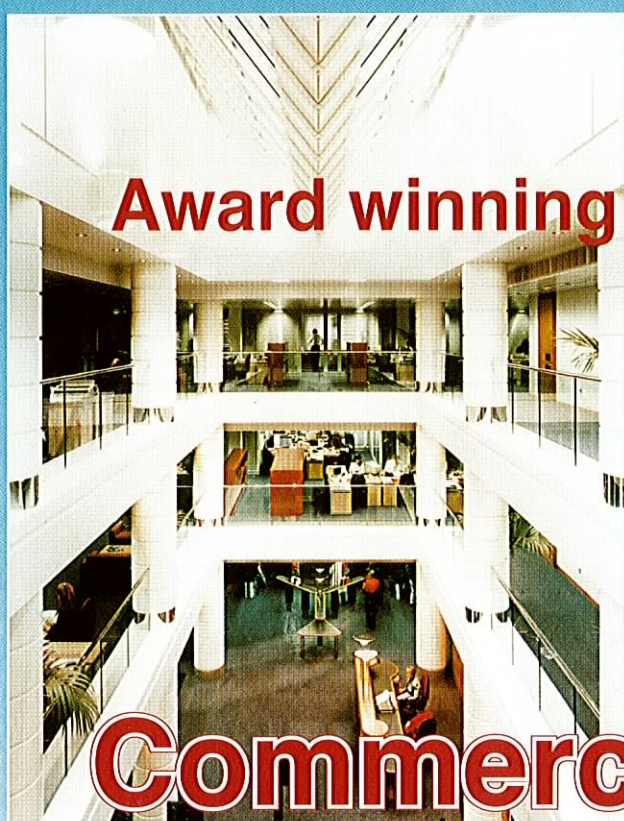


IEA Heat Pump NEWSLETTER

CENTRE 

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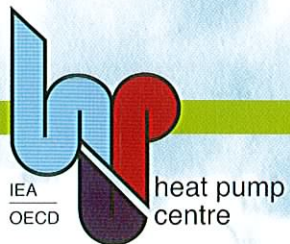


Award winning projects

**Commercial
buildings**



Trends in heat pump technology





In this issue

Heat Pumps in Commercial Buildings

Offices, and other buildings for commercial or institutional uses, are interesting places to install heat pump systems. The widespread use of electrical equipment, such as computers, means that cooling demand is often high. And this makes the heat pump an attractive option, offering savings in both energy resources and money. In this issue, articles from Europe, Japan, and North America, highlight how new concepts such as energy reclaim, thermal storage, and floating loop, are helping to further extend the heat pumping opportunities in the commercial buildings sector.

Front cover:

From award winning projects in the UK (page 24) to the latest equipment from US manufacturers (page 21), this issue provides a global review of heat pump applications in commercial buildings.

COLOPHON

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TOPICAL ARTICLES

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<i>Bert Stuij,</i>		<i>Onno Kleefkens and Kees Jansen,</i>	
<i>IEA Heat Pump Centre</i>		<i>The Netherlands</i>	

While Japan, US and Sweden have strong markets for commercial buildings heat pumps, other countries lag behind. Factors such as cooling demand and energy price ratios can help explain this situation. Current trends suggest that the heat pump market will strengthen.

Dutch experience in office buildings heat pumps dates back to the 1980s. Some systems were successful. Others were not. A new survey has closely examined these experiences, and helps to uncover the factors that make up a heat pump success story.

Meeting heating and cooling demands in a research centre	16	Trends in heat pump technology for commercial buildings	21
<i>Geir Eggen and Jørn Stene,</i>		<i>Mukesh Khattar and Morton Blatt,</i>	
<i>Norway</i>		<i>USA</i>	

Bergen's "High Technology Centre" has a year-round demand for both heating and cooling. Using two heat pumps, heat extracted in cooling, is upgraded to meet heating needs. The savings in energy costs have paid back the initial investment costs within one year.

While many US commercial buildings use heat pumps, much greater market penetration is expected. With the support of research institute EPRI, new technologies, such as dual path, ground-source and floating-loop systems, are enhancing the prospects for further growth.

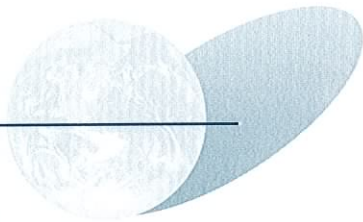
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Enjoying strong growth

For the last several years, the size of the heating, ventilation and air-conditioning (HVAC) market in commercial buildings has annually averaged 25 GW (7 million tons). The equipment market for retrofits and replacements is larger than that for new construction. It is estimated that by the year 2000, the new construction market will average 14 GW (4 million tons) annually, while the retrofit and replacement market will total 21 GW (6 million tons).



Today's highly efficient heat pumps provide energy savings as they replace aged and less energy-efficient equipment. A recent US

Department of Energy survey revealed that a significant portion of the current 385.8 GW (109.6 million tons) of commercial cooling capacity has aged considerably, with approximately 25% of this capacity over 22 years old. Heat pumps represented approximately 15% of the new construction market in 1990, a healthy sign of growing popularity.

Since their introduction, electric heat pumps have rapidly grown in popularity. Their use offers energy efficiency and economical operating costs. And with the latest state-of-the-art technology, maintenance on late model heat pumps is minimal.

Water-source heat pumps are gaining in popularity more rapidly than air-to-air heat pumps. Today, most commercial buildings are tightly built and simultaneously use heating and cooling. With a recycling process, excess heat from one part of the building is used to heat another area. In fact, if one out of three heat pumps are providing cooling, there is no need for supplemental heating. Water-source heat pumps are also popular because of their economical first-cost compared to other HVAC systems. In the northeastern US, a closed-loop water-source heat pump system can be installed for less than 110 US\$/m² with yearly maintenance costs of 1.3 to 1.4 US\$/m², including parts and labour.

Geothermal heat pumps are also gaining market share. These heat pumps have the potential to reduce energy use and greenhouse gas emissions by 20 to 40%. The Geothermal Heat Pump Consortium has been established to coordinate the development of this market.

With the above mentioned activities and trends, it is apparent that the commercial buildings market for heat pump equipment and systems should enjoy strong growth.

Jitendra B. Singh, J and P Engineers, USA

Award winning projects for commercial buildings 24

*Tony Bendall,
United Kingdom*

The reward of excellence within the heat pump industry is a key activity of the UK Heat Pump Association (HPA). The winners of the first HPA awards demonstrate advanced techniques for heat recovery, and highlight the opportunities for heat pump applications in UK commercial buildings.

Ice thermal storage systems 26

*Hideaki Kokubu,
Japan*

A new trend in Japanese commercial buildings is to use heat pumps with ice thermal storage for peak power demand reduction. Today, the required technology is continuing to evolve. But one day, such systems could dominate the market for packaged air conditioners.

NON-TOPICAL ARTICLE

Comparing heat pump test facilities 28

*Osmann Sari and Philippe Moser,
Switzerland*

Quality assurance is essential to the Swiss Heat Pump Programme, and heat pump units must be tested and approved by means of certified test rigs. To verify the accuracy of such tests, measurements at three Swiss testing facilities have been compared.



Canadians form Heat Pump Council

Toronto, Ontario - The Canadian Heat Pump Team and the Heating, Refrigerating and Air Conditioning Institute of Canada (HRAI) have announced the formation of the Canadian Heat Pump Council.

The Council will build on the work of the Canadian Heat Pump Team which has been active since 1991 as the National Team of the IEA Heat Pump Centre (HPC). It is hoped that the formation of the Canadian Heat Pump Council will lead to the renewal of Canada's membership to the HPC, which was withdrawn at the end of 1995.

The mission of this new organization is to be "the preeminent source of independent and objective knowledge and advice in heat pump technologies in Canada". The Heat Pump Council will be involved in promoting the development and application of heat pump technology as a realistic and reliable means of conserving energy and protecting the environment.

"The new Heat Pump Council affiliating with HRAI furthers our goal of providing a single umbrella association for the HVACR industry in Canada," according to HRAI Chair Jim Kennedy. "This affiliation opens up many opportunities to develop the market for heat pump systems through

national training programmes, information and technology transfer and promotional campaigns."

Membership in the Council will be open to all categories of HRAI company membership, including manufacturers, wholesalers and contractors, as well as Associate Members such as utilities, government agencies and consultants. Non-members of HRAI are also welcome to join. The current membership of the Council includes representatives from: Caneta Research Inc., Natural Resources Canada, Ontario Hydro, Cimco-Lock Refrigeration, Enerbest Associates, National Research Council of Canada, Newfoundland Power, Consumers Gas and Union Gas.

HRAI will provide administrative support for the Council and will organize meetings, workshops and seminars. HRAI will distribute a national newsletter to Council members and will sell IEA Heat Pump Centre publications and other heat pump literature.

Source: Ms Louise Hope, Canadian Heat Pump Council, c/o HRAI, Suite 300, Building 11, 5045 Orbitor Drive, Mississauga, ON L4W 4Y4, Canada. Fax: +1-905-602-1197.

Promotion schemes target gas-furnace users

USA - Recent reports to the Electric Power Utilities Research Institute (EPRI) highlight different approaches to promoting heat pumps to gas furnace users. Arizona's Salt River Project encourages the installation of electric heat pumps for monovalent operation. An incentive of around US\$ 10 per installed kW of cooling capacity is offered when customers replace their gas furnace with a heat pump of 10 SEER (cooling COP of 2.9) or higher. The utility's target is to promote 1,200 heat pump installations per annum with this scheme.

In contrast, the Public Power Districts of Omaha and Nebraska focus on bivalent heat pump systems. They encourage their customers to replace their old air conditioner with a heat pump, with the gas furnace retained to provide supplemental heat during the coldest winter days. The Omaha utilities reports that these so-called "add-on" heat pumps now account for 50% of heat pump installations.

Source: EPRI Heat Pump News Exchange, Winter-Spring 1996.

North Americans hold IHP workshop

Canada - A workshop on industrial heat pumps (IHPs) is to be held close to the US border at Windsor, Ontario on 30 October. The one-day meeting will act as a follow up to Annex 21 of the IEA Heat Pump Programme "Global Environmental Benefits of Industrial Heat Pumps", which was completed in 1995.

Information will be presented on Annex 21's findings on the potential benefits of IHPs for North America, and on the screening software developed under the Annex. Other presentations will address recent application experiences, new equipment developments and financing.

The proceedings will be published by the HPC.

Source and further information: Mr Doug Cane, Caneta Research Inc., Mississauga, Ontario, Canada. Fax: +1-905-542-3160.

CEN to make absorption equipment standards

Europe - The European Committee for Standardization (CEN) has expanded the scope of Technical Committee TC113 to include absorption equipment in its work on the drafting of standards for heat pumps and air conditioners for domestic or commercial processes, excluding industrial purposes.

Meanwhile, heat pump standards are progressing at the International Organization for Standardization (ISO). The standard developed by TC86/SC6/WG3 covering water and brine-to-air heat pumps has progressed to Draft International Standard status. And TC86/SC6/WG5 has completed the drafting of a standard entitled "Multi-Split System Air-Conditioners and Air-to-Air Heat Pumps - Testing and Rating for Performance - Part 1: Basic and Multiple Circuit Systems."

Source: CEN and Koldfax from ARI, May 1996.



City hall gets heat from disused mine

USA - When the city hall was built for the new community of Park Hills, in southeast Missouri, city manager, Mr Larry Hughes, asked if water in the nearby abandoned lead mines could be used as a heat source for the heating and cooling system. The answer was yes. With an almost constant temperature of 14°C, the 250 million m³ of mine water makes a perfect heat source for heat pumping technology, and could have many other applications as well.

Water from the mine is pumped to the city hall (see **photo**), where a heat exchanger transfers the heat to and from a water loop running around the building. Nine water-to-

air electric heat pumps, connected to the water loop, use this heat to provide space heating and cooling for the building's 750 m² floor area throughout the year. Even

in January and February this year, when arctic air blanketed the Midwest, and outdoor temperatures fell to below -20°C, the back-up electric resistance heaters installed in each heat pump were not required.

Operating since October 1995, the system was designed by Lester and Buehler Inc, and uses Trane heat pumps. The system cost US\$ 120,000 to install - US\$ 30,000 to 35,000 more than a conventional system using air-source heat pumps or gas heating and electric cooling. But annual energy cost savings are estimated to amount to around US\$ 6,000. Local power utility Union Electric Co. and the Electric Power Research Institute (EPRI) contributed US\$ 40,000 towards the project.

Source: Mr C.A. Lester, Lester & Buehler, Inc., 248 Southwoods Center, Columbia, Illinois 62236, USA. Tel: +1-618-281-6292.



◀ *The City Hall of Park Hills gets its heat from disused lead mines.*

Water-source heat pump in car centre

Czech Republic - Increased energy costs after the collapse of the centrally-planned economy in 1989 has helped establish a heat pump market in the Czech Republic. The Prague based company, Geoterm, is tackling the difficult task of persuading energy consumers that heat pumps are no longer experimental devices and that they are capable of saving them money.

A recent success was the installation of a water-source heat pump in a newly-built Ford car service and sale centre in the town of Decin. For the 10,000 m³ building, the original design proposed using two 320 kW gas boilers and local ventilation units without heat recovery. After Geoterm had completely re-designed the heating and ventilation systems, only a 140 kW (heating capacity) heat pump was required plus 80 kW heating capacity from gas infra-red heaters.

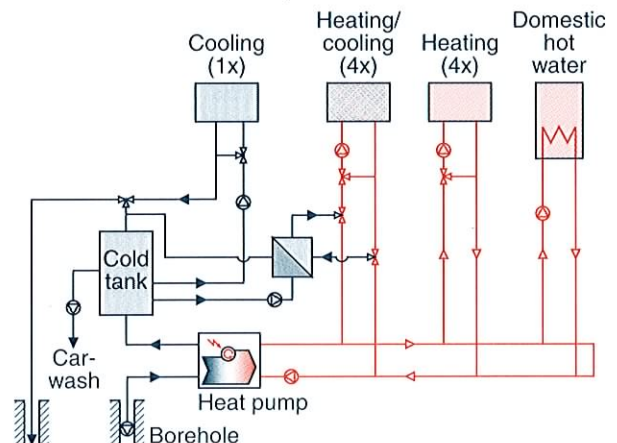
The building is composed of sections, some of which are served only by the heat pump (monovalent operation) and others where the gas heaters provide additional heating (bivalent operation). A partially bivalent system was chosen in order to meet the investor's requirement of not exceeding the cost of conventional (gas) heating. Furthermore, the new design incorporates cooling without cost increase.

Although the building stands on a riverbank, the source water is pumped from two boreholes (10-12 m deep) because the river water is too cold during the winter for direct

use. The pumped water is also used for the car-wash and for cooling. **Figure 1** shows a simplified schematic of the system.

