IEA Heat Pump CENTRE
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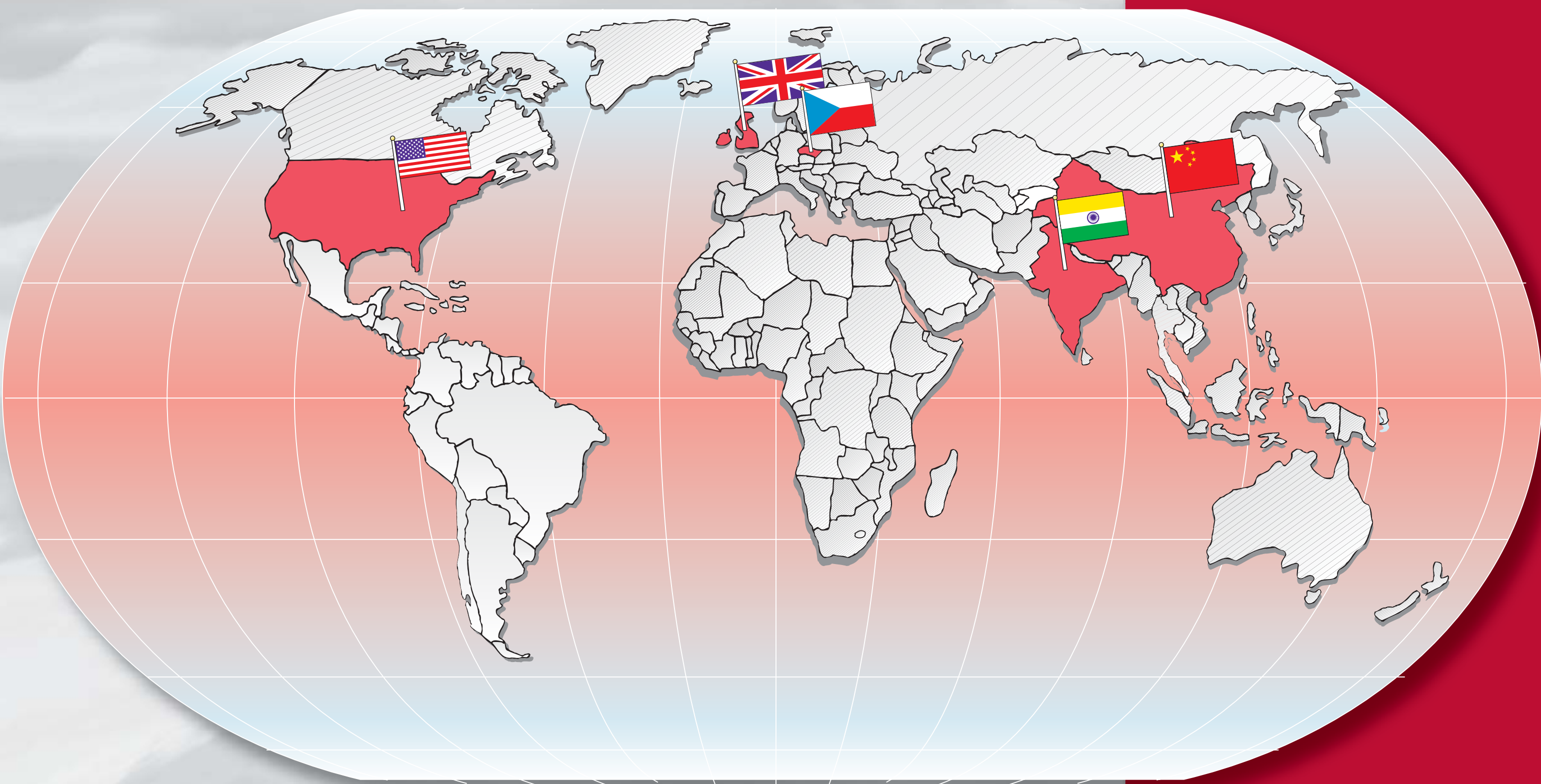
Heat Pumping Technologies in New Markets



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In this issue

Heat Pumping Technologies in New Markets

The topic for this year's final Newsletter is "Heat Pumping Technologies in New Markets". The aim is to introduce the political agenda, climate, buildings, user behaviour etc. that form the prerequisites for heat pumps, air conditioners and refrigeration equipment in countries where the use of heat pumping technologies is quite new or increasing. This issue features articles from the UK, Czech Republic and India. New markets can also be interpreted as new areas of use, and an article from the US describes how and why heat pumps may be used in automotive applications.

Heat pump news

Features

Topical article

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IEA OECD heat pump centre

Market potential for heat pumping techniques

Dr. Monica Axell
SP Swedish National Testing and Research Institute
Borås, Sweden

The theme of the fourth Newsletter for 2004 is heat pumping technology in new markets: an area that has not previously been covered in the Heat Pump Centre's Newsletter. However, we plan to present several articles on this theme, aimed at describing the potentials and conditions on new, growing heat pump markets world-wide.

Although refrigeration and heat pump technology has been well known for a long time, advances in research and development of products and systems have occurred unevenly. One reason for this is that varying physical and other conditions, particularly between countries, have meant that market potentials have varied correspondingly widely.

As far as refrigeration is concerned, there has generally been a need for, and a tradition of, using heat pump technology for such applications as the manufacture, storage and transportation of perishable foodstuffs and pharmaceuticals. The situations for space heating and domestic hot water production have differed more from country to country, largely due to the use of a number of competing methods for their provision. In addition, there are many factors that affect the maturity of technologies, their constraints and their market potentials. Important such factors include climate, the standard of buildings, the price of energy and the level of infrastructure. Another market for heat pumping technology that has growth potential is that of comfort cooling, not only in public buildings but also in residential properties, and particularly if we are facing future climate changes. We're therefore very likely to see a growing market for heat pumps that produce all three services: space heating, cooling and domestic hot water. In this issue, we describe the situation for heat pumps in the Czech Republic, UK and India.

The objective of Heat Pump Centres is to be the largest independent worldwide source of information concerning advances in heat pumping technology. To assist us in this, by extending the spread of the Newsletter, we ask existing readers to tell their contacts about the short e-mail version of the Newsletter, and to encourage them to subscribe to it.

Our first year as the Heat Pump Centre has been intensive and interesting. Both the Newsletter and the web site have been revamped, with a new layout. The Newsletter's layout has been modified to simplify electronic publishing and black-and-white printout. The e-mail version is a development of the Newsletter, with the aim of saving time and simplifying for our readers. We've also introduced a guest columnist in each issue, in order to provide a personal input from those active in the technology. In this issue, Brigitte Bach from EHPA gives her personal comments.

We intend to continue to improve our service and, to this end, we welcome your views, wishes and suggestions.

All of us at the Heat Pump Centre wish you a Merry Christmas and Happy New Year, and look forward to meeting you again in our first issue of 2005, of which the theme will be 'Systems and Controls'.

Monica Axell

Columnist

VISION 2010 for the European Heat Pump Association

Brigitte Bach
Vice-Chair of the European Heat Pump Association (www.ehpa.org)
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The situation on the world energy markets clearly shows that every alternative to fossil energy supply will gain on a short to medium term basis. This is particularly true for the huge energy demand for heat supply. For regenerative heat supply, heat pumping technologies play an increasing role, already evidenced by their steadily increasing market share across Europe. The ratification of the Kyoto protocol will definitely concentrate attention on reducing CO2 emissions.

Elected in June 04 as Vice-Chair of the EHPA, I intend to continue and further to strengthen the successful development of the Association. Our goal is to clearly demonstrate the potential for heat pumps to reduce CO2 emissions and the major role that they can play in achieving the Kyoto target. The EHPA should become the European information platform for heat pumps for all relevant stakeholders, with a particular focus on politicians and administrators.

To ensure a sustainable market growth of heat pumping technologies, we will focus strongly on common quality aspects and standardisation on a European scale. Quality labels and their European standardisation are of interest to both producers and users. It is the intention to host the DACH quality label (Germany, Austria, Switzerland) within the EHPA. Another important task during the next months involves collaboration for the forthcoming EU -Ecolabel for heat pumps.

European quality standards should also involve education and training. The EHPA and some of its member organisations are working closely together in an EU project (EU-CERT.HP) to determine a common training level, including certification, for heat pump installers and planners in all member countries.

We also intend to strengthen the internal and external network of experts to create more research opportunities. This is particularly relevant, due to the success of our first projects (e.g. SHERHPA). More cooperation projects are envisaged, especially in the sectors of Green Heat and quality management for drilling. The collation and distribution of market statistics on a European level will be an important service for decision makers.

To summarise, the EHPA will contribute as an information platform to show clearly the potential of heat pumps to reduce CO2 emissions and deliver the basic work which is necessary to ensure sustainable market growth.

On the theme of co-operation, close cooperation with the IEA and the Heat Pump Centre is very welcome and sensible, as both organisations already complement each other very well. We should further extend this cooperation to other existing contacts to ensure information exchange and the building of partnerships.

I wish everybody all the best for the New Year and fruitful development to the HPC and the EHPA in 2005.

Brigitte Bach

General

Kyoto Protocol to come into force on February 16, 2005

On 18 November, 2004, Russia formally handed over the accession papers on ratification of the Kyoto Protocol to Kofi Annan, Secretary-General of the United Nations. This means that the Kyoto Protocol will come into force on 16 February, 2005, - 90 days after the handover.

When the Protocol comes into force, it means that:

- 30 industrialised countries will be legally bound to meet quantitative targets for reducing or limiting their greenhouse gas emissions;
- The international carbon trading market will become a legal and practical reality;
- The Clean Development Mechanism (CDM) will move from an early implementation phase to full operation. The CDM encourages investments in developing-country projects that limit emissions while promoting sustainable development.
- The Protocol's Adaption Fund, established in 2001, will start preparing itself for assisting developing countries to cope with the adverse effects of climate change.

Industrialised countries must reduce their combined emissions of six major greenhouse gases over the five-year period 2008-2012 to below 1990 levels. Japan should reduce emissions by 6 %, and the European Union should cut emissions by 8 %.

Developing countries, including Brazil, China, India and Indonesia, are also parties to the Kyoto Protocol but do not have emission reduction targets. However, as said by Klaus Toepfer, Executive Director of UNEP: "We have huge challenges in the areas of mobility and transport. We need the active engagement of the rapidly developing economies of China and India so that their development, involving a third of the world's population, is propelled on a cleaner and less carbon-intensive path".

Only four industrialised countries have not yet ratified the Kyoto Protocol, they are Australia, Liechtenstein, Monaco and the United States of America. Australia and the United States, together accounting for over one third of the greenhouse gases emitted by the industrialised world, have declared that they do not plan to ratify the protocol.

The Protocol and related issues were discussed at the 10th Session of the Conference of the Parties to the Climate Change Convention, which was held in Buenos Aires from 6 to 17 December 2004.

Source: Press releases at www.unep.org

New director of the IIR

France – Didier Coulomb has been appointed as the new director of IIR, with effect from October 1, 2004. He replaces François Billiard, who has been in office since 1999. D. Coulomb intends to pursue certain actions, such as making the IIR better known, developing IIR services and products and also attracting more young people.

Source: IIR Newsletter, no. 20, 2004

Agreement on standard for commercial air conditioners

USA – Air conditioner manufacturers and energy efficiency advocates have come to an agreement regarding the Federal energy efficiency standards for air conditioners and heat pumps used in commercial buildings. Current Federal standards were established in 1992, and stipulate that the most common type of equipment must have an energy efficiency ratio (EER) of at least 8.9. Under the new agreement, the EER must be 11.2 as of January 1, 2010; a 26 % increase in efficiency. In addition, the new agreement extends the Federal standards program to large packaged commercial air conditioners and heat pumps. The agreement was negotiated by the Air Conditioning and Refrigeration Institute (ARI) and the American Council for an Energy-Efficient Economy (ACEEE), a non-profit organisation.

If approved by Congress, this standard will - according to ACEEE - reduce the peak power load by about 7 400 MW by 2020, equivalent to the output of 25 new 300 MW power plants. According to William Sutton, president of ARI, "The agreement gives manufacturers regulatory certainty to develop new models for 2010 that will meet both the new efficiency standard and EPA regulations to phase out the use of HCFC refrigerants that can deplete the ozone layer".

Source: ARI News List, www.ari.org

Certification of central air conditioners

EU – Air conditioning constitutes a rapidly growing end use of electricity in the European Union, yet the scope for improving its energy efficiency has not been fully investigated. A just-finished project has identified the most suitable measures for increased efficiency of commercial chillers and AC systems. The work was performed by twelve participants from eight countries, including Eurovent. With present energy efficiencies and the current situation ('business as usual'), the 51 TWh of electricity used in 2000 can be expected to rise to 95 TWh in 2010. Optimising a chiller for its lowest LCC shows considerable scope for applying part-load control. The optimal level of performance for the chiller considered is about 40 % more efficient than present bottom of the market products. The SEER ranges between 3.0 and 3.5, with an initial cost that is 12 % higher than the poorest chiller, so giving a short payback time.

There therefore seems to be a margin for improvement. A grading system for chillers and AC systems has been proposed to Eurovent, taking the part-load operation into account. A European SEER method has been proposed as grading system.

Source: Eurovent/Cecomaf Review, September 2004

ASERCOM energy efficiency award

Germany – The second ASERCOM Energy Efficiency Award has been presented by ASERCOM, the Association of European Refrigeration Compressor and Control Manufacturers. The award was given jointly to Oxycom BV, Netherlands, Volair BV, Netherlands and Carrier Nederland for their commonly-developed dewpoint cooling system, which uses the principle of evaporative cooling. The award was presented at the opening ceremony of the IKK-Exhibition on October 13, 2004, in Nürnberg, Germany.

This dewpoint cooling system is an indirect system where the added water is kept apart from the conditioned air. The technology can produce unusually low temperatures of the conditioned air, below the outdoor wet bulb temperature. Depending on comfort demands, the dewpoint cooling system can be used as a pre-cooler to reduce the energy used by conventional air conditioning systems.

The ASERCOM award is given for the most valuable energy-saving concept or system in refrigeration, air conditioning or heat pump technology.

Source: www.asercom.org

Emilia Müller State Secretary of the Bavarian State Ministry of the Environment, Public Health and Consumer protection, has handed over the ASERCOM Energy Efficiency Award to Oxycom BV, Volair BV and Carrier Nederland. Photo: Nürnbergmesse.

