AN OVERVIEW OF THE RESEARCH AND THE MARKET FOR HEAT PUMPS IN KOREA

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Abstract: The heat pump is one of the most effective among those technologies for carbon dioxide reduction. However the popularity of heat pumps is not so common because of geographical, economical and technical reasons. In Korea, during winter season the ambient temperature is very low (about -5°C) and the unit charge of electricity is expensive, the direct heating from boiler costs less than that of a heat pump system. Continuous efforts have been made by researchers for the last decade to overcome these obstacles. Nowadays the heat pumps systems for specified locations such as cold area, multi-zone and module-based systems with high performance are available in the market. Also with the development of IT, the optimized control techniques are developed and the application of heat pump system became easier. It is commonly used in GSHP with the policy of government. In this article an overview of the researches and the market trend about the heat pumps in Korea are described.

Key Words: ***Heat pumps, Refrigeration, High temperature, Carbon dioxide***

1 INTRODUCTION

Korea imports 85.5 billion dollars of energy from abroad every year and it is nearly 27.7% of gross imports and 96.5% of the total energy consumed. The oil dependence of the total energy is about 43.6% as the details are shown in Table 1. It is expected to increase further in coming years as the oil price is rising near to 100 USD mark.

Table 1: Energy Consumption in Korea

	Unit	'00	'01	'02	'03	'04	'05	06
Primary energy consumption	Mil..TOE	192.9	198.4	208.6	215.1	220.2	228.6	233.4
Final energy consumption	Mil. TOE	149.9	152.9	160.5	164.0	166.0	170.9	173.6
Rate of oil dependence	%	52.0	50.6	49.1	47.6	45.7	44.4	43.6
Overseas oil dependence	%	97.2	97.3	97.1	96.9	96.7	96.8	96.5
Imported energy	Billion $	37.58	33.69	32.29	38.31	49.60	66.70	85.56
Energy weight % in imports	%	23.4	23.9	21.2	21.4	22.1	25.5	27.7
GDP growth rate	%	8.5	3.8	7.0	3.1	4.7	4.0	5.0

* Yearbook of energy statistics (2007), Korea Energy Economics Institute

The distribution of energy consumption in household and commercial sector and their portions of electricity and LNG is increased continuously. (See Table 2 and Figure 1)

Table 2; Energy Consumption Distribution in Household and Commercial Sector

(Unit : TOE/1000)

Year	Sum	Petroleum-based products	Hard coal	Electricity	LNG	Thermal Energy	etc
2000	32370	13492	718	7891	9024	1097	148
2001	32893	12474	727	9005	9412	1125	151
2002	34299	11955	697	9859	10241	1196	215
2003	34965	11156	722	10585	10889	1269	344
2004	34807	9773	775	11352	11293	1312	302
2005	36861	9437	1074	12233	12503	1491	123
2006	35986	7513	1226	12883	12858	1391	115