Source: Mr Jiri Kubias, Geoterm s.r.o., Krokova 9a, 12800 Prague 2, Czech Republic. Fax: +42-2-6122-2146.

Figure 1: Simplified schematic of the heat pump system at the Ford car centre in Decin, Czech Republic.



Adapting air-source equipment to cold weather

USA - An almost totally passive technique for increasing air-source heat pump capacity in cold weather is under development at the National Institutes of Standards and Technology (NIST). The system, shown in **Figure 2**, uses a zeotropic refrigerant mixture and a distillation column that changes the active refrigerant mix as temperatures drop below the balance point.

The distillation column is fitted inside the heat pump's standard accumulator along with a small auxiliary heater (25 W). In operation, as the outdoor temperature gets colder, more refrigerant ends up in the accumulator. Because the refrigerant is a zeotropic mixture, with each mixture component having a separate boiling point, the distillation column removes the more volatile component. This leaves a mixture with higher capacity.

The system is a simpler and cheaper alternative to using two-speed or variable-speed motors. Other approaches to a zeotropic heat pump have been developed but have been either too complex to be practical, or provided limited additional capacity, according to NIST engineer Mr Peter Rothfleisch, inventor of the approach.

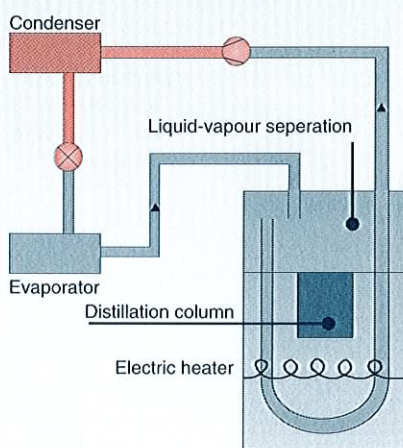
Rothfleisch, reports capacity increases of up to 10%, and expects better results in a second round of tests. The first test used a mixture of HFC-32 (30%) and HFC-134a (70%), which mimics the performance of HCFC-22 in the cooling mode. In the heating mode, the working concentration changes to about 50/50, providing a higher pressure and better cold weather performance.

In the next round of tests, Rothfleisch will use R-407C, a mixture of HFC-32, HFC-125, and HFC-134a. In the heating season the system will distil out all of the HFC-134a, leaving a mixture that matches R-410A, which provides high capacity in the heating mode. Rothfleisch is also in the early stages of negotiating with manufacturers to cooperatively finish development.

For more information, contact: Mr Peter Rothfleisch, National Institute of Standards and Technology, Building 226, Room B114, Building and Fire Research Laboratory, Gaithersburg, MD 20899. Fax: +1-301-208-0485.

Source: Technologies for Energy Management, June 1996, from Cutter Information Corp., USA.

Figure 2: Heat pump system with variable capacity.



Swimming pool system saves money and water

Australia - At an army base in Singleton, New South Wales, the cost of heating a 33 m swimming pool have been reduced by around 75% by using air-source heat pumps. Not only that, the system also provides much needed cooling air for the gymnasium, and the water condensed from outdoor air at the evaporators is collected and used to water the gardens.

At the swimming pool, three air-source electric heat pumps heat the pool to 27°C. Just one unit is used in summer, while all three units operate for 10 to 16 hours a day in winter. A further unit heats 1,400 l of water to 62°C for showers. The system registered a COP of 5.1 during the summer in January this year.

The total cost of the project was AU\$ 100,000 (US\$ 75,000) plus AU\$ 29,000 for a new power supply sub-station. The total costs are expected to be recovered within three and a quarter years.

Source: Energy Focus from New South Wales Department of Energy, July 1996.

Airport taps into groundwater energy

Norway - The new main airport now being built near Oslo, The Gardermoen Airport, will be Norway's largest ever construction project, and will feature an advanced heat pumping system utilizing groundwater.

A combined heat pump and refrigerating system will exploit the energy reserves of the largest groundwater reservoir in Northern Europe, which has an average temperature of 4.5°C. Eighteen wells, each 50 meters deep, will be drilled, at a distance of 50 meters from each other. A Dutch company has been responsible for the analysis of the groundwater reservoir.

Two separate heat pump systems from Sabroe Kulde AS will be installed at the airport's energy plant, using ammonia as working fluid. HFC-134a heat pumps were also offered, but at a higher price and lower seasonal performance factor (SPF). The compressor installation will include five 16 cylinder reciprocating compressors and one eight cylinder compressor. The maximum

cooling and heating capacities are 6 MW and 8 MW, respectively.

In summer the energy plant will provide chilled water to a district cooling system serving the airport. Most of the surplus heat from the condensers will be given off to the groundwater and stored for use in winter. A cooling tower with a maximum capacity of 4 MW will be used if necessary.

In winter the energy plant will serve to a district heating network. Peak load demand will be met by three oil-fired boilers and one electric boiler. The heat pump system will be ready for use from April, 1997.

Source: Mr Jorn Stene, Norwegian National Team.



New motor resists ammonia

Air-cycle system for winter Olympics

USA - The design of heat pumping systems with ammonia refrigerant is hampered by the fact that ammonia is incompatible with synthetic motor materials, usually destroying motor insulation systems in a matter of hours. Now, this major drawback is about to become history with the development of a hermetic motor insulation system that withstands total immersion in non-anhydrous ammonia.

Developed by A.O. Smith Electrical Products Company, the new system has proven to be highly resistant to ammonia, with insulation system and component reliability tests in excess of 1,400 hours with little or no degradation noted. Working closely with Bitzer Kuhlmaschinenbau, GmbH & Co. KG of Germany and Frick Industries of Pennsylvania, USA, A.O. Smith developed an innovative set of materials – including some never before used in ammonia environments – that could withstand the highly corrosive atmosphere. With correct design and sizing, the motor can deliver the same efficiency as a hermetic motor used with traditional refrigerants, such as HCFC-22.

Source: Mr Roger van Malsen, A.O. Smith Electrical Products Company, 513 North Fourth Street, Tipp City, Ohio 45371, USA. Tel: +1 -513-667-2387.

Japan - An air-cycle cooling system is being installed for the bobsled run for the Winter Olympics in Nagano in 1998. The same system is also being demonstrated for a cold storage warehouse.

The Air Refrigerating System (AIRS) was developed by Kajima Corporation and others in response to concerns raised by the International Olympic Committee about the environmental impacts of CFCs and ammonia refrigerants.

As illustrated in **Figure 3**, the system takes air and dehumidifies it through an adsorption device. The air is then compressed and expanded rapidly and adiabatically to produce chilled air. No fans or pumps are required. Heat can be recovered from the compressor as well.

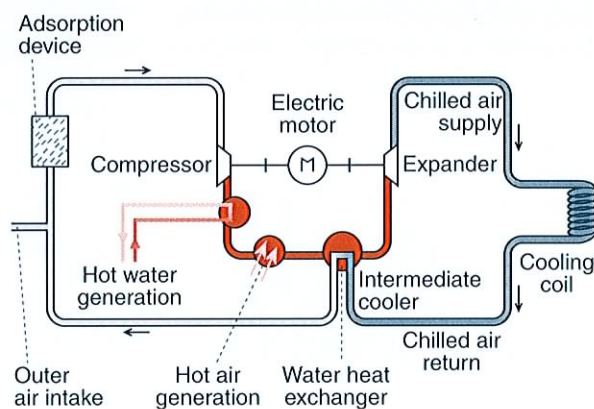
Kajima estimates that running costs at the bobsled facility are 21% lower than for an ammonia-based cooling system, and 54% less than a vapour compression system. The bobsled facility has a design cooling

capacity load of 260 kW to keep the ice at -5°C . With an average outside air temperature of 6.4°C , a chilled supply air temperature of -45°C , and a return air temperature of -15°C , the system has an overall power requirement of 400 kW.

The system is also being used in a commercial prefabricated refrigerated warehouse to be marketed by Kanematsu Corporation, Tokyo. For more information, contact: Mr Kaneko, Kajima Corporation, 2-7 Moto-Akasakai-Chome, Minato-ku, Tokyo 107, Japan. Fax: +81-3-5474-9497.

Source: Technologies for Energy Management, May 1996, from Cutter Information Corp., USA.

Figure 3: Air-cycle system for Olympic bobsled.



Interest grows in hydrocarbons

UK - According to the hydrocarbon manufacturer Calor Gas, most small heat pumps under 8 kW, for the European market at least, will be using hydrocarbon refrigerant in the next few years. This is not because they are much more environmentally benign than conventional working fluids, but because they can offer significant energy and cost savings.

Russell Benstead, manager of the Building Energy Systems Group at consultants EA Technology, said: "Hydrocarbons increase a system's coefficient of performance. They are more compatible with the materials traditionally used in heat pump systems, and

can be used with mineral and ester oils. Also they cause less internal scouring than some of the other refrigerants."

Swedish company Elektro Standard has been marketing a range of three heat pumps using hydrocarbons (HCs) since August 1995. The demand has been high, particularly in Germany and Sweden.

Mats Fehrm, technical manager of Elektro Standards, said: "We have decided to convert our units to hydrocarbons because, as well as people being concerned about the environment, we have found that HCs are more energy efficient and economical."

"We have found HCs to use between 5 and 10 per cent less energy. And, because we only put between 300 and 500 grammes of propane refrigerant in a unit, it is cheaper than the alternatives available."

Sweden's largest installer of air conditioning equipment, ABB Stal, together with Swedish manufacturer Bonus, is promoting a range of water and air-cooled chillers using the Calor Gas HC, CARE 50.

Source: Mr Paul Blacklock, Calor Gas Refrigeration, Appleton Park, Slough SL3 9JG, UK. Fax: +44-1753- 5888905, Internet: www.Calorgas.co.uk



Chinese market up 20%

China - In 1995, the total sales income of industrial and commercial refrigeration and air-conditioning equipment reached a value of 20 thousand million Yuan, an increase of 20% on the previous year. The increase in sales volume was especially large for domestic air conditioners which grew 35% in 1995 to 5.2 million units.

The total market for water chillers for central air-conditioning systems grew to 12,000 units in 1995, of which 2,200 units were large absorption machines. The year 1995 also saw sales of domestic refrigerators rising 21% to a massive 9.3 million units.

All this activity, has increased concerns about power supply with a power shortfall

of 15 to 23 GW predicted by the end of the century. Measures to save energy saving and shift peak power usage are therefore a vital task for the refrigeration and air-conditioning industry in China.

Time-of-use rates will be introduced countrywide over the coming one to two years with the aim of shifting 10 to 20 GW of peak power by the year 2000.

The development of thermal storage technique and absorption refrigeration is being encouraged by Chinese State Government. And the Chinese Association of Refrigeration, in cooperation with other organizations is organizing an exhibition ART '97. All those concerned with advanced heat pumping technology, especially thermal storage and absorption technology are invited to take part. More details are on page 31.

Source: Ms Zhang Ping, Chinese Association of Refrigeration, Fax: +86-10-6217-2249, E-Mail: onis@public3.bta.net.cn

Swiss market has ups and downs

Switzerland - Statistical data from the E2000 programme indicate a mixed performance in the heat pump market in 1995. Overall, the total heating capacity installed last year was 50 MW, about 3 MW less than was added in 1994. This fall is due to a decline in the installation of large

(>20 kW) systems which can be attributed to a slow-down in the construction of commercial buildings.

In contrast, the residential sector (<20kW) exhibited good results in 1995, with installed capacity rising around 6% to over

33 MW. As indicated in **Figures 4 & 5**, growth was especially sharp in the smaller retrofit market which rose around 40%. The total heating capacity of heat pumps installed in Switzerland is now over 300 MW.

Source: Mr Thomas Afjei, Swiss National Team.

8

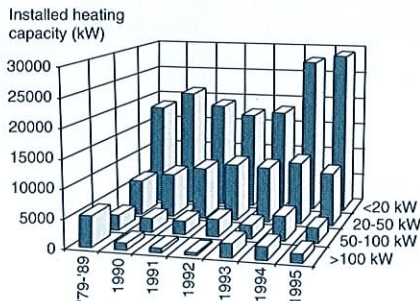


Figure 4: Installed heating capacity of monovalent heat pumps in Switzerland.

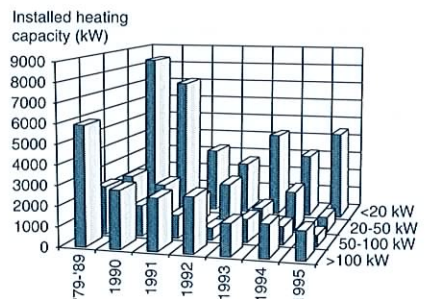


Figure 5: Installed heating capacity of bivalent heat pumps in Switzerland.

Building slow-down affects sales

USA - After several years of steady growth, new house building suffered a set-back in 1995, with the number of completed single-family units dropping 8% in 1995 to 1,066,000 units. With 25% of new single-family houses being equipped with a heat pump system, this slow-down led to the number of electric heat pumps installed in new houses dropping 6% to 264,000 units. Despite this set back, overall shipments of unitary air-to-air heat pumps registered a modest rise of 2% to 1,025,000 units (see previous issue of the *IEA Heat Pump Centre Newsletter*).

Within the market for heat pumps in new houses, the South continues to dominate, accounting for over 80% of heat pump installations. Around 45% of new homes in the South have a heat pump. For the country as a whole, the dominant heating system is the gas-fired warm air furnace which is installed in 67% of new homes.

Source: Data from the Census Bureau published in *Air Conditioning, Heating and Refrigerant News*, 24 June 1996.

Errata

In the previous issue of this Newsletter (No.2/1996), errors occurred in the production of figures for the article by Mr Jostein Pettersen on pages 23 to 25. In Figure 2, the curve showing the distribution of cooling hours was emitted and the temperature scale along the x-axis should have run from approximately 19°C to 39°C. In Figure 3, the curves for building load and heating hours are interchanged. Correct copies of these figures are available from the HPC.



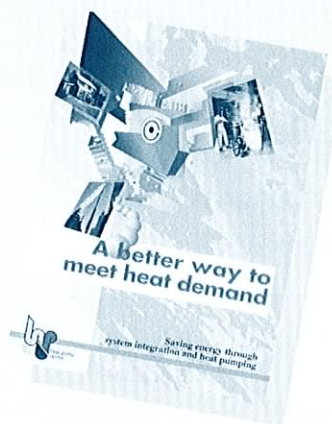
New brochure urges system integration

HPC -The need for better systems integration is being spoken about more and more recently. A newly published brochure from the IEA Heat Pump Centre looks at how the integrated systems approach can be applied to the design of energy systems. Entitled "A better way to meet heat demand", the brochure explains how primary energy consumption can be dramatically reduced through energy cascading and energy upgrading.

The "quality of energy" concept is introduced as a useful tool in systems optimization, and is concisely explained along with the term "exergy". By following the thought processes of designers of an imaginary community, the key role that heat pumps can play in an integrated energy system is graphically illustrated.