The 2004 ASERCOM Symposium

Germany – "Our future in Europe: climate change – environment protection" was the subject of the ASERCOM Symposium held the day before the opening of the IKK Trade Fair in Nürnberg, Germany. The focus of this event was the F-gas legislation proposed by the European Commission. A reduction of emissions of fluorinated gases is requested, and so 'containment' was one of the main topics of the presentations and papers. The use of natural refrigerants as an alternative was also highlighted. Hermann Renz, Bitzer, gave a presentation on the applications of various refrigerants – fluorocarbons and their alternatives.

In another presentation, Erberhard Wobst, ILK, demonstrated that the greatest potential for CO2 emissions reduction is offered by higher system efficiency.

The symposium also heard a presentation by Darcy Nicolle, UTC, on legislative measures such as the WEEE/RoHS Directive on disposal of electric and electronic waste and the handling of hazardous substances.

Source: www.asercom.org

Technology & Applications

LG Electronics, world's first with 10 million units sold in one year

South Korea – Fuji-Keizai, a Japanese market research company, recently announced that LG Electronics sold more than 10 million air-conditioners during 2004. That is the first time ever that a company has sold more than 10 million units in one year: in addition, the sales were achieved in severe competition with Chinese and Japanese manufacturers. For the 2004 season, LGE launched '2in1 plus', an upgraded version of their former '2in1' system (two indoor units connected to one outdoor unit), by adding an air purifier to the system. The price is basically unchanged, thus adding the air purification at no cost.

Source: JARN, no. 11, 2004

New HVAC&R association formed in Switzerland

Switzerland – As a sign of dissatisfaction with the current Suissetec Association, Swiss manufacturers and suppliers of HVAC&R equipment have formed a new association under the name of ProKlima, with effect from January 1, 2005. Approximately 80 companies, representing 70-80 % of the Swiss market, have expressed interest in joining the new association. The main objective for the association is to provide Swiss HVAC&R companies with a common platform for open and constructive information exchange. ProKlima will be organised into market segment groups and working groups, which will each be coordinated by a chairman.

More information on www.proklima.ch

Source: CCI Print, no. 11, 2004

Mahana Blue dairy heat pump water heater

New Zealand – A specialized heat pump water heater called Mahana Blue is being sold by Danfoss New Zealand, designed to recover heat from the milk cooler in a dairy. It can also be used in supermarkets, breweries and other processes where refrigeration equipment is used and where there is a need for hot water for sterilization etc. The Mahana Blue system takes the waste heat from the milk cooler's condensers and raises the temperature to 85 °C. It can be installed as an aftermarket product as a retrofit or in a new system.

Dairy farms use a lot of energy for hot water heating. Electricity bills

can be as high as USD 1000 per month. Hot water at 85 °C is required for sterilizing equipment after each milking. Warm water is also used to wash cows' udders before and after milking. In field tests, the system has shown savings of approximately 60 % over traditional water heating systems, giving a pay-back time of 2.5 – 3 years.

Source: In Hot Water, vol. 2, issue 6, July 2004

Heat pump efficiency dependent on installation

Germany – The energy efficiency of a heat pump installation is dependent not only on the heat pump itself but also on the quality of the installation. In a project run by Eon Energie AG in München, Gemany, field measurements were made on 29 heat pump installations. The effect of the installation was shown to be significant, in that the seasonal performance factor (SPF) of similar heat pumps varied from 2.4 to 3.7. The SPF also showed a higher value for ground-source heat pumps than for air-source heat pumps. Due to lower operating costs, the ground-source heat pumps is more cost-efficient (based on total cost) than gas or oil boilers. In addition, heat pump systems reduce CO2 emissions by 30-50 % compared to oil or gas boilers.

Source: CCI Print, no.11, 2004

Plan for increased use of geothermal heat pumps in Japan

Japan – The Japanese Department for the Environment has started a programme to increase the use of geothermal heat pumps in public buildings. The programme will include geothermal heat pumps in hospitals, libraries and town halls in 60 places around the country. The Government and local authorities will finance the main part (2/3) of the installation costs. The Department claims that the increased use of geothermal heat pumps will reduce energy use by 40 %. In addition to saving energy, it will reduce the "heat island effect" with excessive heating of urban areas.

Source: Kulde Skandinavia (in Norwegian), no. 5, 2004

Reducing air conditioning's contribution to global warming

UK – Much work is being done in the EU to reduce greenhouse gas emissions from air-conditioning equipment. But how much energy is used by air-conditioning systems in real installations? To help answer this question, the Welsh School of Architecture at Cardiff University investigated the energy use of over 30 air conditioning systems in office buildings. The systems, including all-air, fan coil, chilled ceiling, DX split, DX vrf and unitary heat pumps, were monitored at 15-minute intervals over a three-year period. The results show that chilled ceiling and beam systems appear to be the most energy-efficient way to provide cooling in UK offices.

In general, most systems seem to be poorly controlled: 50 % savings seem to be achievable by applying effective time control alone. Also, most system capacities seem to be twice as large as the loads encountered. One of the major implications of the study is that if all air-conditioning equipment, new and existing, was progressively replaced by the most efficient current existing systems, then by 2020 the carbon dioxide emissions from air conditioning systems could be reduced by 58 % from 2000 level, despite the projected market growth of air conditioning systems during this period.

Source: Building Services Journal, August 2004

Hard and hydrophobic layer for coating

Germany - Howatherm Klimatechnik, in Brücken, Germany, has developed a means of coating the inside surfaces of ducts, fans and heat exchangers to prevent moisture deposition and corrosion. The technology uses nano-particles designed to create a hydrophobic layer to repel moisture droplets. They also form a hard surface which resists scratching, and is also said to resist corrosion. In a variant, the film can be made bactericidal by adding titanium dioxide and silver to the mix.

Source: JARN no. 10, 2004

Markets

Goodman Global acquired by Apollo Management

USA – Apollo Management, a New York based investment company, has acquired Goodman Global, the largest family-owned maker of air-conditioning and heating equipment in the US. Goodman is known for its Amana brand air-conditioning and heating systems.

Source: ASHRAE e-Industry, December 9, 2004

Sweden's largest heat pump manufacturer acquired by BBT Termotechnik

Sweden – IVT, the largest heat pump manufacturer in Sweden, has been bought by BBT Termotechnik, a subsidiary company of the German company, Bosch. BBT Termotechnik is Europe's leading manufacturer of heating products. IVT's chief executive, Johnny Wärnelöv, states that IVT will become the heat pump development centre for the entire world-wide Bosch group.

Source: www.ivt.se

The French air conditioning market booms

France – During the first quarter of 2004, French air conditioning manufacturers increased their average turnover by 2.9 %. The largest increase was noted for companies with more than 50 employees. This increase is due to the booming air conditioning market, which on average increased its turnover by 7.9 %. Direct expansion air-conditioning systems increased by 10.7 %, individual reversible units increased by 9.4 %, secondary systems increased by 6.6 % and non-reversible units increased by 4.6 %.

Source: Die Kälte & Klimatechnik, no. 10, 2004

The market for residential central AC systems increases rapidly

China – The market for residential central air conditioning systems is increasing rapidly in China. The sales value for 2003 exceeded RMB 6 billion – a 42 % increase since 2002. Eight enterprises (Daikin, Trane, York, McQuay, Tsinghua Tongfang, Haier, Midea and Tica) dominate the market, with almost 80 % of market value. The market value is expected to exceed RMB 10 billion in 2006 and reach RMB 20 billion in 2020. Central AC systems for the residential market include multi ACs, VRFs and small chillers. The main market is concentrated to the well-off southern regions of China.

Source: JARN, no. 11, 2004

The PAC market in Japan increases

Japan – Shipment of packaged air conditioners in Japan increased by 11 % during the refrigeration year 2004 (Oct 03 – Sept 04) compared with the previous year, reaching an estimated total shipment of 700,000 units. This increase is probably due largely to the 2004 summer heat wave and more stringent regulations concerning energy conservation and the environment.

Source: JARN, no. 11, 2004

Working Fluids

York stops using HCFC-123 in chillers

USA – With effect from November 15, 2004, York International has stopped offering new chillers using HCFC-123. HCFC-123 is designated by the Montreal Protocol and the US Clean Air Act as a transitional refrigerant, to be used only for a limited time. As YORK now has a full portfolio of HFC centrifugal chillers, it has decided to stop producing chillers using HCFC-123. However, it will continue to support existing CFC and HCFC equipment.

Source: ASHRAE e-Industry, November 11, 2004

The EU F-gas regulation

EU – The planned EU regulation on fluorinated gases (F-gases) will provide a common basis for the whole union. The current situation in the member states is that the regulations are far from uniform. If the EU member states reach an agreement at the second reading in 2005, the F-gas Regulation will come into force in 2007.

The planned regulation includes hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). Although these gases constitute only 2 % of the total current volume of greenhouse gases, their overall global warming potential is high. If nothing is done, emissions of fluorinated gases would increase from 65.2 million tonnes of CO2-equivalents in 1995 to 98 million tonnes in 2010. It is estimated that the proposed measures will reduce emissions by more than 20 million tonnes of CO2-equivalents per year until 2012, and then by 40-50 million tonnes per year, once the regulation is fully implemented.

The F-gas Regulation does not ban specific products, but rather aims at a responsible use of F-gases. This includes prevention and minimisation of leakages, compulsory leakage inspections, leakage detection systems and record-keeping. Also, widely-recognised training and certification of responsible personnel is required.

While the F-gas Regulation concerns stationary equipment, an EU Directive is proposed for vehicle air-conditioning. This directive stipulates a gradual phase-out of R134a in vehicle air-conditioning equipment by the year 2017.

Source: Scandinavian Refrigeration, no. 6, 2004

High-capacity chillers using R410A

Carrier Corporation recently launched the world's first high-capacity liquid chiller, for commercial applications, using R410A as refrigerant. The AquaSnap series, at present manufactured in France, includes 14 cooling capacity sizes, from 190 to 760 kW, and eight reversible heat pump models with heating capacities from 220 to 540 kW. The use of R410A is claimed to improve the thermodynamic efficiency of the main components and also improves the overall energy efficiency.

Source: JARN no.11, 2004

ISCEON®79 licensed in the US

USA –ISCEON®79, a refrigerant manufactured by Rhodia UK, has now been licensed in the US by National Refrigerants. The ASHRAE designation is R422A. The recommended safety classification is A1 (non-toxic and non-flammable). R422A is an HFC and is a blend with the following composition: 85.1 % R125, 11.5 % R134a and 3.4 % R600a. Its ozone depletion potential is zero and its global warming potential is lower than for R404A and R507. It is intended as a replacement for R502, R402A/B, R408A, R404A and R507, while low-temperature systems using R22 can be retrofitted to R422.

Source: IIR Newsletter no. 20, 2004

IEA Heat Pump Programme

Annex 30 kick-off meeting in Nürnberg/ Germany

The kick-off meeting of the new Annex 30, Retrofit Heat Pumps for Buildings, was organised in connection with IKK 2004 – 25th International Refrigeration, Air Conditioning and Ventilation Trade Fair on 14th October 2004 at the exhibition venue in Nürnberg/Germany. The meeting was attended by representatives from Belgium, Germany, France and Sweden.

Prof. Dr.-Ing. Dr. h.c. H. Kruse, head of the German IEA HPP National Team and chairman of the German Information Centre on Heat Pumps and Refrigeration – IZW e.V., and Dr. Claus Börner, Projektträger Jülich, German ExCo delegate, opened the meeting and welcomed the participants.

Prof. Kruse underlined the great interest in Germany on the work to be covered by the new annex, and pointed out that IZW e.V. had chosen the same topic for its exhibition stand and lecture at IKK 2004.

Prof. Dr .H.J. Laue, IZW e.V. presented the latest version of the annex proposal. The following modifications have been introduced, to cover the situation in all member countries of the IEA-HPP:

- The annex will be concentrated on residential buildings only.
- Centralised and decentralised heating and cooling systems will both be considered.
- Hydronic and air-to-air distribution systems will be considered.

Prof. Kruse invited the participants to describe the retrofit heat pump situation in their countries/organisations, and started with a summary of German R&D work related to retrofit heat pumps.

Mr. Jean-Benoit Ritz described the French development of a heat pump market as part of EDF's energy efficiency strategy, with specific emphasis on retrofit heat pumps.

Mr. Ansgar Thiemann, DAIKIN Airco Germany, reported on a German retrofit project of an apartment building in the city of Essen, where the old electric overnight heating system has been replaced by an inverter-driven multi-split air-to-air heat pump system. The new system resulted in a 70 % reduction of energy consumption and energy costs.

Mr. Bichler described the heat pump compact ventilation devices for passive solar houses as a possible contribution to the new annex by the Fraunhofer Institute - ISE.

Mr. Urban Kronström, IVT Industries AB, summarised the heat pump situation in Sweden. Of the nearly 50 000 heat-only heat pumps (i.e. not domestic hot water heating as well) sold in 2003, 90 % are ground-coupled brine/water systems. In addition, 15 000 air-to-air reversible heating and cooling heat pumps were sold. First estimates for 2004 indicate an overall increase of about 30 %. At present, around 80 % of all new one- and two-family houses are equipped with heat pumps, but the market is already dominated by retrofit systems in old buildings.

The general discussion indicated a unanimous wish to start the Annex on 01.01.2005, with broad participation from the majority of member countries. It was proposed to charge an annual fee of € 7.000 per participant.

After a summary of the present situation and possible trends for the strengthening of the retrofit heat pump market, major contributions from the present participating countries were defined. The results of meeting have been incorporated in the final version of the Legal Text of Annex 30.

