AN OVERVIEW OF NORTH AMERICAN HEAT PUMP MARKETS

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ABSTRACT

The use of heat pumps has grown slowly but steadily in North America. Recent natural gas price increases make the use of heat pumps more attractive. The pending increase in the minimum efficiency mandated by the federal government will result in a smaller variety but higher efficiency units for sale. Coupled with the transition to HFC refrigerants, significant redesign can be expected. There is also an increased recognition of the importance of refrigerant containment during all phases of the equipment life. American industry is working on several initiatives to reduce emissions. North American industry has found that certification programs are vital to ensure that heat pumps perform as specified and are installed and serviced correctly. While vapor compression cycles using fluorocarbon refrigerants will continue to be the technology that is used to provide heat pumping, a variety of other technologies are being evaluated for long term use.

Key Words: ***heat pump, North American markets, efficiency, statistics, containment, certification, research***

1 THE MARKETS FOR HEAT PUMPS IN NORTH AMERICA

Heat pump equipment represents a mature technology and a growing market in North America. Air to air central system heat pumps were introduced in the U.S. in the 1950s, but suffered from poor reliability and poor service. In the 1970s, a combination of better systems, better training and moratoriums on hookups of natural gas to new buildings gave a big boost to heat pump sales (Groff and Ryan, 2002). The shipment of these products has grown steadily ever since. As shown in Figure 1, the number of unitary, central heat pump shipments in the U.S. has risen to almost 1.9 million annually (http://www.eia.doe.gov/emeu/recs/recs97/decade.html). The reasons for this increase are a strong housing market, especially in regions where heat pumps are popular as well as the growing replacement market for systems that were installed in the 1970s and 1980s. In the southern United States, a strong market for new housing, coupled with a large replacement market and milder temperature has been a boon to heat pump sales. New, single family homes are large and often use two and sometimes three heat pumps. The traditional residential heat pump sold in North America is a split system (separate condenser and evaporator sections), delivering about three refrigeration tons of cool air. Single package central units are also common. Window and through the wall equipment are widespread, but generally for cooling only. The saturation of window air conditioners in the U.S. market is shown in Figure 2 (http://www.eia.doe.gov/emeu/recs/recs97/decade.html).

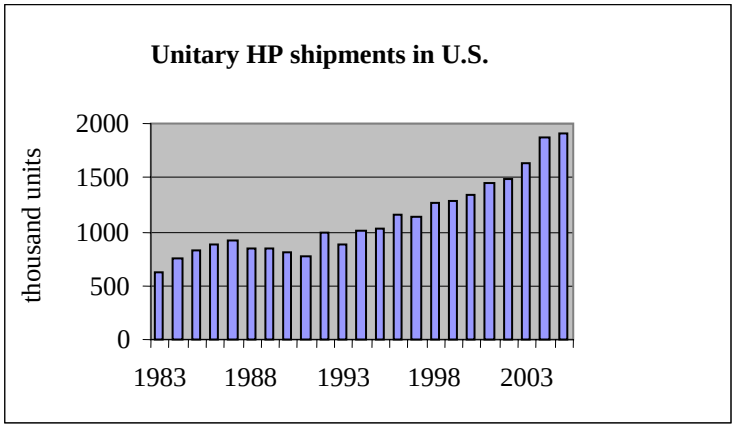

Fig. 1. Unitary heat pump shipments in United States

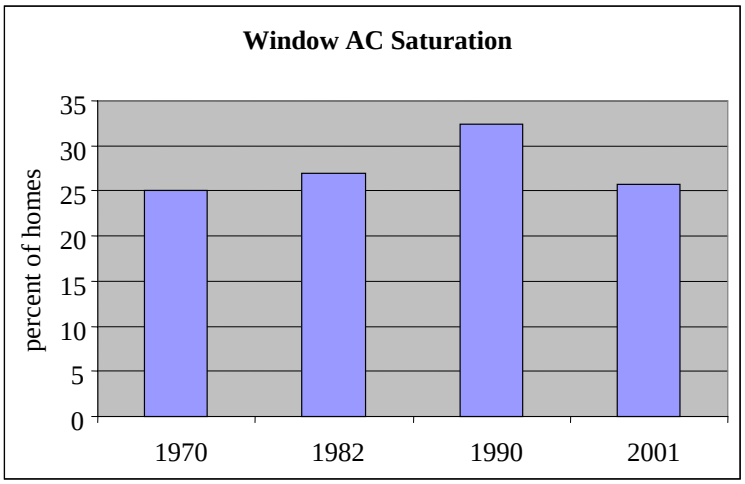

Fig. 2. Window air conditioning saturation

2 THE ECONOMICS OF RESIDENTIAL HEAT PUMPS

Heat pump performance varies by climate. Energy prices vary throughout North America. However, the example in Table 1 gives a general idea of the cost to heat a home using a high efficiency gas furnace and an electric heat pump.

