

HEAT PUMPS IN NORTH AMERICA - 2008

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Abstract: Despite the worst new housing market since the early 1990s the market for heat pump units in North America continues to have a strong base in sales for renovation and replacement. The market has shown a steady growth, reaching more than 2 million units in 2005 and 2006. The shipment-weighted efficiency of these products has increased significantly over the past 20 years, driven by government regulations for minimum seasonal performance. Ground-coupled heat pumps have begun to be sold in significant numbers and sales of these units have nearly doubled in the past four years. The prospects for energy-efficient heat pump technologies in North America continue to be strong as public consciousness to global warming and “green” building options grows. Heat pumps continue to require strong advocacy and future market growth will benefit from consumer education and awareness from government, utility and conservation groups.

Key Words: *heat pumps, air conditioning, North American market, efficiency*

1 INTRODUCTION

Despite the worst downturn in building construction in more than 15 years, sales of heat pumps for residential and commercial buildings continue to be strong, reflecting a robust replacement and renovation market and increasing interest in energy-efficient space heating and cooling systems. This paper reviews the historical evolution of the heat pump market in North America and the underlying factors that have led to current sales of approximately 2 million heat pumps each year.

2 EARLY HEAT PUMP MARKET DEVELOPMENT IN THE U.S.

Following World War II a large demand for residential housing and commercial buildings gave impetus to development of new approaches for construction including curtain wall shells for commercial buildings and mass production approaches for housing tracts. This also provided a market incentive for easily installed factory-built, centralized heating and cooling units and the so-called “unitary products” were born. As large-scale housing projects were initiated in milder climate regions of the U.S., reversible electric heat pumps for heating and cooling became an attractive alternative to the more popular northern climate gas- or oil-fired heating units which had to be combined with a separate cooling unit to provide year-round comfort.

In the late 1950s the advent of nuclear power production provided an attractive prospect for low cost electricity. Major power utilities began to promote “all-electric” homes and, in many regions, the use of heat pumps as an economically advantageous year-round comfort solution for new buildings. Large commercial shopping and office centers began to be built across North America and heat pump systems were frequently the system of choice due to their inherent energy-efficiency (Groff, 2005). Unfortunately, this broad market development encouraged introduction of products by entrepreneurial companies anxious to take advantage of the opportunity, but without solid base of product design experience. Following

several catastrophic heat pump failure experiences in large governmental and private housing projects the utility industry and the Air Conditioning and Refrigeration Institute (ARI), the manufacturer's trade organization, launched an aggressive remedial program. This entailed development of high-reliability models for both split-system and packaged unitary heat pumps, combined with a comprehensive qualification program that took place both in the manufacturer's laboratories and in closely-monitored field installations. The program was very successful in providing a base for design of heat pump products manufactured and sold in North America for the next 20 years or more. But the damage was done; due to the poor reputation that heat pumps had achieved the actual sales of these products was very small until the mid-1970s.

After the oil crises of the early 1970s there was widespread concern over availability of petroleum fuels and interest was rekindled in electric heating products. This interest, combined with growing winter peak loads for northern utilities, stimulated a number of investigations into the suitability of electric heat pumps for northern climate applications. Between 1975 and 1983 electric utility companies initiated several programs (Groff and Reedy, 1978) to demonstrate the effectiveness of air-source heat pumps in the northern U.S. In 1980 this effort was extended to include air-source heat pump programs in France with Electricite' de France (EdF)(Groff and Moreau, 1983) and subsequently in Germany, for both residential commercial building applications. Information developed in these programs was used to develop new product designs with superior performance and reliability.

As a result of the attention given to building energy usage following the oil crises of the 1970s sales of electric heat pumps grew over the next two decades partly due to restrictions on the availability of natural gas. The return of low priced natural gas later substantially suppressed this market growth. Nevertheless, heat pumps had gained acceptance in areas where both heating and cooling were required and winter climate conditions were not extreme.

After the market for residential heat pumps was established in the 1970s the level of sales was influenced by several factors. From year to year, sales were influenced by the level of new home construction and weather patterns (especially for very hot summers). Longer term trends were governed by evolving consumer perceptions of comfort and reliability, the effectiveness of utility promotion programs, the relative cost and availability of competing fuels and the relative volume of older units needing replacement. These same factors continue, today, to impact the sales of heat pump products.