The minutes of the meeting can be downloaded from www.izw-online.de

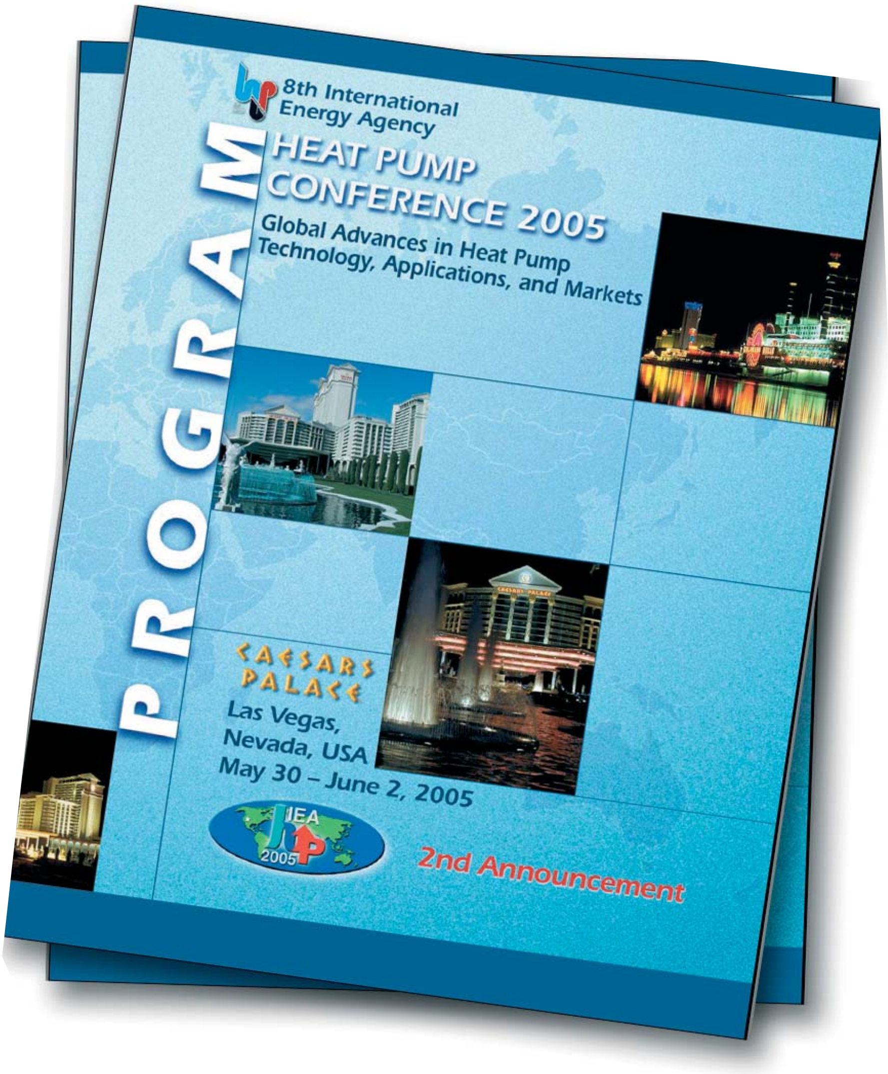
For further information, please contact the proposed operating agent, IZW e.V., Hannover: email@izw-online.de

Source: IZW e.V. Hannover, Germany

Heat pump conference in Las Vegas

The 8th IEA Heat Pump Conference will be held on May 30 to June 2, 2005 in Las Vegas, Nevada, USA. The second announcement with general information, technical programme and registration information, is now available. It can be downloaded from the conference web site, http://www.ornl.gov/hp2005/

Source: Heat Pump Centre



Ongoing Annexes

Bold text indicates Operating Agent.

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IEA Heat Pump Programme participating countries: Austria (AT), Canada (CA), France (FR), Germany (DE), Japan (JP), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US). All countries are member of the IEA Heat Pump Centre (HPC). Sweden is Operating Agent of the HPC.

The UK heat pump market

Roger Hitchin, UK

Background

The UK is not, strictly speaking, a new market for heat pumps: the first domestic installation is said to have been over 100 years ago; in the early 1950s London's Royal Festival Hall was heated by a water-source (the River Thames) heat pump; in the 1970's air-source heat pumps were promoted and sold as energy-efficiency products. On the whole, these installations did not live up to expectations and have left a legacy of half-remembered suspicion which means that today's products start from a somewhat worse position than technologies that are perceived to be "new".

Nevertheless the carbon emissions case for heat pumps is now stronger than ever, the use of heat pumps is slowly growing, perceptions of today's products are generally positive, and the major players are careful to learn from the lessons of the past.

The UK has been described as an island of coal, sitting on a bubble of gas, surrounded by a sea of oil. We might also add all the wind, wave and solar energy that falls on our shores and land. It has well-developed national gas and electricity supply networks which, for the last decade or so, have been regulated private businesses serving a competitive market of energy suppliers. Although there are some interconnections with mainland Europe, relatively small amounts of gas or electricity are traded internationally – though gas imports are expected to rise appreciably during the next decade. Oil, of course, is a globally traded commodity but is hardly used in buildings in the UK.

Electricity generation, traditionally coal-based, is now split between nuclear, coal and gas, with coal use declining as gas increases. The increase in gas imports is expected to be associated with increases in prices, but the competitive position of coal will suffer from the effects of carbon when the European Emissions Trading system comes into force.

The climate is maritime, with relatively mild, moist winters – the usual outdoor design temperature is -4C. Defrost energy for air-source heat pumps is a significant issue for this type of climate. Although the summers are not hot by southern or central European standards, the use of air-conditioning is growing steadily in commercial buildings. Although use of cooling in dwellings is projected to grow rapidly, this is from a very low base and the commercial sector will continue to dominate the market

The government's goals for energy policy are:

- to put ourselves on a path to cut the UK's carbon dioxide emissions - the main contributor to global warming - by some 60% by about 2050 with real progress by 2020;
- to maintain the reliability of energy supplies;
- to promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve our productivity; and
- to ensure that every home is adequately and affordably heated.

There are a number of initiatives and programme to encourage energy efficiency and to support renewable energy – albeit these not as well-integrated as they might be.

The goal of reducing carbon emissions by 60% by 2050 originated in a report by the Royal Commission on Environmental Pollution in 2000. This included four illustrative scenarios to outline how the goal might be achieved. Although it was not spelt out in the report, the scenarios assumed that heat pumps would have a major role to play. In the most extreme case, electric heat pumps would satisfy most of the demand for low-temperature heat and over a third of the demand for high-grade heat. For this scenario to happen there would have to be substantial changes to the gas and electricity supply infrastructure: however, the scenarios are not policy blueprints, but illustrations of technical feasibility.

Today, by far the most common form of heating is still the individual gas-fired radiator system. Because of the relatively mild climate, it is usual to switch the heating off at night, and during the day when dwellings are unoccupied. The need to reheat the building reasonably quickly in the morning usually creates the biggest heating load. Water heating is traditionally with a storage cylinder supplied by the heating boiler, but combi-systems are gaining in popularity. There is very little oil-fired heating, and only a small proportion of district heating.

A significant minority of dwellings have electric heating. This is almost always a mixture of storage and direct heaters. It is usual for a dwelling to have a single-phase (230v) electricity supply. This restricts the connected load that is possible – and therefore the size of heat pump - without incurring the additional costs of a three-phase supply.

Potential Carbon Saving through Heat Pump Use

With the decreasing carbon intensity of power generation in the UK, as coal has been replaced by gas, the carbon-saving potential of electric heat pumps has increased substantially during the last 20 years. The carbon break-even seasonal Coefficient of Performance compared to a condensing gas boiler has fallen from about 4 in 1980 and 3.5 in 1990 to just over 2 today. Based on projections of power generation mix, it will fall still further, if not so spectacularly, during the next two decades. Today's breakeven COPs are well within the technical capabilities of existing equipment for many applications. With the commercialisation of combined-cycle gas turbine power generation, it is now more carbon-efficient to generate electricity from gas and convert it to heat in a heat pump, than to burn gas in a condensing boiler. Thus, from a carbon emission perspective, many heat pump applications that would not have been attractive 10 years ago, are now worthy of serious consideration.

The technical potential for carbon savings by the use of heat pumps for heating buildings - if all existing heating systems were replaced by current technology heat pumps - is over 5 MtC pa.[1]. Of this, about 2 MtC pa is attributable the replacement of direct and storage electric heating in dwellings, another 2 MtC pa to the replacement of fossil fuel systems in dwellings and 1 MtC pa to the replacement of fossil fuel heating in non-domestic buildings. With technically feasible performance improvements [2] the potential rises to over 8 MtC pa. There are additional smaller, but still worthwhile, savings in applications to industrial processes. It is clear that the technical potential is predominantly in housing – though the existing market is overwhelmingly in commercial buildings.

Only a very small proportion of this potential is being tapped. The principal market barriers are cost-effectiveness and purchaser confidence – itself reflecting the absence of an established, well-regulated supply and installation structure. Many potential purchasers are wary of the technology, having memories of inadequate systems installed in the 1970s. The cost-effectiveness gap is generally smaller than for some other high-profile low-carbon and renewable alternatives, but nevertheless real, especially in competition with fossil fuel heating.

Markets and Hurdles

Non-domestic buildings

By far the largest existing heat pump market is for air-conditioning equipment that also has a heat pumping capability – that is, it can operate in a "reverse cycle" mode. The additional cost of providing reversibility is low - probably 10% or less of the equipment cost. In new buildings, where it is possible to avoid the cost of a conventional heating system, and provided that careful design is employed to ensure comfortable heat distribution, such systems are probably already cost-effective (assuming that the air-conditioning service can be justified in the first place) - and certainly meet the carbon emissions criteria of the Building Regulations. In retrofit applications, the off-setting capital savings from fossil fuel systems will only exist where the heating system needs replacing, but the running costs for heating will be comparable with those for gas. Analysis by BRE for the IEA Heat Pump Centre [3] suggests that this market currently provides carbon savings of about 0.04 MtC pa, which could rise to around 0.22 MtC pa by 2020. The current figure represents about 5% of the (technical) potential savings from heat pumps in non-domestic buildings. The 2020 figures assume continuing market penetration and technical improvement. Tax incentives, in the form of Enhanced Capital Allowances (allowing the cost to be written off in one year instead of over several) exist for heat pumps of suitable performance and, together with the EU Energy Labelling Directive for air-conditioners, should help to move the market in the direction of improved performance.

A new market opportunity – currently comprising only a few UK systems – is the application of ground-source heat pumps (see below) to commercial buildings. These promise to deliver heating and cooling at lower carbon costs than for conventional systems.

Dwellings

The carbon savings and economics for heat pump heating are better when heat pumps replace electric heating than when gas heating is available (though the avoided cost of mandatory annual safety checks for gas appliances in rented property can tip the balance in some new dwellings). Electrically-heated buildings – and especially dwellings situated outside the gas supply area - therefore provide an attractive market segment.

[1] *Assuming a seasonal CoP of 2.5.*

[2] *Say a seasonal CoP of 3, which is typical for today's ground-source heat pumps*

[3] *Reported in "J.Bouma, Achieving domestic Kyoto targets with building heat pumps in the UK, IEA Heat Pump Conference, Beijing, June 2002"*

This has become a target market for ground-source heat pumps. There are currently only a few hundred installations. Like other unfamiliar technologies, market penetration is restricted by the small size and fragmented nature of the industry and a lack of consumer awareness. The Clear-Skies programme provides grants and, perhaps more importantly, lists of manufacturers and installers. Apart from solar water-heaters, more grants are sought from the programme for heat pumps than for other renewable systems, but this is only about 100 per year. During 2004, the VAT rate on heat pumps was reduced to 5% in reflection of their energy saving role. The energy supplier Powergen has a programme to install 1000 systems over several years, principally in social housing.

There are around 4.5M households outside the gas supply area. Of these, about 1.3M are currently heated by electricity and either have reasonably high levels of insulation, or could economically have their insulation upgraded (heat pump economics improve if the dwelling is first insulated). If these systems are replaced every 20 years on average, that would represent a potential market of 65,000 systems. New housing is running at around 400,000 dwellings per year of which perhaps 80,000 are outside the gas supply area and 40,000 have electric heating. This suggests a total potential market size of the order of 100,000 per year. This is a relatively small proportion of the total heating market (though very much larger than current sales), but is focussed on an otherwise hard-to-reach sector. If the market was this large the carbon savings would still only be about one tenth of those from the existing non-domestic heat pump market.

The ground source heat pump industry believes that the potential market is rather larger than this, mainly because of the additional potential in major refurbishments. However, there is general agreement that market size is not likely to be a constraining factor in the medium term.

There are two key market barriers:

- Capital costs are high, but not impossibly so. The high cost item is the ground loop, typically representing 35%-40% of the total cost. UK costs appear to be higher than those overseas, so increasing market size and the consequent more efficient use of resources and increasing skill levels could lead to cost reductions.
- Consumer barriers: unfamiliar technology, uncertainty about continuing maintenance and service availability. Successful (but relatively costly) ways of reducing these barriers have been demonstrated in other countries but the relatively small companies currently trying to develop the UK market do not have the resources to set up support infrastructure on a comparable scale.

As can be seen from the figures given earlier, the replacement of fossil-fuelled heating systems offers the potential for substantial carbon savings. This is a much bigger challenge from an economic perspective. Even in new, well-insulated housing the pay-back period for a GSHP system is long relative to a gas system. A market on this scale seems unlikely to emerge without technical developments that substantially improve cost-effectiveness or substantial changes in the relative prices of electricity and gas.

While technical development may improve market penetration, especially within the gas supply area, the greater need is for market development – especially in terms of having a skilled design and installation workforce supported by an enforceable accreditation system in which consumers can have confidence.

Air source heat pumps are likely to be less costly but less efficient than ground source heat pumps– not least because of the defrost energy use - but could be easier to install in existing housing. They had disappeared from the market, but field trials of new products are now taking place.

Conclusions

The technical potential for carbon-saving through the use of heat pumps is large, the economically accessible market is much smaller, and the current market smaller still. As with other technologies that are unfamiliar to prospective purchasers, it is difficult for a small and fragmented industry to put in place effective market development and support mechanisms.

Nevertheless markets are developing, and at a pace that should allow the industry's capabilities and structures to grow in step with demand – which ought to mean sustainable growth rather than "boom and bust".

Clearly, there are countries with better-developed markets for heat pumps than the UK. This largely results from their different energy situations and consequent energy policies. Nevertheless the UK can learn from the technologies and market mechanisms developed in these countries. The IEA Heat Pump programme can be an important part of this process – but the most important issues are not essentially technical

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Heat pumping technologies in the Czech Republic – a short overview

Zdenek CEJKA, Czech Republic

Introduction

The Czech Republic belongs to the countries with developed industrial production. The main industrial sectors include mechanical engineering, chemical production, power generation, metallurgy, car production, electronics, glass and ceramics production and the food industry. The heat pump sector has a long tradition, as part of refrigeration industry. Some systems were built during 1960s – e.g. residential heating in Galanta, using geothermal energy as a source for an R12 W/W heat pump.

