NORTH AMERICAN MARKET OVERVIEW

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Abstract

The U.S. market for heat pumps and air conditioning units for residential and commercial buildings continues to be one of the strongest in the world, with annual factory shipments of nearly 6 million unitary cooling units and approximately 1.5 million unitary heat pumps. Canada provides an additional market for 25,000 units annually. During 2000 and 2001 North American unit sales suffered due to colder summer temperatures and a weak economy. In the U.S., heat pump sales have been increasing as a percentage of total unitary shipments reflecting higher residential building activity in regions where heat pumps are an attractive choice and a growing replacement market. Concerns over future fuel availability and cost are also a factor in the increased sale of heat pumps (often in conjunction with gas or oil-fired heating units).

Evolution of the North American Market

Following World War II, pent-up demand for residential housing gave impetus to development of new approaches for housing construction. 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 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 separate cooling units to provide year-round comfort.

In the late 1950's the advent of nuclear power generating plants provided an attractive future for low-cost electricity and most 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. Unfortunately this broad market development effort led to the introduction of products by entrepreneurial companies anxious to take advantage of the opportunity, but without a solid base of product design and reliability experience. Following several catastrophic heat pump failure experiences in large governmental and private projects, the utility industry and the Air-Conditioning and Refrigeration Institute (ARI), the manufacturer's trade organization, launched a recovery program. This entailed the 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 the heat pump products that were manufactured and sold in North America for the next 20 years or more. Due to the poor reputation that heat pumps had achieved, however, the actual sales quantity of these products was very small until the mid-1970's.

After the market for residential heat pumps was firmly established in the mid-1970s, the level of heat pump sales was influenced by several factors. From year to year, sales were influenced the level of new home construction and weather patterns (especially for air-conditioning units). Longer-term trends were governed by consumers' evolving perceptions of

reliability, the effectiveness of utility promotion programs, the relative cost and availability of natural gas and the relative volume of older units needing to be replaced.

After the oil crises of the early 1970's, there was widespread concern over availability of petroleum fuels, and interest returned to electric heating products. This general interest, combined with growing winter peak load problems with northern utilities, stimulated a number of investigations of the suitability of electric heat pumps for northern climate applications. Between 1975 and 1983 electric utilities initiated several programs (see, e.g. 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 EdF (Groff and Moreau 1983), and subsequently in Germany (with RWE) for both residential and commercial building applications (air-to-water systems). Information developed in these programs was used to develop new product designs with superior northern climate 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 markedly in the late 1970's, partly due to restrictions on the availability of natural gas. The return of available, low priced natural gas later suppressed this growth substantially. Nevertheless, heat pumps had gained acceptance in areas where both heating and cooling were required and winter climate conditions were not extreme.