The 12-page full-colour brochure has been produced as part of the HPC's campaign to promote the widespread use of heat pumps. It is available from the HPC, free-of-charge.

A new brochure from the HPC.



Internet site gets busy

HPC - More and more people are discovering the IEA Heat Pump Centre's Internet facility on the world wide web and are checking in on a regular basis. The number of visitors is estimated at around 350 per week.

The IEA Heat Pump Programme Library is the most popular attraction. This is used to search on over 1000 records of books, papers and articles published under the IEA Heat Pump Programme. The most popular subject to search on is ground-source heat pumps. As shown in **Figure 6**, visits to the library have risen sharply in recent months.

Many people are viewing the news pages, where up-to-date information on IEA Heat Pump Programme activities is given, along with announcements of forthcoming conferences, exhibitions and other events. These pages also includes news items taken from past issues of the *IEA Heat Pump Centre Newsletter*. Also attracting significant interest are the pages providing basic information on heat pumps.

Figure 6: Trend in visits to the IEA Heat Pump Programme Library at the HPC's internet site.



Reader profile revealed

HPC - A market research study indicates that readers of the IEA Heat Pump Centre Newsletter are working in a broad spectrum of activities. Many can be classified as academics, with 25% working for research and development organizations, while a further 12% are in education. Heat pump manufacturers account for 10% of readers while a further 10% are involved in heat pump marketing, installation or servicing, and 7% are equipment users.

Power and gas utilities employ 10% of readers while a further 10% are involved in information exchange or consultancy. In the IEA Heat Pump Programme strategy plan, a key target is to reach national and regional policy makers. The market survey shows that good progress is being made, with around 10% of readers working for organizations that support national, regional or global energy programmes.

The results are based on a study of around 100 readers in various countries. All those who returned the questionnaire are thanked for their support. More results are available from the HPC.

Ongoing Annexes

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IEA Heat Pump Centre

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NO, CH, US

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NL, NO, CH,
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Annex 23
Heat Pump Systems
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CA, ES, FR,
SE, CH, US

IEA Heat Pump Programme participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).



Heat pumps in commercial buildings

An international overview

Bert Stuij, IEA Heat Pump Centre

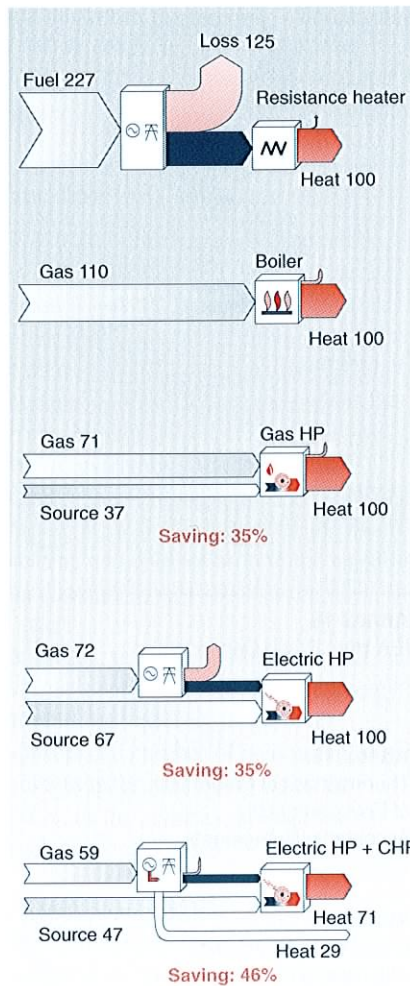
The prospects for heat pumps in the commercial and institutional sector look good. Today, about ten million systems are installed worldwide, and around one million are added each year. In Japan and the US about 12% of all the heat demand in commercial buildings is met by heat pumps. But even in ‘cool’ markets, such as in Sweden and the UK, heat pumps can contribute up to 7% of heat demand. This article provides a brief review of the main technologies and applications, the current market status and factors, and notes some relevant developments. In the ‘country blocks’ around this article the situation in a number of countries is highlighted, with illustrations of some practical examples.

In this article, the term “commercial buildings” is used to refer to all building applications outside the residential and industrial sectors, including offices, shops, restaurants and sports facilities, as well as institutional buildings such as schools, hospitals and government offices.

The commercial buildings market has a number of inherent advantages compared to the residential market. First of all, there will more often be a cooling demand, mainly because of greater internal heat gains. A cooling demand leads in most cases ‘naturally’ to a reversible heat pump market. And secondly, the installations in commercial buildings will be larger, which offers opportunities for a greater variety of technologies, and reduces the price per installed kW.

Technology and applications

A great variety of heat pump types are potentially relevant for the commercial buildings sector, and the most common configurations (in a gas based energy economy) are shown in **Figure 1**, with an indication of achievable savings compared to a gas boiler. The large and mature markets of the US and Japan are dominated by electric systems. In Japan two types are particularly common, the decentralized packaged units for small to medium buildings, and the central heat pumps for medium to large buildings.



▲ *Figure 1: Heat pump options and potential energy savings.*

	Cooling	Heating
Condensation [°C]	37	45
Evaporation [°C]	8	7
COP	6.5	5.8
Thermal output [kW]	1200	1350
COP variation per °C	0.042	0.027

▲ *Table 1: Performance data of a Super Heat Pump installed in the head office of a Japanese utility.*

	Total installed (x 1000)	Annual placement (x 1000)
Austria	3.8	0.2
Japan	6720	750
The Netherlands	0.25	0.1
Norway	4.0	0.2
Sweden	40	3
Switzerland	1.1	0.1
UK	362	50
USA	2700	270

▲ *Table 2: Total number and annual placement of heat pump systems in the commercial buildings sector.*



World-wide, of the ten million installed systems only about 10,000 are gas driven.

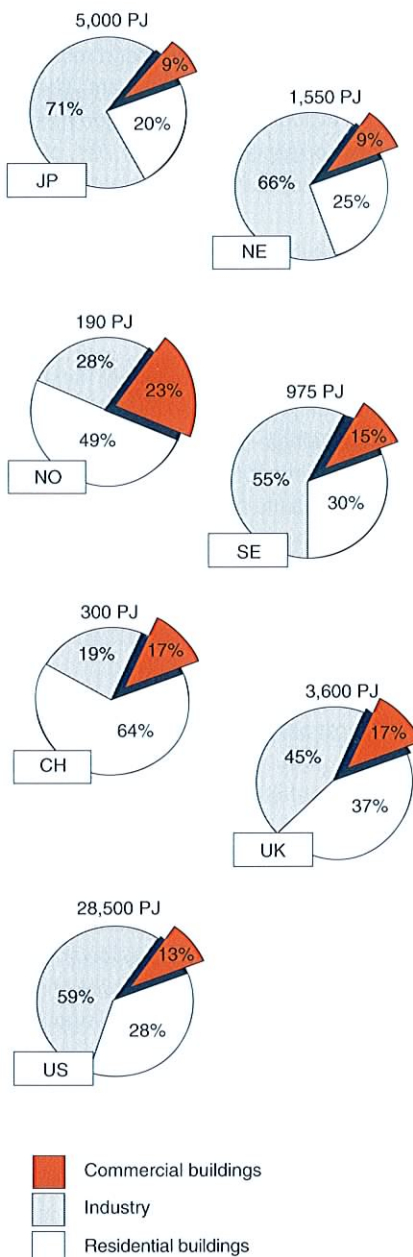
In the country blocks around this article a variety of applications and typical configurations are highlighted. They are found in hotels, offices, hospitals, schools, sport centres, recreation facilities, etc.

The performance of the heat pumps continues to improve. By way of illustration, the performance of a Japanese Super Heat Pump is shown in **Table 1**, highlighting the result of developments with little investment constraints. In heating mode the heat pump realizes a COP of 6, here equivalent to about 75% of what is theoretically achievable. Conventional heat pumps reach about 50%.

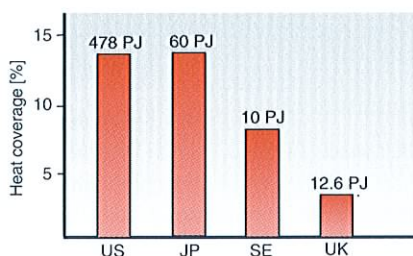
Market status

The pie charts of **Figure 2** give an idea of the significance of the commercial buildings heating market. As shown, the heat demand in this sector is typically between 10 and 20% of the total societal heat demand. Norway is remarkably high with 23%. In Switzerland, the heat demand from commercial buildings is about one quarter of the demand from the residential sector. In the other countries shown, the fraction is nearer one half.

To what degree this heat demand is met by heat pumps is shown in **Figure 3**. In the mature, cooling driven markets of Japan and the US the coverage is 12-13%. Sweden is a heat demand driven market, which still achieves a coverage of about 7%. This relatively high percentage is partially explained by the fact that many large buildings are connected to district heating grids that are fed by heat pumps. The UK reaches 4% in what is a cooling demand driven market despite the climate. The cooling demand is almost completely the effect of internal heat loads.



▲ **Figure 2:** Heat demand in commercial and residential buildings and in industry.



▲ **Figure 3:** Heat demand coverage by heat pumps in the commercial buildings sector.

Austria

Heat pumping equipment is used increasingly in recently built, large commercial buildings, which require space cooling because of high internal heat loads and because they lack the

thermal storage mass of traditional buildings. Compression type systems are the most common, although absorption units are also used. A new trend, is to utilize waste heat from combined heat and power (CHP) or district heating during the summer to drive absorption cooling equipment.

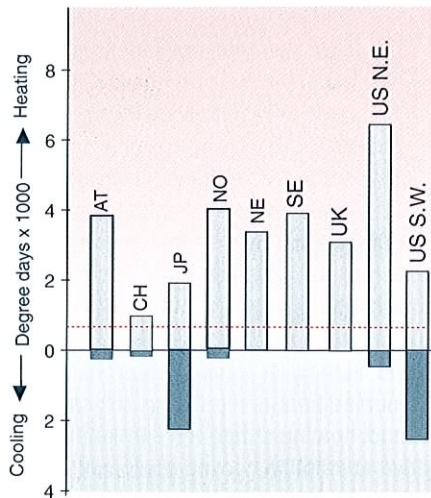
Distribution is mainly via 4-pipe water-based systems with fan coils, and recently with cooling ceilings as well. The equipment is often only used for cooling, with heat demand covered by district heating, combined heat and power (CHP), or by fossil fuel fired boilers. Other systems incorporate thermal shifting, with the heat removed in cooling transferred to help meet heating needs. Full coverage of both heating and cooling loads by heat pumping occurs in applications with high internal loads or where a high-temperature heat source is available.

Recreation centres and hotels are increasingly using heat pumps. Some recover heat from hot springs. Heat pumps are also widely used in schools, especially those in rural regions, many of which were renovated in the 1980s. Dehumidification of indoor swimming pools is also popular, as is the use of ice rinks as a heat source for heating of other facilities.

A special application is hospitals. The largest hospital in Austria, the "Allgemeines Krankenhaus" in Vienna, is equipped with 300 semi-central air conditioning units with 760 air handling units. Eight electric centrifugals and four gas-fired absorption chillers with a total cooling capacity of 58 MW are installed. Heating is carried out by means of district heating from a CHP plant.

Source: Dr Hermann Halozan, Austrian National Team





▲ Figure 4: Typical comfort demand in various countries and in north-east and south-west USA.

In Japan and the US the annual sale of commercial buildings heat pumps is about 10% of the total number of systems in place. These are, to a significant degree, replacement markets. The market situation for a number of countries is shown in Table 2.

Market factors

The most important market factor is the comfort demand. More specifically, the heat pump market tends to develop easily if there is both a cooling and a heating demand. In commercial buildings this will be more often the case than in homes, because internal heat gains are typically high, especially in well-equipped offices. The comfort demand is illustrated in Figure 4. The climate induced cooling demand is indicated by the number of degree days below the solid line in the figure. But the internal heat gains have an effect that can be illustrated by moving the horizontal axis up. Even in cool climates, cooling will be required, as indicated by the number of degree days below the red dotted line.

The position of this line is only illustrative. Its exact location cannot be generalized as it varies from building to building. It will depend on local

Japan

Heat pumps have been recognized as indispensable items for commercial buildings for many years. The market size is about 0.7 million units a year, including small packaged heat pumps and central heat pumps. This corresponds to about 70% of the total heating and cooling requirements of newly-built commercial buildings.

The table below illustrates the two main heat pump types. Decentralized packaged systems are used in small to medium-sized buildings, while central heat pump are used in medium to large-sized buildings.

The decentralized systems are mostly air-to-air split systems with indoor and outdoor units connected by refrigerant piping. A limited number of through-the-wall mounted single-packaged heat pumps are used in combination with central heat pumps for interior-zone space conditioning. Water-loop heat pump systems are also used in small to medium size buildings.

Very many multi-split systems are installed, with a wide range of options including simultaneous heating and cooling with heat reclaim, and ventilation air heat recovery. A recent development is the addition of ice thermal storage to such systems to shift power consumption to off-peak periods. The need to reduce the peak power demand in summer has also led to a growing market for gas engine driven air-to-air multi-split heat pumps for small buildings.

Central heat pumps are generally electric air-to-water systems that use either outside air or ventilation air as the heat source in winter, depending on the internal heat production of the building. They are usually coupled with large water thermal storage tanks which are built at low cost into the bottom structure of the building to provide both heat and cold storage. This not only allows the use of off-peak electricity, but can also substantially lower the required cooling capacity of the heat pump, thus reducing both the initial cost and the power demand charges. Central gas engine heat pumps are used in applications, such as swimming pools, with a high heating demand.

While central heat pumps offer high-quality air conditioning with low noise and low peak power demand, the decentralized systems are relatively less expensive and offer greater flexibility in operation and installation.

Source: Mr Yoshio Igarashi and Mr Takeshi Yoshii of the Japanese National Team

	Decentralized heat pump	Central heat pump
Equipment	Packaged air-to-air, split or multi-split system with inverter speed control, rotary or scroll compressor and direct expansion coil.	Air-to-water heat pump with reciprocal, screw or centrifugal compressor.
Refrigerant	HCFC-22	HCFC-22, HFC-134a or HCFC-123
Dry/wet bulb heat source temp.	Rated at 7/6°C	Rated at 7/6°C or 0/-3°C
Dry bulb heat sink temp.	Rated at 35°C	Rated at 35°C or 32°C
Heat distribution temp.	Direct heating and cooling of room air	45°C heating / 7°C cooling
COP heating/cooling	3.0 to 4.0 / 2.5 to 3.5	3.0 to 4.5 / 2.5 to 4.0



Norway

Data on the accumulated heat pump installations in Norway (see table below) show that systems with a heating capacity of 25 kW or more, are significant in terms of heating capacity if not numerically. Key applications areas for these large heat pumps are hotels, office blocks, hospitals, homes for the elderly, schools, sport centres (swimming pools etc.) and blocks of flats. They are used for space heating using hydronic heat distribution, heating of ventilation air, hot water heating, space cooling and computer cooling.