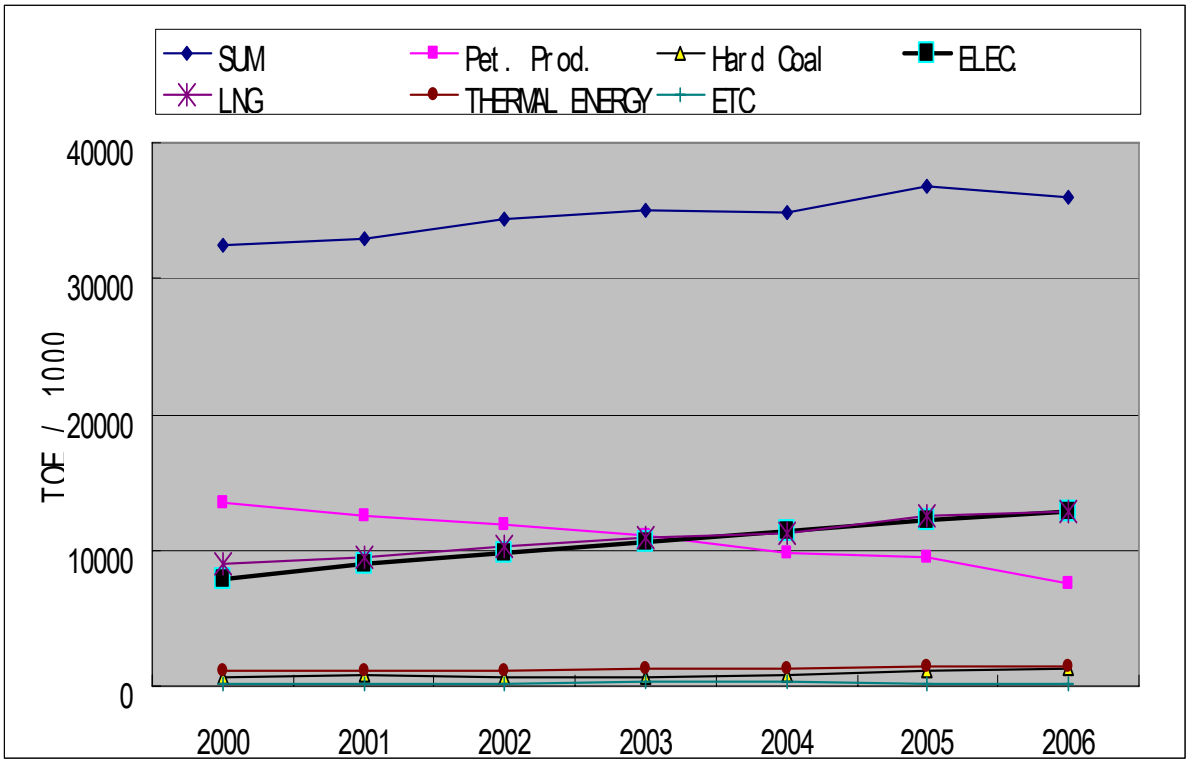


Figure 1: Energy Consumption Distribution in Household and Commercial Sector

In the early 90s, Korea was expending enormous energy and heat pump was less popular because electricity unit price was expensive than those of LNG or Oil. However, in the middle of 90s, distribution of heat pump has increased because the electricity price has reduced relatively. Therefore, in order to develop continuously the HVAC industry, energy efficient and effective devices must be developed because progressive taxes on electricity is high in household and commercial sector which the heat pump is more distributed (See Table 3). In this article, the heat pump as the device reducing the green house gas resulting in an enormous impact on energy conservation in Korean market are reviewed.

Table 3: Energy Price Index and Progressive taxes in Electricity

Energy	1990		1995		2003	
	PRICE(WON)	INDEX	PRICE(WON)	INDEX	PRICE(WON)	INDEX
B-C (ℓ)	87.4	100	105.6	121	339.2	388
Right Oil (ℓ)	179.0	100	231.5	129	772.0	431
Kerosene (ℓ)	191.3	100	261.6	137	640.0	335
LNG(m^3)	224.9	100	238.6	106	447.6	199
Electricity (kWh)	52.9	100	61.3	116	74.7	141

	Below 100kWh	100~200 kWh	200~300 kWh	300~400 kWh	400~500 kWh	Over 500kWh
Electricity Price (won/kWh)	54.60	112.80	162.90	235.20	345.90	606.80

* Based on Energy Conservation Statistics, KEMCO, 2005
* 1 USD ~ 950 Won Korean currency

2 TECHNOLOGY DEVELOPMENT ACTIVITIES

R&D budget through Korea government is expected to be almost 10 billion dollars in 2008. Recently government has prepared “roadmap for mid & long term national R&D program” for strategic meditation and effective distribution of funding. It is conventionally used as the fundamental data for evaluation and allocation of national R&D budget. Heat pump is classified in road map under “Environment and Energy” session as “energy conversion device”.
Researches in heat pump field have been mostly concentrating in high temperature generating system design, improvement of energy efficiency, larger size system manufacturing and alternative technology to preventing the green house gases. KIER(Korea Institute of Energy Research), KIMM(Korea Institute of Machinery & Materials), KITECH(Korea Institute of Industrial Technology), Seoul National University, Korea University, Kyunghee University, Sogang University, Samsung Electronics, LG Electronics and Sinsung Engineering Co. are involved in the research of heat pumps in Korea. As heat pump is the device to reduce global warming and CO_2 reduction, it is hoped that budget allocation to this field of research is steadily increasing.

