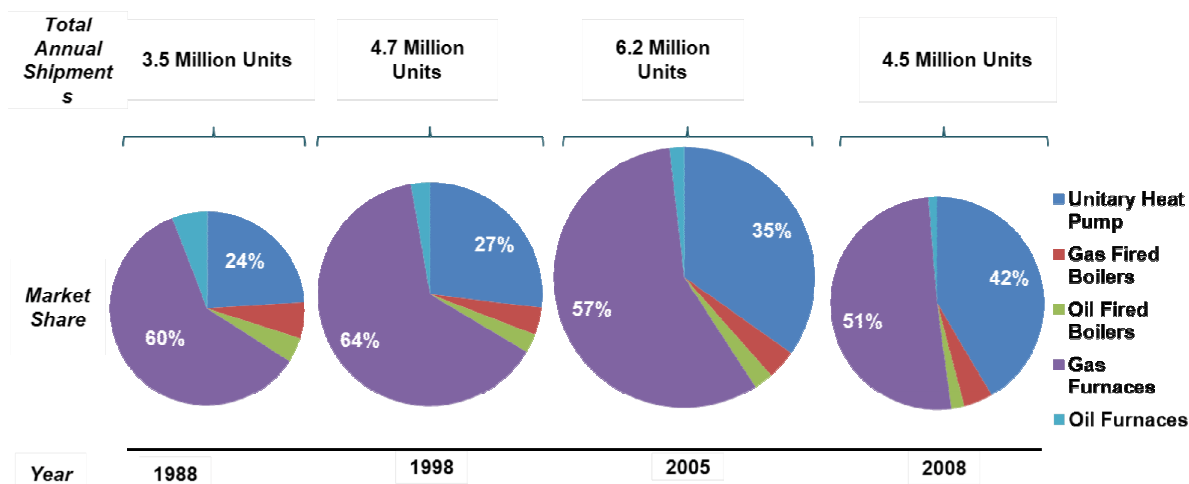
It is of interest to examine the sales of competing residential heating products during this period of reduced market activity. In Figures 4 and 5 the annual shipments of natural gas and oil boilers and warm air furnaces are presented, respectively, based on AHRI statistics. As shown in Figure 4 total shipments of residential boilers are less than 300,000 units annually, with oil boiler shipments having dropped to below 100,000 annually.



**Figure 5 Annual Shipments of Residential Gas and Oil Furnaces**

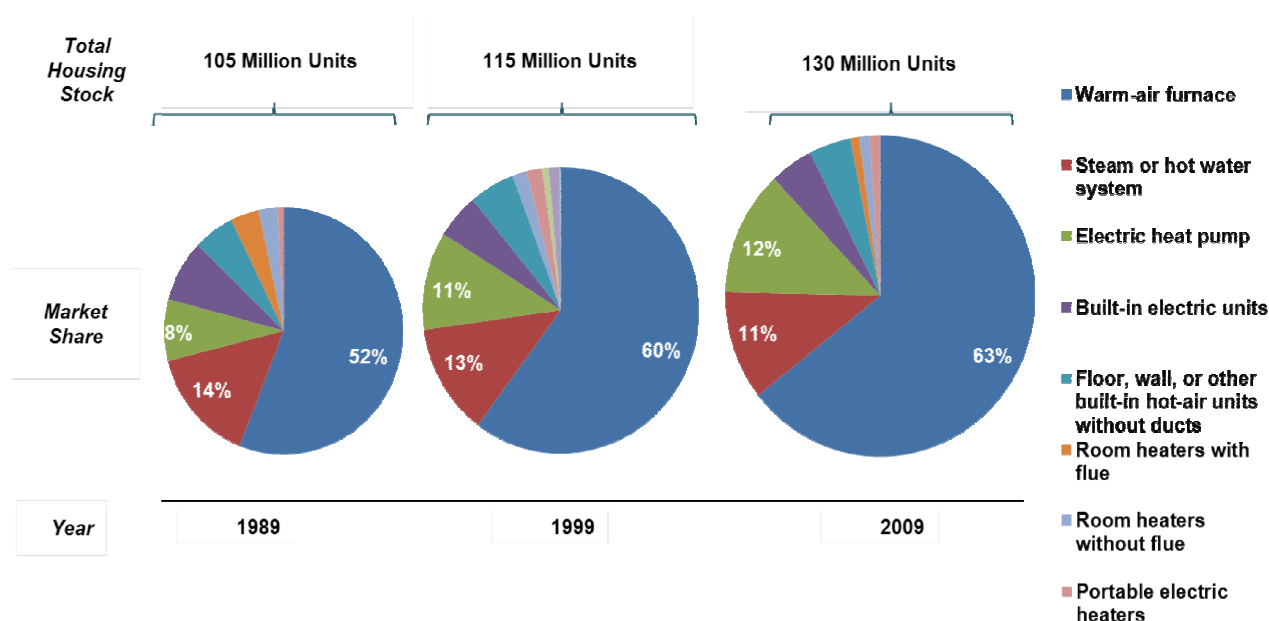
The graph of gas-fired warm air furnace shipments in Figure 5 shows clearly the effect of the housing market decline with a drop in annual shipments from 3.5 million units in 2005 to slightly over 2 million in 2009. There has been a slight increase in 2010 and 2011 but this increase is most likely due to sales for replacement of older units, perhaps to enhance sale of homes in the depressed market. Heat pump shipments are included in this chart to illustrate the increase in sales for these units in comparison to furnaces. Sales of heat pumps now are nearly equal to those of gas furnaces.

