HEAT PUMPING TECHNOLOGIES IN ASIA AND THE PACIFIC: AN OVERVIEW

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ABSTRACT

The current overall picture of "heat pumping technologies" in Asia and the Pacific is briefly reviewed in this paper. Of the various facets of heat pumping technologies in Asia and the Pacific, the most outstanding feature of this region is the increasing demand for air conditioning of residential and commercial buildings. The rapid proliferation of air conditioning has been the main cause for pushing up power demand, causing shortage in power supply and deterioration of power load factor.

As the measure for power load leveling, cool storage system and thermally driven cooling system have extensively been used for air conditioning of buildings, shaping a unique market structure in this region. On the other hand, heat pumping technologies for heating purposes have vigorously been exploited in this region for space heating, tap water heating and industrial process heating.

Considering the huge market potential for air conditioning and heating, still left unexplored in this region, and the resulting future impact on global environment, development of advanced energy efficient and environmentally friendly technologies is of vital importance for the sustainable development in the foreseeable future.

Key Words: ***heat pumping technology, air conditioning, heat pump, Asia & Pacific***

1 INTRODUCTION

The market of heat pumping technologies in Asia and the Pacific, quite different from North America and Europe, is not a unified quasi-single market, where there are so many countries with variety of socio-economic and climatic conditions. In spite of the insufficient market data and relevant information available, we allowed ourselves to prepare this overview, focusing on heat pumping technologies for space conditioning, tap water heating and industrial heating and cooling, with the best use of information available. What helped us most, in collating the market data and information, was those collected and published by the Japan Air Conditioning and Refrigeration News (JARN) and world market survey by the Japan Refrigeration and Air Conditioning Industries Association (JRAIA).

2 CLIMATE & POPULATION

The region, we are going to cover in this paper, by our definition, is more precisely "East Asia and Oceania" as the area within the circle in Fig.1, geographically dispersed in both hemispheres stepping over

the equator. This region has a wide variety of climate condition, roughly be divided into several climate zones: very cold, cold, moderate, hot (sub-tropical), and very hot (tropical), with variations in humidity depending on whether it is coastal or continental climate.

Table 1 shows the population in countries and the annual average temperature in major cities. In this region, densely populated zone extend in the East to South Asia where climate is hot in summer or hot all the year round. The total population in this region is estimated to be over one half of the world total population. However, with the high percentage of developing countries, the total GDP of this region is estimated to be far below one half of the world total, and is still growing at a higher pace than other regions.

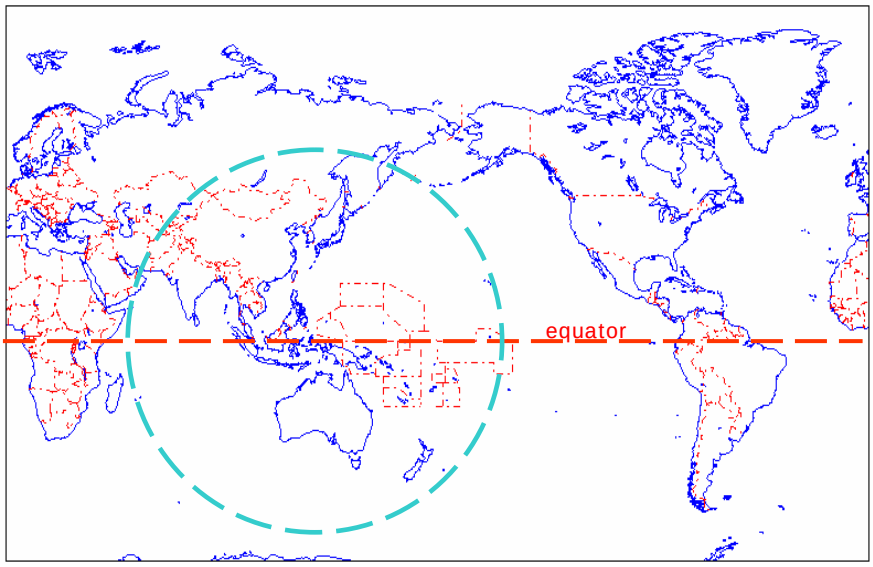

Fig. 1. Geographical location of the "Asia and Pacific" region discussed in this report