The most profitable installations provide simultaneous heating and cooling or meet a large and steady hot water demand. With 20% of buildings using electric resistance (baseboard) heating, the retrofit market is difficult. Lack of knowledge and low energy prices are other market impediments.

Even though HFC-134a is the dominating heat pump working fluid in Norway, there is a strong trend towards the use of ammonia (NH₃) in medium and large capacity systems (> 150-200 kW). The ammonia heat pumps are reliable and offer high energy efficiency. And as long as the systems are designed in accordance with the "Norwegian Code of Good Practice-Refrigeration", they are considered as safe as conventional HFC-systems.

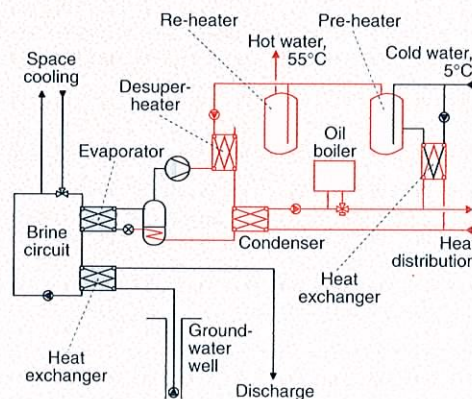
The figure below shows an ammonia groundwater heat pump which provides space heating and cooling and hot water for a college at Rena, in south-east Norway. With a heating capacity of 200 kW at 6°C inlet water temperature, and 48°C outlet water temperature. The estimated heating COP is 3.6. The heat pump covers about 40% of the maximum peak load demand, with the remainder met by an oil boiler. Heat distribution is via a hydronic system with radiators and floor heating system, as well as ventilators. Sanitary water is preheated in a separate plate heat exchanger and reheated in a desuperheater.

Source: Mr Jørn Stene, Norwegian National Team

Table: Heat pump installations in Norway, January 1996

Heat pump output (kW)	< 25	25 - 100	100 - 1000	> 1000
Number of HP units installed	15,000	3,000	1,000	30
Total heating capacity (MW)	110	200	200	100

Figure: Groundwater-source heat pump serving a college. ▶



climate, building style, level of office automation, etc. And it should be noted that in a cool climate, cooling can in principle be achieved by other means, such as ventilation and architectural design.

The second important factor is the energy price ratio. In many cases heating can also be achieved by fossil-fuel heating systems, notably gas boilers and furnaces. The ratio is shown for some countries in Figure 5. Given a typical heat pump SPF of three, the ratio should be below three for heat pumps to compete effectively with a high efficiency boiler, and below 2.4 to compete with a conventional boiler or furnace.

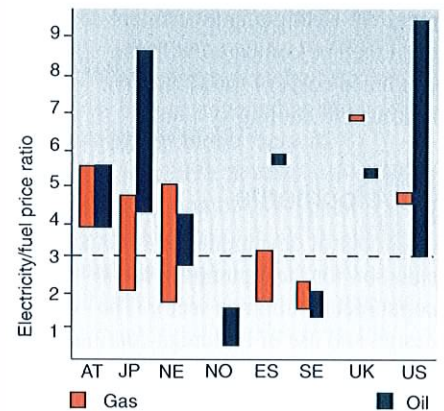
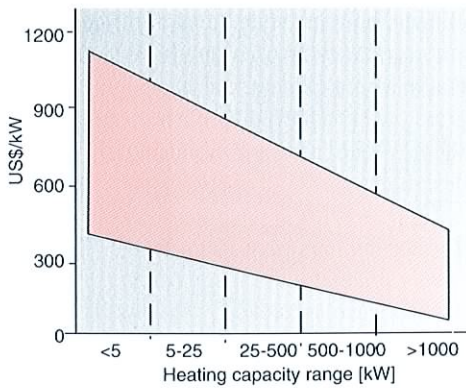


Figure 5: Energy price ratio. The length of the bars is due to differences between day and night-time electricity tariffs, amongst other factors.

A closely related factor is the relative amount of heat pump investment costs. Figure 6 shows the range of current heat pump system investment costs. For heat pumps in the commercial sector, typically with a thermal output of 25 to 500 kW, prices range from an estimated 300 to 1000 US\$ per kW. Absorption heat pumps tend to be high in this range, while mass produced electric systems are rather low. The price for high efficiency boilers is around 60 US\$ per kW—the difference in investment costs is thus significant. Clearly, this difference is strongly moderated if a cooling system is





▲ Figure 6: An indication of the range of heat pump system investment costs.

required. Heat pump investment costs must then be compared with the combined costs of the alternative heating and cooling system.

Developments

A number of developments affect the situation for heat pumps in the commercial buildings sector. The design and use of buildings continues to evolve, society steers developments with regulations, and equipment performance improves. More specifically the following factors may be highlighted:

Rising internal heat gains, as a result of two decades of radical office automation, increase cooling demand. However, the peak may now have been reached. Office computerization is perhaps about complete, and the efficiency of lighting and equipment is increasing.

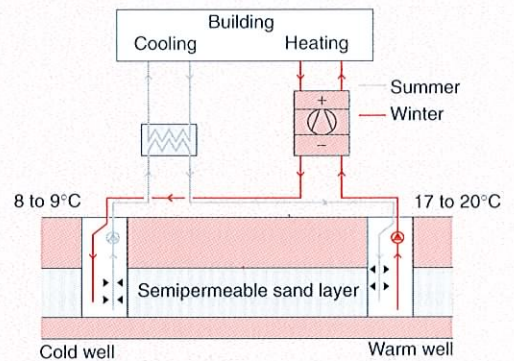
Improved insulation and the low thermal mass of modern buildings leads to higher cooling demands even in countries with a cool climate.

Regulations are beginning to constrain the cooling demand in cool countries to a degree. In parts of Germany and Switzerland, for instance, local or

The Netherlands

With sales of around 100 units per annum, the market for heat pumps in commercial buildings is very small. However, the market is showing sign of some recovery after the problems of the 1980s when a few poorly performing systems gave heat pumps a bad reputation. Given favourable market conditions, it has been estimated that the market will grow substantially over the coming years, so as to provide energy savings of around 700 MJ per annum by 2005. The applications considered to be of greatest potential are offices, hospitals and other health care centres, homes for the elderly, restaurants and hotels.

A recent trend to combine heat pumps with thermal storage. At the offices of insurance company Anova Verzekering in Amersfoort, heat or cooling capacity is stored in two groundwater aquifers (see Figure). In winter, groundwater from one aquifer – the warm well – is used as the heat source for an electric heat pump. The groundwater, which is cooled to 8°C, is transferred to a second aquifer – the cold well. By the end of the heating season, sufficient cold groundwater has been stored to meet the building's cooling needs throughout the summer, without using heat pumping equipment. During cooling, the groundwater is transferred to the warm well at between 17 and 20°C to provide a warm heat source.



Source: Mr Onno Kleefkens, Dutch National Team

Switzerland

Heat pumps in large buildings are mainly used for heat recovery or in bivalent systems with and without hot water heating. The demand for office cooling is small. In the canton of Zurich, the requirements to prove the cooling demand are quite restrictive.

Data from the renewable energy department of the E2000 programme show that the market for large heat pumps for commercial buildings applications is small. In 1995, around 13 MW of heating capacity was installed with units of 20 kW heating capacity or more - around a third less than in 1994. This drop is probably due to the low amount of commercial buildings built in 1995. Around 90% of installed capacity with large heat pumps in 1995 was for monovalent systems.

The heat pump system at the Alpenquai college in Lucerne (see IEA Heat Pump Centre Newsletter Vol.12 No.3) shows how heating applications for large buildings can offer the opportunity to build fully integrated systems. Here, two heat pumps work together with a combined heat and power (CHP) unit to serve the college with heat for space conditioning and hot water with a primary energy ratio (PER) of 1.4. A two-step ammonia heat pump recovers heat from Lake Lucerne and from a nearby cold storage depot. An HCFC-134a heat pump recovers heat from the CHP unit. Both are driven by the CHP unit.

Source: Dr Thomas Afjei, Swiss National Team



USA

Innovative technologies and applications are being used to address changing environments in commercial buildings. Heating ventilation and air-conditioning system design must now consider the increased use of personal computers, facsimile machines, and other electronic equipment.

Heat generated by these items, combined with improvements in the thermal performance of building envelopes and the recycling of exhaust air energy, have increased the number of commercial structures that are cooling-load-dominated in northern climates. In these locations, there are more annual heating hours than cooling hours; however, the peak cooling load exceeds the peak heating load. This has led to the deployment of innovative heat pumping applications and the development of more efficient commercial heat pumps.

One such application is the installation of a hybrid geothermal (ground coupled) heat pump system in Allentown, Pennsylvania. The system combines extended-range water-source heat pumps with a vertical closed-loop well field and a ground-mounted closed-circuit fluid cooler. The facility's heating requirements are being met through the ground-coupled closed-loop vertical heat exchanger. To supplement this capacity, air-to-air heat recovery is being applied to 3,800 l/s of outdoor air. Cooling requirements are being met through the ground loop with assistance from the fluid cooler.

By combining the fluid cooler with the geothermal well field, the system's initial cost is lower than a complete well field installation. Since one of the factors limiting widespread use of geothermal technology is higher initial cost, this hybrid system can help to expand the market for geothermal systems. Use of the fluid cooler can also be beneficial in installations concerned about long-term thermal effects on the ground from a cooling-dominated geothermal installation. A report on the two-year operation of this hybrid system will be available in Spring 1997. Data from this installation is being used to assist the Geothermal Heat Pump Consortium's effort to develop design tools for engineers to use in evaluating applications of the hybrid geothermal system.

High efficiency heat pumps for commercial use are appearing with more frequency. The Electric Power Research Institute sponsored development by Lennox Industries of a complete 10.6 to 105.6 kW high-efficiency packaged rooftop line which includes a 52.8 kW single-package rooftop heat pump unit with a COP of 2.9, an integrated part load value (IPLV) of 11.2, and 8°C heating COP of 3.3. A similar 70.4 kW heat pump was also developed and introduced with ratings of 3.1, 11.5, and 3.2 respectively. Standard features of this product line include a fully integrated modular electronic control and diagnostic system for all required internal operating and safety controls, as well as control of accessories such as the outdoor air economizer and smoke alarms.

Other features include no-tool hinged service access panels, slide-out blower decks for easy blower and motor service, and a wide array of factory-installed options including smoke detectors, corrosion protection coil coating, internally-mounted main power disconnect switch, and 115 volt GFI convenience outlets available on a "configure-to-order" basis. A new initiative is underway to evaluate the possibility of maintaining these efficiency levels with new refrigerants, such as the higher pressure R-410A.

Source: Sandy Smith of Oak Ridge National Laboratory, Dennis McGraw of Pennsylvania Power and Light Company and Ted Gilles of Lennox Industries.

regional building codes require building measures that reduce the mechanical cooling demand to an absolute minimum. And even in the UK, where heat pumps are generally installed because of the cooling demand, such measures are under consideration. Such regulations will dampen the reversible heat pump market.

Other developments are the *optimization and integration* of energy functions in large buildings, the continuing rise in system and component *performance*, and the gradual progress of *thermal storage*. Short-term storage is used to reduce peak demands for electricity in the US and notably in Japan. Seasonal storage is for instance applied in the Netherlands to provide year round comfort with a very high overall efficiency.

A strong position

Heat pumps have achieved a notable penetration in the commercial buildings sector, and are likely to strengthen their position further. The high level of office automation in well-insulated buildings leads to a summer cooling demand, even in relatively cool countries. Reversible heat pumps are well placed to provide year round comfort in this environment. In heating-only situations heat pumps face the same challenges as heating-only heat pumps in the residential sector—relatively high investment costs, and relatively modest returns on investments because of high electricity/fuel price ratios. In this competitive market, work must continue to make heat pumps both cheaper and better. The IEA Heat Pump Centre is committed to the information flow which will help manufacturers and developers to face up to this challenge.

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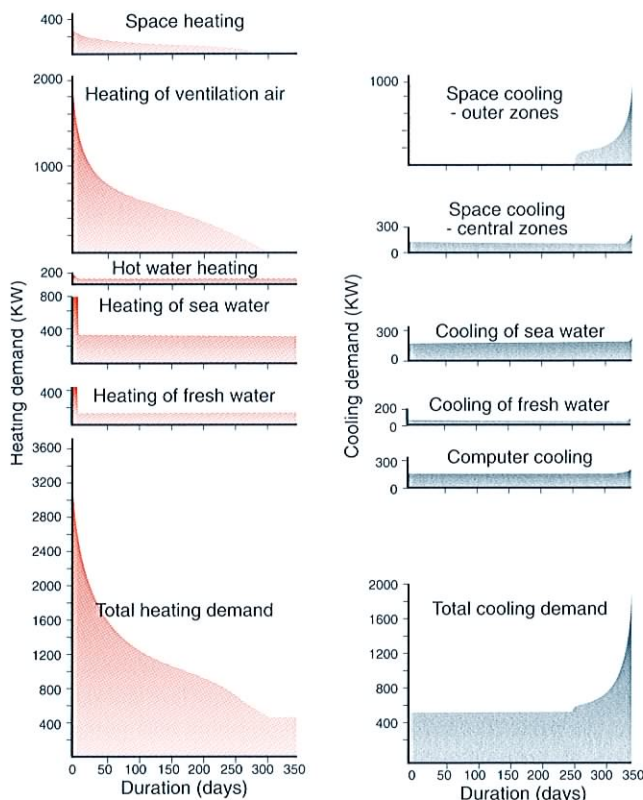
Mr Bert Stuij, IEA Heat Pump Centre



Meeting heating and cooling demands in a research centre

Geir Eggen and Jørn Stene, Norway

Significant trends in the construction and application of commercial buildings are improved thermal envelopes, increased internal heat gain and growing comfort requirements. Such trends are expanding the market for space conditioning heat pumps, even in cold regions without a natural air-conditioning market. The advanced installation at a research centre in Bergen, Norway, demonstrates that when there is a simultaneous demand for heating and cooling, heat pumps can be both energy efficient and economical.



▲ Figure 1: Heating and cooling demand duration curves for the building.

In October 1990, the research centre known as the High Technology Centre (Høyteknologisenteret) in Bergen, Norway opened a new building with a total floor area of 14,500 m², combining both office and laboratory facilities. **Figure 1** shows the building's estimated heating and cooling demand duration curves which were used in the design of its energy system. Even though the maximum heating and cooling loads occur at different periods of the year, there is a rather good compliance between heating and cooling demands over the year.