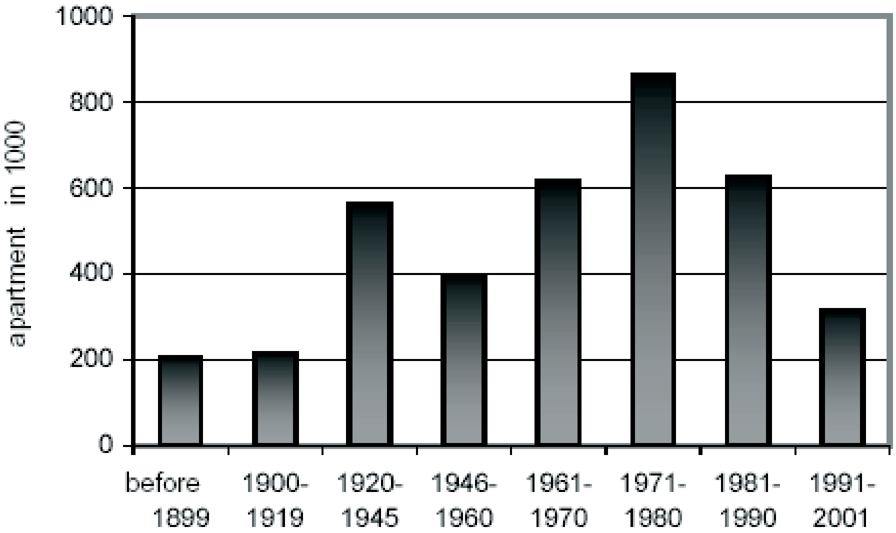


Diagram 1. Number of apartments (and small private houses) built in different periods up to 2001.

Climate

The Czech Republic is situated in the very centre of Europe, bordered by Germany, Austria, Slovakia and Poland. Its area is almost 79 000 sq km (30 000 sq miles). Several chains of mountains surround the country. The highest point is Sn žka, 1602 m (5222 ft). The capital, Prague, is in the middle of the western part of the country, 300 m above sea level. Forests cover one-third of the Czech Republic. The country is a four-seasoned country with a continental climate: the summers tend to be sunny and quite hot, the winters cold, spring and fall mild but changeable.

For detailed information on the Czech Republic, see http://www.czechsite.com

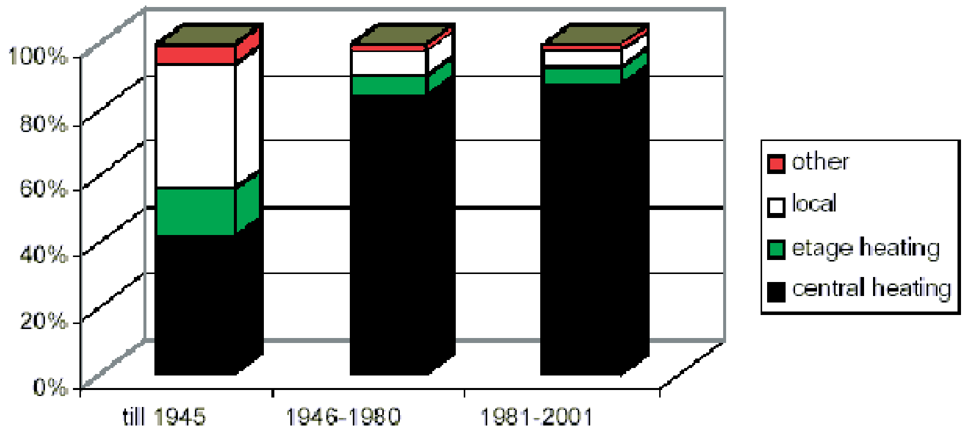


Diagram 2. Different types of heating systems: 'etage heating' means that there is a separate heating system for each floor in the building.

The housing situation

Diagram 1 shows the number of apartments (and small private houses) built in different periods up to 2001. The heating system depends on the type of building and when it was built. Diagram 2 shows types of heating systems: 'etage heating' means that there is a separate heating system for each floor in the building.

Heating-cooling, hot water systems

From the previous pictures it can be seen that most residential accommodation is heated by central heating systems. Space for heat pump installations is limited, especially for local heating systems, and sometimes for the etage type of heating and hot water production. A/C systems are relatively rare, especially in the private sector, but this situation is changing as split type aircon systems from Far East manufacturers are finding their way into the country, assisted by very low prices. As standard, the split units from China are reversible devices, capable of supplying heat during cold periods.

Some large cities use the waste heat from a nearby power station – distributing steam or hot water over several km. A plan was prepared to use the heat from a power station in the form of low-temperature water (low heat losses), with additional heating of this water at the delivery end by means of huge heat pumps.

Direct electric water heaters were recommended during the early 1990s until about 2000. However, this has fallen out of favour as a result of the state's new energy cost policy - also for heat pump application. The continuous process of gas distribution network installation has brought gas to small villages and towns with gas boilers and heaters.

Large frozen food stores, with temperatures down to 40 °C, are the main application in the refrigeration sector, although the continuous expansion of supermarket chains is also very important.

Certification

The Czech Republic's laws and rules say that every appliance, machine, device etc. must be certified by either a Czech national authority or by the authority approved by EU. Domestic production of heat pumps passes the certification process in one of the state's certification institutions (Prague, Brno), while imported products must have valid documentation – at least a Conformity Certificate and Manufacturer's Declaration, sometimes also PED approval and other declarations. The main Czech regulations are nos. 168/97, 169/97 and 170/97, and European Standard 97/23/EC. The majority of European standards have been issued as Czech standards in the national language and with some national amendments. ISO 9001:2000 quality certification of heat pump manufacturers is standard even for smaller organizations.

Electricity

The Czech Republic has a relatively high production of electricity, and exports electricity to neighbouring countries. The nuclear power stations are important and play a significant role in power production. The state company CEZ has a monopoly for energy production and distribution, although the distribution network is in process of privatisation. The energy distributors are divided according to the corresponding region, with each region having its own energy policy. Consider, for example, the tariffs in the East Bohemia region. The distribution company is VCE. Tariff D55 applies for heat pumps: two different prices of energy according to the time of day and the main fuse capacity. The price consists of two parts – the first part is fee for the electricity meter, the second for the electricity itself. Example: With a three-phase 20 A main fuse, a month's fee will be EUR 5,37: with a 32 A fuse, it will be EUR 8,59 etc. Two tariffs apply during the day: 0,125 EUR/kWh at peak hours, 0,031 EUR/kWh at off-peak hours. To use this system it is necessary to declare that the heat pump system is installed according to the heat demand and all corresponding standards. The time periods for the low tariff application are decided by VCE according to VCE rules.

Refrigerants

The Czech refrigeration, air conditioning and heat pump sectors use a very wide range of refrigerants. Ammonia is an important refrigerant, particularly for industrial refrigeration. The large cold store facilities use mostly R717, while the chemical industry typical uses R717. R717 is also used in the heat pump sector – the W/W heat pump of around 1,5 MW in the Kostelec food company uses it. The Czech producers of heat pumps use mostly R404A/R507 for A/W systems, and R407C for W/W and G/W types.

The imported heat pumps also use other refrigerants including R410A, and several Sanyo CO2 machines have been installed. R134a is used for high water temperatures, and R600 and R290 may also be used in heat pump applications.

Support of heat pump installation

As a result of continuous rises in the price of energy and gas, money and energy savings are increasingly interesting to the Czech legislative as well as to final users. The interest in heat pumps can be due to two sources: electricity distributor's price policies and the state policy. The Ministry of Environment has a program supporting heat pump installations. Every year, it publishes a new notice on how to obtain financial support for installation of a heat pump. The notice varies according to the final user of a heat pump – public sector, state sector or domestic - and according to the aim of support – training of installers, education of interested persons, publicity of the need to save energy, installation itself, etc. Some examples : a central heat source for a village(public sector), can obtain up to 40 % of investment costs, while a health centre, school, mental hospital up to 60 %, or a private house up to 10 % etc. An audit of the existing situation is required. All grants are of course limited by the total amount of funds available. Grants are paid after putting the heat pump into operation – but must be claimed within twelve months. Claims for grants must be submitted to the corresponding regional institution after installation of the heat pump, not before. The absolute value of grants is limited - for private houses, it amounts to a maximum of about EUR 3 000.

It is also possible to ask for grants for publication of books dealing with the theme specified by the Ministry, or for training of those involved in the heat pump sector– but support is not offered to private persons. The state support can provide up to about 60 % of the costs for a training program, to a maximum of EUR 4500, and up to about 25 % for publication of books etc. up to a maximum of EUR 7800. Those programs must be approved by the corresponding authorities.

In addition to the grants, the state offers a system of loans for different energy saving schemes. The public sector (town halls etc.) can ask a loan for up to 30 % of investment costs at an interest rate of about 1,5 % for twelve years. A company can ask for a loan of up to 70 %, with an interest rate of 4% for twelve years. Private houses are excluded from this part of state support.

In addition to other conditions for grants, the directive specifies the minimum COP of a heat pump:

Type HP: ground / water		
ground temperature in	water temperature out	minimum COP
0	35	3,7
0	50	2,7
Type HP: water/water		
water temperature in	condenser water temperature out	minimum COP
10	35	5
10	50	3,5
Type HP: air / water		
air temperature in	water temperature out	minimum COP
7	35	3,5
-7	50	1,8

Heat pumps using non ozone-friendly refrigerants are excluded from the program.

Heat pumps on the market

Heat pumps are delivered and installed by different suppliers

- Importer of heat pump represented by a Czech company: AEG, Trane, York, Daikin, Nibe, Carrier, Electrolux, IVT, Stiebel Eltron, Liebert Hiross, Buderus, Hennlich etc
- Importer of heat pumps of different origins: – "Master Term" represents Climat Master (USA) and Multiclima (F), "Tepelna cerpadla IVT" represents IVT Industries AB, "Polymat" imports Int. Comfort Product (US), "Geoterm" represents Ochsner (A), "Termo Komfort" represents Dimplex, "Bernako" handles LG heat pumps, "Klima-Classic" markets Toshiba, "Klima-Comfort" represents Hitachi, etc.

Heat pumps are also produced by domestic companies, which could be 100 % nationally owned, or partially international. This sector could be divided into regular producers and those making heat pumps as a tailor-made product. There is a surprising number of persons who make heat pumps for their personal use or for their neighbours. The amount of heat pumps made by these "heat pump fans" is not negligible.

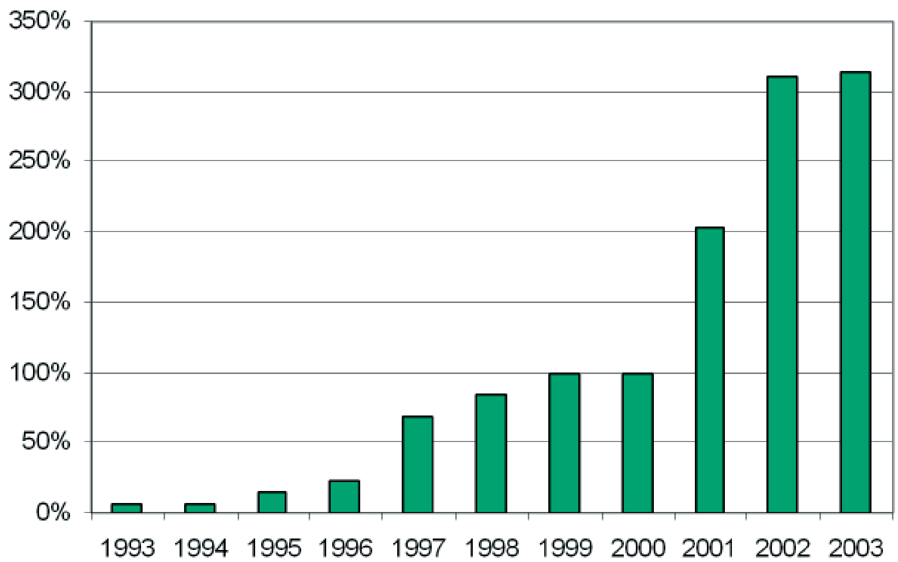
Some manufacturers operate under licences or operate as the local manufacturing facility of an international company:

- Airconfuji – air/water and ground/water heat pumps, producing about 100 units/year, up to 30 kW
- Protherm - air/water and ground/water heat pumps, about 50 units/year, up to 30 kW
- Ish - ground/water heat pumps, about 50 units/year, up to 30 kW

In the list of domestic producer we can include:

- PZP Komplet a.s., a company with a range of air/water and water/water heat pumps up to 40 kW heating capacity, producing up to 100 units per year
- Secespol s.r.o. produces ground/water heat pumps up to 100 kW, about 20 units per year
- ETL-Ekotherm s.r.o.
- TC Mach s.r.o. with a range of air/water and ground/water heat pumps up to 200 kW, and production about 100 units per year
- Jesy s.r.o. A/W and G/W heat pumps up to about 20 kW heating capacity, about 20 units per year
- Several manufacturers producing less than 15 units per year

New installation numbers are as shown in the diagram below.



It is very hard to provide exact data, as no official system of HP statistics exists. The diagram is taken from research by Prague University. The three pie charts below show the heat sources used.

Systems under development

Some Czech producers (PZP, TC Mach..) develop their own heat pump systems. Several solutions are protected by patent in different countries. Most development work is in the field of air / water defrosting technologies, although improvement in COP is also a working area. The first steps in CO2 transcritical HP systems are being made. Non-standard defrosting systems include, for example, the use of pre-heated liquid stored in an accumulator and used in separate liquid internal parts of an evaporator. Another design uses the liquid refrigerant. Some solutions use split air coolers, with one part being used as a heat source while the other is defrosting. This solution avoids decreasing heat production, which usually occurs in a reverse-flow system.

Market potential

There are some limits for heat pump installations. The first one is the purchasing power of its users. For the time being, heat pumps can be afforded only by high-income purchasers. This group is of course limited. The step ahead could be made by the Government by improving support. This is also limited by the economic situation of the state (unlikely at present, as the Czech Republic is running a deficit). Another barrier is the price of energy, which is relatively low and therefore gives a long pay-back time, of about ten years. This aspect will become less important with time. Environmental conditions also play their role – low air temperature in winter decrease the efficiency of an air/water heat pump, while the geological situation gives strict limits on ground/water applications. To use the ground as a source of heat for the heat pump requires compliance with Czech law no. 254/2001, and the system must be designed by a person approved by law no. 360/1992. The Czech laws no. 71/1967, no. 62/1988 and no. 100/2001 must also be respected. All those laws deals with groundwater and its use. In practice, a hydro-geological survey must be carried out before a ground/water heat pump system can be installed. Drilling deeper than 30 m requires permission under mining laws. Application of all these regulations and other directives makes ground/water or water/water heat pumps expensive and complicated.