### 3.3 RESIDENTIAL HEATING SYSTEM SALES



**Figure 6 The Changing Heat Pump Share in Shipments of Heating Equipment in the U.S.**

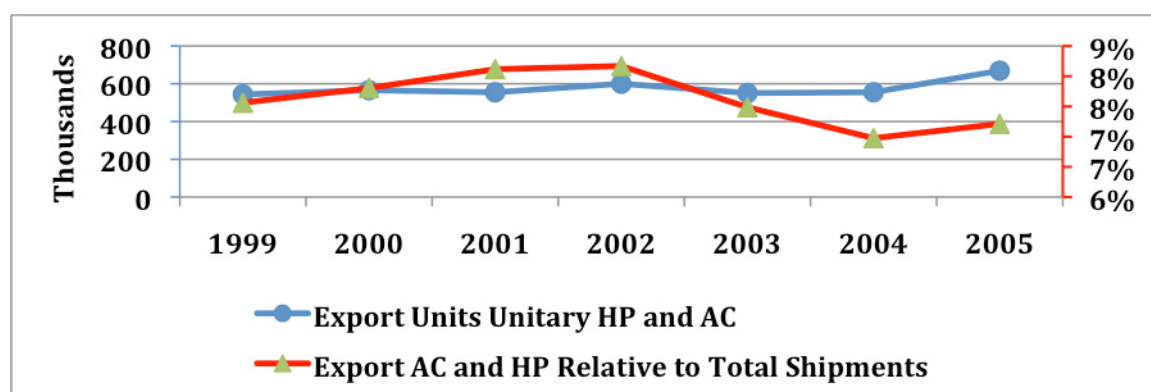
Figure 6 (Lapsa and Khowailed 2011) illustrates the changes that have occurred in the U.S. sales of heating equipment over the past decade. The recent changes result from the lower rate of new home building, increased cost of home heating oil and, more importantly, the rise in natural gas prices since 2005. Discussion with manufacturers suggests that the increased heat pump sales also represent increasing popularity for installation of dual systems (heat pump and gas furnace) as a hedge against high gas and oil prices relative to electricity. Over the past few years, residential electricity cost has risen more slowly than fossil fuel.



**Figure 7 The Changing Heat Pump Share in the Total U.S. Housing Stock**

The increased share of heat pump sales is also reflected in a change in the share of residential home heating equipment in the total U.S. residential building stock, as shown in Figure 7 (Lapsa and Khowailed 2011). Changes in the existing building stock occur more slowly, especially with decreased new home building.