Table 1. Population and annual average temperature in Asia and pacific countries

Country	Population (million / 2002)	Annual average temperature (degree C)
Japan	127.44	15.6 (Tokyo), 16.3 (Osaka), 8.2 (Sapporo),
South Korea	47.64	11.4 (In chon)
China	1,280.40	11.8 (Beijing), 15.8 (Shanghai), 21.9 (Guangzhou)
(Taiwan)	22.45	22.3 (Taipei)
(Hong Kong)	6.79	22.9 (Hong Kong)
Vietnam	80.42	27.2 (Ho Chi Minh)
Thailand	61.61	28.4 (Bangkok)
Myanmar	48.79	27.3 (Yangon)
Malaysia	24.31	26.6 (Kuala Lumpur)
Singapore	4.16	26.7 (Singapore)
Indonesia	211.72	27.2 (Jakarta)
Philippine	79.94	27.4 (Manila)
Bangladesh	135.68	—
India	1,048.64	25.0 (New Deli), 27.5 (Mumbai)
Sri Lanka	18.97	27.4 (Colombo)
Australia	19.75	13.0 (Canberra), 17.9 (Sydney)
New Zealand	3.98	12.5 (Wellington)

3 DEVELOPMENTS IN MARKET & TECHNOLOGY

When we talk about the market of “heat pumping technologies“ in Asia and the Pacific, “refrigeration” for food preservation and “air conditioning” for comfort cooling and dehumidification seems to be of dominating importance, specifically in densely populated warm climate zone.

The current most significant feature of this region is the rapid growth of the air conditioning market. Furthermore, there still is a huge market potential for air conditioning, considering the large population and warm climate in Asia. The main driving force for the growth of air conditioning market in Asia and the Pacific has been decades of favorable economic growth during the 1980s and 1990s, symbolically expressed as “new emerging east,” although it slowed down after the financial crisis in 1997, which fit most of the Asian countries.

Recently, China has made the most significant progress in the demand and production of air conditioning equipment, becoming the largest market and supplier in the world of today. On the other hand, the demands in Japan and other Asian countries have been, more or less, in a standstill during the last decade, due to the staggering economy, and also to the saturation of market specifically in Japan.

3.1 Space Conditioning

3.1.1 Unitary air conditioners and heat pumps (RACs & PACs)

According to the world market survey by JRAIA, the market for residential and commercial unitary air conditioners and heat pumps (RACs: room air conditioners and heat pumps + PACs: packaged air conditioners and heat pumps) in East Asia has steadily been growing during the last 10 to 20 years. Fig.2 shows the market trend of RAC/PACs of the seven regions of the world, in which we can see that the RAC/PAC market in Asia & Oceania nearly tripled, during the last 15 years, to about 28 million units in 2003 from 11 million units in 1989, and the share of Asia & Oceania of the gross world market increased to 57 % in 2003 from 42% in 1989.

The break down of the RAC/PAC market by countries in Asia and Oceania in 2003 is estimated to be as shown in Fig.3, with the largest demand in China 18.0 million units/year, followed by Japan 7.2 million units/year, South Korea 1.5 million units/year and India 1.0 million units/year. The first wave of demand started in the 1960/70s in Japan, followed by the second wave in other Asian countries in the 1980s as shown in Fig.4. And then in China, as the third wave, the market has grown at an exceptionally high speed to a world’s leading position at the turn of the millennium from insignificant market size at the beginning of the 1990s.

The market penetration of RAC/PACs racks uniformity by countries in this region. For example, the penetration rate of RACs in Japan is estimated to have reached nearly 90 % (nearly 100% in urban area), on the other hand it is estimated to be far below 10 % in some of the developing countries like India, which shows a very sharp contrast between countries in Asia. It also signifies that there still is a huge market potential in this region.