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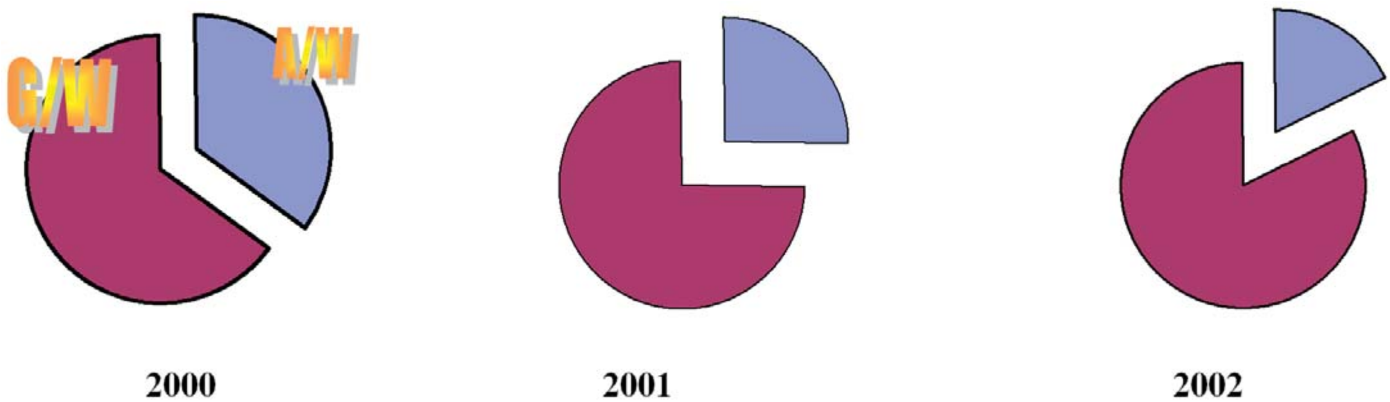

The three pie charts below show the heat sources used.

Indian Tropical Conditions – A Boon for Air Source Heat Pumps

Anup Nalamwar, India

India is surrounded on three sides by sea, by Himalayan ranges on the north and north-east, and by desert in the north-west. These extremes of terrain mean that Indian climatic conditions range from permanent snowfields to extremely hot, and from extreme drought to extreme floods. Air source heat pumps therefore have a very great potential for water heating, space cooling and space heating applications, but are still at a nascent stage in India.

Climatic conditions in India and applications of heat pumps

Let us have a look of Indian climatic conditions at various places covering almost the entire Indian territory in terms of minimum and maximum temperatures ever recorded, average minimum and maximum monthly temperatures, wet days and relative humidity.

It can be seen from the graphs in figure 1 and 2 that monthly temperatures for each region vary between extreme conditions. While the southern part of the country (Chennai) is experiencing the start of the monsoon (end of May / first week in June), the northern of the country (Delhi) is experiencing the hottest days of summer.

The temperature across India varies, with a minimum temperature of 40 °C (Siachen Glacier) to +57 °C (Rajasthan). In cold regions, such as in north and north-east India, where hot water is needed most, it cannot be supplied by solar water heaters, and electrical energy prices are very high. In these areas, air-source heat pumps could be used for space heating and space cooling application at different times of the year. During the winter, air source heat pumps can be used for water heating. In desert regions, such as Rajasthan, air source heat pumps can be used for space cooling applications.

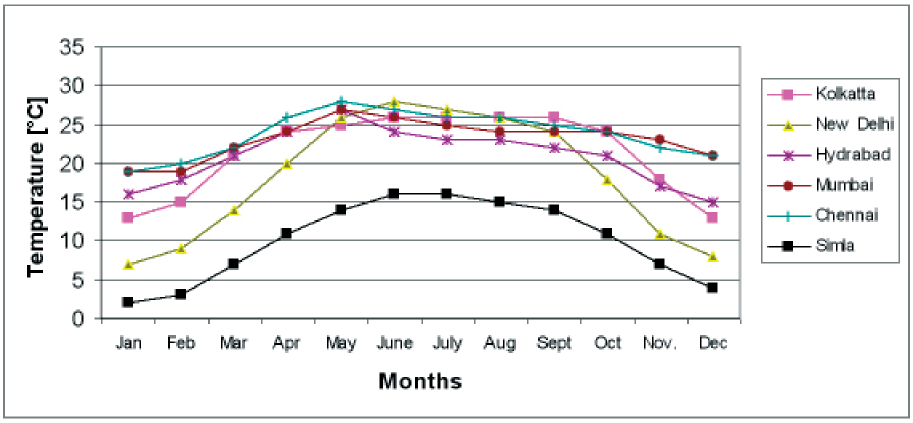

Figure 1 Average monthly minimum temperatures in Indian cities

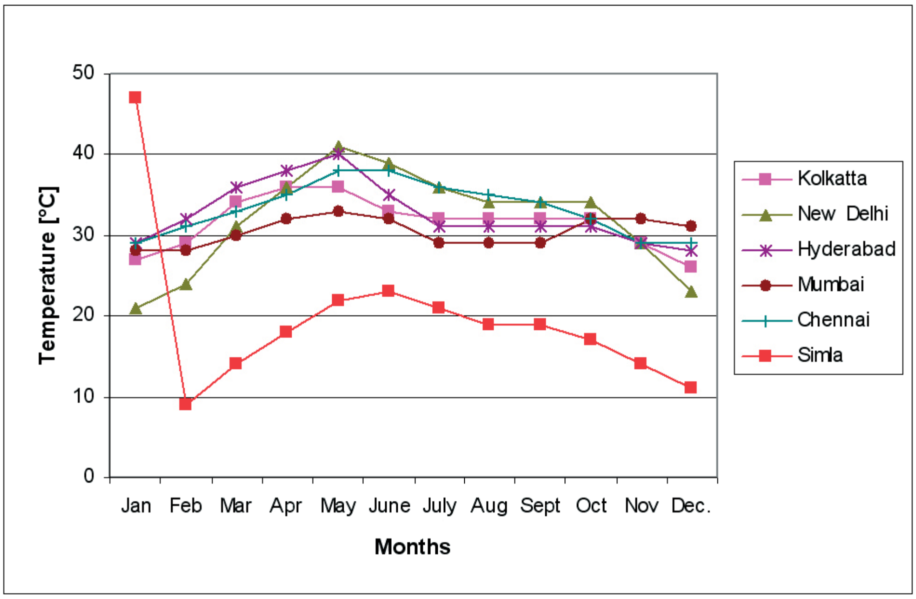

Figure 2 Average monthly maximum temperatures in Indian cities

Though the system is designed normally for average conditions, it is interesting to note that temperatures at particular locations sometime reach both highest and lowest values, see figure 3. These conditions must be considered in order to ensure system safety, even if not for operating conditions.

In certain parts of the country, rainfall exceeds the average: elsewhere, winters can see highly foggy weather. Both conditions increased the demand for hot water, which at the same time cannot be supplied by solar water heaters. These are also areas where there will be greater demand for air source heat pumps for water heating.

India has a very long coastline. In fact, three of the four major metropolitan cities (Mumbai, Chennai and Kolkatta) are located on the coast, and are major business centres. Real estate prices are very high, while the number of rainy days means that solar water heaters are out of the question. Humidity levels are also quite high as can be seen in figure 5. This means that there is very high demand for air source heat pumps for space cooling and hot water production.

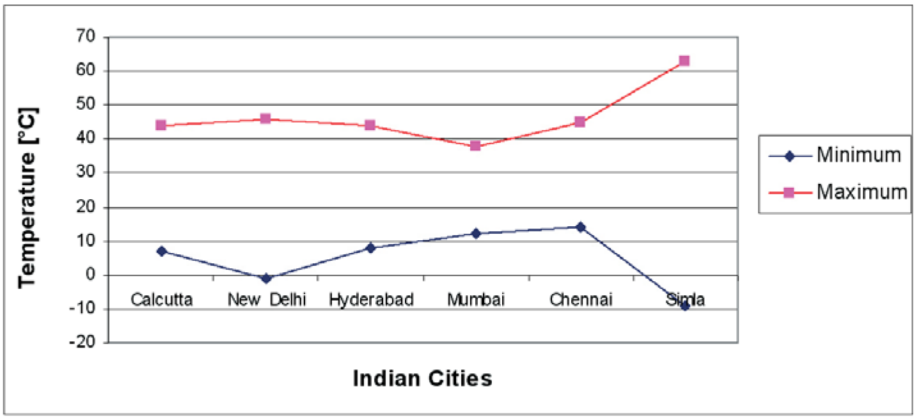

Figure 3 Minimum and maximum temperatures recorded at various cities across India

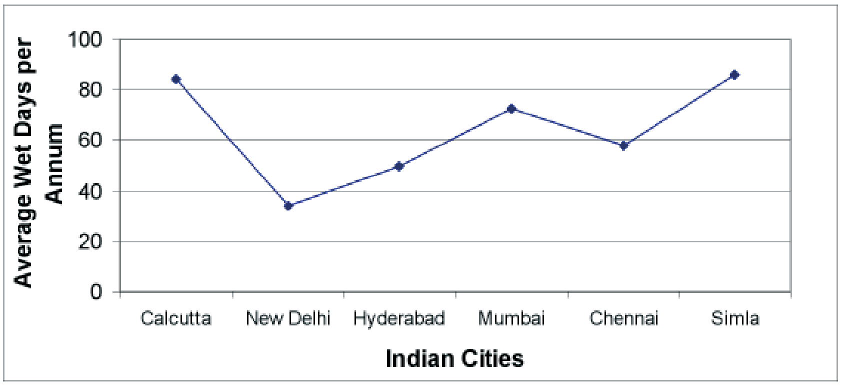

Figure 4 Number of rainy days (+0.25 mm of rain) across India

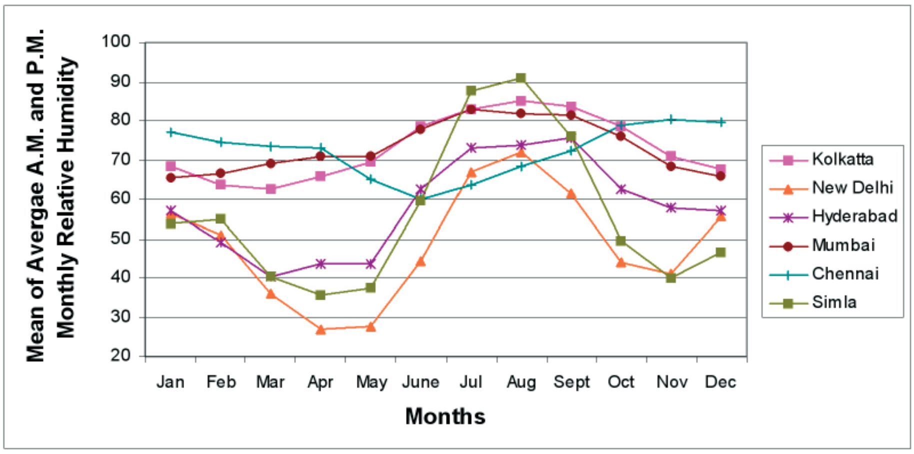

Figure 5 Mean relative humidity in various Indian cities

Heating /cooling / domestic hot water systems in buildings

The main conventional sources of energy for heating and cooling applications are electricity, petroleum fuels and other solid fuels. Electricity is used mainly for heating (water heaters and space heating), for chillers, refrigerators, and air conditioners. Oil is used as fuel for all other heating purposes: use of natural gas is minimal.

The use of non-conventional energy sources in India is increasing due to support from Ministry of Non-conventional Energy Sources and ever-increasing prices of other conventional energy sources, including electricity. Among non-conventional energy sources, solar water heaters are most commonly used for water heating, but mainly for residential purposes. Solar water heaters are seldom used for commercial or industrial applications, due to weather conditions. The other disadvantage of solar water heaters is that they require a very large space if they are to heat large quantities of water. In metro cities, real estate costs are very high and savings relative to real estate costs mean that solar water heating is not viable.

For domestic applications, solar water heaters are considered best because of low initial investment and finance availability at a special subsidised rate of interest. Climatically, India is more appropriate for air source heat pumps, both for heating and cooling applications.

Comparison of air source heat pumps with solar water heaters, electric water heaters and oil fired boiler

For comparison, we have considered various air source heat pump models being offered by NESPL/Solitaire combine, who are the only supplier in India. The following assumptions have been made for the comparison:

1. Heat pump operating hours is 90% of a day (24 hours). Each heat pump will operate for 21.6 hours per day.
2. Electricity cost is USD 0.133 per kWh.
3. Oil cost is USD 0.436 per litre.
4. Solar water heaters are of a size that will supply the same water heating capacity per day as the heat pump with which they are compared.
5. Solar water heaters work for 300 days/year. Power is required for an electrically driven circulation pump. For the remaining period, water heating is provided exclusively by electric heating. The sum of both becomes the operating cost of solar water heater.