2.1 Research Activities

2.1.1 High Temperature Producing Heat Pump

Vapor compression cycle using widely the pure refrigerant as working fluid has the temperature gradient between heat sources and refrigerant during evaporation and condensation processes of the heat exchanger. This is causing efficiency decline in the system. Also, it is hard to regulate the capacity, when compared to the absorption system, which is the relatively lower system efficiency than that of vapor compression system. If the vapor compression cycle which employ working fluid mixtures instead of pure components is considered, the heat pumps can give a number of advantages. That is, it can be applied in high temperature generating system with the mixtures which have a wide-boiling, large temperature lifts and less pressure ratios during the processes. It can be seen from figure 2, that driving force is basically same as the vapor compression system but heating and cooling load can be obtained from absorber or desorber during the processes between the mixtures of refrigerant vapor and absorbents respectively.

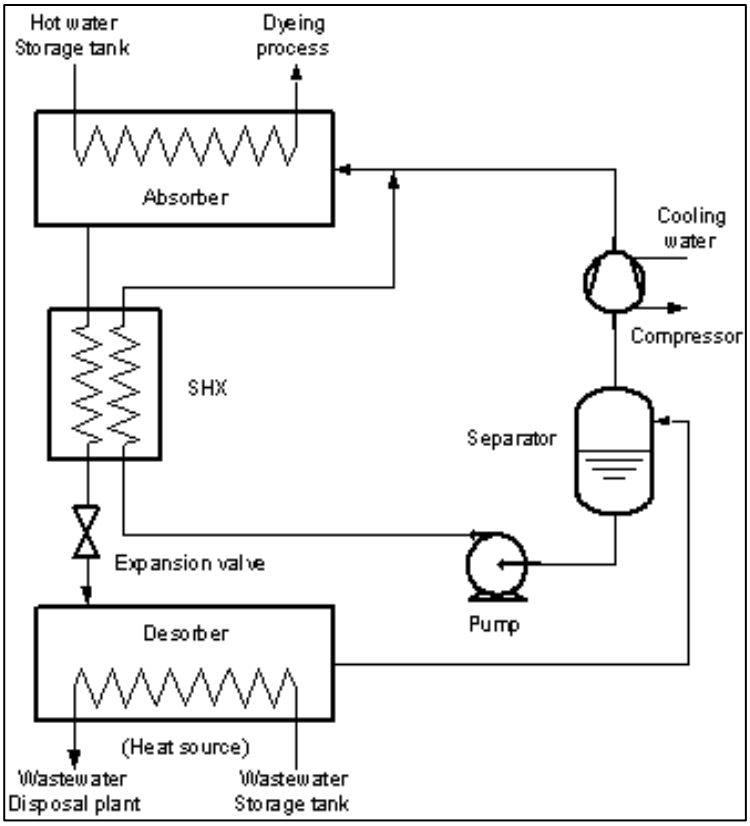


Figure 2: High Temperature Heat Pump Schematic Diagram

This system can be applied in a wide operating temperature range and can increase the COP with temperature gradient of working mixture in absorber and desorber.

2.1.2 CO2 Heat Pump

As a substitute for the ozone layer destructive and global warming refrigerants such as CFCs, HCFCs, some researches have worked on benign refrigerants such as CO_2, NH3, water and air etc. Among them, water heater, automobile A/C, dryer using CO_2 as the refrigerant were studied in detail in USA, Europe and Japan. In Korea, from the beginning of 2000, the CO_2 HP system has been developed by management of Korea Refrigeration and Air-Conditioning Industry Association (KRAIA), under the cooperation between universities and companies and with the support of Korean government. They have mainly focused on high efficiency compressor, key elements' design and manufacture such as gas cooler, cycle analysis and standardization. They also tried to increase the reliability of the system because the performance is relatively lower than that the conventional system. Therefore research group is also investigating the technologies such as the internal heat exchanger, multi-stage compression and ejector in order to increase the system performance. The product is expected to be seen in the Korean market within a span of 2-3 years.