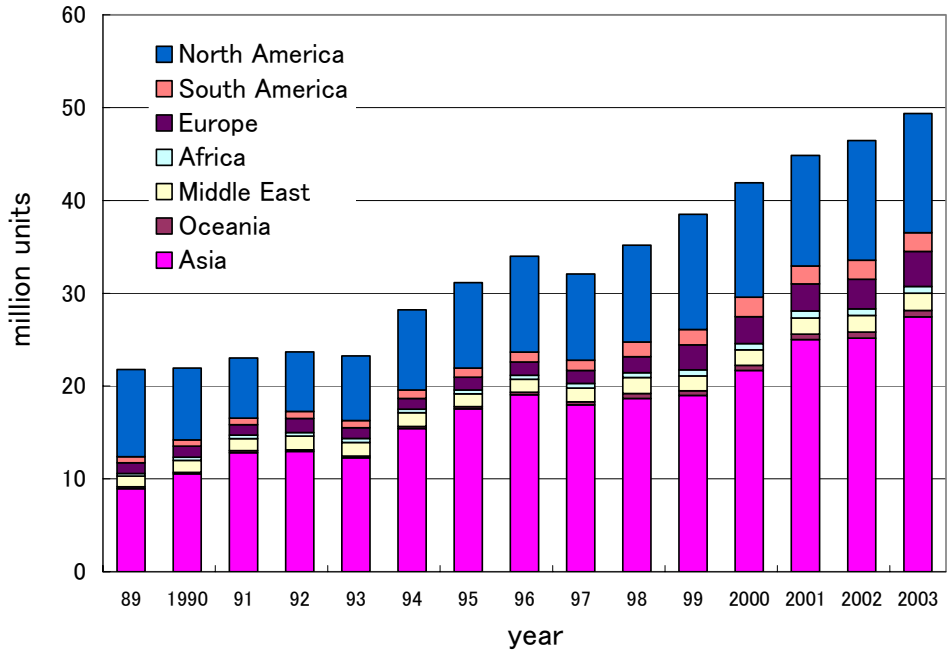

Fig. 2. Trend of regional RAC/PAC market (by JRAIA survey data)

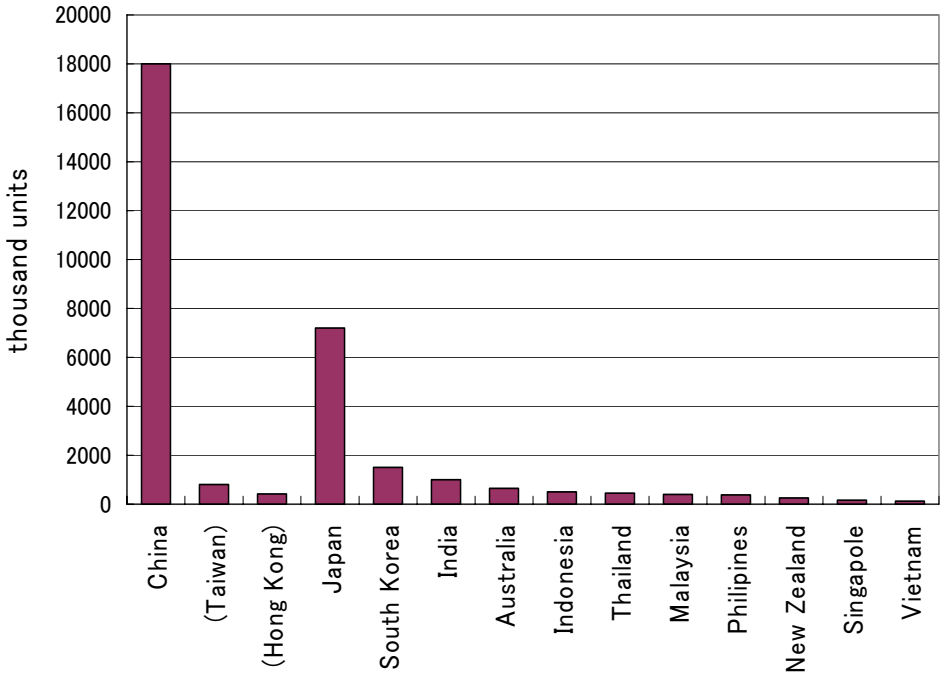

Fig. 3. RAC/PAC demand in countries of Asia & Oceania (year 2003, by JARN)