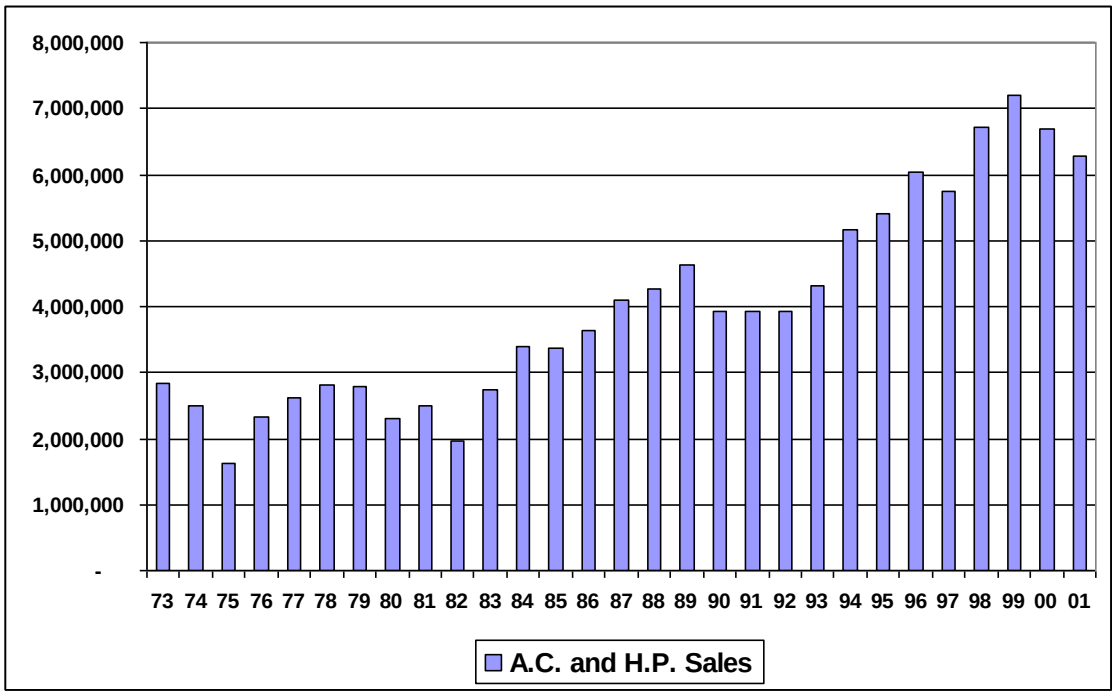

Figure 1 Unitary Air Conditioner and Heat Pump Shipment History

Growing construction of new homes and apartments, and increasing consumer desire for year-round comfort systems stimulated growth of unitary air conditioner and heat pump sales

throughout the 1980's. Figure 1 illustrates the evolution of the U.S. "unitary" air conditioning and heat pump market over the past 25 years. (Figure 1 includes only central, air-source products and excludes room air conditioners and water-source heat pumps.) As shown in Figure 1, annual shipments of unitary air conditioners and heat pumps have grown steadily from around 2.8 million units in 1973 to more than 6.2 million units in 2001. The dips in this growth curve relate, in general, to periods of economic downturn when home building activity was reduced.

In each of the last two years, shipments of unitary air conditioners declined significantly, due primarily to cooler summers (especially the early summer period when orders are generated) and a slowdown in the overall U.S. economy in 2001. As a result, the overall unitary shipments declined 13% from 1999 to 2001.

Figure 2 shows shipments of air-source unitary heat pumps. The trend closely matches the growth pattern of Figure 1, with heat pumps consistently representing approximately 20% of total unitary shipments. During the mid-1970's the surge of interest in heat pumps led to predictions that heat pump sales would reach more than 1 million units by 1980. As noted earlier, the return of lower natural gas prices dampened this surge and it was not until 1994 that heat pump shipments finally reached the 1 million-unit mark.