### 3.4 U.S. EXPORT SALES

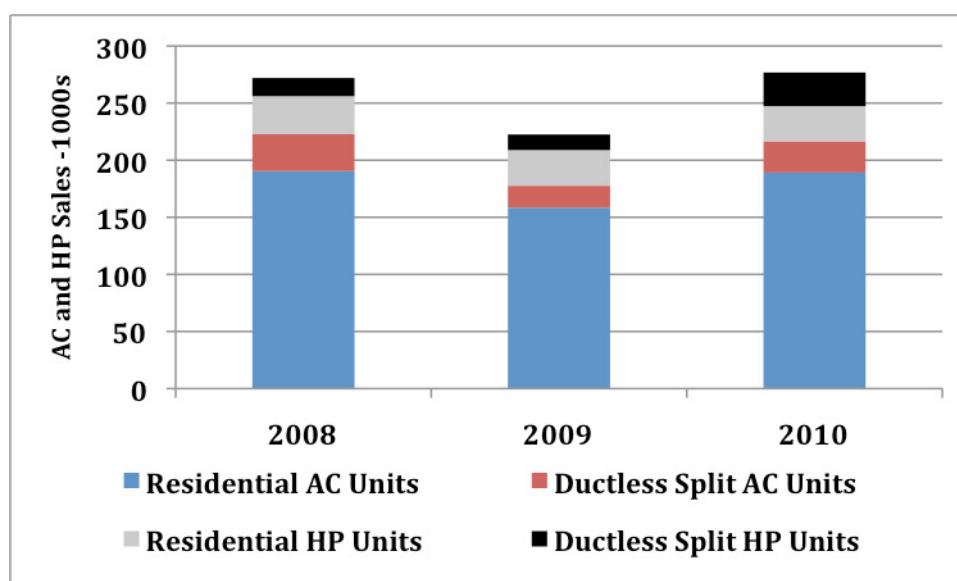


**Figure 8 U.S. Heat Pump and Air Conditioner Exports**

In Figure 8 the U.S. export sales of unitary air conditioners and heat pumps are presented, along with a graph showing the percentage of total U.S. shipments that are exported (AHRI

2011). Most of these units are shipped to Canada or South America; exports can be seen to represent less than 10% of total U.S. shipments.

### 3.5 CANADIAN HEAT PUMP SALES



**Figure 9 Canadian HP and AC Shipments**

Canadian shipments of unitary and ductless air conditioners and heat pumps are shown in Figure 9 (HRAI, the Canadian Heating, Refrigeration and Air Conditioning Institute 2011). The drop in shipments in 2009 is due more to the economic recession and not to the major housing credit crisis experienced in the U.S. Canadian residential construction dropped nearly 40% from 2004 to 2009 with the majority of this drop occurring in 2008 and 2009. Some recovery has occurred in 2010 and 2011. As seen in this figure annual shipment of unitary air conditioners and heat pumps is less than 300,000 units, or about half the value of U.S. exports (ground-source heat pumps are discussed separately in the next section of this report).