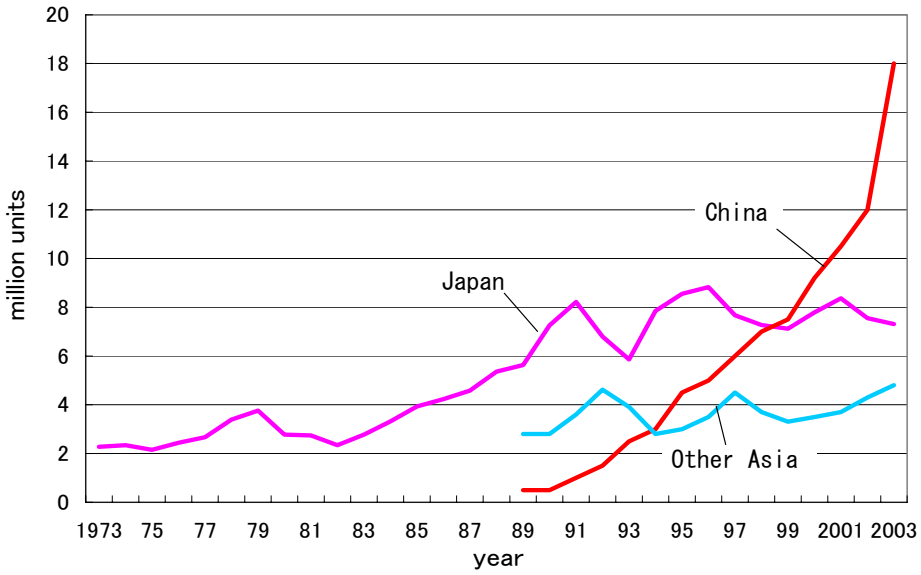

Fig. 4. Historical development of RAC/PAC market in Asia (estimation)

Of the variety of system configuration of RACs & PACs for residential and light commercial use, ductless split system is increasingly dominating the market. In the residential sector, ductless "mini-split" room air conditioners and heat pumps are increasing the market share in place of window-type room air conditioners by their flexibility of installation, quiet operation and other advantageous features. However, window-type air conditioner is still dominating the residential market in India although it is losing its market share. Also in the commercial sector, ductless "multi-split" variable refrigerant flow (VRF) system is increasing its market share.

Ductless split air-to-air reversible heat pump was originated and evolved in Japan after many years of insatiable cut-and-try development since its market introduction in the early 1960s, as products with more flexibility in installation with variations of indoor unit, e.g. floor, high-wall or ceiling installation than those of the US origin; window-type room air conditioners or ducted unitary equipment.

Of the many technological developments in Japan, two key developments contributed to the improvement of performances of ductless split systems. Firstly, the inverter driven variable speed technology in the early 1980s dramatically improved heating performance and thermal comfort of reversible heat pumps to a level competitive with conventional fossil fuel fired heating devices. Secondly the DC motor technology employed in the 1990s was one of the main drivers for enhancing energy efficiency.

We can also find fairly significant market for heat pumps for space heating in regions with moderate climate, typically in China and Japan, mostly with air-to-air reversible heat pump for heating in winter and cooling in summer. Of the total RAC/PAC market in Asia & Oceania, of about 28 million units, nearly 60% is estimated to be reversible heat pumps, since the Asia and Pacific market is predominated by the two big markets in China and Japan, where reversible heat pumps have high market share of about 60% and 98% respectively.

Technological development of heat pumps, to expand the operating temperature range to a lower ambient temperature, has been explored sporadically and is still on going. Commercial air-to-air heat pump that can be operated under cold climate condition down to minus 20 degree C is available in Japan.

3.1.2 Electric chillers and heat pumps

Electrically driven water-cooled or air-cooled chillers and heat pumps, with reciprocating, scroll, screw and centrifugal compressors, specifically for central air conditioning and heating of commercial buildings are widely employed in this region with the estimated current market size of about 70,000. As well as common water-cooled chillers, air source heat pump chillers are widely used for heating and cooling of residential and commercial buildings specifically in mild climate zone in China and Japan, with current market size of some 40,000 units/year by rough estimation, mostly with reciprocating or screw compressor.

Present market size of centrifugal chiller is estimated to be about 2,500 units constituting nearly 30% of the world market. High efficiency inverter driven centrifugal chillers, and as a quite recent development, “micro-turbo” (small centrifugal) chiller is in the market in Japan.

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3.1.3 Absorption/adsorption chillers

Outstandingly, Asia has the largest demand for water/LiBr absorption machines of all capacity ranges, with the estimated world market share of more than 90 % of the gross world market of about 10,000 units. The absorption chiller market is concentrated in China, South Korea, India and Japan. They are mostly installed in small to large commercial buildings, district cooling plants and in factories as steam or gas fired chillers. The market for NH_3/water system is still very limited in this region.