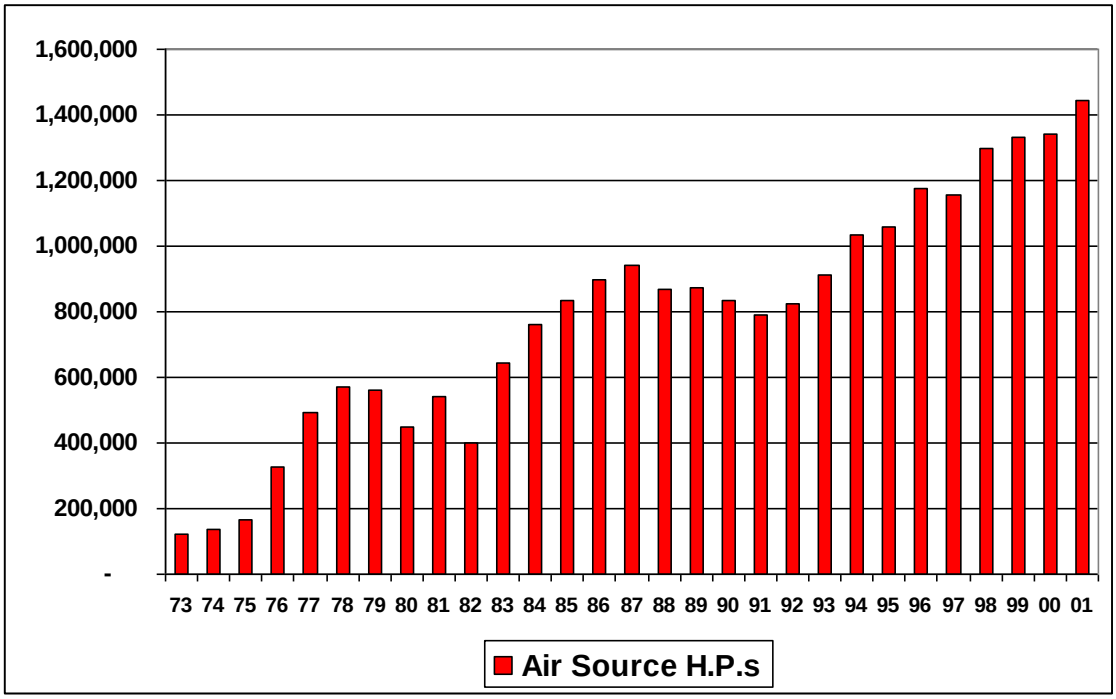

Figure 2 Unitary Air Source Heat Pump Shipment History

The relationship between natural gas availability and the electric heat pump market is best illustrated by comparing the relative shipments of gas furnaces to electric heat pumps. Figure 3 shows the relevant data. There are definite periods in which gas furnace shipments declined dramatically, partly as a result of limited natural gas availability for new homes. In many cases, there is a corresponding increase in electric heat pump sales. However, this relationship is only approximate since there are many factors influencing product sales from year to year.

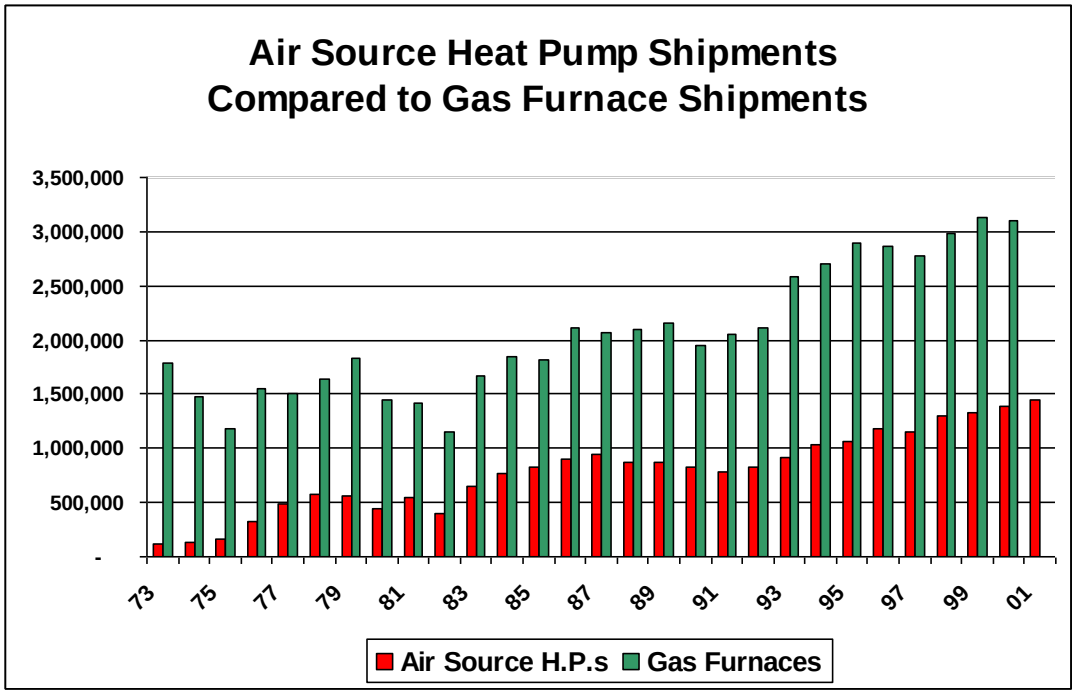

Figure 3. Gas Furnace and Unitary Air Source Heat Pump Shipment History

In each of the last two years, shipments of unitary heat pumps countered the sales declines of cooling-only equipment. Heat pump shipments in 2001 were -8% higher than in 1999. In the first months of 2002, heat pump sales continue to be strong with shipments up 8% over the 2001 levels. There are several reasons for the counter trend in heat pump shipments.