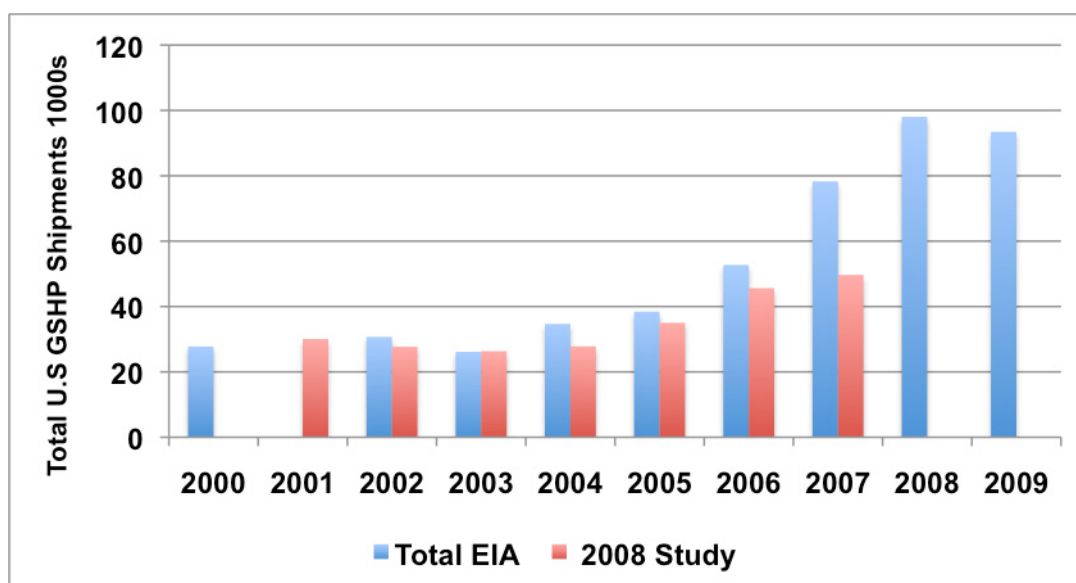
The number of installed heat pumps in Canada is estimated (Natural Resources Canada 2009) to be approximately 235,000, compared to almost 8.2 million furnaces and boilers and 3.2 million electric baseboard-heating systems. The relatively high cost of heat pumps and comparatively higher operating cost in this colder climate area have been a deterrent to heat pump popularity. The total number of residential and multi-family housing units in Canada was approximately 13.5 million in 2007 and grew at an average rate of 1.5% per year over the 1990 to 2007 period. There are approximately 7 million air conditioners installed in Canada (62% central units, 38 % window/room units). Approximately 80% of houses in Ontario province are equipped with air conditioners.

### 3.6 GROUND-SOURCE HEAT PUMPS

Hughes, et al (2011) describes recent U.S. Government initiatives to advance technology and market development for ground-source heat pumps (including ground water source heat pumps). Sales of these systems in the U.S. have increased during the past decade without much promotional assistance. In a report presented at the 9<sup>th</sup> International Heat Pump Conference (Groff 2008) the author presented results of a private study showing the growth in ground-source heat pump shipments in the U.S. in the period 2001 to 2007. This study showed an increase of 65% over this six-year period. The U.S. Department of Energy EIA



(Energy Information Administration) website provides market data on ground-source heat pump sales by AHRI product category.



**Figure 10 Annual U.S. Shipments of Ground-Source Heat Pumps**

The residential and commercial unit shipments from the 2008 study were combined in order to compare with the EIA data (U.S. EIA 2010), as shown in Figure 10. One of the difficulties in obtaining good comparative data for these products is that the equipment used in these systems (packaged water (or brine)-to-air heat pumps) is classified in several different product areas by AHRI and some product types are not included in the classification areas. Thus it is necessary to separate out the products that are used in loop systems in commercial buildings from those used in ground-source heat pump systems to extract heat from ground and ground water sources. Nevertheless the data from the two sources presented in Figure 10 gives clear indication that sales of ground-source systems are increasing. With efforts to improve the infrastructure for design and installation it is expected that these systems will play an increasingly important role in the U.S. heating market in the future.

During the past 5 or 6 years ground-source heat pump system installations have grown rapidly in Canada, with impetus provided by Canadian GeoExchange Coalition initiatives. Installed systems have increased from approximately 2,400 in 2004 to nearly 16,000 in 2009. Approximately 55% of these are for residential applications. Rising fuel oil prices in this period have stimulated growth in these systems, but the phenomenal growth also coincides with various grant and financial assistance programs deployed by utilities, provincial governments and the federal government (Canadian GeoExchange Coalition 2010 Market Survey). Similar incentives have generally not been available in the U.S.

### 3.7 HEAT PUMP WATER HEATERS

Electric heat pump water heaters (HPWH) have received a great deal of interest in North America, beginning in the late 1970s. First, small entrepreneurial companies and niche manufacturers introduced products. Later, major water heater makers and major air-conditioning manufacturers entered the market. By the mid-1980s, there were at least 15 manufacturers of such units for residential and small commercial buildings. This surge of interest in HPWHs quickly dissipated when consumer interest in energy efficiency became insufficient to overcome HPWHs higher cost, reliability problems and institutional barriers.