As shown, the energy demands include the heating and cooling of fresh water and sea water for aquaculture research, computer cooling, and hot water heating. Space heating demand is met by heating ventilation air and by hydronic radiators and underfloor heating. The central zones of the building have a steady demand for space cooling throughout the year while outer zones only require space cooling on warm days.

Heat pump system design

To meet the simultaneous heating and cooling demands, the advanced electric heat pump system shown in **Figure 2** was installed.

The heat pump was designed to cover the maximum cooling load of 1.5 MW, which in turn gives a total heating capacity of 2.0 MW at the condenser side. Since the maximum heating load at design conditions is approximately 3.6 MW, additional heating (peak load) is met by a district heating system based on oil-fired boilers. During a normal year of operation, the heat pump will cover typically 85-90% of the heat requirement.

The system comprises two heat pump units with eight reciprocating compressors in total. Since each compressor may be regulated in two steps (100%, 50% and off), smooth capacity control is obtained. Shell-and-tube condensers are used as evaporators and condensers. In the tender competition both ammonia and HCFC-22 heat pumps were offered by several suppliers at almost similar costs. Since an ammonia installation amongst others would involve a separate machinery room outside the building, HCFC-22 was chosen as the working fluid. However, a similar plant today would most likely use ammonia, since the recent installations of ammonia heat pumps in commercial buildings in Norway, have shown outstanding performance and reliability.



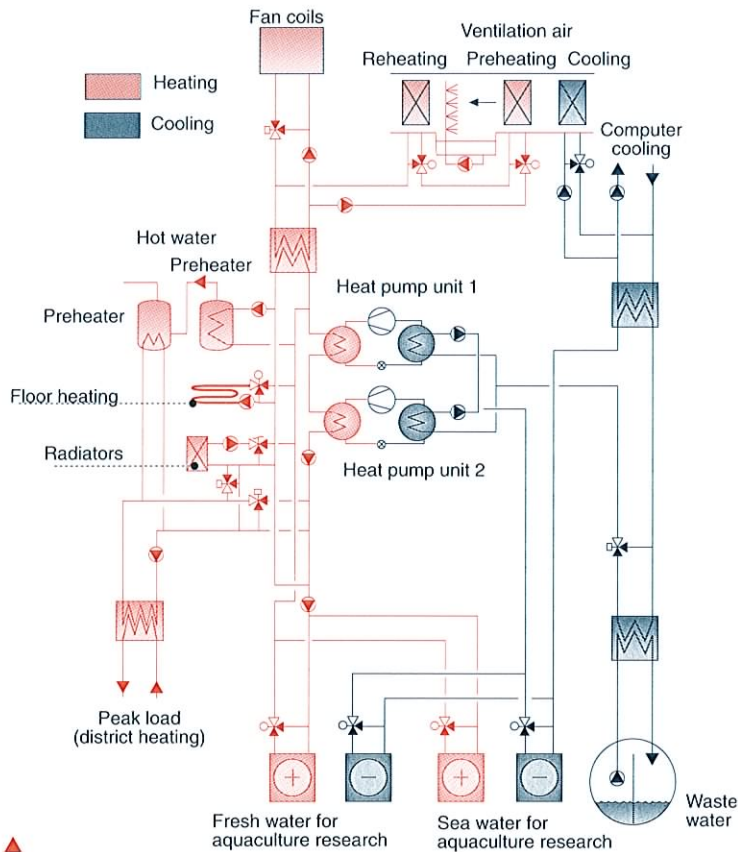


Figure 2 - The heat pump energy system for combined heating and cooling.

With the exception of two compressor failures (one in the guarantee period), no significant operation problems have been reported. During the first four years of operation, the heating and cooling demands have only been 60% of design value due to less extensive use of the building than originally planned.

Table 1: Energy flow of the heat pump system in 1995.

Heat production from heat pump installation	
Hydronic system	1,530 MWh
Ventilation air	2,160 MWh
Excess heat given off to ambient air	2,870 MWh
Total heat production	6,560 MWh
Cold production from heat pump installation	
Heat from waste water	830 MWh
Heat from ventilation batteries	3,220 MWh
Total cold production	4,050 MWh
Energy consumption, energy system	
Electricity for heat pump	1,540 MWh
Supplementary heating (peak load)	950 MWh
Total energy consumption	2,490 MWh
SPF heat pump	3.6
SPF total system - heating only	2.6
SPF total system - heating and cooling	4.3

Sources and sinks

The heat source is primarily the low-temperature heat extracted in meeting the various cooling demands. If the heating demand exceeds the cooling demand, waste water is used as an additional heat source. If the cooling demand is pre-dominant, surplus heat is given off to the ambient air through fan coil units on the roof.

Some space heating is provided through a hydronic heating system connected to radiators operating at a distribution temperature of 70°C at design conditions. The heat exchangers for heating of ventilation air are designed for a supply/return water temperature of 45°C/35°C. The condenser heat is used for pre-heating hot sanitary water as well as heating of fresh water and sea water for the aquaculture research activity.

Efficient and profitable

In order to monitor the heat and cold production, energy consumption and the Seasonal Performance Factor (SPF), the heat pump system has been instrumented with energy meters, electricity meters and temperature sensors.

As shown in Table 1, the system exhibits a high energy efficiency. The listed data are from monitoring carried out over the whole of 1995. SPFs are calculated for the heat pump alone, for the total energy system in heating mode, including the energy consumption of the peak load boilers, and for the total energy system in both heating and cooling mode.

The total installation cost of the heat pump system was approximately US\$ 450,000, resulting in a pay-off period of less than one year.

Due to the favourable experience with the heat pump system at the High Technology Centre, the University of Bergen decided to install a heat pump district heating and cooling system on its campus. This system is described in detail in the Heat Pump Centre Newsletter, 1/1996.

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New opportunities for heat pumps in office buildings

Onno Kleefkens and Kees Jansen, The Netherlands

Future energy systems for office buildings in the Netherlands will need to further reduce the use of fossil fuel to below that stipulated by current legislation. The technologies that have emerged to achieve this are cogeneration (combined heat and power) and heat pumps. Current economic factors favour cogeneration, even though heat pumps are more attractive from the point-of-view of energy conservation, especially when fully integrated into the energy system. Despite this, studies carried out on existing and new heat pump installations show that the future for heat pumps in commercial buildings is bright.

In the Netherlands, the heat pump has only just succeeded in casting off its image of a problem child. This image partly originates from the early 1980s, when the Dutch government launched its first heat pump programme. Unfortunately, the problems with heat pumps installed under the programme drew more attention than did the successes. As a result, the heat pump is still not very popular, and the total number of installed heat pumps is far lower than could reasonably be expected.

Since 1995, a new heat pump programme has been in operation, carried out in the Netherlands by the Netherlands Agency for Energy and Environment (Novem). To examine the market barriers, and the applications and technologies that can bring success, a survey was carried out by the Centre for Energy Saving and Clean Technology (CE - Centrum voor Energiebesparing en Schone Technologie) and De Beijer RTB in 1995, and was followed up by a workshop with the relevant market-parties.

The survey found that the key application areas were offices with an area larger than 5000 m², especially government buildings, insurance companies, hotels and shopping areas. To gain more insight, GASTEC (the Dutch Centre for Gas Technology) and Van Heugten were asked to study the history of installed heat pumps.

It was noted that real data on the results of older projects were hard to get. Some of the heat pumps had been taken out of operation, either due to economic factors or because of a malfunction in peripheral equipment. Information on newer installations was more easily obtained.

The systems studied can be split into three main categories: gas engine heat pumps, electric heat pumps and absorption heat pumps.

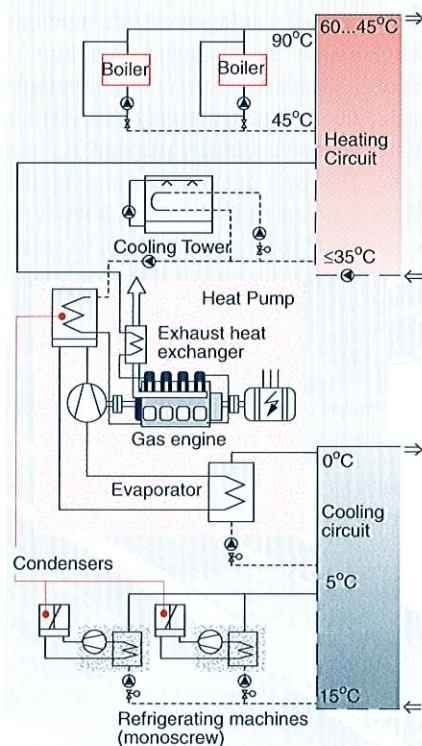
be refitted with a new working fluid and the costs were considered too high. In contrast, a new extension with a heat pump is under consideration at the Stopera building.

At the Patrimonium housing complex in Vlaardingen, two identical multi-storey apartment blocks were fitted with gas engine heat pumps. These have been functioning with few problems for the last ten years. Yet, the over-capacity of the heat pumps meant

Gas engine heat pumps

In the World Trade Center, Amsterdam, a 2900 kW gas engine heat pump, used for both heating and cooling of offices, has been operating continuously since the early 1980s. Its capacity is high and well chosen, and gives the largest energy conservation in a single building in the Netherlands of approximately 420,000 m³ of natural gas. The system can boast good economics, partly because it provides both heating and cooling, but also because the gas engine is designed to be able to supply emergency power. The payback period at current energy prices is less than four years. Experience also shows that the maintenance costs are relatively low.

The same type of gas engine heat pumps are installed at the Stopera building in Amsterdam (2 x 2200 kW), at the Bouwfonds offices in Hoevelaken (300 kW) and at the OHRA offices in Arnhem (460 kW). However, the heat pump at the Bouwfonds offices was taken out of operation because it had to

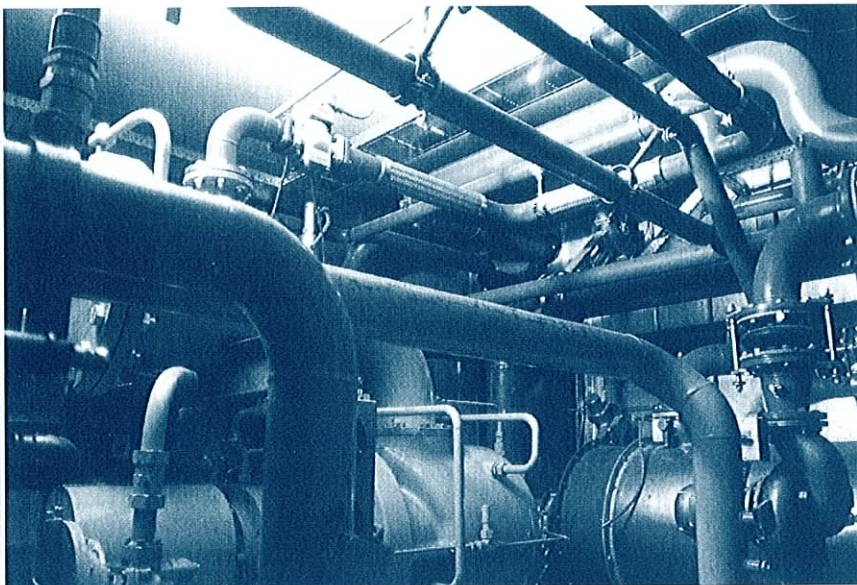


that the performance has not come up to expectations, while maintenance costs are higher than estimated—partly because of CFC leakage checks. Since gas prices have dropped, it is understandable that the owner is considering putting the heat pumps out of operation. Re-engineering could result in a profitable situation by using one of the heat pumps to supply both apartment blocks, or even three apartment blocks.

Electric heat pumps

An important reason why electric heat pumps have not been installed in greater numbers is because of the tariff-structure which favours gas applications. Those installed include projects at “de Heuvelgalerie” shopping centre in Eindhoven, “de Hoep” water utility building at Castricum (40 kW), “Bellevue” power utility offices at Arnhem (380 kW) and the offices of the

No.4 p.8). The heat pump provides heating in winter and stores up a cold heat sink which is sufficient to provide summer cooling without operating the heat pump or any other active cooling system. With an energy conservation on heating and cooling of around 50%, this system is showing the way for the design of heating and cooling systems for large buildings in the Netherlands. The heat pump has a COP of over 4.5. This example has been emulated by projects at Zwitserleven offices at Amstelveen and the new central airport-building of Oslo in Norway.



power utility ENW at Alkmaar (44 kW). In addition, there are many small-sized reversible systems installed in small offices.

Past experience suggests that gas engine heat pumps have given a better primary energy conservation than electric systems. The study by van Heugten shows a primary energy conservation of just 15% with a typical electric heat pump compared with up to 35% for gas engine systems. However, these results were from electric heat pumps installed in the eighties with COPs of less than three. In more recent projects, with low-temperature heating systems and a better designed heat source, higher values for conservation are reached.

A perfect example is the Anova building in Amersfoort. In this system, heat is transferred to and from two wells in an aquifer (see *HPC Newsletter Vol.12,*

Absorption heat pumps

The, by now, more than famous absorption heat pump at the Regional Government building in Maastricht, built by Colibri, has registered an energy conservation of up to 20%. This 250 kW heat pump, which uses river water as its heat source, has shown no operational problems since its installation in 1993. Several case-studies on the application of this type of absorption heat pump have shown that considerable energy-savings can be gained in comparison to other options such as cogeneration. However, the investment costs, especially in the peripheral low-temperature system, are high.

Recently, a second 250 kW absorption heat pump has been installed at the Oranje Nassau government building in Heerlen. A combination of heating and cooling made this heat pump an attractive option. Furthermore, it was considered important that the local government building should comply with the latest regulations for energy conservation in new buildings. The only way to achieve this in this historic building, where changes to the outside were not allowed, was to install an efficient energy system.

A third, smaller, absorption heat pump, which is not well documented, was installed by the power utility MEGA-Limburg at the offices of the energy company Energie ABC in Maasbracht.



▲ *These new offices of the financial services company Zwitserleven will be heated and cooled with high efficiency by a system using underground aquifers and a heat pump.*

This 22 kW ammonia-based system extracts heat from ventilation air to heat the visitors centre.

What factors bring success?

Heat pumps can certainly make considerable energy savings compared to competing options, and the survey has shown that reliable installations can be built with an acceptable payback time. If the heat pump market in the Netherlands is to grow, the factors that lead to successful projects have to be found and built on.

Combining functions

One way to get an economic installation, is to provide additional advantages to conventional systems. The combination of heating and cooling at the same time makes the heat pump an attractive and economic alternative, when the heat pump is geared to substantially meet both heating and cooling demand. However, when a heat pump is used for heating in winter and cooling in summer, it does not increase the overall energy-efficiency because of the peak-summer demand for electricity. A better solution is to use an aquifer system such as in the Anova and Zwitserleven-building projects. Peak electricity demand in summer is avoided and the performance of the heat pump is increased by at least 40% due to the warm heat source.