3 GROWTH OF THE NORTH AMERICAN MARKET AFTER 1980

Figure 1 illustrates the growth of unitary air conditioner and heat pump sales in the U.S. from the early 1980s through 2007 (AHRI, 2008). In the mid-1970s the renewed interest in heat pumps prompted many to project a market growth to over a million units per year by 1980. But the million unit sales figure was not achieved until more than a decade later.

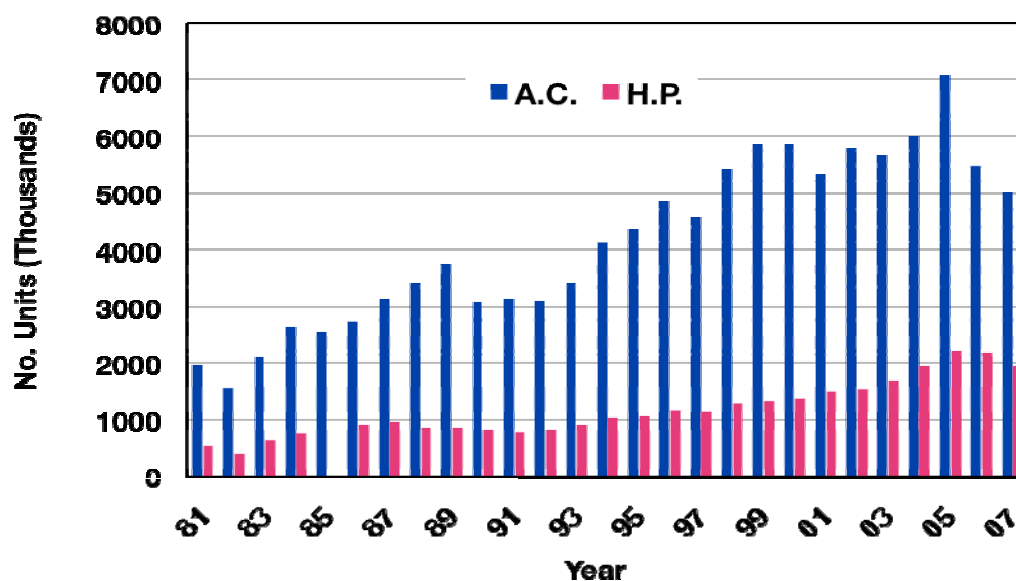


Figure 1 Total U.S. Unitary Air Conditioner and Heat Pump Shipments

The shipment numbers shown in Figure 1 include both domestic U.S. shipments and export shipments, including to Canada and Mexico. Canadian heat pump and air conditioner sales history is shown in Figure 2. U.S. export shipments of unitary air conditioners and heat pumps totaled approximately 670,000 units in 2005. Canadian heat pump sales average approximately 25,000 units per year and include both ducted and ductless units (HRAI, 2008).

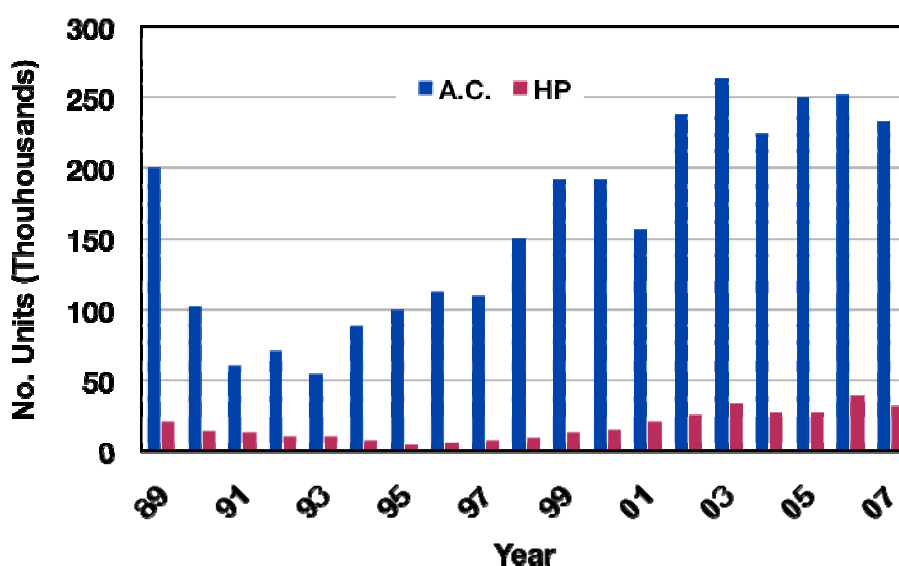


Figure 2 Canadian Unitary Air Conditioner and Heat Pump Shipments

U.S. shipments of gas-fired warm air furnaces (AHRI, 2008) are compared to unitary heat pump shipments in Figure 3.