The average price of residential electricity in the U.S. was 9.1 cents per kWh in September 2004, or $26.61 per MMBtu (http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html).

The average price of residential natural gas at the same time was $13.27 MMBtu. (http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm) It should be noted that the average price of electricity for residential users increased only 10% in the period 1999-2004, while the residential price of natural gas rose 60% during that same period. (http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls and http://tonto.eia.doe.gov/dnav/ng/hist/n3010us3m.htm)

For this typical example, it is considerably less expensive to heat a home using an electric heat pump. In spite of this, natural gas furnaces continue to be the equipment of choice in most of the U.S. This may stem from the early poor reputation of heat pumps.

Table 1. Typical gas and heat pump energy cost

	Natural Gas Furnace	Electric Heat Pump
Residential Energy Cost	$13.27	$26.61
Typical Efficiency	.90	3.8*
Delivered cost per MMBtu	$14.74	$7.00

* 13 SEER converted to a non-dimensional COP

The efficiency of both natural gas furnaces and electric heat pumps has steadily risen in the past 25 years. The shipment weighted average of heat pump SEERs shipped in the U.S. is shown in Figure 3.

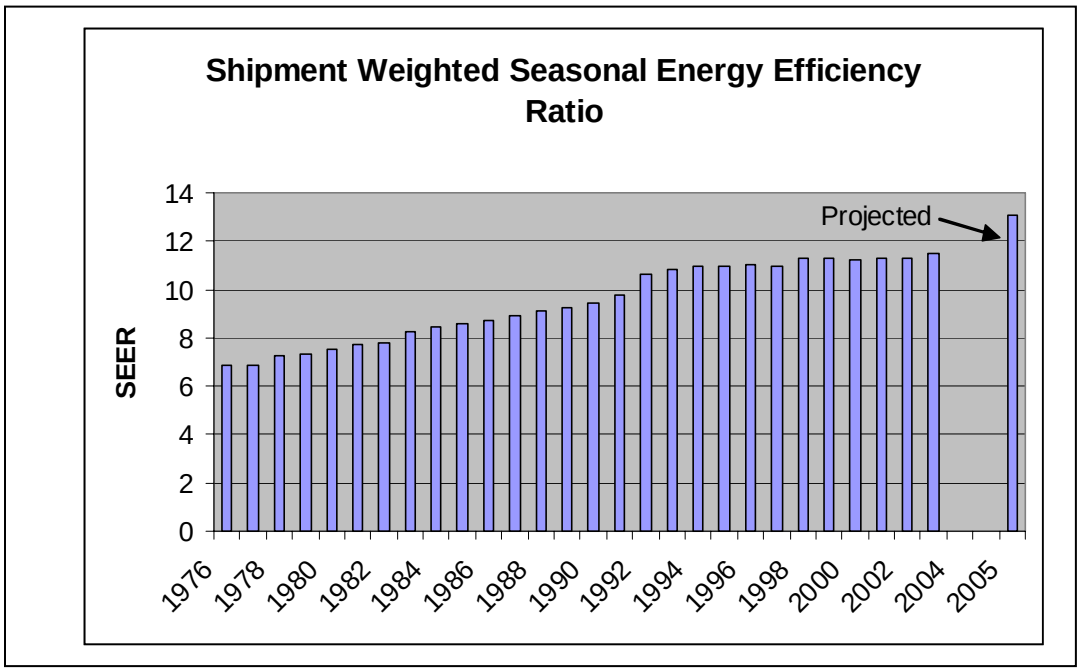

Fig. 3. Shipment weighted seasonal energy efficiency ratio

2.1 Market Saturation of Residential Heat Pumps

The market saturation for heating systems in North American homes is shown in Figure 4 (ftp://ftp.eia.doe.gov/pub/consumption/residential/2001hc_tables/spaceheat_household2001.pdf). Heat pumps represented just 10% of the heating systems of U.S. homes in 2001.