When using a gas engine heat pump, an additional advantage is the possibility of using the engine as an emergency power utility and even as a cogeneration unit.

Choosing the right design

The optimum use of heat pumps is achieved when the system is designed for average outdoor temperatures and for low-temperature heating systems. This applies to both the assessment of the capacity and to the design of the control system. Since maximum heat demand only rarely occurs, it is not relevant to the operation of heat pumps. Direct-fired heating boilers are more suitable for that purpose from an economic standpoint.

Buffer reservoirs, on the other hand, can increase the peak load operating time of a heat pump and thus increase energy savings. In designing heat pump systems, the optimum balance should be found between reliability and energy savings. Very efficient designs can be vulnerable to failure.

A pioneer spirit

For a successful heat pump project at this phase of market-introduction in the Netherlands, the operator of the installation has a key role, and needs to have something of a pioneer spirit. However, when a heat pump is to be operated by other persons as well, the heat pump should not require more attention than conventional systems.

Close monitoring, though, can be important. Experience with heat pumps that have been taken out of operation suggests that a better monitoring of the situation would have given solutions for operating the heat pump and solving the problems. Very often, problems occurred not with the heat pump but in the peripheral equipment.

With larger systems, it can be better to contract out the heat pump operation to service companies specialized in heat pumps. Utilities, too, have useful

experience gained from operating cogeneration systems.

A programme for success

Heat pumps deserve to be judged by their opportunities for success, not by potential problems. Judging by the experiences from heat pumps which have been installed in the past in the Netherlands, heat pumps should certainly be considered a success.

However, the failures of the past cannot be overlooked, and the lessons learned must not be forgotten in the re-introduction of heat pumps in commercial buildings under the Dutch Heat Pump Programme.

The strategy of the programme is to focus on the applications highlighted by the 1995 survey, such as government buildings, insurance companies, hotels and shopping areas. Important preconditions seem to be essential for success. The programme is therefore working to encourage building designers to install low-temperature heating systems in new buildings, and to encourage utilities to introduce special electricity tariffs.

In addition, efforts are being made in promotion and education on heat pumps, including the provision of courses for consultants, installers and building owners. Above all, at this early phase, the programme must focus its efforts on the close monitoring of new and existing installations so as to overcome possible design and operating failures.

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Trends in heat pump technology for commercial buildings

Mukesh Khattar and Morton Blatt, USA

Heat pumps available now can meet the needs of many commercial customers. Nonetheless, the market penetration of commercial buildings heat pumps in the US is lagging behind the residential market. Given the many benefits commercial customers in all climates can receive from heat pumps – lower energy bills, comfort, reliable service, opportunities for efficient humidity control – making incremental improvements to increase acceptance will serve this sector well. This article examines the needs of the commercial buildings market and describes recent improvements that are allowing heat pumps to better meet these needs.

Heat pumps have captured only 10% of the total air-conditioning capacity installed in commercial buildings, versus 18% of the total installed in residences. However, there has been an overall upward trend in heat pump market share.

Markets: air-to-air

The unitary air-to-air heat pump is the most popular heat pump in commercial buildings. **Table 1** compares the markets for commercial unitary air-to-air heat pumps, conventional, large-size, commercial air conditioners and residential equipment.

Markets: water source

Water-source heat pumps are used in two general configurations in the US: conventional *water-loop* heat pump systems and *ground-source* water-loop systems. *Hybrid* systems are also emerging. All three types are described below.

Water-loop heat pump (WLHP) systems heat or cool by extracting or rejecting heat to a water piping loop. They provide an excellent alternative to central chiller/boiler systems, as they can recover excess heat from the core of a large building and use it to warm perimeter offices. A cooling tower and boiler ensure that loop water temperature is maintained at an optimum range, about 16-32°C (60-90°F), allowing the use of low-cost

uninsulated piping. WLHP systems can also recover and use waste heat from data centres or refrigeration equipment. WLHPs have advantages in all climates but are especially competitive in cooler climates, where commercial buildings tend to have year-round cooling requirements in core areas along with reasonable heating demands in perimeter zones.

Ground-source heat pump (GSHP) systems, or “geothermal” heat pumps, are water-loop systems in which the loop is extended through pipes buried in the ground as a heat source. This “ground loop” typically replaces the usual WLHP boiler and cooling tower. The thermal mass of the earth provides a nearly constant and moderate temperature source year-round. This allows GSHP systems to have higher efficiency than air-source heat pumps both in heating and cooling, and

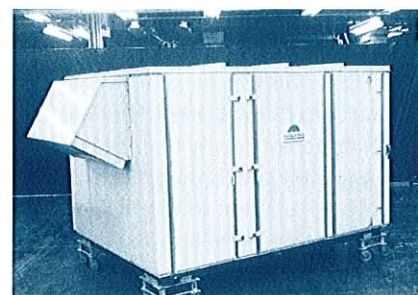


Figure 1: “ClimaDry” dual-path heat pumps such as this are used in an advanced heating and cooling system for a shopping centre in Moore, Oklahoma.

supplemental heating requirements are reduced or eliminated. Although this type of heat pump configuration is the most efficient heating system available, it has only begun to enter the US market.

Major barriers to wider use of GSHP systems are the ground-coupling field’s land and excavation costs. Nonetheless,

Table 1: Annual sales numbers for air conditioners in the USA.

	Air conditioners			Heat pump market share
	Heat pump	Cooling only	Total	
Residential (8.8-17.6 kW) ¹⁾	900,000	3,400,000	4,300,000	21%
Commercial (8.8-17.6 kW) ²⁾	80,000	500,000	580,000	14%
Commercial (>26.4 kW) ³⁾	20,000	250,000	270,000	7%
Total Commercial Installations	100,000	750,000	850,000	12%

Source: Personal communication with J. Pietsch of Pietsch Engineering.

¹⁾ 2.5-5.0 ton ²⁾ 2.5-5.0 ton ³⁾ >7.5 ton



they are usually cost-effective in northern climates with higher heating requirements. As lower-cost methods emerge for installing the ground-coupling field, cost-effectiveness in warmer US regions will improve. Federal agencies, individual electric utilities, the Electric Power Research Institute (EPRI) and others have recently formed the Geothermal Heat Pump Consortium, which is seeking to increase market share in both the commercial and residential sectors.

Hybrid heat pump systems include both a ground loop sized to meet the heating demand, and a cooling tower or other heat exchanger to reject heat in summer. This allows for smaller sizing of the ground loop in situations where cooling demands are especially high and ground loop costs are prohibitive.

Cooling load

The higher lighting, equipment, and occupancy levels in commercial buildings create larger cooling loads and lower heating loads relative to residences. While residences usually have a cooling vs. heating balance point temperature in the 13-18°C (55-65°F) range, commercial buildings may require cooling above a balance-point temperature of 2-7°C (35-45°F) and thus need relatively little heating in all but very cold periods. High cooling efficiency is therefore particularly important, and high-efficiency air-source and water-source heat pumps are widely available now. WLHP systems are especially efficient because they can transport and make use of the waste heat from the heat pumps operating in cooling mode. GSHP systems are even more efficient in many climates because of the moderate temperature of the ground source in both summer and winter.

Air quality

Residences can generally maintain indoor air quality with natural infiltration of outdoor air. Because of higher occupancy levels, less

infiltration, and the need to meet strict new ventilation air volume standards (specifically ASHRAE 62-1989), commercial buildings require the introduction of large amounts of outdoor air. This can lead to excess summer humidity and increased heating in winter. Dual-path heat pumps, which treat ventilation air separately from return air, are providing new solutions to humidity problems.

Utility rates

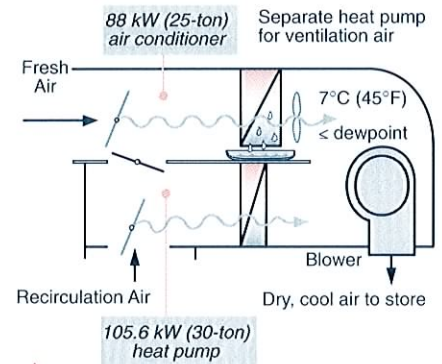
Residences generally have a flat US\$/kWh energy rate, while commercial properties may see a wide variety of utility rate structures, including demand charges and time-of-day energy rates. High-efficiency heat pump systems with reduced peak kW input and advanced controls serve electric utility goals for selective load retention and peak load management. And they respond to societal concerns for conservation of primary energy resources and control of air pollution.

Meeting customer needs

As US electric utilities enter an era of increased competition, there is a need to re-define the goals of heat pump development according to customer needs and preferences. EPRI has formed the Heat Pump Initiative to focus R&D on customer needs in order to promote wider acceptance of heat pumps.

Customer needs include raising system efficiency to cut HVAC costs. The highly efficient ground-coupled systems and water-loop systems could become very widely used within the next decade, despite limited market penetration to date, with more cost-effective system designs.

More efficient loop controller logic and water-source heat pumps optimized for specific applications, such as large fraction ventilation air applications in schools, will significantly increase the market for commercial water-loop systems.



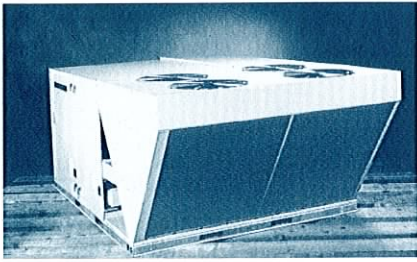
▲ *Figure 2: This dual-path heat pump system installed at a shopping centre in Moore, Oklahoma uses a separate heat pump for cooling and dehumidifying ventilation air.*

As CFC and HCFC refrigerants are phased out, a few heat pumps using non-CFC (zero-ozone depletion potential (ODP)) refrigerants are now appearing. EPRI funded research played a major role in bringing these refrigerants to the market place. Ongoing and future research is focusing on 2nd generation, zero ODP, refrigerants which are superior in efficiency and performance to 1st generation options. More zero-ODP heat pump development and testing is needed to provide the choices necessary to meet customer demands for non-CFC technologies.

Many customer complaints of inefficiency and lack of comfort are due to improper installation and maintenance. These problems are often related to the lack of heat pump training for the vast majority of HVAC technicians. In response, EPRI is organizing a national heat pump technical training and certification programme.

EPRI's primary role in the electric utility industry is to lead development and demonstration of the needed technology innovations. Funding is shared with established developers and manufacturers and through collaborative partnerships with electric utilities. Some of EPRI's technology development projects are outlined further in this article.





▲ *Figure 3: The Lennox: "L-Series" is an example of new commercial air-source heat pumps with increased energy-efficiency at low outside temperature.*

Zero-ODP heat pumps

Working with EPRI, ClimateMaster has developed a series of zero-ODP water source heat pumps in the 3 to 20 ton (10 to 70 kW) cooling capacity range, in the rooftop package configuration. Proto-type units have been operating in a retail store as a demonstration project since July 1995.

Dual-path heat pumps

EPRI has developed the Dual Path Dry Air™ system which enhances cooling system energy efficiency by dehumidifying only the ventilation air. Re-circulated air is cooled separately, eliminating extra cooling and re-heat energy associated with dehumidification. EPRI worked with ClimateMaster Corporation to develop the ClimaDry™ heat pump, – a non-CFC, dual-path, water-source rooftop unit (see **Figures 1** and **2**). The first units have been installed in a new Wal-Mart shopping centre in Moore, Oklahoma. The system integrates the space conditioning function with space heating, cooling, dehumidification, refrigeration and water heating on a single water loop, for substantial energy cost savings through more effective heat recovery.

Floating-loop controllers

EPRI has developed the concept of the "floating loop" to constantly adjust the water-loop temperature to optimize energy use and cost. The EPRI-

sponsored SmartLoop 2000™ is a combined software-hardware unit that includes advanced control logic in an installation-ready electronic control box. This unit has a low projected cost and 10-35% HVAC energy savings are forecast.

Ground-source systems

EPRI plans call for developing optimal control logic for GSHP systems. EPRI also sees a need for market studies to identify the cost range and other features needed to ensure broader commercial success. Another need is the compilation of a national database of GSHP operating experience, technology characteristics, and performance. This database would provide the foundation for improved understanding of sizing and configuration of GSHP systems.

Heating at low temperatures

Manufacturers are commercializing heat pumps with improved heating performance at low outdoor temperatures. EPRI collaborated with Lennox Industries on the highly efficient L-series of rooftop air-to-air heat pumps with improved low-temperature heating performance (see **Figure 3**.) This product offers enhanced defrost plus simplified maintenance at a competitive price. Another EPRI collaborative initiative is intended to produce a new generation of economical heat pumps that will deliver air close to the temperature of a furnace while operating at outdoor temperatures as low as -20°C.

Dual-fuel heat pumps

The Dual-Fuel Heat Pump (DFHP) uses a gas furnace instead of the conventional resistance heater for supplemental heating requirements. The furnace operates either in conjunction with the heat pump or alone below specified temperatures. The DFHP is a good retrofit option for replacing aging rooftop gas-electric units, which make up a large share of the commercial

sector's space conditioning equipment. EPRI cosponsored the development and field testing of the first rooftop DFHP, manufactured by Lennox Industries. York, Carrier, Trane, and other leading manufacturers now also offer DFHP products.

Future prospects

Collaborating with its member utilities, EPRI is working closely with HVAC developers and manufacturers to refine heat pump technologies and bring improved products to the commercial sector market, as well as to homes. Water-loop heat pump systems, geothermal options, and unitary heat pumps are becoming more and more suited to the needs of commercial customers. As a result, today's heat pumps already provide good choices for commercial buildings in every US climate.

Both technology innovations and the prospect of electric utility price competition are expected to improve heat pump economics and contribute to broader use of heat pumps in commercial buildings. With the advantages provided through the research efforts of EPRI and others, heat pump technology is poised for a major gain in market acceptance.

Acknowledgments

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Award winning projects for commercial buildings

Tony Bendall, United Kingdom

The UK Heat Pump Association (HPA) was created to encourage education, innovation and reward excellence within the heat pump industry. Last year it awarded a number of projects that demonstrated an excellent achievement in the application of heat pumps. The awarded projects illustrate some of the latest equipment now employed in commercial buildings in the UK. The secretary of the HPA reports on the winners.

The members of the UK Heat Pump Association (HPA) include many of the UK's leading manufacturers of heat pumps and members of the electricity utilities industry. They are keen to increase awareness of heat pumps in the general market place – with specifiers, developers, building owners, industrial processors, local and national legislators and the general public.

The annual heat pump award ceremony is one of the ways in which the HPA achieves this objective. The awards provide a platform for system designers and building occupiers to showcase the benefits, efficiency and versatility of their heat pump installations.

Winning first prize

First place in 1995 went to a Versatemp system, manufactured by Temperature, which was installed in the Royal Bank of Scotland's headquarters in St Helier, Jersey (see illustrations). This is a water-source (closed-loop) energy reclaim (heat recovery) system which provides an excellent environment-conscious solution for the high-tech, high heat gain building.