To a larger extent the demand for absorption machines has been driven by the need for power load leveling to cope with ever increasing peak power demand in summer. Other needs for absorption machine are waste heat utilization in industrial processes or cogeneration systems. The energy efficiency of absorption chillers has steadily been enhanced since the development of two-stage system in the 1960’s, and currently a project is underway in Japan on three-stage gas fired absorption chillers with a target COP of higher than 1.6.

Adsorption chillers, silica gel as adsorbent, have been in the market for years in Japan with limited number, specifically for low temperature waste heat utilization from industrial processes and cogeneration systems. Relatively active research and development on advanced adsorption system is seen in Japan.

3.1.4 Thermal (cool) storage systems

As a mean to shift peak power demand to off-peak time, ice or water thermal (cool) storage systems, coupled with chillers or heat pumps, have extensively been used in Japan, with total cumulative system installation of over 20, 000. There are also growing demand for ice thermal storage systems in Korea and China with an estimated total cumulative installation of about 1,000 systems. In addition to ice or water storage central air conditioning system, ductless multi-split ice storage system was uniquely developed in Japan in the early 1990’s, and the market has grown to about 10 thousands units/year with total cumulative

installation of about 50,000 units. Large ice or water thermal storage systems have rather extensively been used for district cooling in Malaysia and Japan.

The key motivation for the installation of thermal storage system is the employment of time-of-use electricity price structure favorable for peak power shift, with the current largest peak to off-peak price ratio of about four to one as seen in China and Japan, additionally backed up by incentives prepared by the government or electric utilities.

3.1.5 Gas heat pumps

Gas-engine heat pumps, or more precisely engine driven ductless multi-split heat pumps, have been developed in Japan in around 1990, successfully expanded the market to more than 40 thousands units/year with the total cumulative installation of about 600,000 units,. They are mainly installed in light commercial and institutional buildings such as schools, super-market and restaurants. The development of small gas absorption heat pump was active in South Korea and Japan for residential use. However, up to now there seems to be no commercial product available in the market.

There has also been a growing concern about gas-engine heat pumps in South Korea and China, and their market introduction started recently under the stringent need for mitigating peak power demand. Specifically in China, gas engine heat pumps are looked at as a promising alternative for space conditioning, since natural gas is becoming available in large cities in the east, under the big national project “transporting natural gas from the west to the east”.

3.1.6 Ground source heat pumps

The market development of ground coupled heat pump system has been rather slow in this region, although ground water was, in the past, used extensively in Japan as heat source and sink specifically before outdoor air came to be more commonly used as heat source and sink. Australia seems to be leading in the market development of ground coupled heat pumps, influenced by the US technology, with larger number of installations. As an example, in Canberra, a ground coupled system, possibly largest in the south hemisphere, is in operation since 1999 employing water loop system with 350 borehole heat exchangers and 220 water-to-air heat pumps.

There is also a growing concern about ground source heat pumps in China, South Korea and Japan. Specifically in China ground water is coming to be used extensively as heat source and sink, using water-to-water heat pump typically with modular heat pump system. In South Korea and Japan, ground coupled systems are more interested than ground water systems, influenced by the development in the US and Europe where the market of ground coupled heat pump has established a solid market position.

Concern about the use of building foundation piles as the ground heat exchangers, or as “energy pile”, is growing in Japan, from the need to reduce the ground heat exchanger cost since borehole drilling cost is usually by far expensive than in Europe and the US due mainly to the complicated ground structure and from the seismic nature of the country.

3.1.7 Desiccant systems

There is a growing concern about dehumidification of air by desiccant systems in countries of humid climate in this region, typically for application in supermarket where low humidity is specifically required. Other advantage for desiccant system is that it can be operated by low temperature waste heat, e.g. from cogeneration or industrial processes.

3.2 Tap Water Heating

3.2.1 CO_2 heat pump water heaters

Although the attempt to use air-source heat pump for tap water heating has been in place for many years in Japan, with very little market acceptance, due to the lack of economic feasibility. A new tap water heating heat pump, as the first commercial product using CO_2 as refrigerant, was developed in 2001 and is successfully being introduced into the market in Japan with the current market size of about 120,000 units/year and total cumulative installation of about 250,000 units, The unique feature of this heat pump is basically full storage system using off-peak cheap electricity, taking advantage of CO_2 system for the energy-efficient production of high temperature hot water of up to 90 degree C for hot water storage.

3.2.2 Solar boosted heat pumps

In Australia and New Zealand, direct expansion solar source heat pump tap water heaters have been used in numbers. This technology was developed in Australia using solar panel without glazing as a direct expansion evaporator.