From the mid-1980s through late-2008, there were only a few small manufacturers of residential electric HPWHs operating in the U.S. The market for these products has been almost entirely driven by utility support programs in the Northeastern part of the U.S. In 2008 the U.S. government's Energy Star program ([www.energystar.gov](http://www.energystar.gov)) announced the establishment of an Energy Star incentive for electric and gas water heaters. For electric water heaters the efficiency requirement was to achieve a rated Energy Factor (EF, a metric established by a standard 24-h use test procedure) of at least 2.0, effectively requiring use of heat pump technology. That same year General Electric Corporation announced plans to introduce a residential electric storage (50 gallon or 190 l) HPWH product by late 2009. Since that time the number of U.S. manufacturers of these appliances has grown to a dozen or so. Sales of these units have grown from approximately 2,500 per year in 2008 to over 14,000 in 2009 (US DOE, 2010).

Electric heat pump water heaters (HPWHs) for use in commercial buildings are also available from a few manufacturers, in sizes up to 220kW thermal output. Commercial units are being used in commercial laundries, hotels and restaurants – wherever there is a coincident need for hot water and space cooling. Commercial HPWHs (with their cooling benefits included) have about the same operating cost as gas water heating. Consequently, electric utilities have generally been more interested in promoting commercial HPWHs and less interested in residential HPWHs. New federal minimum efficiency standards for electric water heaters will virtually mandate use of heat pump technology for any heater larger than the standard residential size.