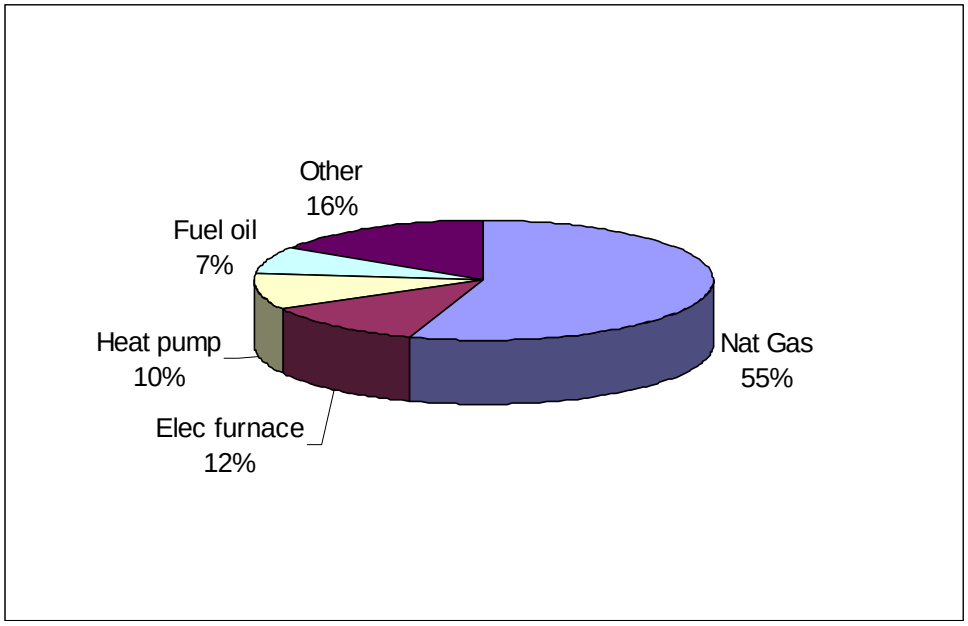

Fig. 4. Share of residential heating fuel in United States—2001

As shown in Figure 5 (ftp://ftp.eia.doe.gov/pub/consumption/residential/2001hc_tables/spaceheat_household2001.pdf), heat pump penetration has increased in recent years, but in the 1990's still only accounted for a fraction of all heating systems sold.

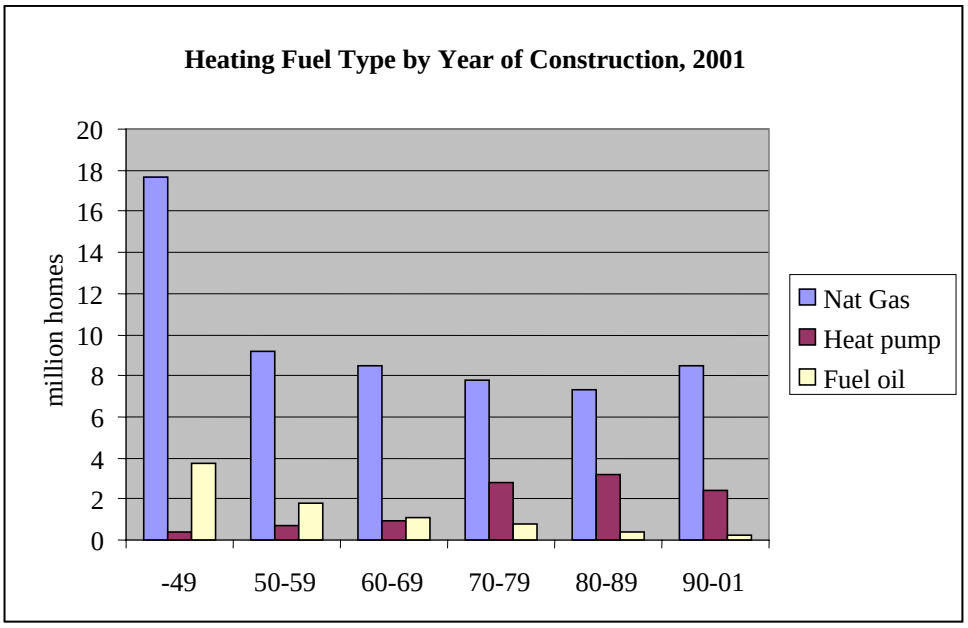

Fig. 5. Heating Fuel Type by Year of Construction - 2001

Heats pumps enjoy more relative popularity in rural areas, where natural gas pipelines are not available as shown in Figure 6 (ftp://ftp.eia.doe.gov/pub/consumption/residential/2001hc_tables/spaceheat_household2001.pdf.)