Heat pump sales are aided by stronger home building activity in milder regions of the country (South, Southwest), consumer concerns over fuel security (heat pumps are being sold together with natural gas furnaces) and by a growing replacement market. The large volumes of heat pumps sold in the late 1970's and 1980's, are reaching the end of their economic life (Lovvorn 2001). As a consequence, there is a growing market for replacement heat pumps that is contributing to the strong sales pattern, even in weak economic times. This market growth is shown in Figure 4 where heat pumps sold for new buildings are compared with those sold for add-on or replacement. The total heat pump shipments (on a different scale) are shown for comparison. Compared to the mid-1980s, the heat pump market is now dominated by sales for add-on and replacement purposes.

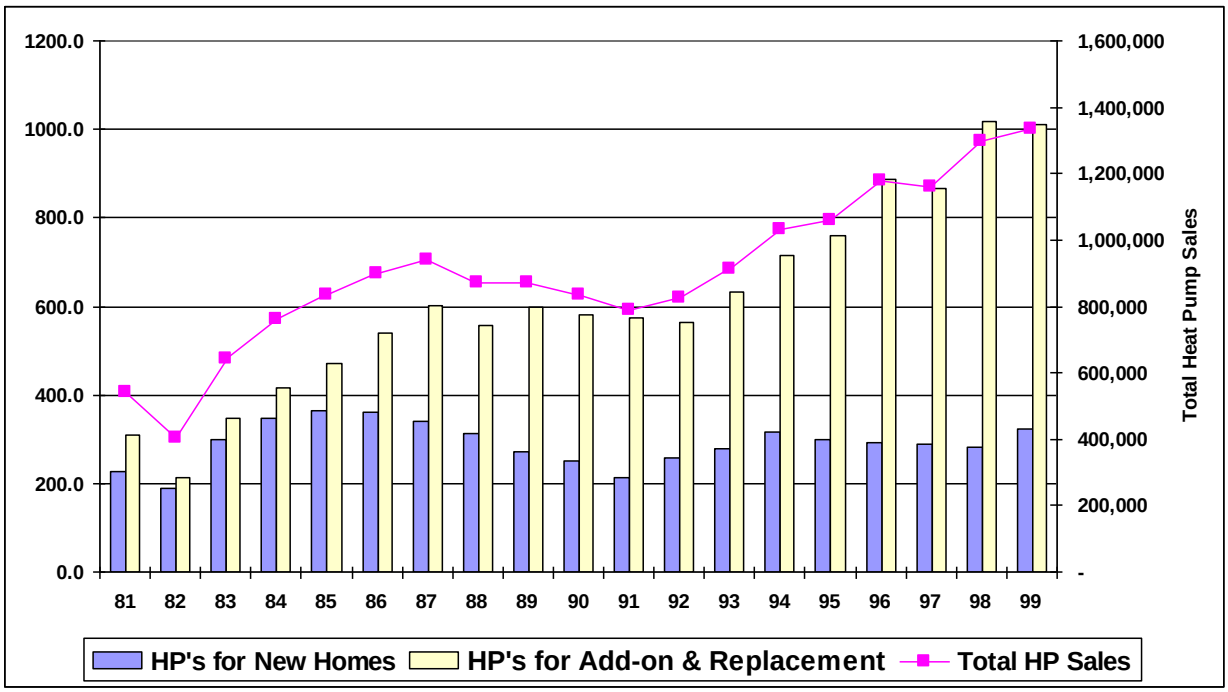

Figure 4. Comparison of Heat Pump Sales for New Homes and Replacement

The size of new U.S. single-family homes has steadily and continuously increased over the past two decades. The 1980's saw the average floor area of new homes increase by 18% while the 1990's experienced a further 9% size increase. In terms of energy use, the size growth has offset to some extent the considerable increases in thermal integrity of the building envelope and heat pump efficiency over the period. In addition, many of the largest homes have two or more heat pump units to separately condition different areas of the home. As a consequence of these offsetting factors, the average heat pump size has not changed significantly. The growth in average home size is shown in Figure 5.