Comparison of NESPL-Solitaire air source heat pump with electric water heater, oil fired boiler and solar water heater with different models

	Parameters	Unit	Heat pump models					
			HP-2.4	HP-5.3	HP-7.4	HP-10.4	HP-13.1	HP-14.6
1	Ambient temp	°C	30	30	30	30	30	30
2	Water inlet temp	°C	28	28	28	28	28	28
3	Water outlet temp	°C	60	60	60	60	60	60
4	Temp rise	°C	32	32	32	32	32	32
5	Water heating capacity per day	Ltrs	1445	3669	5045	7108	8943	9860
6	Energy input	kWh	0.63	1.6	2.2	3.1	3.9	4.3
7	Energy output with reference to COP at 30 °C	kWh	2.49	6.32	8.69	12.25	15.41	16.99
8	Heat pump power consumption per day	kW	13.61	34.56	47.52	66.96	84.24	92.88
9	Electric water heater power consumption per day	kW	67.19	170.64	234.63	330.62	415.94	458.60
10	Oil Consumption per day	Ltrs	6	12	16	29	37	40
11	Heat pump operating cost per day	US$	1.81	4.61	6.34	8.93	11.23	12.38
12	Electric water heater operating cost per day	US$	8.96	22.75	31.28	44.08	55.46	61.15
13	Oil fired boiler, operating cost per day	US$	2.62	6.67	9.16	12.91	16.24	17.91
14	Saving as against electric geyser per annum	US$	2608	6623	9106	12831	16142	17798
15	Saving as against oil fired boiler per annum	US$	648	1647	2265	3191	4015	4427
16	Solar water heater operating cost per 100 litres	US$	0.125	0.116	0.123	0.122	0.12	0.119
17	Heat pump operating cost per 100 litres	US$	0.126	0.126	0.126	0.126	0.126	0.126
18	Oil fired boiler operating cost per 100 litres	US$	0.181	0.181	0.181	0.181	0.181	0.181
19	Electric water heater operating cost per 100 litres	US$	0.62	0.62	0.62	0.62	0.62	0.62
20	Space required - Heat pump	m²	1.20	0.95	0.95	1.42	1.68	1.68
21	Space required - Solar water heater	m²	35	88	121	171	215	237
22	Empty weight - Heat pump	Kg	145	210	255	295	335	335
23	Empty weight - Solar water heater	Kg	578	1467	2017	2843	3583	3950
24	In addition to the above savings, there are savings in terms of mandatory demand charges as applicable, due to reduction in contractual demand load from state electricity board.							

Due to high initial investment, air source heat pumps are not economically viable for single residence use in India. For maximum benefits, heat pumps need to be used at full capacity. As shown in the above table, the HP-2.4 heat pump can heat 1445 litres of water in a day if operated for 21.6 hours (90 % of 24 hours), but will be economically viable only if it can be operated at this load. But if used for domestic purposes in Australia or European countries, the same model is economic if supplying 250 - 400 litres per day.

As can bee seen from figure 6 the operating costs of air source heat pumps and solar water heaters are almost equal.

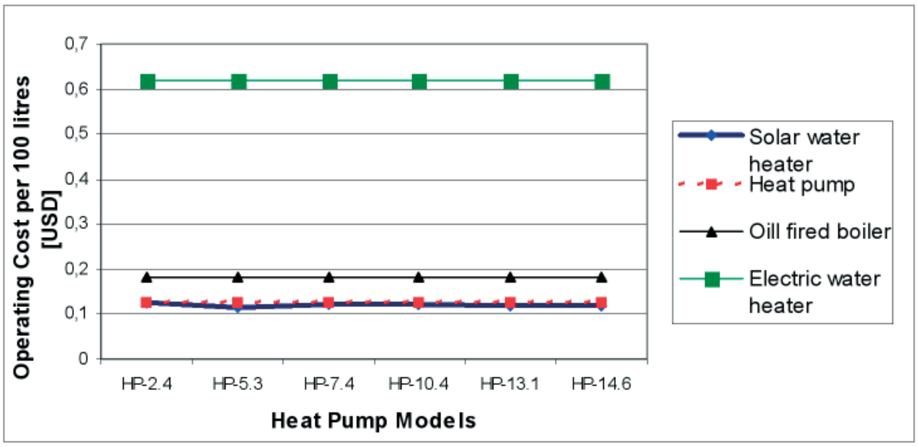

Figure 6 Operating costs for the four different heat sources; solar water heater, heat pump, oil fired boiler and electric water heater

Electricity scenario

Demand greatly exceeds supply capacity: not only because of lower installed capacity but also because of high T&D losses. Electricity costs per kWh also vary widely from state to state, ranging from USD 0.07 to USD 0.17 per kWh. Efforts are being made to conserve energy and increase the use of renewable and non-conventional energy, by enacting a law requiring conventional electricity producers to buy/generate certain amounts of non-conventional energy.

The political situation and certification

In some countries, air source heat pumps are classified as renewable energy products. However, in India, the heat pump is a new concept even for a certification authority. Import duty of 39.2 % is imposed on air source heat pump modules, while some other type of renewable energy products pay no duty. Such products are also exempted from all type of taxes and duties of the central and respective state governments. An Indian company, Nalamwar Energy Systems Pvt. Ltd., along with Solitaire, from Denmark, who are jointly promoting this technology in India, have taken up the matter with the Ministry of Non-conventional Energy Sources, for heat pumps to be regarded as equivalent to other renewable energy products.
Once the import duty is reduced, heat pumps will be affordable and a huge demand can be expected from the residential sector.

Heat pumps on the market

At present, waste heat recovery heat pumps are commercially available. Geothermal type heat pumps are being tested, and one company, Avin Solar, is seriously trying to commercialise this technology for power generation in India. India's leading energy company, Thermax Limited, commercialised another type of technology, vapour absorption cooling for industrial and commercial applications.

Conclusions

There are two types of segments: residential, and industrial and commercial. There would be a great demand for air source heat pumps for water heating, space cooling and space heating for industrial and commercial applications in India. Although the necessary initial investment in the industrial and commercial segment is high, it can be easily accommodated when considering the payback period, which ranges from 12 months to 20 months.

The other segment is for residential application. There would be a tremendous demand for air source heat pumps for space cooling/heating, with about 125 250 litres/day of hot water as a by-product. However, efforts must be made to make these systems affordable.

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A Heat Pump for Automotive Applications

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A dual heat pump/air conditioning system for automotive applications is presented in this article. There is a continuing problem with the heating systems in most cars due to the inadequate heat available during the initial engine warm-up period, especially in cold weather. A dual heat pump/air conditioning system may be designed for cars, so that the passenger cabin is heated shortly after engine start-up in winter condition. The proposed dual system design has the potential to overcome the delayed heating problem. Furthermore, by using special valves it is possible to switch between the heating and cooling modes for appropriate outdoor conditions. The results of the extensive testing of the proposed system showed that the heat pump coefficient of performance varied between 2.0 and 5.0 depending on the outdoor air conditions. It appears that with the system optimization the heat pump would be viable for automotive applications

Dual HP/AC System

The automotive heating-cooling system used in this study includes both a heat pump (HP) mode and an air conditioning (AC) mode. The two modes can be switched for the summer or winter conditions by using special valves. The integrated dual system includes a standard refrigeration cycle consisting of a condenser, an evaporator, a compressor and an expansion valve using the refrigerant R134a as the working fluid. Furthermore, the system has two separate secondary fluid loops using a 50% glycol-water mixture to exchange energy with the main refrigeration loop.

During the cold weather season, the system is operated in the heat pump mode, so that the heat rejected from the condenser is used to warm up the cabin through a heater-core and the cold ambient air heats the evaporator. One of the secondary fluid loops is formed between the condenser and heater-core, and the other one between the evaporator and radiator of the car. The engine power is used to run the refrigerant compressor and the glycol-water pumps. Many experiments were conducted to investigate the overall performance of the combined system. For each test point, an energy balance was applied to the individual components (e.g. condenser and evaporator) to obtain the coefficient of performance of the entire system.

Experimental Test Facility

A flow diagram of the main refrigeration loop, the two secondary fluid loops and the two conditioned air loops are shown in Figure 1.

Refrigeration loop

The refrigeration loop includes an evaporator, a condenser, a compressor, and an expansion valve. Thermocouples and pressure transducers were installed at the inlet and outlet ports of all the system components to measure temperatures and pressures, respectively. A coriolis-effect flow meter was used to measure the refrigerant mass flow rate which was controlled by varying the compressor RPM using a frequency controlled AC motor. The refrigerant charge varied for each test condition to control the degree of sub-cooling or super-heating at the outlet of the heat exchangers. The minimum degree of super-heating in the evaporator and sub-cooling in the condenser was maintained at about 5 °C during stable system operation.

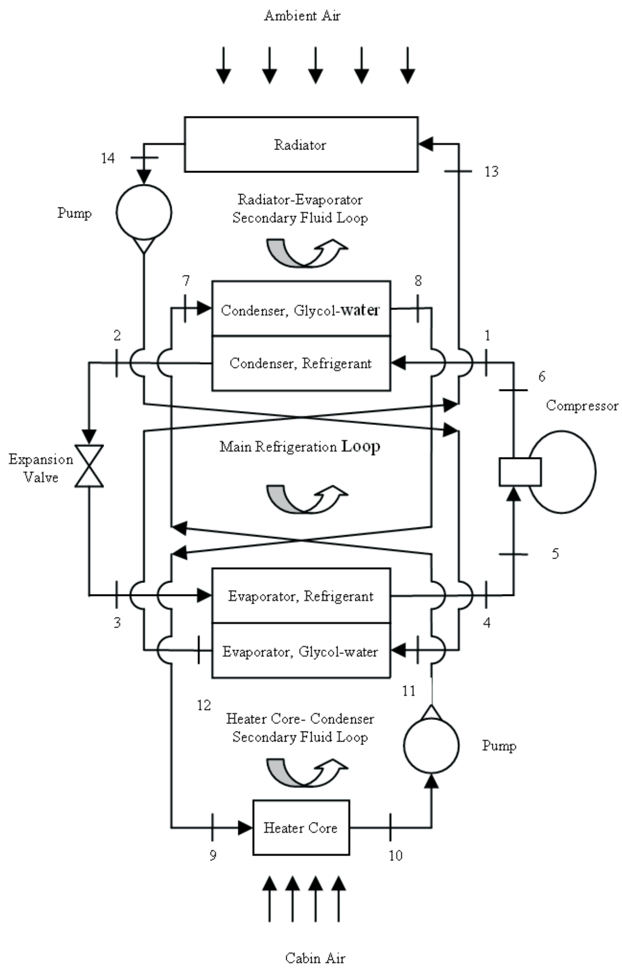

Figure 1. Flow diagram of the system including the main refrigeration loop and the two secondary fluid loops in heat pump mode

Secondary fluid loops

Secondary glycol-water mixture loops were designed to exchange energy with the evaporator and condenser. The temperatures were measured using 20 cm long thermocouple probes. The thermocouple probes were inserted a minimum of 10 cm into the flow longitudinally and fixed in the center of the 2 cm inner diameter tubes such that the bulk temperature could be measured. The pressure drop of glycol-water mixture passing through the heat exchangers was measured by differential pressure transducers installed between their inlet and outlet ports. The glycol-water mixture flow rates in each loop were measured by a turbine-type flow meter.

Conditioned air loops

Two environmental chambers were used in this study. In each chamber, the air temperature and humidity were controlled using conditioned air from external heating/cooling and humidifying/dehumidifying systems. In one of the environmental chambers, cold air was circulated through the radiator to simulate winter condition and in the other chamber, warmer air was moved through the heater-core to simulate cabin condition. Two ducts were designed and built for moving air through the heater-core and radiator. The duct for the heater-core is shown in Figure 2.

The heater-core was installed in the middle of the duct. An induction fan was installed at the entrance and a calibrated 12.5 cm ASME standard nozzle was used at the exit to measure air flow rate. The air temperature flowing through the heat exchangers was measured using several type-K thermocouples installed in different regions at the front and back of the heat exchangers, as shown in Figure 2.

Test procedure

The system was set up in heat pump mode and a series of test conditions were used to obtain adequate data for analyzing the heat pump performance. All the system variables such as temperatures, pressures and flow rates were recorded every 10 seconds as raw data. Once the fluctuations in glycol-water temperature within the heater-core became stable (within ± 1 °C) and the average was steady, the system was considered to be at a steady state condition. The data collection then began and continued for at least 10 minutes for each test condition. The 10-minute averaged data were then used to analyze the heater-core characteristics

System Test Analysis

Many experiments were conducted to investigate the performance of the combined system both in heat pump (HP) and air conditioning (AC) modes. For each test point, an energy balance was applied to each individual component (e.g. condenser, evaporator and compressor) to obtain the coefficient of performance of the entire system. The coefficient of performance was then plotted versus different parameters. The goal was to understand how system performance changed with the primary variables of the system. Since this article with the heat pump mode only, the results for system testing in air conditioning mode are not presented.

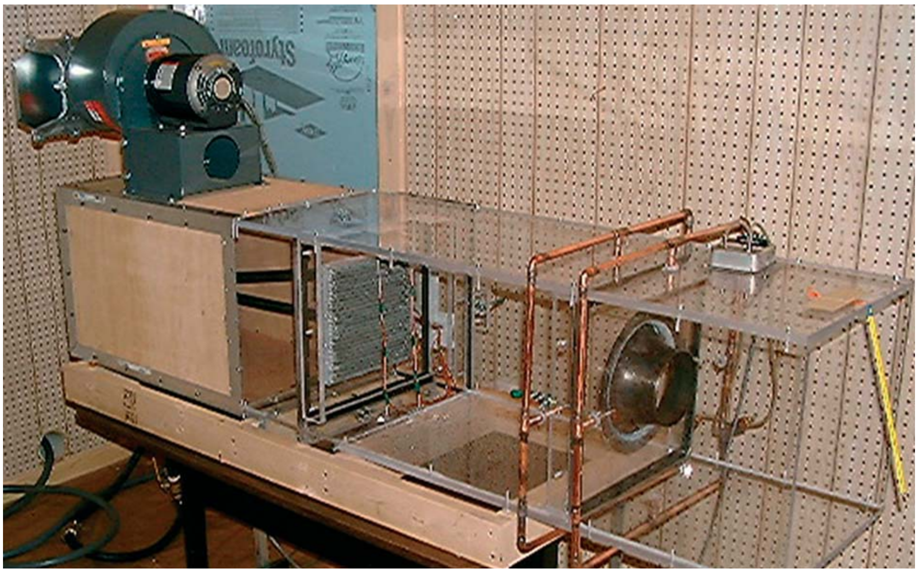

Figure 2. A duct designed for circulating cabin air through the heater-core.

System test in HP mode

Several test procedures were used to study the performance of the system in HP mode by changing different variables. These variables along with their associated ranges are listed in Table 1. A typical example of the system analysis in HP mode is given here for the variation of the refrigerant superheat at the evaporator exit at different compressor speed. In this test procedure, the superheat temperature varies from 8 to 30 °C at three different compressor speeds, i.e. 800, 2000 and 3000 rpm, to study the effect of refrigerant superheat temperature on the system performance.

Figure 3 shows a plot of coefficient of performance versus the refrigerant superheat temperature at the evaporator exit in the HP mode. This figure shows the COP is decreasing for the low compressor speed, while it is nearly invariable with the superheat temperature at higher speed; 2000 and 3000 rpm. Similar to the AC mode of the system, the closer the high and low pressures in the HP mode of a refrigeration cycle are, the less input power is needed by the compressor. Less input power has a positive effect on the system and it improves the coefficient of performance of the heat pump.