2.2 Improvements of other heat sources

2.2.1 ASHP

Vapor compression air source heat pump (ASHP) as the energy saving device, is easy to install and initial cost is less expensive. It is reported from BRSIA/JARN(2002) that the ASHP market occupies around 16 billion USD, with 47% of the market share and HVAC market is

expected to be around 34 billion USD worldwide. Most of the products of ASHP is occupied by the separated room air-conditioner (SRAC) and separated packaged air-conditioner (SPAC). On the other hand, in Korea, SRAC and SPAC have occupied about 86% in HVAC systems in 2005 and it was only 2% (38 million USD) of market share although Korea ranked 4th after US, China and Japan in the world market. in HVAC products. It is mainly due to the traditional floor heating system, very low temperature during the winter and expensive electricity charges. Therefore, SRAC application is limited with heating capacity decline caused by low ambient temperature (about -5°C) but SPAC is growing with 22% of market share.

One of the most contributing products to promote the spread of ASHP is the multi-system, the other is gas engine driven heat pump system (GHP). In domestic, most of the GHP system for school and public buildings are supplied with 10~30 HP in size based on outdoor unit capacity. Recently the ASHP market is growing fast with the technology development to overcome the increase in number of indoor units, pipe lengths, elevation differences in the system. Also control system is studied for variable capacity change with Inverter or PWM (pulse width modulation) method.

Table 4: Statistics of heat pump market in Korea* (Unit: count, 1,000 USD)

Year	Electric Heat Pump				Gas Engine Heat Pump			
	Quantity (unit)		Money(USD)		Quantity(unit)		Money (USD)	
	Product	Sale	Product	Sale	Product	Sale	Product	Sale
2003	262	275	4,469	4,390	3,211	17,849	56,398	72,046
2004	N/A	N/A	N/A	N/A	2,555	2,998	95,532	98,073
2005	0	37	0	736	20,897	20,810	39,646	44,518
2006	994	773	8,715	8,570	1,084	9,417	15,048	80,725
Sum	1,256	1,085	13,184	13,696	27,747	51,074	206,624	295,362

*Data based on Korea Refrigeration and Air-Conditioning Association, Aug. 2007.

2.2.2 WSHP

Often water source heat pump (WSHP) is considered as the most energy efficient and saving device not only because of its high efficiency but also due to alternative energy operation, such as unutilized energy. (waste industrial water, sewage water, river water etc.) Its applications are limited due to short market approach, expensive initial cost and space problems.

Nevertheless, WSHP was applied for cooling load of the main current transformer in one prefecture (Mapo-ku) in Seoul and used for heating of the building inside the western branch of Korea Electric Power co.(KEPCO) in 1991. In 1995, KEPCO at Sokcho city has supplied the heating and cooling water into the building through WSHP system using sewage water, In 1996, heating and cooling was supplied by WSHP at the sewage water treatment plant (Tancheon), Seoul. Also, using “Nak-dong” river water as heat source, heating water was supplied to the floricultural complex near the system. In 2002, the system was used at fish-raising farm in Yeosu city with sea water as heat source. They are all demonstration cases for WSHP system. Enormous efforts are necessary for large capacity applications of WSHP system. Additional research on heat recovery, conversion, transport and storages are also needed. Furthermore administrative support and capital investment are highly essential.

2.2.3 GSHP

Based on the Korean government policy to accelerate the utilization of alternative and renewable energy, newly constructing public buildings over 3000m^2 should employ construction facilities utilizing alternative and renewable energy. Table 5 shows the obligation of public buildings legislated in Feb. 2005 on alternative and renewable energy. After the legislation, geothermal energy was preferred from the application point of view and installation of ground source heat pumps (GSHP) has been increasing. The GSHP increased from 670RT in 2003 to 12,720RT in 2007 and the data is tabulated at Table 6. The data in Table 7 shows that the system is widely applied on 50 ~100RT in educational and social welfare facilities.