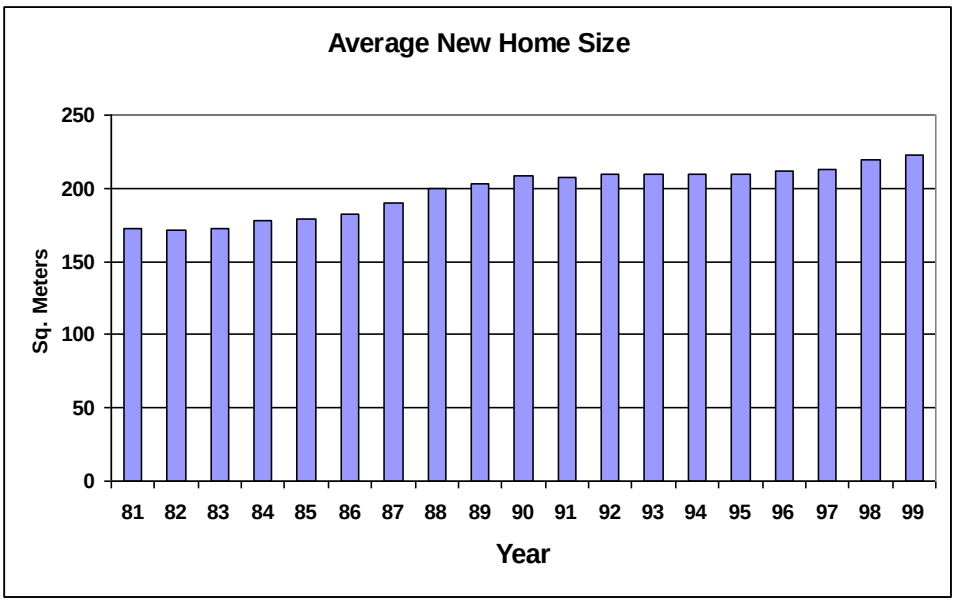

Figure 5. Growth in Average Size of New U.S. Single-family Homes

The Electric Utility Role

Historically, electric utilities have been a major force behind the successful development and application of heat pumps in the U.S. They have contributed substantially to market growth through testing, certification and quality assurance programs, advertising and promotion, and research and development. Originally, the primary goals of these programs were to gain competitive advantage over competing fuels and/or to improve customer satisfaction. For example, reliability data collected by U.S. utilities such as the Alabama Power Company (Lovvorn 2001) were invaluable in providing feedback on actual field experience to assist manufacturers in designing more reliable and more efficient products.

Beginning in the late 1980's, utilities in some states initiated or greatly strengthened their demand-side management (DSM) programs in response to pressure from state regulatory agencies. From the regulatory perspective, DSM programs were intended to promote energy efficiency as an alternative to increased generation. These utility programs often promoted high efficiency heat pumps. For example, in the mid-1990s, about one-quarter of all heat pumps sold had efficiencies 20% or more above the minimum standard, largely due to utility promotion programs.

Deregulation of the energy markets in North America has also taken its toll in distracting attention of manufacturers, utilities and other industry groups from advancing new energy-efficient product approaches. As deregulation began to take hold across the country, utilities rapidly abandoned their DSM programs. As a result, beginning in 1997, some state governments began to establish new, mandatory programs to replace the old DSM programs. The new programs have some similarity to DSM programs but also have significant differences. Utilities often, but not always, have a major role in administering the new programs in cooperation with the state government or independent organizations.