### 3.8 COMMERCIAL HEAT PUMP AND AIR CONDITIONING SALES

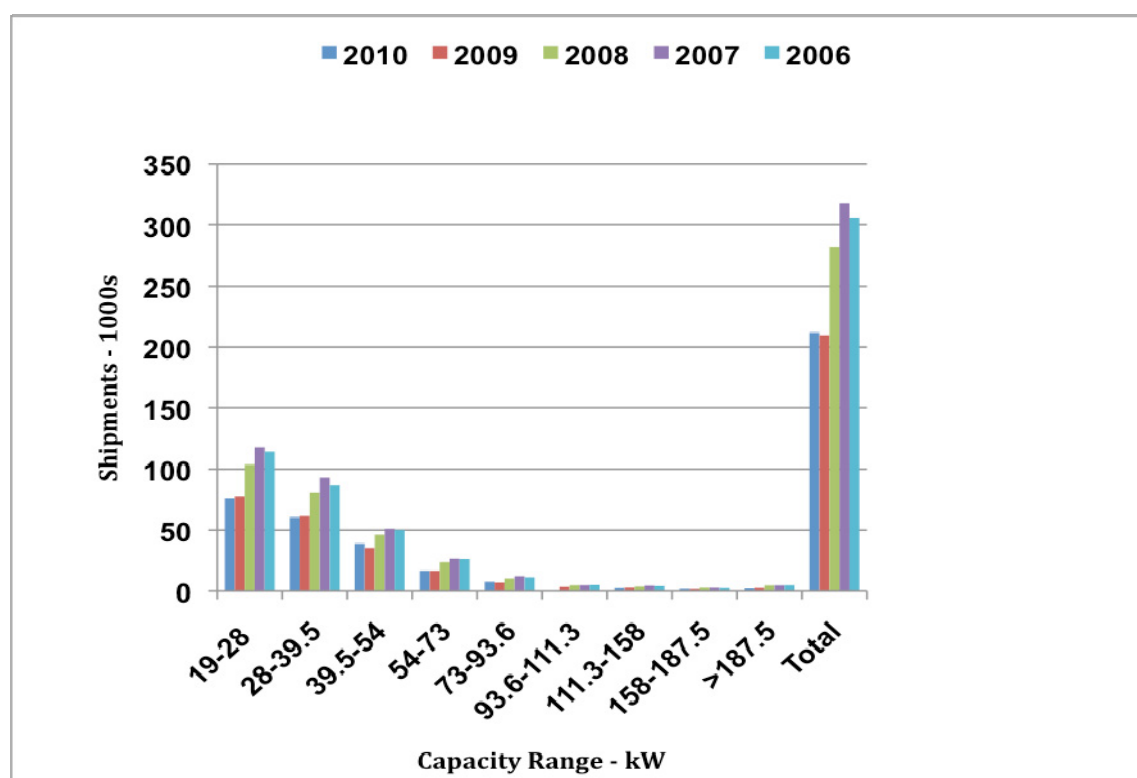


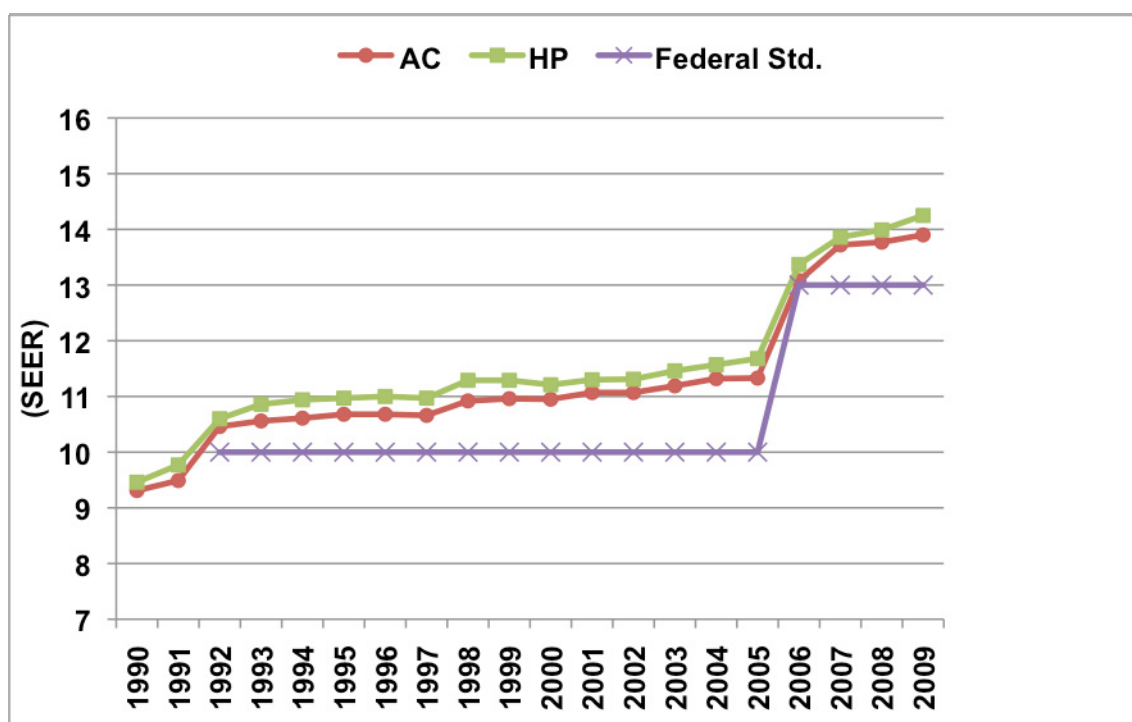
Figure 11 Annual Shipments of Larger Air Conditioners and Heat Pumps



The unitary heat pump and air conditioner sales statistics presented previously in this report cover products up to approximately 5.5 tons (19 kW) in cooling capacity. Many of the residential units are applied to commercial buildings. Larger capacity units, whose sales are not captured in the small unitary statistics, are applied to large residences as well as to commercial buildings. Accordingly, it is of interest to review recent sales history for the larger unitary products (19 to nearly 200 kW). Sales of these products are largely in the smaller capacity range – up to 100 kW in cooling capacity. Figure 11 presents shipment data for these larger units (AHRI 2011). The individual heat pump and air conditioner statistics are not available but it is estimated that only a small portion of these shipments are heat pumps.