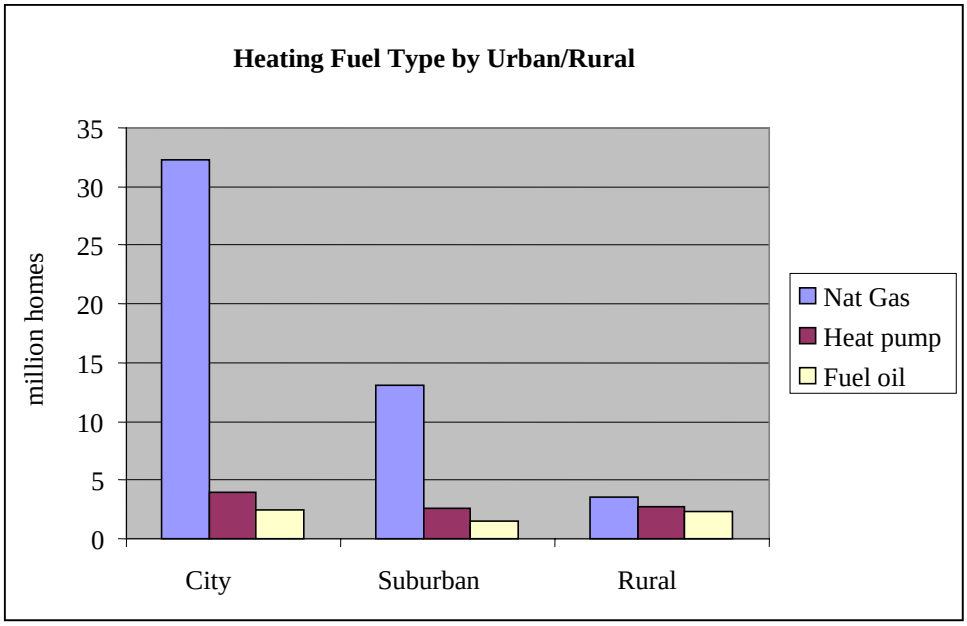

Fig. 6. Heating Fuel Type by Urban/ Rural

3 HEAT PUMP RELIABILITY

One of the greatest improvements in heat pumps has been their reliability. Advances in scroll and advanced reciprocating compressors have had the most impact. Heat pump controls have improved as well. Demand defrost has virtually replaced timed defrost, so a heat pump only goes into defrost mode when it is necessary. Better refrigerant management within the cycle has also led to better performance and reliability.

4 PROMOTING THE USE OF HEAT PUMPS

In the past, it was common for electric utilities to offer rebates for customers who installed efficient air conditioners or heat pumps that replaced other fuels or that replaced less efficient electric units. A recent review of investor-owned utility programs showed that, while many utilities offer home energy audits or advice on selecting high efficiency equipment, few now provide rebates. This is due to a changing climate of electric utility deregulation.

The U.S. government promotes the use of high efficiency equipment thorough the Energy Star program. Managed by the U.S. Environmental Protection Agency, Energy Star recognizes equipment meeting certain energy performance criteria, above minimum efficiencies. Currently, to meet Energy Star requirements, split system heat pumps must have an SEER of at least 13, an EER of at least 11, and an HSPF of at least eight. (For packaged systems these requirements are 12, 10.5 and 7, respectively.) EPA literature and web sites guide the consumer in purchasing and installing high efficiency equipment. The Consortium for Energy Efficiency (CEE), in conjunction with the Air-conditioning and Refrigeration Institute (ARI) has produced a list of ARI certified equipment that meets Energy Star requirement (http://www.ceehvacdirectory.org).

Since the federally mandated minimum split system efficiency will rise to 13 SEER in January 2006, it is anticipated that Energy Star requirements will also rise. One proposal is to meet Energy Star requirements when a unit must have a high efficiency and be installed properly by a qualified technician.

5 TECHNOLOGY CONSIDERATIONS

5.1 Challenges: Higher Efficiencies and a Transition to HFCs

Currently, most air conditioners and heat pumps shipped in North America utilized HCFC-22 as their refrigerant. HCFC-22 will be phased out as of January 2010, at which time it is expected that North American manufacturers will transition to HFC-410A. Manufacturers are now preparing to comply with new minimum efficiencies of 13 SEER for heat pumps in cooling mode, 7.7 Heating Seasonal Performance Factor in heating mode. Manufacturers had hoped that these two transition dates would occur simultaneously or at least close to one another, so that the two changes, refrigerants and minimum efficiency, could be made at once. It is likely, however, that the refrigerant change will take longer to implement for most manufacturers. As with the change of any technology, the change from HCFC-22 to HCF-410A will require fundamental redesign, extensive field testing, and re-training of installers and service technicians.