To understand the variation of COP with the superheat temperature in Figure 3, it is useful to look at the low and high cycle pressures before and after the compressor, respectively. These pressures are plotted versus the superheat temperature in Figure 4. This figure shows the low cycle pressure decreases with increasing superheat temperature for all compressor speeds, causing the COP to decrease. However, the high cycle pressure is also decreasing, as seen Figure 4, caus-

Variable	Variation Range	Compressor Speed
superheat temperature	8 to 30 °C	800, 2000 and 3000 rpm
radiator glycol-water flow rate	300 to 1200 l/h	800, 2000 and 3000 rpm
heater-core glycol-water flow rate	600 to 1200 l/h	2000 rpm

Table 1. The variables changed in the HP system test.

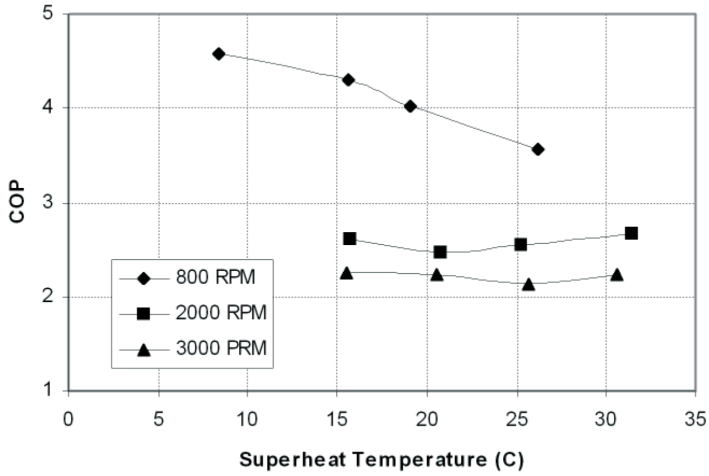

Figure 3. Variation of coefficient of performance in HP mode versus the refrigerant superheat temperature at the evaporator exit.

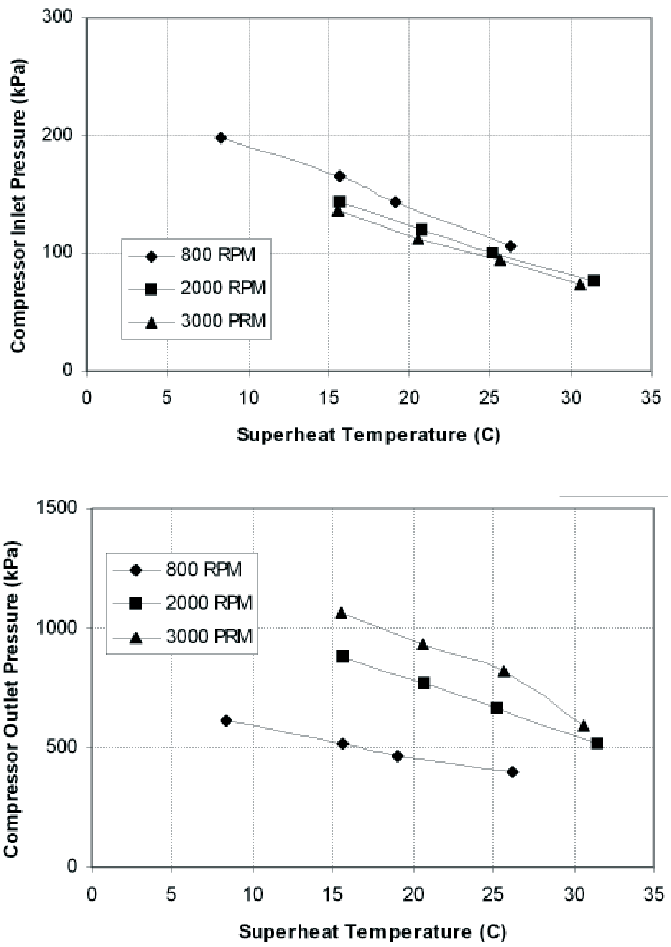

Figure 4 Variation of the low and high cycle pressures versus the refrigerant superheat temperature at the evaporator exit.

ing the COP to increase. Superposition of these two effects makes the required power less in the compressor which is positive and improves the system performance. On the other hand, decreasing the energy transfer rate in the condenser has a negative effect on the COP. So, the superposition of these effects on the performance of the system results in the COP behaviour previously shown in Figure 3.

It should be noted that the system was much more unstable and has less temperature fluctuation in low compressor speed (800rpm) than at the higher speeds (2000 and 3000 rpm). There were also conditions that caused ice to form over the radiator and covered a part of its frontal surface area. An effective surface area was measured and accounted in this case.

Conclusions

A dual refrigeration system was studied in both heat pump (HP) and air conditioning (AC) modes. Many experiments were conducted to investigate the performance of the combined system. In each experiment, the variation of the COP was analyzed for different conditions. The coefficients of performance for the heat pump cycle were within practical operation range (2-5). Using the developed heat pump within the compact dual system may have many benefits. There is also a caveat of using this system that it may increase the engine emission due to the work the compressor extracts from the engine. The results of this experimental study may be used for the design of the integrated system in AC and HP mode. They can also be a good source for validation of numerical simulation models.

Reference

Detail results of this study are presented at the 8th International Energy Agency Heat Pump Conference, Las Vegas, NV, USA, 30 May- 2 June 2005.

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China: the Issue of Residential Air Conditioning

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Introduction

In 2000, the percentage of the population living in cities and towns was 36.1% in China, which means that about 457 million people lived in cities and towns. Shanghai ranked first, with more than 88% of its citizens living in the urban area. In 2000, the population of Shanghai had reached 16.7 million, but the land area of Shanghai is only 6340.5 km²; therefore, the population density in the downtown area is very high — up to 53 326 people/km².1

The providing of settling spaces for such a large and dense population is a daunting challenge. By the end of 2001, the total floor area of residential buildings in China rose to 6.7 billion m² in urban areas, this being far higher than in 2000 (China Statistical Yearbook, 2003) The per-capita gross living area was 15.5 m², which was still at a low level if one considers global figures; therefore, about 5.7 billion m² of residential buildings will need to be constructed in the coming 5 years.

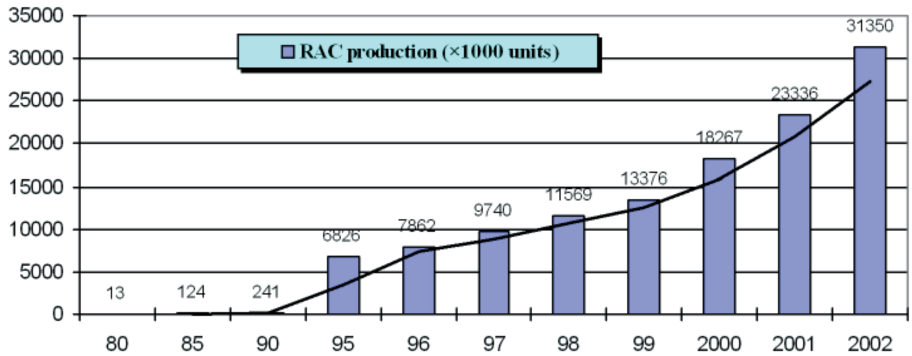

Figure 1. Rapid growth of room air conditioner production in China (China Statistical Yearbook, 2003)

With the fast development of housing construction, the residential building service sector has expanded dramatically in recent years in China. According to the 2003 China Statistical Yearbook, in 2001, the production of room air conditioners (RACs) reached 23.3 million units, ranking first in the world (see Figure 1).

Table 1. RACs owned by 100 families in 2001 (Source: National Bureau of Statistics of China)

Province/City	Per capita annual income (RMB)	Per capita annual income (USD) 1 RMB = 0.1215 USD	RACs owned by 100 families
Guangdong	11 137	1353	126
Shanghai	13 249	1610	114
Beijing	12 463	1514	106
Chongqing	7238	879	107
Tianjin	9337	1134	77
Zhejiang	11 715	1423	82
Fujian	9189	1116	74
Hubei	6788	825	71
Jiangsu	8177	994	67
Anhui	6032	733	51
Whole country average	7702	936	51

RACs in residential buildings: the situation

Table 1 shows the number of RACs owned by 100 families in some economically developed Chinese provinces and metropolises in 2001.

We set up a survey involving 780 randomly sampled families in summer 2001 and in 400 families in 2002 in Shanghai; students supervised by the authors performed the survey, entitled Study on the Status and Energy Consumption of Residential Air Conditioning in Shanghai. The average household size was 3.2 people. The average monthly income of each family was 3680 RMB (about 447 USD). The average floor area per household was 78 m² and the average number of air conditioners owned by each family was 1.8 units. The findings differed from those of the National Bureau of Statistics (NBS), since different statistical methods were used. We used a simple random sampling method, whereas NBS used a symmetrical equidistant sampling method.

Of the 1143 families surveyed and for whom data were available, only 37 families did not have a RAC. This means that RAC penetration had reached 96.8% in Shanghai, which is striking. However, within the group of 1143 families surveyed, only two had an installed household central air-conditioning system, meaning that penetration was only 0.17%; in the US, the 47.1% of households have central air-conditioning systems. About 39.7% of families in Shanghai had installed only one RAC unit serving one of several rooms, and about 39.5% of families owned two RAC units. It is hard to ensure a comfortable indoor environment in all rooms during hot summers or cold winters if only one or two RAC units are installed.

On the other hand, the operating hours of RACs in Shanghai homes are shorter than in the US. The actual survey data from 1106 families are summarized in Table 2. It can be seen from this table that although all the RACs in 1106 Shanghai families were air-source heat pumps, most families with no other heating facilities rarely used them in winter. It is rather cold in Shanghai in winter, with 109 days when the mean daily temperature is lower than 8°C.[1] The main reason for the low usage in winter is the high cost of electricity with respect to income. Figure 2 shows the average monthly electrical consumption per family in 2001. From these data, we estimated that per-capita annual residential electrical consumption in Shanghai is 485 kWh (about 1520 kWh for each family). The annual electrical consumption of RACs, on a per-family basis, can be estimated as being 450 kWh, which means that about 30% of the electricity budget of a family is spent on air conditioning.

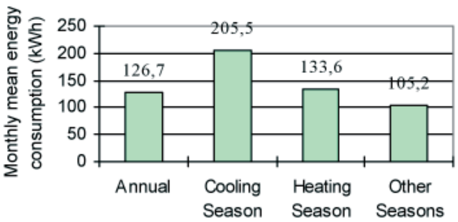

Figure 2. Monthly electrical consumption per family (Statistical Yearbook of Shanghai)

Summer (1106 families)		
Conditions for RAC operated	**%**	**Estimated average operating hours per day**
Basically never turn on	3.7	6 hours
Turn on once occupied	6.7	
Turn on when feeling a little bit hot	35.5	
Turn on when feeling hot	54.1	
Winter (1106 families)		
Conditions for RAC operated	**%**	**Estimated average operating hours per day**
operating hours per day		
Basically never turn on	32.7	3 hours
Turn on once occupied	2.9	
Turn on when feeling a little bit cold	18.8	
Turn on when feeling cold	45.6	

Table 2. Usage of RAC in Shanghai families (Survey Report)

Impact of residential air conditioning on energy and the environment

After analysing the number of household RACs owned by 100 families in Shanghai, we can conclude that the total electrical load accounted for almost 70% of the local power generation capacity. This constitutes a potential critical danger for the power supply grid. Due to the use of air conditioning, the peak load and on-peak/off-peak load difference of electric power in Shanghai on summer days has risen greatly in recent years (see Figure 3).

Because the electric power in coastal Chinese cities is mostly supplied by coal-fired thermal power plants, electrically-driven RAC is a serious source of air pollution. If we assume that there are 4 million household RACs in Shanghai, and that these RACs operate average 1000 hours full-loaded annually, then we can estimate that 30 000 tons of SO2 will be produced, accounting for 7.4% of the total SO2 emissions in Shanghai in 1999. This quantity represented almost twice the total SO2 emissions of Hainan Province in 1997. According to an UNDP Human Development report, it can also be estimated that 5.1 million tons of CO2 will be emitted, which is equal to the total amount emitted by the whole nation of Georgia or Bosnia in 1998.

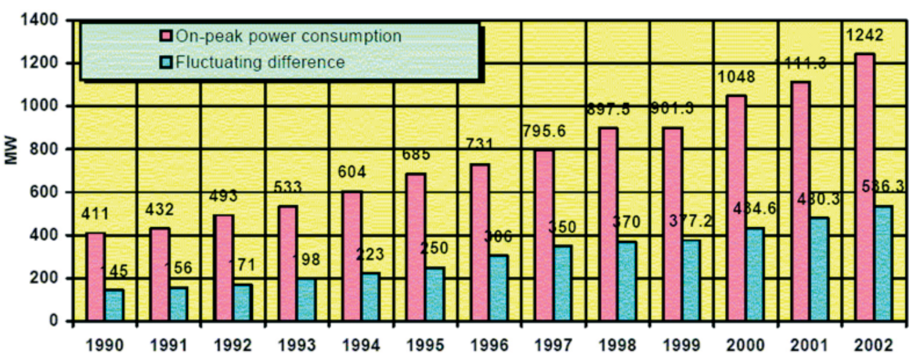

Figure 3. Peak load and on/off-peak load difference of electric power on summer days in Shanghai

The total population of open coastal cities and special economic zones in China is 91.9 million (China Statistical Yearbook, 2003). The average per-capita GDP in these areas is about 2500 USD. If the GDP growth rate was 10% in these areas, per-capita GDP would increase to 4000 USD in the coming 5 years (per-capita GDPs in Beijing, Shanghai, Guangzhou and Shenzhen have already reached 4000 USD). Over the same time period, the quantity of household RACs in these areas would increase to 22.4 million and the total electric load will exceed 2000 MW, which would account for 18% of the total power generation capacity of China in 1999. Annual SO2 and CO2 emissions would be about 180 000 tons (equal to the total SO2 emissions in Jilin Province in 1997) and 32 million tons (equal to the total CO2 emissions in Vietnam in 1998) respectively.