Table 5: Obligation for public buildings in the utilization of alternative and renewable energy

Directed organization	Newly constructed buildings with floorage over than 3,000 m^2 by government organization, local government, government invested organization, and government funded institutes
Directed building	Public buildings, cultural and conventional facilities, medical centers, sports complex, social welfare facilities, memorial parks, leisure facilities, hotels and accommodations, recreations, and office buildings
Obligations	Minimum 5% of the total construction cost

Table 6: Total GSHP capacity in Korea

Year	Capacity (RT)
2001	88
2002	207
2003	670
2004	1,768
2005	2,331
2006	7,656
2007	12,720

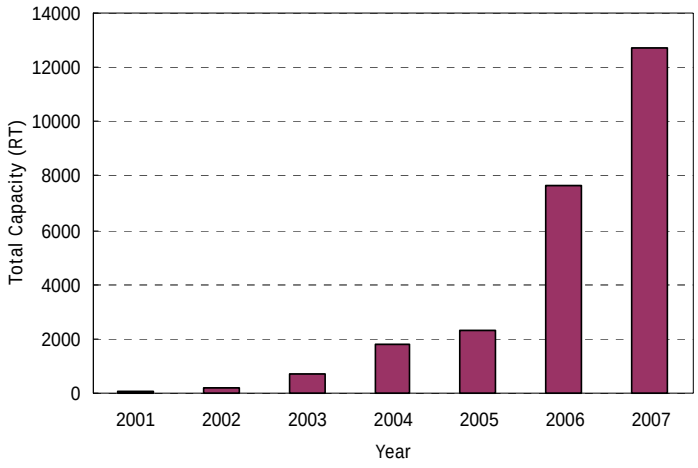


Figure 3: Total capacity of GSHP supply in Korea

Table 7a: Capacity of GSHP in terms of Supplies (2005 base)

Category	Capacity (RT)
Residential	39
Public	261
Educational	570
Social welfare	569
Industrial	307
Commercial	243
Others	342
Total	2,331

Table 7b: Capacity of GSHP system in size (2005 base)

Unit capacity (RT)	Capacity (RT)
< 10	68
10~50	186
50~100	920
100~200	857
> 200	300
Total	2,331

* Korea Energy Management Corporation, 2006,
* 2005 statistics on alternative and renewable energy in Korea

3 HVAC MARKET

The market of HVAC in Korea was growing by 5% annually and it would grow upto 30 % in the hottest summer in a span of 100 years as per weather forecast in 2005 due to average temperature raise caused by global warming. The market size was 13.95 billion USD in 2005, where in the air-conditioner portion was 9.37 billion USD with a market share of 67% (see Table 8). Freezer & Refrigeration device, compressor, HVAC equipment are the 1st , 2nd , and 3rd ranked items in the market. (See Table 9)

Table 8: Domestic Market in Refrigeration Industry

(Unit : Quantity : X 1000, Amount : billion USD)

		2001	2002	2003	2004	2005
Domestic Market	Quantity	46,300	44,847	62,019	71,024	72,878
	Amount of Money	8.267	8.145	8.035	9.521	13.954

※ Data based on Korea Refrigeration and Air-Conditioning Association, Aug. 2007.

Table 9: Domestic Market in key elements in 2005

(Unit : Quantity : X1000, Amount : billion USD)

Item	Market size in 2005			
	Quantities	%	Amount of Money	%
Summary	**72,878**	**100**	**13.954**	**100**
Compressor	38,058	52.2	1.686	12.1
A/C	11,220	15.4	9.433	67.6
HVAC utilities	170	0.2	0.332	2.4
Ref.& Freezer	6,106	8.4	2.391	17.1
Components	17,324	23.8	0.110	0.8

*Data based on Korea Refrigeration and Air-Conditioning Association, Aug. 2006.