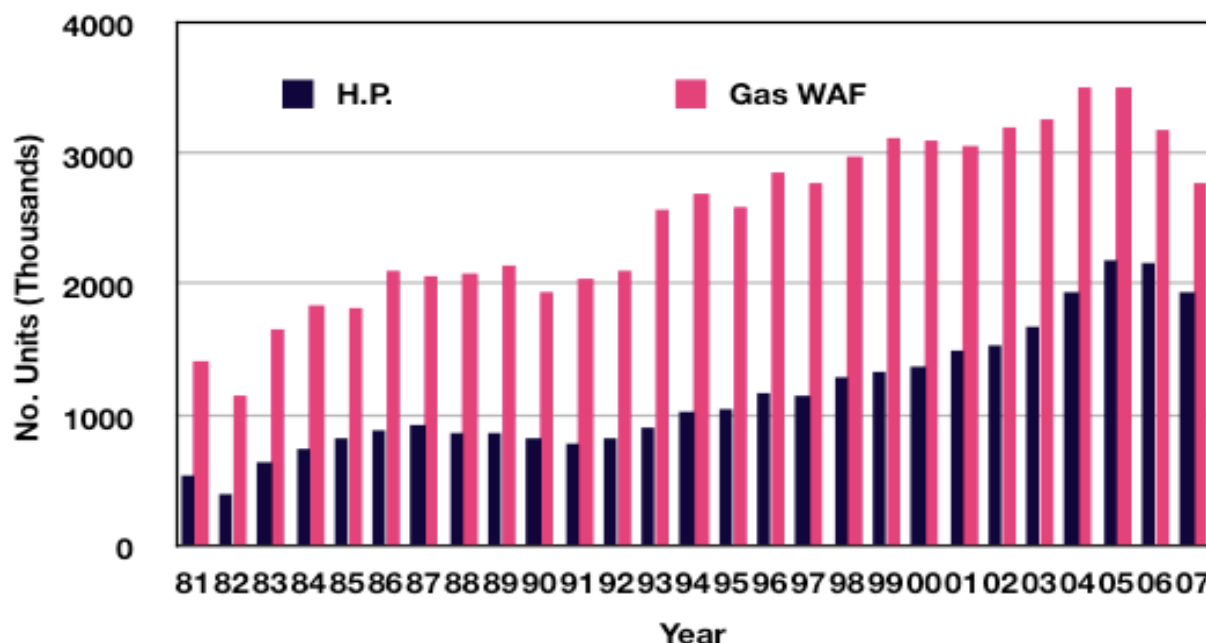


Figure 3 Unitary Heat Pump and Gas-Fired Warm Air Furnace Shipments

The shipment patterns for heat pumps and gas furnaces are similar, reflecting economic ups and downs, along with growth in overall housing trends and a growing replacement market. This chart indicates that heat pumps represent approximately 40% of U.S. heating unit sales, but they are installed in areas that have a substantial cooling demand. It is noted that the majority of North American air conditioner and heat pump sales are split-systems, with an outdoor section and indoor fan-coil unit. Gas furnaces are installed with indoor cooling coils (evaporators) and outdoor condensing units to provide year-round comfort systems. The downturn in building activity in North America is associated with the “credit-crunch” and declining economic conditions in the U.S. The sharp decline in residential building activity in the U.S. is shown in the housing start figures of Figure 4, taken from the National Association of Home Builders website (NAHB, 2008). The forecast shown in this chart and current industry projections indicate that this trend will not bottom-out until the end of 2008, and even this is thought by some to be very optimistic. Current building activity is at the lowest level since 1991. SAAR is the seasonally-adjusted annual rate.