The system combines energy reclamation efficiency with simplicity in design and installation, providing the four-year-old, four-floor building, with a flexible and economic year-round heating and cooling solution.

Low energy consumption and maximum use of space were top priorities for the consulting engineer. Total flexibility was another important factor. This was because the bank wanted to be able to convert the current

open plan layout, with central atrium, into cellular offices if necessary. The system was also required to operate quietly.

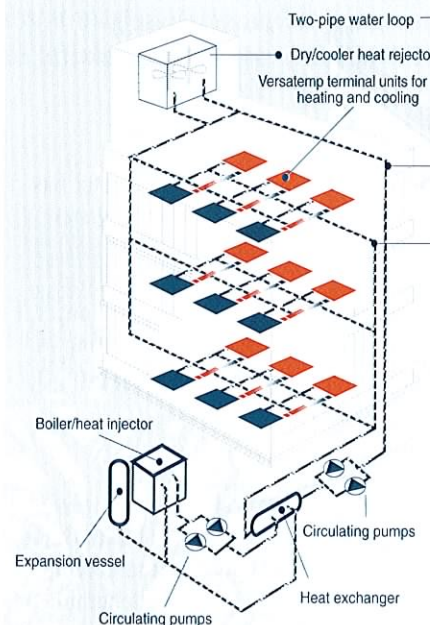
Entirely satisfying all the demands of the project, Versatemp was chosen as the answer to the building's heating and cooling needs and for high-quality indoor air. The system was installed with minimal disruption to the client.

Reclaiming energy

The award winning system actively manages the free and pre-paid energy created by solar gain, computers and other electronic office equipment, as well as by staff – the bank has a high occupancy level. The system cools the zones of energy excess by extracting and transferring it to the zones of energy shortage, which are thereby heated. The system provides unlimited heating and cooling around the building on demand.

A simple, unlagged, two-pipe water loop is used to transfer thermal energy around the building, to where an appropriate number of heat pump room units transfer it from the air to the water, or the contrary, as required in each particular space.

Central plant space is reduced to a minimum and the plant is only ever activated to provide for the occasional imbalance, keeping energy consumption to a minimum. Heat is provided by gas-fired boilers and is rejected through dry coolers. The building now contains a total of 138 VH Versatemp terminal units, all mounted out of sight within the ceiling voids to maximize floor space.



Terminal unit controllers are remotely mounted. The units also incorporate a self-diagnostics feature which automatically detects and displays the condition and location of any malfunction. The whole system is monitored and controlled by a Trend modem linked Building Management System. Additionally, any system faults are automatically registered in the reception area.

Coming in second

The runner-up in the 1995 awards ceremony was a Mitsubishi Electric heat pump system installed in the Pearl Centre, the Peterborough offices of Pearl Assurance plc. This application demonstrated a similar innovation and flexibility with heat pump technology.



As part of a refurbishment upgrade, Pearl Assurance wanted to improve the environment for employees. Key considerations for Pearl Assurance were that the installed system was capable of conditioning 350 m² of open plan office spaces and that it had good heat recovery performance. Energy efficiency, low noise level, capital costs and reliability were other elements which needed addressing.

Mitsubishi Electric came up with an excellent solution in the form of its City Multi R2 system consisting of six above-ceiling ducted indoor units and one outdoor unit.

Since commissioning, and with constant monitoring, the City Multi R2's energy efficiency system shows a remarkable coefficient of performance (COP) of 4.2. The system achieves this efficiency by using inverter-controlled scroll compressors, with fuzzy logic control. This significantly improves operating efficiency by minimizing the start-up currents and by optimizing performance against energy consumption.

Four above-ceiling ducted units have been installed on the first floor open plan office area and two units have been fitted in the basement. Maximum energy efficiency is achieved by recovering waste heat from the basement room for use in heating the large office area on the first floor. During summer, the units in the basement can be controlled separately and isolated.

Awards for students

Every year, the HPA members sponsor an award scheme for students. The award is open to students studying for a degree in building services or environmental engineering, and entries take the form of a dissertation on a set project.

Last year, students had to design a system for a city centre hotel using heat pumps in the most energy-efficient way. The national winner, from an all-female regional short list, was Emma Ford from the University of Surrey. Encouraging student enthusiasm and

knowledge with regard to heat pumps is a vital concern for the HPA which regards the development of education and innovation as the lifeblood of the industry. The HPA is keen to nurture student interest and knowledge whenever possible to help ensure the continued development of heat pump technology into the next century.

Conveying the message

The HPA's most important role is to convey the message about the benefits of heat pumps as effectively as possible. We do this by raising awareness concerning heat pumps, informing prospective specifiers of their long-term benefits, reassuring end-users, and providing up-to-the minute advice on the various systems available.

The HPA also influences legislation and other issues that might affect the interests of the heat pump industry in general. And we coordinate technical and market research into areas of mutual interest to our members, with the aim of improving market opportunities both at home and abroad.

Importantly, the HPA will continue to liaise and work closely with other national and international bodies who are actively promoting the use of heat pumps, and with anyone whose aim it is to reduce the costs of heating bills.

At the HPA, we see the award ceremony as a chance for us to highlight the versatility and benefits, environmental and financial, of heat pumps, and to encourage innovative applications in the future. A second annual award ceremony will be held later this year.

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▲ *The award winning heat pump system at the Royal Bank of Scotland in Jersey features 138 heat pumps mounted out-of-sight in ceiling voids. As shown in the diagram, heat is transferred via a two-pipe water loop from cooling-mode heat pumps to provide a heat source for the units operating in heating mode.*



Ice thermal storage systems

A new trend for Japanese buildings

Hideaki Kokubu, Japan

With concerns about the rapidly growing peak in electric power demand from air conditioners in summer, the market for thermal storage systems for commercial buildings in Japan has been increasing rapidly in recent years. Such systems are used to shift the electric power demand to night-time, thus helping to lower the daytime peak. Because of its high thermal density, ice is used increasingly as the storage medium. To compete in this expanding market, manufacturers have developed a range of technologies to further enhance the benefits of ice thermal storage to the consumer.

The employment of thermal storage air conditioning systems in the territory of the Tokyo Electric Power Company from 1989 to 1995 has grown steadily as shown in **Figure 1**. Although some assumptions are contained in the data, it can be found that the ratio of ice thermal storage to water thermal storage has grown as the market for thermal storage systems has expanded. One reason for this trend is the aggressive technological development of the ice storage air conditioning system.

Technical developments

Ice storage systems can be roughly classified into the static system to pack hard ice on the surface of ice packing coils, and the dynamic system which packs ice in a powdered state. In some systems, ice is made by exchanging heat with the refrigerant in a direct-expansion configuration. Other systems use brine to make the ice.

In the past, most thermal storage air conditioning systems were configured as a central system using chilled water or brine as the cooling distribution medium. More recently, the packaged system, which uses refrigerant to make

ice, has increased in popularity. Packaged systems include both single and multi-unit systems.

Figure 2 shows two cycle examples: the refrigerant sub-cooling system and the refrigerant gas pump system. Both systems offer excellent features. Sub-cooling involves a simple cycle and can achieve peak shifting of 20 to 30%, such as in **Figure 3 (b)**. The gas pump system is a more complicated cycle but realizes a peak shift and peak cut operation of more than 30%, as in **Figure 3 (c)**.

The thermal storage tank is normally made of FRP (Fibre-glass Reinforced

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Figure 1: Trend in thermal storage air conditioning systems.

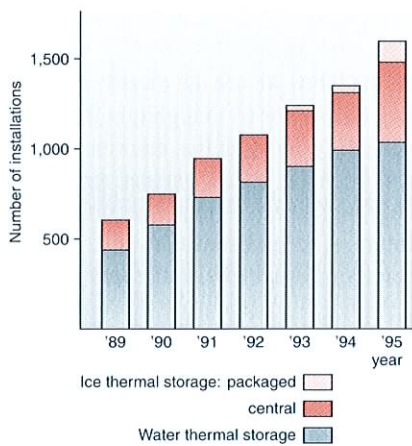
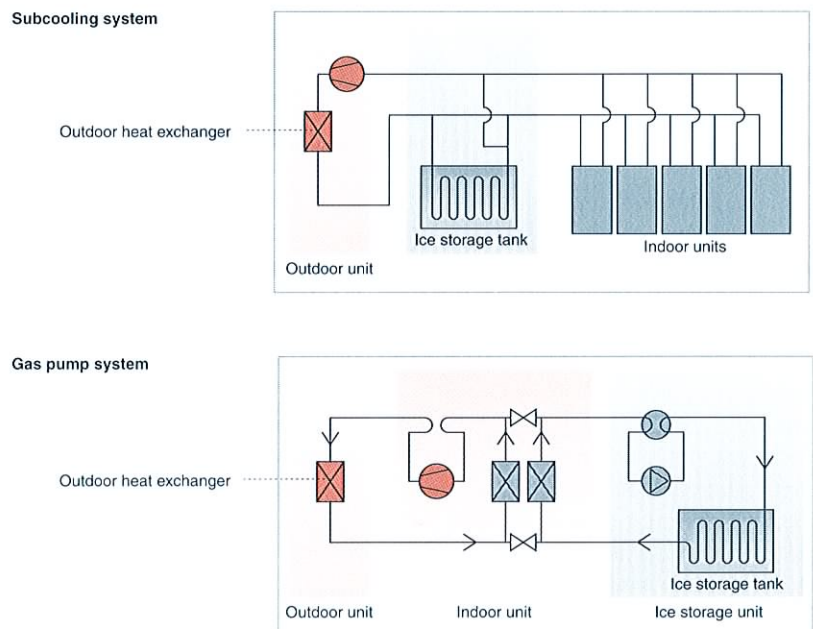
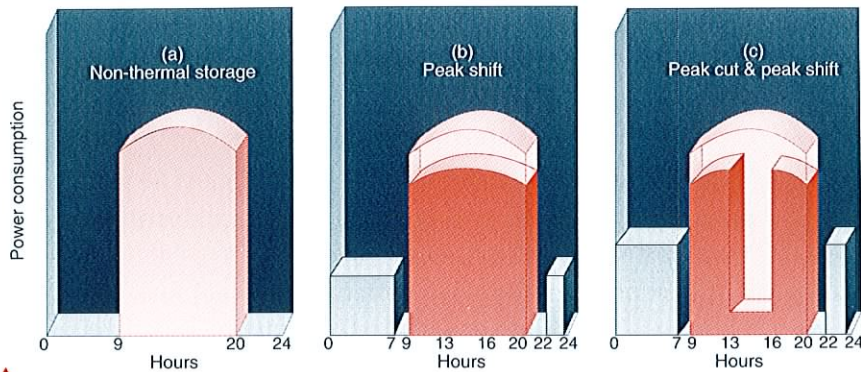


Figure 2: Examples of ice thermal storage systems.





▲ Figure 3: How thermal storage systems can shift power consumption to off-peak periods.

Plastic), although stainless steel tanks are also marketed in order to reduce their size. Furthermore, some systems can also store heat for use during heating operation or in defrosting. A typical ice thermal storage system is the Hitachi RAS-J280 which has a heating and cooling capacity of 25 kW and 28 kW respectively, and a thermal storage tank weighing 1,300 kg (in operation) and with an effective water volume of 1 m³.

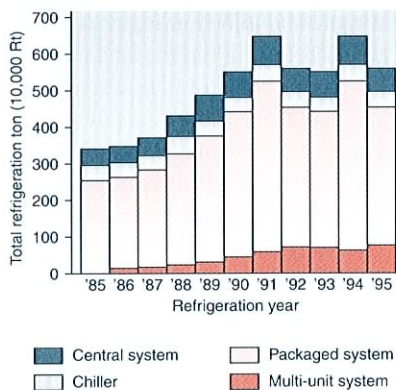
Market development

The expanding market for ice thermal storage air-conditioning systems is partly due to the government subsidy scheme, which was introduced in 1995,

and the promotion efforts of electric power companies. Equally important is the enriched product line-up now offered by manufacturers.

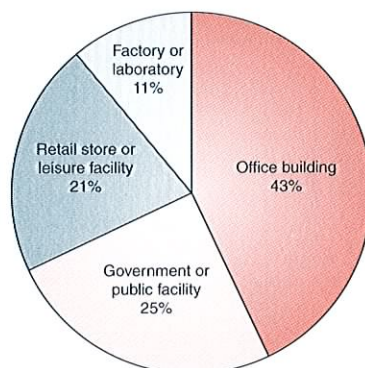
Figure 4 shows the shipment (for the Japanese market) of air conditioning equipment for commercial buildings applications. As indicated, packaged air-conditioners, including multi-unit systems, account for 80% of the total refrigeration capacity, which suggests that the adoption of thermal storage systems in this product range is an extremely important market sector. Multi-unit systems offer an important market opportunity, and multi-unit systems with ice thermal storage are now being aggressively promoted.

It is estimated that around 1,000 single, and multi-unit packaged systems with thermal storage were shipped in 1995.



▲ Figure 4: Annual shipments of air-conditioning equipment for Japanese commercial buildings.

▼ Figure 5: Share in demand for ice thermal storage multi-unit air conditioners.



With the entire market for packaged air conditioners accounting for 800,000 sets annually, the market share of thermal storage systems is still very low.

According to manufacturer's data, the demand for ice thermal storage multi-unit air conditioners is mainly from office buildings and public facilities (see Figure 5). At the initial stage of the development, the demand was concentrated in large business firms and governmental organizations, where environmental benefits can be a key selling point. However, the present data indicates that the demand is getting similar to that of conventional (non-heat storage) systems.

The choice of the future

Ice thermal storage packaged air conditioners, both single and multi-unit systems, have begun to be appreciated in the commercial buildings market as an economical system to utilize the discounted night-time electric power rate. In order to popularize this system on a larger scale, efforts are needed to increase its recognition among users.

Although the price of equipment is considered to be reaching a marketable level, simplification and standardization of the equipment is essential to make it easier to install. In response to requirements from users, manufacturers are presently promoting new developments for further reducing equipment size and weight (this is difficult when ice is used) and for increasing the peak shift ratio. Furthermore the range of models is increasing and costs are being reduced.

At present, the market for ice thermal storage systems is at an early stage. But it is no dream to suggest that thermal storage systems will be the most common choice for all packaged air conditioners in the future.