The new programs are called Public Benefit Programs and are funded by a required surcharge on consumer utility bills. The scope of these programs vary, but generally speaking, they cover low-income assistance, technical research, and technical and economic support for renewable energy and energy efficiency, potentially including heat pumps. While the move toward deregulation has slowed considerably as a result of the severe electricity problems in California in 2000, a total of 22 U.S. states and the District of Columbia have already established Public Benefit Programs. All but one of these includes funding for market support of energy-efficient technology, for a total of $890 million, covering nearly 60% of the nation's population. It is not clear exactly how much overall support heat pumps will receive from these programs. However, some of the programs include substantial market support for heat pumps with higher efficiency than standard models and may impact the market significantly in the future.

Energy Efficiency Standards

The first minimum energy efficiency standards for air conditioners (excluding heat pumps for space heating) were established by the State of California in 1977. The first U.S. national efficiency standards became effective in 1990 for room air conditioners and in 1992 for central air conditioners and heat pumps.

Manufacturers' efforts during most of the 1980's were directed to developing high efficiency product designs in response to the new efficiency standards and the incentives introduced by utilities to promote sale of higher efficiency models. Beginning in the late 1980s, attention was shifted to developing products with new refrigerants that are less aggressive in their contribution to global warming and ozone depletion. Prior to 1990, unitary heat pumps were generally less efficient, design for design, than their cooling-only counterparts. This resulted from internal heat losses, and thermodynamic inefficiencies due to reversing valves, etc. With the introduction of mandatory performance standards, manufacturers were obliged to overcome these inherent inefficiencies and since 1990 heat pump models shipped show higher seasonal energy efficiency (SEER) than their cooling-only counterparts. The shipment-weighted efficiencies (presented as seasonal COP's) are shown in Figure 6. The sharply increased levels beginning in 1992 reflect the fact that the federal minimum efficiency standards became effective that year.

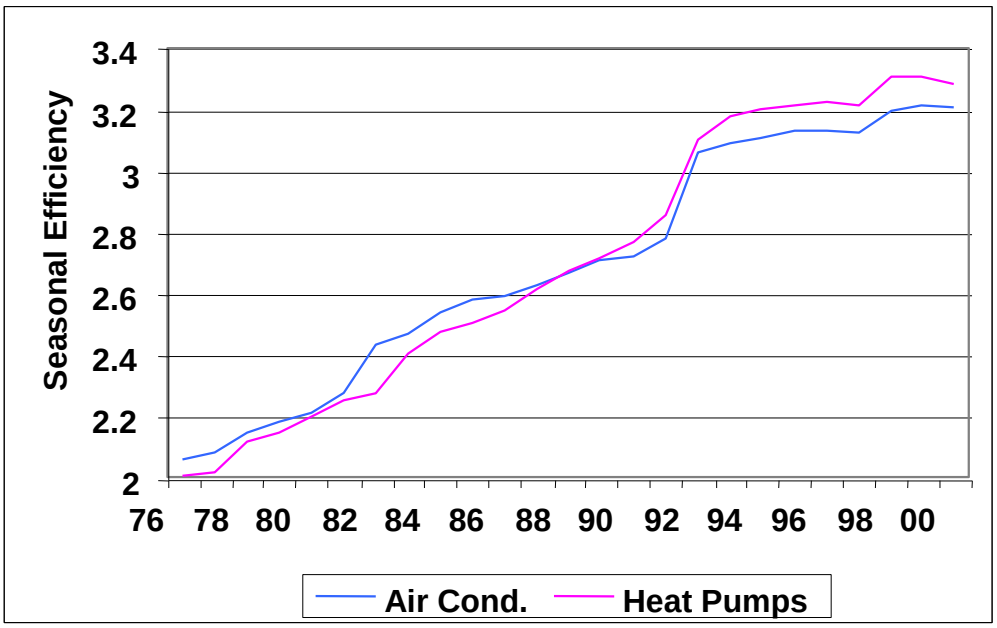

Figure 6. Seasonal Efficiency Increase History

The U.S. Department of Energy is in the process of revising its minimum efficiency standard for residential air conditioners and heat pumps. Unitary air conditioners and heat pumps sold in the U.S. are of two types: split-systems and single-packaged. Split system units require field connection of refrigerant lines, whereas the packaged units are fully assembled at the factory and require only air duct and electrical connections at the job-site. Split-system cooling-only units have been most popular (more than 75% of shipments) since 1970. For heat pumps, most shipments were packaged units until 1975. Today 80 to 85% of heat pump shipments are split systems.