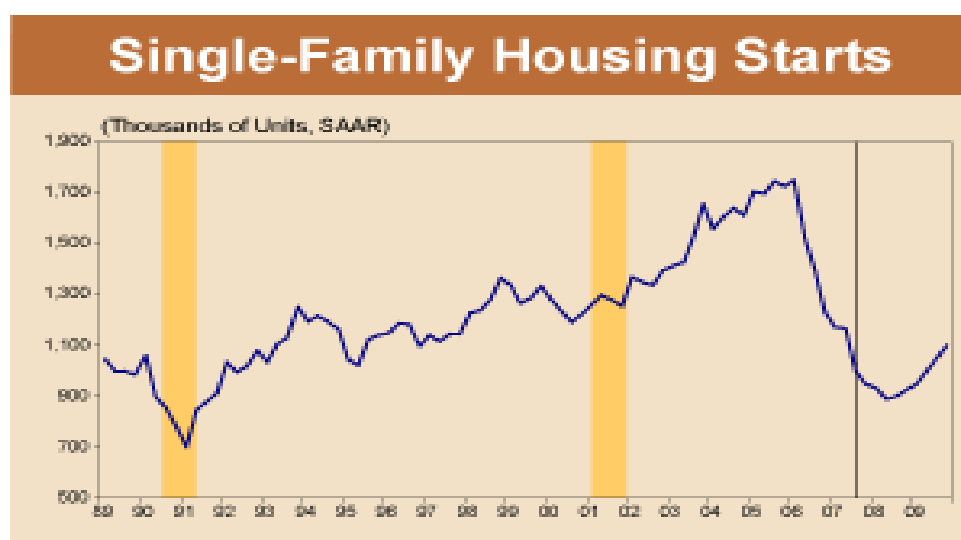


Figure 4 U.S. Housing Start History (NAHB)

Another element of the data shown in Figure 1 through Figure 3 is the impact of the increased efficiency requirement introduced by the U.S. Government in January 2006. This requires that unitary air conditioners have a minimum seasonal energy efficiency (SEER) of at least 13 and heat pumps have a minimum heating seasonal performance factor (HSPF) of 7.7. The prospect of these higher efficiency levels stimulated sale of lower efficiency models to clear inventories in 2005; this is reflected in the spike in the air conditioner and, to a lesser degree, heat pump, shipments for 2005. This also produced a lower 2006 shipment level, but the major factor in 2006 and 2007 sales was the decrease in home building activity.

4 ENERGY 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 ratings (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. 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.

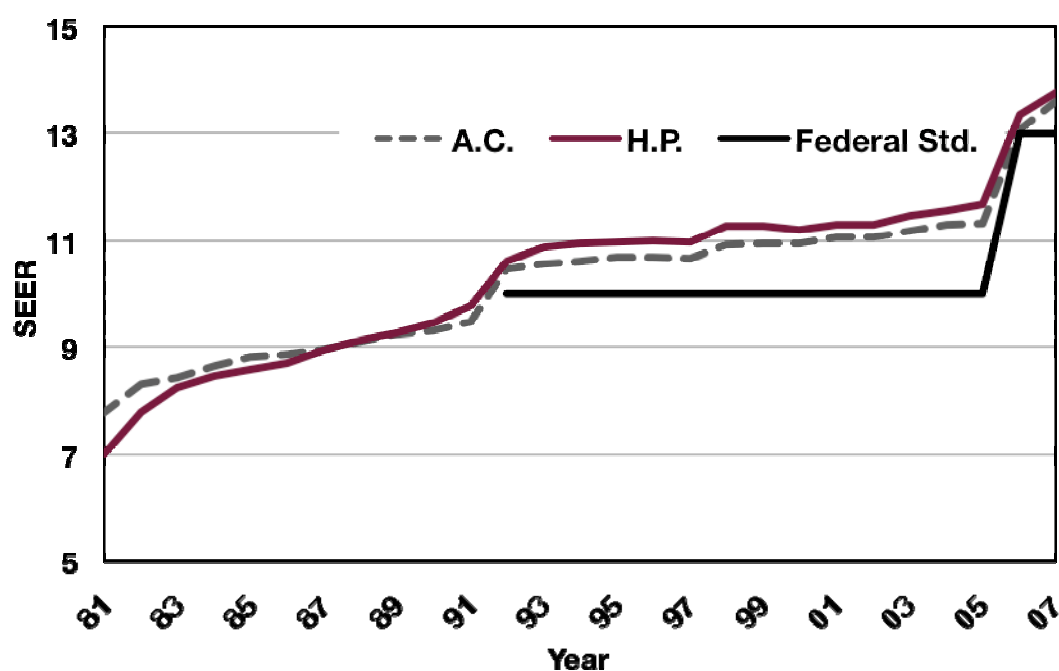


Figure 5 Shipment-Weighted Unitary A.C. and Heat Pump Seasonal Cooling Efficiency