3.3 Industrial Heating & Cooling

3.3.1 Industrial process heating & cooling

For industrial processes, e.g. distillation of alcohol or chemical products and condensation of milk or juice, limited number of VRC heat pump or absorption heat pump (type-1 and type-2) has been installed in Japan. Also limited number of heat pump has been used for drying lumber, aquaculture and horticulture in New Zealand, Singapore, China and Japan. However, as a whole, the market progress of industrial heat pump has been slow for a long time since oil price was stabilized in the late 1980s. For industrial process cooling, along with conventional chillers, increased number of absorption or adsorption systems driven by industrial or co-generation waste heat is coming to be used.

3.3.2 District heating & cooling

For urban district heating and cooling, large centrifugal chillers have been used in variety of ways, driven by electric motor or steam turbine. Water-to-water heat pumps have also been extensively used mainly in Japan utilizing various heat sources and sinks, like seawater, river water and sewage water. Heat recovery systems with water storage for simultaneous heating and cooling in winter, is a very common practice in Japan, not only for large buildings but also for district heating and cooling systems, coupled with water thermal storage systems. Surface water is also looked at as the heat source of heat pumps for district heating and cooling in China and South Korea.

In Japan, large air-source centrifugal heat pump chillers with “open heating tower” have been used mainly for district heating and cooling. Ice storage systems are also widely used for district cooling in Malaysia and Japan. Steam or water fired absorption chillers are also commonly used with co-generation system in Japan. A large number of water fired absorption chillers are used in South Korea installed on site of buildings and driven by hot water from the district heating networks.

4 POLICY & REGULATORY MEASURES

There is a growing impact of the market penetration of heat pumping technologies on the political issues like stable energy supply and global environment protection for the sustainable development. Followings are some of the measures being implemented in Asia & Oceania in this respect.

4.1 Energy Conservation

Energy resources are not evenly distributed in this region as in other regions. For countries like Japan, that have little energy resources and depend largely on imported energy, to curb energy consumption is of prime importance, and heat pumps for heating have been politically situated as a key technology for energy saving.

Along with the national program on energy efficiency of buildings, programs for the improvement of energy efficiency of equipment, e.g. air conditioners and heat pumps, through labeling or minimum energy performance standard is coming to be widely implemented in countries in Asia & Oceania. Specifically in Japan, an ambitious energy efficiency regulation have been put in place in 1998 as the “Top-Runner” energy-efficiency program” with a target COP of e.g. 5.27 for smallest capacity range mini-split air conditioners and heat pumps, as part of the revision of so called “energy conservation law”. In China a new energy efficiency standards for residential air conditioners will come to be in effect as of March 2005 to reduce the tension between power supply and demand and to help protect the environment.

In Japan, CO_2 heat pump water heater is highly expected to contribute to the greenhouse gas emission reduction, since energy consumption for tap water heating, mostly done with gas or oil fired heaters today, comprises about one third of the total energy consumption in the residential sector. As a measure taken by the government for greenhouse gas emission reduction, a robust subsidy program for residential and commercial CO_2 heat pump tap water heater is currently in place in Japan.

4.2 Power Load Leveling

As a result of the expanded use of air conditioning and the subsequent increase in power demand, in countries like China, South Korea, Thailand and Japan, it became stringent to sustain stable and efficient electric power supply coping with power shortage and deteriorating power load factor. Fig.5 shows, as an example, historical trend in the decrease of power load factor experienced during the last 40 years in Japan, which clearly correspond to the history of penetration of air conditioning starting at around 1970.

In order to cope with the deteriorating power load factor, typically in China, South Korea and Japan, thermal (cool) storage system or thermally driven absorption chillers or gas heat pump have actively been

promoted by the government and utilities. For example, in South Korea it is mandated to employ thermal storage system or absorption system for cooling of buildings with floor area larger than 3,000m^2. Price structures of electricity and gas, favorable for diurnal thermal (cool) storage or gas cooling in summer, have been in place in Japan for many years since low power load factor became an issue. For the last several years government's subsidy was available for multi-split ice storage systems in Japan.