### 3.9 HEAT PUMP EFFICIENCY STANDARDS

In the U.S. the energy difficulties of the 1970s gave impetus to a wave of government initiatives directed to energy conservation. In the U.S. this led to the promulgation of mandatory efficiency standards for household appliances. In 1992 federal mandatory standards for unitary air conditioners and heat pumps were instituted, utilizing new efficiency indicators: seasonal energy efficiency ratios (SEERs) for air conditioners and heat pumps in the cooling mode, and heating seasonal performance factors (HSPFs) for heating performance of heat pumps. Seasonal performance requirements were also issued for gas and oil warm air furnaces and boilers. All of these rating indicators are based on specific test procedures that involve cycling tests to capture the dynamic performance characteristics of the products. The resulting seasonal ratings may then be used to calculate annual operating costs for specific climatic regions that are used in labeling of the appliance.



**Figure 12 Unitary Equipment Shipment-weighted Seasonal Efficiency (Cooling) History**

Figure 12 illustrates the increase in shipment-weighted SEERs over the past decade (AHRI 2011). Introduction of new minimum energy efficiency requirements presented significant challenges to manufacturers to achieve the technology improvements necessary to achieve the increased standards and to incorporate the more sophisticated testing regimens. The step increase in the cooling efficiency requirement that occurred with the 1992 standard (10 SEER) has led to a continuing advance in efficiency during the last 14 years. The SEER data in Figure 12 (AHRI 2011) are the cooling seasonal efficiencies, for both cooling-only and heat pump units. Heating seasonal performance (HSPF) levels have shown a similar increase

over the period. It is also to be noted that the SEER and HSPF values are expressed in Btu/Wh units. The equivalent seasonal coefficient of performance (COP) or seasonal performance values (heating) (SPF) may be obtained by dividing these by 3.413 (Btu/Wh). A new minimum SEER level became effective in January of 2006 (13 SEER). It is equivalent to a Seasonal COP (dimensionless) of 3.8. Currently there are products in the AHRI Directory with SEER levels in excess of 23 (with variable speed compressors), and minimum efficiency standards are stimulating continuing increases in the shipment-weighted efficiency levels. Further increases in these required minimum standard levels are expected but will apply to specific climate regions of the country.

Prior to 1987 heat pump seasonal efficiencies were lower than cooling-only cooling units. This resulted from heat transfer losses in heat pump refrigerant circuits and compressors. These losses were overcome in later years with technology improvements. Achievement of higher efficiency levels has necessitated use of larger heat exchanger surfaces and numerous refinements in the refrigeration components. The current outdoor units are, consequently, physically larger. In the last 30 years shipment-weighted SEERs have doubled.

#### **4. SUMMARY AND OUTLOOK**

Despite the severe housing market recession of the past 3 or 4 years the popularity of heat pumps has shown remarkable strength and it is encouraging to see heat pumps gaining market share in annual shipments of residential heating equipment, and also in the existing building stock. The combination of concerns for energy security and increased price of fossil fuels for residential heating and water heating has given strong stimulus for interest in alternative heating systems. The long track record of reliable, energy efficient performance for contemporary heat pump products has provided end-users with confidence to move to heat pumps for primary or dual-system installations. The commensurate growth in ground-source heat pump systems (even without incentives and strong market promotion in the U.S.) and for heat pump water heaters, gives further evidence of a bright future for heat pump systems in the U.S. and when the housing market recovers it is expected that sales of these systems will continue at even greater growth rates. Although heat pump sales in Canada are relatively smaller it is likely that a robust market activity in the U.S., coupled with greater visibility to heat pumps as a result of the geothermal heat pump initiatives, will stimulate increased heat pump sales there as well. Continuing technological improvements and increased efficiency, stimulated by continuing elevation of minimum efficiency standards and competition, will provide an even better competitive position for heat pumps against conventional fossil fuel heating systems. It should be an exciting time for heat pumps over the next decade.

#### **5. ACKNOWLEDGEMENTS**

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