Introduction of new minimum energy efficiencies 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 cooling efficiency requirement that occurred with the 1992 standard (10 SEER) has led to a continuing advance in efficiency during the last 14 years. Note that the data in Figure 5 are the seasonal efficiencies on cooling operation, for both cooling-only and heat pump units. Heating seasonal performance 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). Thus the new 2006 standard (13 SEER) is equivalent to a SCOP (dimensionless) of 3.8. Currently there are products in the AHRI Directory with SEER levels up to 23 (with variable speed compressors), and it is expected that the new minimum efficiency standards will stimulate continuing increases in the shipment-weighted efficiency levels.

As shown in Figure 5 heat pump seasonal efficiencies were lower than cooling-only cooling units prior to 1987. This resulted from heat transfer losses in the refrigerant circuits and from the compressor for heat pumps. 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.

5 APPLICATIONS AND RELIABILITY

Over the past 20 years the North American heat pump market has undergone a transformation with the majority of units now being sold as replacements for products installed during the preceding years. This replacement market has developed primarily in response to the introduction of new products with higher efficiency and new features, and not as a result of failure of the older units (Lovvorn, 2001). Data obtained from the U.S. Census suggests that only around 25% of new heat pump sales are for new building installations with the majority sold as replacements and for building additions. In the mid-1980s this figure was closer to 50%. Clearly, with more efficient units offered each year, there has been a continuing improvement of the installed stock of heat pump units in North America. The majority of residential heat pumps installed in North America are split systems (approximately 70%). Single package units (Figure 6) are popular choices in certain markets (e.g. southwestern U.S.) where many are installed on roofs (see photo below). Many homes in this region do not have basements. Evaporative coolers are also combined with these units in the drier climate.

In the northern climates split system heat pumps may be combined with gas or oil-fired warm air furnaces with controls that determine which heating fuel is used (the priority is given to the gas or oil furnace at lower outside temperatures). Newer, high efficiency, heat pump models incorporate multiple stages of heating (and cooling) with multi-speed or variable speed compressors and circulating blowers.

The systems may also incorporate communication capabilities to enable long distance monitoring and control of the heating and cooling functions. Ducted warm air systems, which are common in



Figure 6 Rooftop Single-Package Heat Pump Installation in Las Vegas

North America, permit centralized cleaning and humidification. Humidifiers can be installed directly on the air handler (fan coil or furnace) thereby providing humidity to the entire residence. Ductless systems have become more popular in recent years but are a small part of the North American market. These systems are also used in small commercial buildings.

5.1 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 the consumer's waning interest in energy efficiency was insufficient to overcome the HPWHs high cost, reliability problems and institutional barriers.

During the past few years, there have only been 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. The total annual production of all manufacturers is now about 2700 units per year, and is expected to grow modestly. General Electric recently announced the introduction of a "hybrid" electric residential HPWH. Participation in the market by larger companies like GE could substantially help market growth.

Electric heat pump water heaters for use in commercial buildings are available from five 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 are generally more interested in promoting commercial HPWHs and less interested in residential HPWHs. Overall, today's residential HPWH is a much better product than earlier models; they are smaller, easier to install and less expensive. Utility involvement is an important element in market development and the market in North America could grow significantly with such support, but will remain a relatively small niche market for the next several years, compared to either electric resistance water heating or heat pumps for space conditioning. One deterrent to introduction of combined residential heating/cooling/water heating units in the U.S. has been the absence of a credit for water heater energy savings in the federal SEER rating methods.

5.2 Ground-Coupled Heat Pumps

Ground-coupled heat pumps (GCHP) have been on the market for more than a decade in North America. There are at least 16 current manufacturers of GCHPs in the U.S., serving the residential, commercial and institutional markets. The GCHP market developed in the late 1970s, with impetus from the energy crisis and tax incentives introduced by the government. After the incentives ended in the early 1980s the market retreated, but began to grow again in the 1990s as a result of market development activities stimulated by the U.S. and Canadian governments, the Clinton administration Climate Change Action Program and utility technology development and marketing programs. Recent increases in ground-coupled heat pump sales are attributed to rising fossil fuel prices and concerns over energy security. The greatest market expansion has been in commercial and institutional sectors, especially schools, and in federal government facilities. Continued growth of this market is a distinct possibility as the benefits become more widely recognized

and the infrastructure expands. This in turn depends greatly on the overall level of government and utility support.