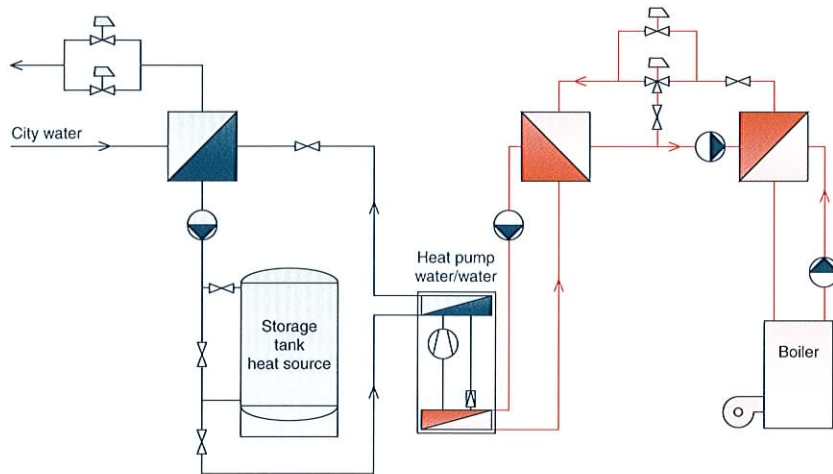
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Comparing heat pump test facilities

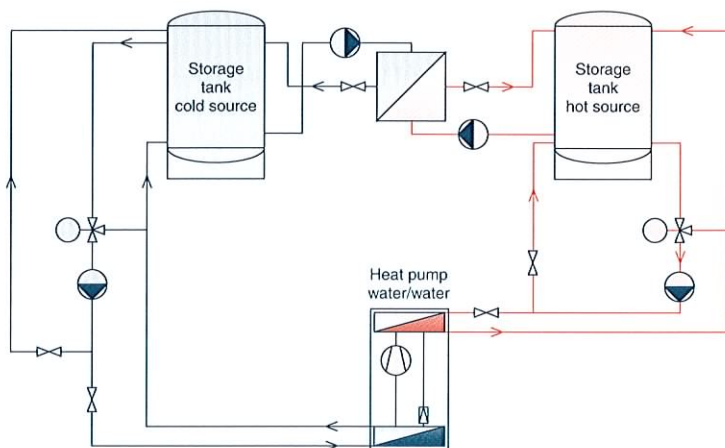
Osmann Sari and Philippe Moser, Switzerland

Quality assurance is essential to the Swiss heat pump programme, and heat pump units must be tested and approved by means of certified test rigs. The measurements of the heat pump performance distribution are performed at different temperature levels, for both heat sink and heat source, according to established standards and regulations for the measurement of heat pump performance. An experimental investigation of three different Swiss testing facilities has confirmed the validity of such tests by finding that there is good agreement between the measured performance.



▲ *Figure 1: Schematic view of the LENI-EPFL heat pump testing facility (section for water-water heat pump).*

▼ *Figure 2: Schematic view of the LGT-EINEV heat pump testing facility.*



A study has been implemented to measure the coefficient of performance (COP) of the same heat pump unit in three different testing facilities in Switzerland, namely:

- The Töss test rig at the Heat Pump Testing and Training Centre at Winterthur, Töss
- The LENI test rig at the Laboratory for Industrial Energy (Laboratoire d'Énergétique Industrielle (LENI)) at the Swiss Federal Institute of Technology (EPFL), in Lausanne
- The LGT test rig at the Laboratory of Thermal Studies (Laboratoire de Génie Thermique (LGT), Engineering School of the State of Vaud (EINEV), in Yverdon-les-Bains.

The Töss test rig is described in HPC Newsletter Vol.11, No.3, p. 27 and in more detail in [1]. The LENI and LGT test rigs are outlined in **Figures 1** and **2**. The LENI test rig has the advantage of allowing the study of both water-to-water and air-to-water heat pumps at several working conditions. The LGT test rig is for the experimental study of water-to-water heat pumps. This test rig is able to operate at different temperature levels at both condenser and evaporator side.

Measurements

In this study, the heat pump coefficient of performance (COP) was evaluated only with regard to the electrical power absorbed by the compressor.



The heat pump used in the study was a B/W ZR61-R22 with a heating capacity of 14 kW and using HCFC-22 working fluid. The measurement of the heat pump performance was performed under steady-state conditions according to established standards and regulations [2,3,4]. All measurements were carried out with a heat source flow rate of 2.4 m³/h, a heat sink flow rate of 1.7 m³/h, cold-side temperatures of -5°C, 0°C and +5°C, and heat side temperatures of 35°C and 50°C.

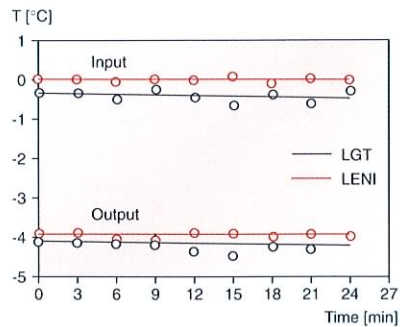
Experimental results

Figure 3 shows the inlet temperature distribution (cold side) for the LENI and LGT test rigs. A temperature fluctuation of less than $\pm 0.3^\circ\text{C}$ has been obtained around the mean value as permitted by EN255 [3]. **Figure 4** shows a good agreement between the volume flow rate distribution as determined by the LENI and LGT test rigs.

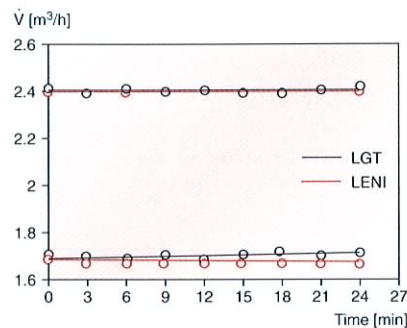
Figure 5 and **6** shows a good agreement between the coefficient of performance distribution, with a variation of between 3.5% and 4.3% for the evaluations on the three different heat pump test rigs at the two condenser temperature levels. According to the energy conservation equation condenser heat flow = evaporator heat flow + electric power the numerical evaluation of the heating capacity with data measurements is 3 to 7% less than the heating capacity actually measured at the condenser.

Good agreement

An experimental investigation has been realized with three different testing facilities by using the same and unique heat pump unit. The experimental results show a good agreement between the measured coefficient of performance distributions.

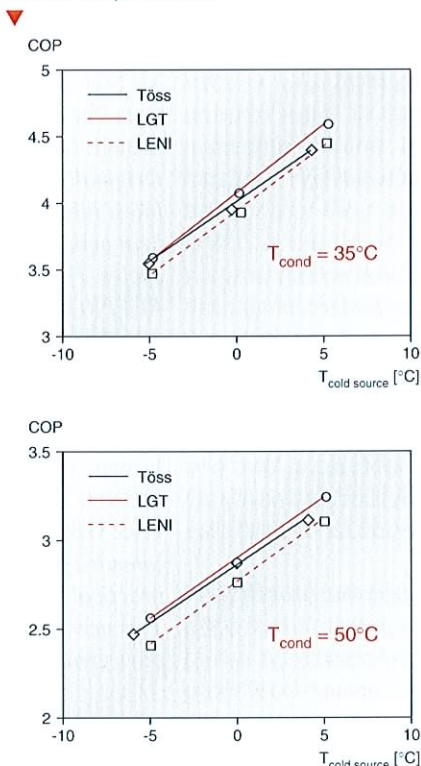


▲ **Figure 3:** Cold side temperature versus time.



▲ **Figure 4:** Volume flow rate distribution versus time.

Figures 5 and 6: COP versus the cold source temperature at different heat source temperatures.



References

- [1] "Pompe à chaleur Bo/W ZR61" (Heat Pump Bo/W ZR61), Heat Pump Testing and Training Centre, Töss, Switzerland, 1994.
- [2] "Comparaison des stands d'essai pour pompe à chaleur : Töss, EPF-L/LENI et EINEV/LGT" (Comparison of tests for heat pumps), Sari, O., Panico, A., Moser, Ph, Report EINEV/LGT 01-95, Yverdon-les-Bains, Switzerland, 1995.
- [3] "Réglementation pour les contrôles et essais de pompes à chaleur A/E au centre d'essais et de contrôle de Töss" (Regulations for the control and testing of air/water heat pumps at the Heat Pump Testing and Training Centre, Töss), Hinder, B., Ehrbar, M., 1994, Nordostschweizerische Kraftwerke AG, 5401 Baden, Switzerland, 1994.
- [4] European standard EN 255, "Heat Pumps; Heat Pump Units with Electrically Driven Compressors for Heating or for Heating and Cooling" CEN, Brussels, Belgium, 1988

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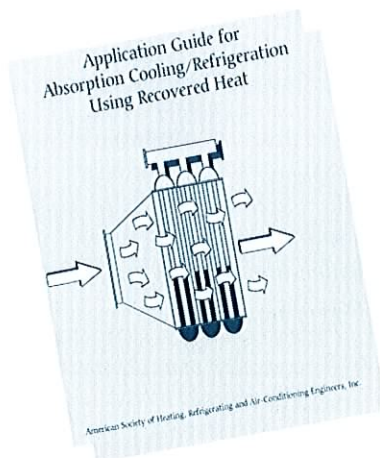
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Application Guide for Absorption Cooling/Refrigeration Using Recovered Heat

Published by ASHRAE, USA. Fax: +1-404-321-5478.
Order code: 90378. Published in 1995. Price: US\$ 79.



A comprehensive reference manual that introduces absorption technology and helps in the evaluation of potential applications. It aims to encourage building owners, engineers, and developers, to consider the use of recovered heat for cooling and refrigeration. A computer program, which comes with the report, can be used for system selection and economic analysis.

A Guide to Energy Efficient Ventilation

Published by the IEA Information Centre, AIVC (Air Infiltration & Ventilation Centre), University of Warwick Science Park, UK.
Fax: +44-1203-416306,

E-mail: airvent@aivc.org. Published in 1996. Price GB£ 50.
This guide reviews ventilation in the context of both energy efficiency and achieving good indoor air quality. Emphasis is placed on describing the rationale and background to ventilation and in the decision making in selecting and planning for ventilation.

Heat Pumps in Office Buildings

(Warmtepompen in kantoorgebouwen)
Report compiled by Van Heugten bv, The Netherlands.
Fax: +31-24-323-50016.
Report No. 01N1653. Published May 1996.

In a study carried out for Novem (the Netherlands Agency for Energy and the Environment), eight heat pump projects in office building in the Netherlands have been evaluated. The report provides a detailed overview of the performance of these systems including data on energy consumption and economics.

Design Tools Benchmarking Study

Geothermal Heat Pump Consortium, Inc. USA.
Contact Wael M. El-Sharif at Fax: +1-202-508-5222,
E-mail: elsharif@ghpc.org

This study describes and compares both software and printed design tools for analyzing ground-source heat pump systems. Appendices to the report describe more than 40 software packages, including eight specifically aimed at ground-loop analysis. (Source: Technologies for Energy Management, May 1996)

GS2000

Software package from Caneta Research Inc. Canada. Fax: +1-905-542-3160. Price US\$ 350. A demo is available at the Internet site of the Green Building Information Council: <http://greenbuilding.ca>

Operating under Windows 3.1 or higher, this software package can be used to size vertical or horizontal ground loops. Screen choices guide the user through a wide selection of soil, antifreeze and pipe properties. Using ground temperature data from 129 locations in Canada and USA, the program is able to account for seasonal changes in soil properties. (Source: Technologies for Energy Management, May 1996)

GEOCALC

Software package from Thermal Works Software, USA.
Contact Mr Don Steeby. Fax: +1-616-243-0212. Price US\$ 50.
Developed at Ferris State University, this software package aims to give dealers and contractors an easy-to-use tool for sizing ground coils. It is currently being enhanced to handle slinky loops as well as conventional vertical and horizontal loops. (Source: Technologies for Energy Management, May 1996)

Program for Integrated Energy Systems with Heat Pumps and Energy Storage

Software package PIA-15 from DWA Installatie-en Energieadvies, The Netherlands. Fax: +31-172-651499.
This simulation software will help developers in the execution of feasibility studies, system optimization and sensitivity analysis of integrated heating and cooling systems using heat pumps and long-term energy storage.

CYCLE

Computer program from TNO-MEP, The Netherlands.
For more information and a free demo diskette contact: Mr Marcel Verschoor, Department of Refrigeration and Heat Pump Technology, Fax: +31-55-549-3740,
E-mail: M.J.E.Verschoor@mep.tno.nl
Originally developed to model power generating systems, the latest release of CYCLE can now also model vapour compression heat pumps and refrigeration machines, and organic Rankine cycles. The program can be supplied together with the REFPROP database, from NIST, USA, to provide a selection of 38 refrigerants for heat pumping equipment.

Air Conditioning Applications and Design

Jones, W.P. Published by Arnold, UK. Fax: +44-171-873-6325,
E-mail: arnold@hodder.mhs.compuserve.com.
ISBN: 0 340 64554 7. 2nd Edition: November 1996.
Price GB£ 45.

Intended for advanced students of building services, this practical book describes the design of air-conditioning systems. This new edition takes account of the latest building codes and pays greater attention to energy conservation.



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17-22 Nov '96 / Atlanta, Georgia, USA

Contact: Dennis L.O'Neal, Texas A&M
University. Fax: +1-409-862-2762,
E-mail: doneal@mengr.tamu.edu

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4-7 Feb '97 / New Orleans, USA

Contact: CTI, Houston.
Fax: +1-713-537-1721.

**Fortschrittliche Energieverwandlung
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Düsseldorf. Fax: +47-211-6214-575

**ART '97: Air-Conditioning &
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25-28 Mar '97 / Nanjing, China

Contact: Ms Zhang Ping, Chinese
Association of Refrigeration.
Fax: +86-10-6217-2249,
E-mail: onis@public3.bta.net.cn

Cold Climate HVAC '97

30 Apr - 2 May '97 / Reykjavik, Iceland

Contact: Cold Climate HVAC '97,
Reykjavik. Fax: +354-562-5859

**International Appliance Technical
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Location: Ohio State University
Contact: Mr James Stevens, Tampa,
Florida. Fax: +1-813-969-0904,
E-mail: JSteve1061.aol.com

**CO₂ Technologies in Heat Pumps and
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Contact: Mr Jørn Stene, Sintef Energy,
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Refrigeration. Fax: +86-21-6327-7108

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University of Nottingham.
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**Heat Pump Systems, Energy Efficiency
and Global Warming**

Sep '97 / Graz, Austria

Contact: Dr Hermann Halozan, TU Graz,
Austria (see back cover).

IEA HEAT PUMP PROGRAMME EVENTS

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30 Oct. 1996 / Windsor, Ontario, Canada.

Contact: Mr Doug Cane,
Caneta Research Inc.
Fax: +1-905-542-3160

Next Issue

5th IEA Heat Pump Conference
Volume 14 - No. 4/1996



National Team Contacts

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.



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IEA Heat Pump Programme

Set up by the IEA in 1978, the IEA Heat Pump Programme carries out a strategy to accelerate the development and use of heat pumps, in all applications where they can reduce energy consumption for the benefit of the environment. Within the framework of the programme, participants from different countries collaborate in specific heat pump projects known as Annexes.



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IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC), itself an Annex. 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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