For the split-system products, the revised standard will raise the energy efficiency by at least 20 percent in cooling and 9 percent in heating (for heat pumps). The new required minimum performance is for a seasonal energy efficiency rating (SEER) of 12 in cooling (equivalent to a seasonal COP (SCOP) of 3.5). The Heating Seasonal Performance Factor (HSPF) in heating is 7.4 for heat pumps (equivalent to a SCOP of 2.2). The new standards will apply to products manufactured for sale in the U.S. as of January 23, 2006.

The efficiency levels in the revised standard can be met by central air conditioner and heat pump designs that are already available in the market. In fact, about 24% of the sales of split-system heat pumps and 13% of similar cooling-only units today meet or exceed the new standard. Heat pumps that meet the new standard are estimated to have a payback period of less than 3 years, compared to units that just meet the old standard. Air conditioners would have payback periods about twice as long.

Market Experiences

Although the air-source heat pumps that are typical to the U.S. market have certain inherent disadvantages (decreasing capacity with lower ambient temperatures, frosting of the outdoor heat exchanger, lower indoor air supply temperatures than for fossil-fired heating units,

etc.), the market acceptance of unitary heat pumps has been generally good. Reliability problems experienced with the units introduced in the 1950's and '60's have largely been overcome and the experience of both manufacturers and installers with larger numbers of installations has aided in achieving product designs and installation practices that result in successful results. The higher cost of such units and the lack of familiarity of customers with these products in many parts of the country, represent the primary barriers to larger penetration of heat pumps in the U.S. market. Discussion of reliability and service experience with heat pumps will not be covered here since a recent workshop paper (Lovvorn 2001) covers this topic thoroughly.

New Market Opportunities

The perennial favorites among the new opportunities for increased use of heat pumps (other than simply increasing the market for the conventional electrically-driven, air-air systems) include natural gas heat pumps, heat pump water heaters, ground-coupled heat pumps and systems using hydronic distribution. In addition, there may be newly emerging system concepts to add to this list. The history, current situation and possible future trends in these areas are discussed below.

Natural Gas- or Thermally-Activated Heat Pumps

The principal technical and market opportunity (and challenge) in terms of energy savings is the small gas-fired heat pump for space heating and cooling in residential and small commercial buildings. Efforts to develop such a product have been a part of U.S. government and gas utility research programs for several decades. Although one or two products were introduced to the market in the past, these products were not commercially successful and at present no such units are available. With continuing Department of Energy and utility effort, however, it now appears that the goal will be reached within the next few years.

Three companies or consortia have or will soon introduce more efficient absorption air conditioners, based on the GAX concept using ammonia and water as working fluids. Perhaps the most robust of these is the Ambian consortium of manufacturers and gas utility companies. Ambian plans to introduce a range of gas air conditioners and space heating/cooling heat pumps for commercial and residential use (10 to 18 kW). The gas cooling products will be introduced beginning in 2003 followed by the heat pumps. The efficiency of these products is a cooling COP of 0.7 at 35° C and a heating COP of 1.40 at 8.3° C.

Conventional cooling-only, thermally-activated absorption chillers are familiar technology and have been widely used in some global markets for many years. Sales of these large tonnage units in the U.S. have increased somewhat during the 1990s but still have not reached the levels of the late 1960s and remain very much a small niche product in the U.S. Expanded use of this technology in the U.S. may hinge on the introduction of new products using higher efficiency cycles such as various “triple effect” technologies. Based on field test of a 450 ton (1580 kW) unit initiated in 2002, it is expected that triple effect products will be on the market within the next couple of years. Perhaps more importantly, absorption chiller products can be adapted to use the waste heat from on-site power generation. Programs at the Department of Energy are now increasingly focused on such integrated systems as the primary new energy-efficient market opportunity for the technology.