Figure 7 shows ground-coupled heat pump shipments in the U.S., as compiled by Dan Ellis of Climatemaster (Ellis 2008). Determination of these shipment quantities is complex due to different product types and their deployment in commercial water loop heat pump systems rather than as ground- or water-coupled installations.

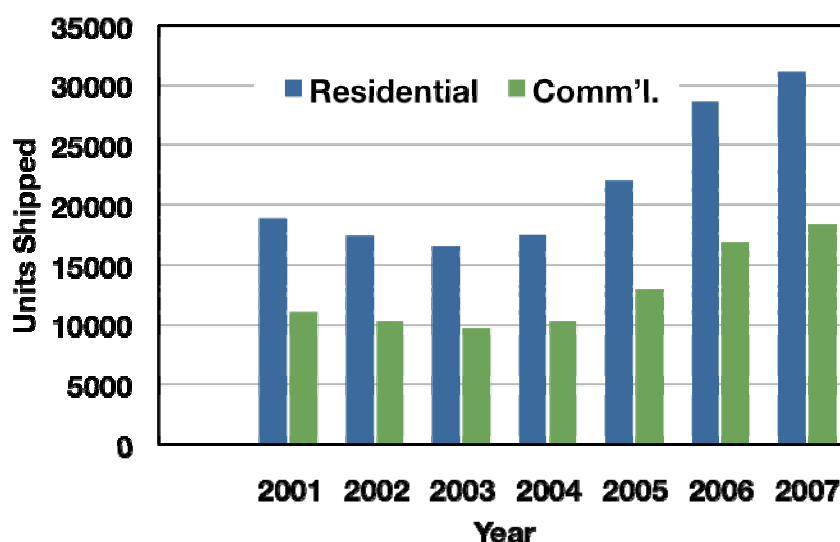


Figure 7 U.S. Shipments of Ground-Coupled Heat Pumps

As shown in Figure 7 shipments nearly doubled from 2003 to 2007, despite the new housing start situation. Ellis's study indicated that 75% of the residential units are estimated to be installed in newly constructed homes. Ellis notes that "the installation of round heat exchange piping in the earth is labor and capital intensive" and during the recent growth period for these systems the infrastructure was found severely limiting. This infrastructure issue will continue to limit the sustainable growth rate for sales of these systems for some time to come.

Although electric utility support overall has been significantly reduced because of deregulation since the mid-1990s, several utilities continue to support the technology.

6 PROSPECTS FOR THE FUTURE

The heat pump market in North America is mature and continues to grow with increasing penetration of central heating and cooling systems in both new and renovated homes and commercial buildings. The systems differ from those in Europe (relatively few hydronic heating systems except in the Northeast and North Central regions), and the Far East (ductless). This practice resulted from the shift in home construction following World War II when new factory-assembled heating and cooling products evolved to meet the large scale home building needs for easily-installed systems.

The introduction of federally-mandated minimum efficiency standards has driven the growth in higher efficiency products with new and improved features to provide more complete year-round comfort. These newer products have stimulated replacement of older, lower efficiency units. Reliability of the products has been established and is no longer a major deterrent to acceptance of heat pumps. Despite these favorable attributes, heat pumps continue to capture a smaller portion of the heating product

market and misconceptions exist concerning the suitability of the heat pumps for northern climates and with other performance matters. Government programs to educate consumers concerning the energy and environmental benefits of heat pumps have been modest, at best, and the strong role that electric utilities historically played in heat pump education and promotion has been largely abrogated by deregulation.

On the technology side government-supported programs in Canada and the U.S. are currently emphasizing ground-coupled heat pumps (Tanguay, 2008) and net zero energy buildings, respectively. The U.S. program is focused on combined (or integrated) HVAC and water heating systems for both residential and commercial zero net energy buildings. Another conference paper (Baxter, 2008) describes one approach for an advanced system.

Overall, heat pumps have bright prospects in North America. With increasing public recognition to the need for energy conservation and reduced global warming, efforts to achieve lower energy use buildings and building systems are expected to escalate. Heat pumps offer unique opportunities for integration in these building designs, but greater efforts in consumer education and awareness are needed. The term “heat pump” continues to generate confusion with consumers, a situation which is unlikely to be remedied without large educational and promotional programs directed to consumers and building system design professionals.

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