HVAC industry occupies a portion of 44% in quantity and 74% in amount respectively among the total shipping items. It is the key export commodity. In HVAC industry, A/C, Freezer & Refrigeration device, compressor, etc., are taken about 75% of the export market.(see Table 11).

Table 10: Import and export business status in HVAC industry

(Unit: Quantities : X 1000, Amount : million USD)

		2001	2002	2003	2004	2005
Export	Quantities	20,318	24,550	26,945	28,961	23,085
	Amount	2,460	2,436	3,158	3,423	3,603
Import	Quantities	2,759	3,797	4,077	4,289	3,870
	Amount	527	563	690	720	859

* Data based on Korea Refrigeration and Air-Conditioning Association, Aug. 2006

Table 11: Import and Export business Size of 2005 in key components

(Unit: Quantities : X 1000, Amount : millino USD)

Item	Import / Export business size			
	Export		Import	
	Quantity	Amount	Quantity	Amount
Sum	**23,085**	**3,603**	**3,870**	**859**
Compressor	13,573	514	3,152	216
A/C for transportation	347	34	38	0.3
Room A/C	2,594	723	502	61
Package A/C	41	36	72	71
Ref. & Freezer Show case	34	23	19	18
Office	202	11	7	0.8
Unit for compression	56	8	-	12
Ref. & Freezer	4,232	1,396	62	35
Components	2,071	858	18	445

* Data based on Korea Refrigeration and Air-Conditioning Association, Aug. 2006
* Above data, air devices (vacuum pump, air compressor, fan) are excepted.

From Table 12, it is noted that production of package A/C and heat pump are gradually increasing.

Table 12: Import and Export business size of 2005 in key components

Year	Product	Room	Package	Thermal Devices	Heat Pump	EHP	GHP
2001	54,060,253	6,036,427	681,124	2,857	22,550	-	-
2002	49,260,933	6,493,963	853,023	2,988	39,505	-	-
2003	61,897,796	5,788,630	939,198	8,885	3,593	262	3,211
2004	71,023,903	7,147,983	659,195	7,311	2,555	-	2,555
2005	72,878,785	4,273,868	1,583,409	4,117	20,897	-	20,897

4 CONCLUSIONS

In Korea, during winter season the ambient temperature is very low (about -5°C) and the unit charge of electricity is expensive, the direct heating from boiler costs less than that of a heat pump system. This is the bottle-neck in spreading of heat pump system in the market.

Most important thing to promote the heat pump industry is to develop the system to increase the energy efficiency and conservation. Environmentally safe refrigerant must be applied to prevent ozone layer depletion. It is important to improve the components of the heat exchange equipment such that it influences greatly both the COP values and cost.

Research in high temperature generating system design, improvement of energy efficiency, larger size system manufacturing etc. should be increases as they are very few in number.

Appropriate political support is necessary, besides the increase of market. The policy decisions should be based on the wide and trusty database from the market and technical history. Presently, it is encouraging for Korea to join IEA HPP as a member country to identify their roles for the heat pump industry in the world.

5 REFERENCES

Data Base of Korea Refrigeration and Air-Conditioning Association, 2006 & 2007

Final Report, Pusan, 2000, “Heating system for floricultural complex by using Nakdong river water”

IEA Heat Pump Newsletter, 2003, Vol. 21. No. 3

J.T Oh, 2002, April, KARSE journal, “Heat pump development for fish raising farm with sea water”

KNEI, Year Book, 2007, “Yearbook of energy statistics”

KSCIA, 2003, CFC Focus 109, “Heat pump tendency in the world”, pp.5~8

Ministry of Commerce, Industry and Energy, 1997, Final Report, “Development of heat pump with sewage water”

Ministry of Science and Technology, 2001, Nov, “National technology road map”

S.R Park, 2002, March, KARSE journal, ”Heat pump case study by using river water and its technologies”

USA Energy Information Administration web site (2006). www.eia.doe.gov.