Heat Pump Water Heaters

Electric heat pump water heaters (HPWH) received a tremendous amount of interest in the U.S. beginning in the late 1970s. First, small entrepreneurial companies and niche manufacturers introduced products. Later, both 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 high cost of HPWHs, scattered reliability problems and institutional barriers.

During the last few years, there have only been two small manufacturers of residential electric HPWHs operating in the U.S. The market for these products is almost entirely driven by utility support programs in the Northeastern part of the U.S. A third (and larger) manufacturer entered the market within the last year with a new product developed with support from the U.S. Department of Energy. The total annual production of all three manufacturers is now about 2700 units per year, but is expected to grow moderately.

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, optimized and easier to install and less expensive. If utilities provide strong market support, the HPWH market in the U.S. can grow significantly, 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.

Ground-Coupled Heat Pumps

Ground-coupled heat pumps (GCHP) have been on the market for more than a decade in the U.S. There are at least 16 current manufacturers of GCHP in the U.S. serving the residential, commercial and institutional markets. The GCHP market has been gradually increasing over the last half of the 1990's, from sales of 28,000 units in 1994 to nearly 50,000 units in 1999. This increase is partly due to government and utility technology development and marketing programs. The most intense market expansion has been in commercial and institutional sectors, especially schools and in federal government facilities. Continued growth of this niche 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.

The Department of Energy conducted a major program from 1995 through 1999 specifically to support widespread commercial application of GCHP. The closure of this program significantly reduced the level of technical and market support from the federal government. However, the Department continues to support GCHP market deployment in federal government facilities and through community mobilization efforts. Although electric

utility support overall has been significantly reduced because of deregulation since the mid-1990s, several utilities remain involved in supporting the technology.

Prospects for the Future

Current events in the United States introduce considerable uncertainty to any projections with respect to changing priorities for residential and commercial building systems and equipment. Several market changes are clear, however, with the changing nature of the energy markets, concerns over energy availability and cost, and government interests in further improvements in energy-efficiency of heating and cooling products.

Deregulation of the U.S. energy markets is also having an effect on market behavior for heating and cooling products. While some utilities are focusing on end-use technologies, most are not and deregulation has some utilities focusing on "customer choice," meaning "which utility company do I want to use as my energy supplier?"

Other utilities are de-emphasizing marketing in favor of customer retention. Some are challenged to find the best use of company resources with the products available in their arsenal. For example, a rather new technology focuses on electric transportation - not in cars, but in off-road types, such as forklift trucks, airport baggage handling equipment, etc. These are more popular now due to some environmental regulations and improved efficiencies of this equipment relative to maintenance and fuel costs for gas or diesel units.

The U.S. government continues to support R & D programs for new technologies, such as heat pump water heaters and ground-source heat pumps (although government support has declined in the past year or so). The government also continues to support the deployment of emerging technologies, especially in federal facilities and through programs aimed at communities, local school districts and local government buildings.

Conclusions

The North American market continues to grow and the saturation level for unitary heat pumps for residential and small commercial buildings remains low despite the growth of sales in recent years. This low penetration, coupled with a rapidly growing replacement market provides a very optimistic future for heat pumps in the years to come. As in most countries, the cost and availability of competing fossil fuels plays a major part in the opportunity for greater sales growth. Recent experiences in the U.S. with insufficient electrical supplies and high electricity cost also present negative ingredients to future growth. Deregulation of the energy markets and longer-term petroleum fuel availability issues further cloud the picture.

On the product performance and reliability side the picture is bright. As a recent workshop paper (Lovvorn 2001) indicates, the service life of unitary heat pumps is very satisfactory, and with greater experiences with these products by equipment designers, installers and service personnel there is no reason to expect that these products should be inferior to other competing products. Performance and overall owning and operating economics for unitary heat pumps can be expected to become even better with the advent of increased performance standards, provided that the cost of these higher efficiency models is not detrimental to market growth and is reduced with greater sales volumes.

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