Residential air conditioning in china: developmental trends

In their survey, the authors rated user satisfaction with the current household air-conditioning modes. Over 50% of the surveyed families were dissatisfied with their RACs. The main complaints are given in Table 3. For the question: "Is DHC (District Heating and Cooling) a trend for future residential air conditioning?", the statistics concerning answers are presented in Table 4.

Main complaints	Percentage (%)
Stuffy, stale indoor air with an unpleasant odour	40.5
Electrical consumption is too high and too costly	37.3
Air conditioning can not cover all zones in the house	
Sudden warming up or cooling down when somebody enters or leaves rooms	29.1
Noise	10.2
Troublesome maintenance	10.1

Table 3. Complaints concerning current household air conditioning systems

Answer	Percentage (%)
Yes	47.9
No	6.0
Cannot say	33.8
Do not know	12.3

Table 4. Questionnaire on DHC trends

Due to the dense population and the shortage of land resources in Chinese cities and towns, the best way to solve housing problems for the Chinese people is to construct residential buildings with higher densities and higher Floor Area Ratios (FARs). According to a speech made by a representative of the Chinese Ministry of Construction, a recent survey conducted in 20 cities showed that about 87.7% of families live in buildings without elevators and only 3.7% live in buildings with elevators. Only 64.4% of potential house-buying families have incomes of 1000-3500 RMB per month. We can thus expect that multi-family residential high-rise buildings with higher densities and higher FAR will be the main type of residential buildings in the coming years in most cities of China.

The most suitable air-conditioning system for multi-family residences is the central air-conditioning system, i.e. DHC. DHC has already been successfully used in several central-city areas in China. Currently used cooling and heating sources include:
a) water-cooled electrically driven chiller for cooling + gas-fired boiler for heating and hot water supply;
b) direct-fired LiBr absorption chiller for cooling, heating and hot water supply;
c) LiBr absorption chiller driven by waste heat from a power generation plant + waste heat for heating and hot water supply;
d) water-cooled electrically driven chiller + ice storage system + gas-fired boiler for heating and hot water supply;
e) water-source heat pump/ground-source heat pump + auxiliary heating source.

DHC is an energy-efficient option for the cooling and heating of residential buildings. The simultaneous usage factor (SUF) of air conditioning in typical central-city residential areas is very small. According to the authors' study, SUFs for cooling in typical central-city areas in Shanghai are listed in Table 5.
Therefore, the cooling capacity of DHC can be defined as 50-60% of design cooling load, although the heating capacity must meet the design heating load of total floor areas. In the climate zone of Shanghai and the Yangtze River drainage basin area, the heating load of well-insulated residential building is about 50-70% of the cooling load. This means that chillers with a higher Energy Efficiency Ratio (EER) may be used, and the peak electric load, along with the operating costs, would decrease a lot.

Number of families living in the downtown area	SUF
<100	0.70
100-150	0.65-0. 70
150-200	0.60
>200	0.50

Table 5. Simultaneous Usage Factor (SUF) of air conditioning in residential uptowns

A magnificent project designed to enable natural gas to be transported from Western to Eastern China is under way. According to the plan, 30 billion m3 of natural gas will be transported to Shanghai annually by the end of 2004. Therefore, Combined Cooling, Heating and Power (CCHP) generation using a gas-fired micro-turbine, a gas engine, a fuel cell, an absorption chiller and/or a waste heat boiler, will be the best choice for cooling and heating sources for residential air conditioning in Eastern Chinese metropolises in the near future.

Household central air conditioning, which is "one family with one air-conditioning system", is still the main type of air conditioning used for individual houses (or town houses). The currently used types of cooling and heating sources are:

- air-source heat pump/ground-source heat pump/water-source heat pump (chiller);
- air-source heat pump/ground-source heat pump/water-source heat pump (air-handling unit);
- variable-refrigerant-volume multi air-conditioning system (VRV);
- packaged electrically driven chiller and ice-storage system;
- gas engine heat pump (GEHP);
- small direct-fired LiBr absorption chiller.

Finally, RACs will still have a broad market in old buildings, retrofitted buildings and apartments in the future. According to the authors' survey, about 40% of families in Shanghai owned only one RAC unit. If half of these families were to buy a new one in the coming 5 years, demand will rise to 900 000 units. If 10% of existing RACs were to be retrofitted, this would involve an estimated 800 000 units. If RACs were to be installed in half of newly constructed housing in Shanghai in the coming 5 years, about 700 000 units would be needed. However, the EER, the indoor environment improving function and the automation control level of RACs must be updated.

Conclusion

China has the biggest residential air-conditioning market in the world. The production of RACs in China ranks first in the world. Penetration of residential air conditioning in Shanghai has reached 96.8%. However, the usage ratio in Shanghai is still low due to high energy costs. Use of large numbers of RACs has already caused enormous pressure on energy supply and the environment of China. Electrically driven RACs have created the biggest unstable power grid load and the biggest source of CO2 emissions in most Chinese metropolises.

The residential air-conditioning trend in Chinese metropolises should be DHC with CCHP using natural gas as an energy source. Household central air conditioning will become the main type of air conditioning for individual houses or town houses. RACs will still have a broad market.

Acknowledgement

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Selected Issues on CO_2 in Compression Systems
Carbon Dioxide (CO_2) has shown promising results as an alternative working fluid compared to the CFCs, HFCs and HCFCs. CO_2 provides an environmental friendly alternative in a number of heat pump applications, in automobile air conditioning, and as a secondary fluid in refrigeration systems. The physical and the thermodynamic properties of CO_2 differ considerably from the more conventional working fluids and offer new possibilities as well as design challenges for systems and components.

On this background IEA Heat Pump Programme's Annex 27 was established. The main objective of the Annex has been to bring the CO_2 heat pump technology closer to commercialization, by addressing critical issues of both basic and applied character.

The scope of the work under this Annex includes compression heat pump, refrigeration and air-conditioning systems and components, with the main emphasis on heat pumps, using CO_2 as working fluid. The term "compression heat pump" covers vapor compression circuits with phase change. The term "system" includes all the components used in a heating/cooling system from the heat pump to the inside unit, controls included.

Results from 12 different research projects together with an extensive literature survey are presented. The projects are carried out as independent research projects, and the findings and the results are the sole responsibility of the authors. The following projects are presented:

- Feasibility of transcritical CO_2 systems for mobile space conditioning applications
- Use of CO_2- and propane thermosyphons in combination with compact cooler in domestic freezer
- Heat transfer of carbon dioxide in an evaporator
- Correlating the heat transfer coefficient during in-tube cooling of turbulent supercritical CO_2
- Heat transfer and pressure drop characteristics of super-critical CO_2 in microchannel tubes under cooling
- Flow vaporization of CO_2 in microchannel tubes
- Two-phase flow patterns during microchannel vaporization of CO_2 at near-critical pressures
- Small oil-free piston type compressor
- Some safety aspects of CO_2 vapor compression systems
- Boiling liquid expanding vapor explosions (BLEVE) in CO_2 vessels: initial experiments
- Experimental study on boiling liquid expansion in a CO_2 vessel
- CO_2 as secondary refrigerant (Sweden)

Participating countries were: Japan, Norway, Sweden, Switzerland, and USA. The report is during the first two years available for Annex 27 member countries only.

This report is available from the Heat Pump Centre at: http://www.heatpumpcentre.org

IEA World Energy Outlook 2004
This report provides comprehensive information on many aspects of the energy sector, as well as insight into how energy supply and demand are likely to evolve over coming decades. It contain special reports on oil and gas reserve uncertainties, Russia as an energy superpower, world alternative policy scenario and energy development index.

The IEA World Energy Outlook's analysis, statistics and supply and demand projections cover oil, gas, coal, renewables, nuclear and electricity and also energy related CO_2 emissions.

This report can be ordered from the IEA online bookshop at: www.iea.org

Proceedings from the IIR Gustav Lorentzen Conference, 2004
The proceedings from the conference held in Glasgow cover new developments in the field of natural working fluids: CO_2, hydrocarbons, absorption systems, ammonia, air cycles and miscellaneous. The CD-ROM also include all the slides used in the four short courses held during the conference.

Price: 50 €

This CD-ROM can be ordered from the IIR at: www.iifiir.org

2005

ASHRAE Winter Meeting
5 – 9 February 2005
Orlando, Florida, USA
Tel: +1 404 636 8400
E-mail: jyoung@ashrae.org
www.ashrae.org

International Air-Conditioning, Heating, refrigeration Exposition (AHR Expo)
7 – 9 February
Orlando, Florida, USA
www.ahrexpo.com

RIO 5 – World Climate and Energy Event
15 – 17 February, 2005 in Rio de Janeiro, Brazil and
18 – 20 February, 2005 in Fortaleza, Brazil
Organization Office
a/c PML, Av. Rio Branco, 25-18° andar
20093-900 Rio de Janeiro – RJ, Brazil
Phone: (+55-21)-22 33 51 84, (+55-21)-88 23 19 63,
(+55-21)-25 47 82 98, (+55-21)-98 14 30 31
Fax: (+55-21)-25 18 22 20
E-mail: info@rio5.com
http://www.rio5.com

Climatizacion 2005, International HVAC&R Expo
23 – 26 February, 2005
Madrid, Spain
Contact: Marietta Vázquez, International Press
Tel: +34 91 722 51 74
Fax: +34 91 722 57 93
E-mail: marieta@ifema.es
www.prensa.ifema.es

RAC 2005
1 – 3 March, 2005
Birmingham, England
www.racexhibition.com

IIAR Ammonia Refrigeration Conference & Exhibition
13 – 16 March, 2005
Acapulco, Mexico
www.iiar.org

GeoExchange 2005 - International Conference and Trade Show
17 – 18 March, 2005
Burnaby, British Columbia, Canada
Contact: GeoExchangeBC
P.O. Box 72026, Old Orchard PO
Burnaby, BC Canada V5H 4P9
Tel: 604 453 6438 (Linda Mackay)
Fax: 604 453 6283
http://www.geoexchangebc.ca/pdf/brochure.pdf

Latest Developments in Refrigerated Storage, Transportation and Display of Food Products
28 – 30 March, 2005
Amman, Jordan
Contact: Mahmoud A. Hammad
University of Jordan
Faculty of Engineering
PO Box 13240
11942 Amman
Tel: +962 652 38783
Fax: +962 653 55588
E-mail: hammad@fet.ju.edu.jo
www.fetweb.ju.edu.jo

HEAT-SET 2005 - Heat Transfer In Components And Systems For Sustainable Energy Technologies
5 – 7 April, 2005
Grenoble, France
Contact: GRETh
Fax: +33 (0)4 38 78 51 61
E-mail: greth@cea.fr
http://www.greth.fr/heatset2005

Ammonia Refrigeration Systems, Renewal and Improvement
6-8 May, 2005
Ohrid, Republic of Macedonia
Contact: Prof. R Ciconkov
Box 464
1000 Skopje
Macedonia
E-mail: ristoci@ukim.edu.mk
www.mf.ukim.edu.mk

8th IEA Heat Pump Conference 2005
30 May – 2 June 2005
Las Vegas, Nevada, USA
Contact: The Conference Secretariat
Oak Ridge National Laboratory
P.O.Box 2008, MS-6067
Oak Ridge, TN 37831
Tel: +1 865 576 8620
Fax: +1 865 574 9331
E-mail: hp2005@ornl.gov
http://www.ornl.gov/hp2005

International Sorption Heat Pump Conference
22 – 24 June, 2005
Broomfield, Colorado, USA
Contact: Mrs. Lori C. Puente
University of Maryland
Tel: (301) 405 5439
Fax: (301) 405 2025
E-mail: lpuente@umd.edu
www.enme.umd.edu/ceee/ishpc

5th International Conference on Compressors and Refrigeration
19 – 22 July
Dalian, China
Contact: Xueyuan Peng
School of Energy and Power Engineering
Xi'an Jiaotong University
Tel: +86 29 8266 3785
Fax: +86 29 8266 8724
E-mail: xypeng@mail.xjtu.edu.cn

ASHRAE Annual Meeting
25 – 29 June, 2005
Denver, Colorado, USA
www.ashrae.org

17:e Nordiska Kyl- och Värmepumpmötet
(the 17th Nordic Refrigeration and Heat Pump conference)
24 – 26 August 2005
Stockholm, Sweden
Conference Secretariat
Stockholm Convention Bureau
Box 6911
102 39 Stockholm
Sweden
Tel: +46-8-5465 1500
Fax: +46-8-5465 1599
E-mail: stocon@stocon.se
http://www.kylvp2005.se/

Commercial Refrigeration
30 - 31 August 2005
Vicenza (Padua), Italy
Contact: Alberto Cavallini
Fax: +390 49 827 6896
Tel: +390 49 827 6890
E-mail: alcav@unipd.it

Thermophysical Properties and Transfer Processes of New Refrigerants
31 August – 2 September 2005
Vicenza (Padua), Italy
Contact: Alberto Cavallini
Fax: +390 49 827 6896
Tel: +390 49 827 6890
E-mail: alcav@unipd.it

International Conference on Compressors and their Systems
4 – 7 September, 2005
London, United Kingdom
Contact: Madeline Willis
Institution of Mechanical Engineers
Tel: +44 (0)20 7973 1260
Fax: +44 (0)20 7222 9881
E-mail: m_willis@imeche.org.uk
www.imeche.org.uk

For further publications and events, visit the HPC internet site at http://www.heatpumpcentre.org.

In the next Issue

Systems and Controls

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International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

IEA Heat Pump Programme

International collaboration for energy efficient heating, refrigeration and air-conditioning

Vision

The Programme is the foremost world-wide source of independent information & expertise on heat pump, refrigeration and air–conditioning systems for buildings, commerce and industry. Its international collaborative activities to improve energy efficiency and minimise adverse environmental impact are highly valued by stakeholders.

Mission

The Programme serves the needs of policy makers, national and international energy & environmental agencies, utilities, manufacturers, designers & researchers. It also works through national agencies to influence installers and end-users.
The Programme develops and disseminates factual, balanced information to achieve environmental and energy efficiency benefit through deployment of appropriate high quality heat pump, refrigeration & air-conditioning technologies.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC). The HPC contributes to the general aim of the IEA Heat Pump Programme, through information exchange and promotion. In the member countries (see right), activities are coordinated by National Teams. For further information on HPC products and activities, or for general enquiries on heat pumps and the IEA Heat Pump Programme, contact your National Team or the address below.

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IEA OECD heat pump centre

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