5.2 Material Considerations

Due to the larger heat exchange area required for 13 SEER as compared to 10 SEER units, more copper and aluminum will be required. One manufacturer estimates that heat exchanger on 13 SEER units are 30-40% larger than on 10 SEER units. In a time of tight supplies of raw materials, this is expected to add considerable expense to new units. It is feared that some manufacturers may not have raw materials available and might have to cut back or even cancel production.

5.3 Refrigerant Containment

The production of leak-free equipment has always been a priority for HVACR equipment manufacturers. In light of the Kyoto Agreement and pressures to eliminate emissions of global warming gases, manufacturers are taking a new look at steps to reduce the emissions of HCFCs and HFCs. One effort is to convince the U.S. Congress to pass legislation to strengthen the Clean Air Act so that the same provisions for recovery and recycling that hold for HCFC refrigerants will also hold for HFCs. Another initiative is the investigation of a mechanism that will provide incentives for contractors to return used refrigerant for reclamation or destruction. This investigation is in its early stages. Without such incentives, it is feared the only a small amount of refrigerant will be recovered.

6 NON-TECHNOLOGY CONSIDERATIONS

6.1 Equipment Performance Certification

During the early penetration of air conditioning in the U.S. market, some manufacturers made unsubstantiated claims of the units' cooling capacity and efficiency. ARI Standard 210, *Unitary Air Conditioning Equipment* was first published in 1957 followed by Standard 240, *Unitary Heat Pump Equipment*, in 1958. They were combined in 1984 and continue today as the North American standard. In 1959, ARI initiated a third party certification program to verify the performance of equipment that was rated to the ARI standard. The program included 31 manufacturers and it claimed to be the first consumer protection certification program sponsored by an industry association. (Heat pumps were added in 1962.) Today, over 200 companies participate in 22 ARI certification programs, comprising more than 1800 tests per year.

ARI product certification is a voluntary program under which virtually all of the units sold in North America are tested. Many thousands of models have been tested and their performance verified in ARI air conditioning and heat pump certification programs. Any unit that is found not to meet its rating claims must be properly re-rated or removed form the market. The ratings are made available to the public at

http://www.ari.org/cert/index.html. These ratings are used by utilities and governments to determine what equipment are eligible for rebates or other marketing incentives. In addition, ARI has cooperated with the Consortium for Energy Efficiency (http://www.cee1.org) to develop an online listing of residential equipment that complies with Energy Star requirements.

6.2 Technician Certification

In addition to equipment performance certification, the HVAC industry in North America recognized the need to increase the level of competence of the technicians that install and service air conditioning and heating equipment. In 1997 they established NATE, North American Technician Excellence (http://www.natex.org). NATE exams reflect a consensus opinion of what technicians need to know to effectively service and install today's sophisticated HVAC systems. Exams are given in the areas of gas heating, oil heating, air conditioning, air distribution, and heat pumps. In each of these areas, technicians can earn certification as an installer or service technician. There are over 21,000 NATE certified technicians in the U.S. and elsewhere. Recently, the city of Terre Haute, Indiana announced that they would require NATE certification for a contractor license to do work on HVAC equipment in their jurisdiction.

7 R&D DEVELOPMENT

Research in advanced heat pump concepts is underway at a variety of institutions in North America. Among them is Air Conditioning and Refrigeration Technology Institute (ARTI). Associated with ARI, ARTI undertakes research to improve the efficiency of heat pump systems. ARTI is conducting research or has recently completed research on flattened tube heat exchangers, extruded microchannel heat exchangers, and smart refrigerant distributors for evaporators. ARTI is also investigating other, less traditional cycles for pumping heat, including thermo-acoustic cycles, magneto-caloric systems, absorption, water vapor cycles, and transcritical carbon dioxide systems. Some of these cycles show long term potential, however, significant technical barriers have to be overcome.

8 CONCLUSIONS

The use of heat pumps has grown slowly but steadily in North America. Recent natural gas price increases make the use of heat pumps more attractive relative to natural gas heating. Heat pumps are more efficient and more reliable than in the past. The pending increase in the minimum efficiency mandated by the federal government will result in a smaller variety but higher efficiency units for sale. Coupled with the transition to HFC refrigerants, significant redesign can be expected. There is an increased recognition of the importance of refrigerant containment during the manufacturing process, shipping, during equipment operation, and during servicing and eventual removal of the equipment. American industry is working on several initiatives to reduce emissions at each phase of the equipment's life. Certification programs are vital to ensure that heat pumps perform as specified and are installed and serviced correctly. American industry has robust product and technician certification programs. While vapor compression using fluorocarbon refrigerants will continue to be the technology that is used to provide heat pumping, a variety of other technologies are being evaluated for long term use.

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