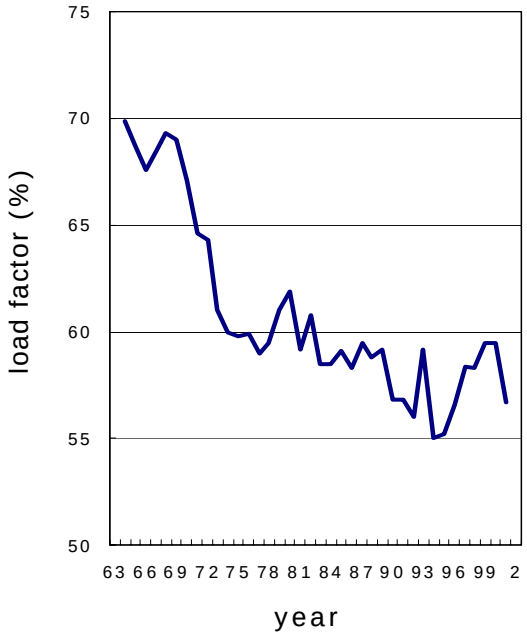

Fig. 5. Historical trend of power load factor in Japan

4.3 Environmental Issues

4.3.1 Phase-out and recovery of ODSs

Under the 1987 Montreal Protocol, countries in Asia and the Pacific have phased-out or are in the process of phasing-out ODSs (Ozone Depleting Substances: CFCs and HCFCs) as refrigerant. The situation of phasing out ODSs is different from country to country in this region. For countries defined as article 5 countries in the Montreal Protocol, phasing out ODSs is an issue to be tackled by the refrigeration and air conditioning industries. Other countries like Australia, New Zealand, South Korea and Japan have already phased out CFCs and are in the process of phasing out HCFCs and shifting to HFCs or other natural working fluids like ammonia, hydrocarbon and carbon dioxide. In Australia, hydrocarbons are being used in significant volume as refrigerant for refrigerators and mobile air conditioners.

Recovery, recycling and destruction of ODSs from scrapped equipment is an issue, and as part of the home appliances recycling law, refrigerant recovery from scrapped room air conditioners and household refrigerators is mandated in Japan since April 2001. Furthermore recovery and destruction of all fluorinated gases from commercial air-conditioning and refrigeration equipment and mobile air conditioners is mandated in Japan since April 2002 under the "fluorinated gas recovery and destruction law".

4.3.2 Greenhouse gas emission reduction

The issue of greenhouse gas emission reduction is closely related to the issue of energy conservation, as issues of both side of a coin. Extensive use of air conditioning and refrigeration is one of the main causes of increasing energy demand and subsequent increase in greenhouse gas emission. And this will become a more and more serious issue to be tackled in the coming years specifically in Asia, in order to comply with the 1997 Kyoto protocol in the short term and beyond the Kyoto protocol in the long term.

In addition to the issue of energy efficiency enhancement of heat pumping equipment, alternative refrigerant HFCs will come to be under some restriction of their use, which might give more chance for natural working fluids as the next generation working fluids. Natural working fluids are increasingly being examined as potential future working fluids in Asian countries.

4.3.3 Recycling of materials

For the purpose of natural resource conservation, the “home appliances recycling law” was enacted as of April 2001 in Japan which mandates recycling of materials, including refrigerants, from scrapped room air conditioners and heat pumps along with many other designated home appliances and equipment, and manufacturers are responsible for recovering and recycling their products by their own facilities. China is also moving toward the same direction, preparing laws and regulations, experimentally deploying disposal-recycling system in model cities.

5 CONCLUSIONS

During the last couple of decades we have seen a surge of air conditioning market expansion in Asian countries driven by economic growth in the region. Furthermore there still is a huge air conditioning market potential left uncultivated which will, in due course, bring about increased demand for energy and refrigerants in the coming years. Anticipated increase in demand for energy and refrigerants in this region will inevitably give birth to a fairly significant global environmental issue. Heat pumping technologies, on the other hand, has a large potential for contributing to energy saving in heating systems as alternatives to fossil fuel fired heating devices.

What we have to take into account today is to find a solution in achieving harmonious balance in economic growth, energy security and environmental protection. Therefore, the main challenge imposed for heat pumping technology, in achieving sustainable development, is to develop and deploy advanced technologies for the enhancement of energy efficiency of equipment and systems and environmentally friendly refrigerants and systems.

It is also expected that IEA heat pump program will contribute, as a vehicle for promoting international collaboration, to the development of heat pumping technologies with more active involvement of countries in Asia and the Pacific.

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