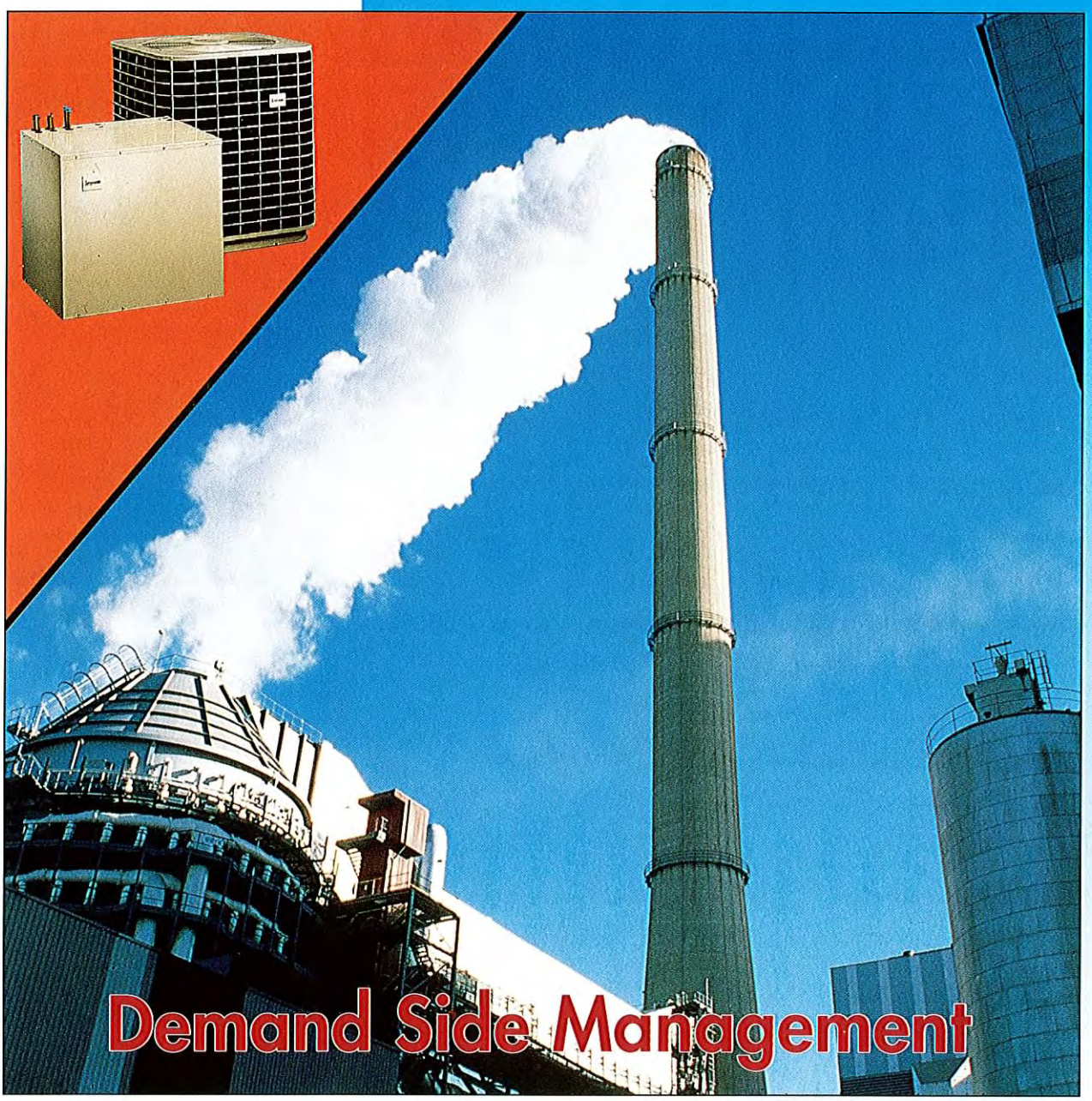
Vol. 12, No. 2, June 1994

IEA Heat Pump Centre

NEWSLETTER



Demand Side Management

IEA heat pump centre

OECD

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Front Cover: *By minimizing energy consumption and instantaneous power demand, the integrated heat pump is an important technology for demand side management. More details are given on page 34.*

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an International Energy Programme.

A basic aim of the IEA is to foster cooperation among the 23 IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 35 Implementing Agreements, containing a total of more than 60 separate collaboration projects.

IEA Heat Pump Centre

The eight member countries of the IEA Heat Pump Centre (HPC) form a network for exchanging information on heat pump technology. By increasing awareness and understanding worldwide, the HPC aims to accelerate the implementation of heat pump technology as a means to reduce energy consumption and thereby to limit harmful environmental effects. This publication is one element of the HPC activities.

Any part of this publication may be reproduced, with acknowledgement to the IEA Heat Pump Centre, Sittard, the Netherlands.

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An Excellent Contribution



As chairman of the Dutch Electricity Generating Board (Sep), I am most grateful for the opportunity to put forward the Dutch point of view on the use of heat pumps in demand side management of the electricity supply. For the power utilities which Sep represents, the most important criteria for power generation are to provide a reliable electricity supply at lowest cost with due regard to the public interest and environment. And this concerns not only the production of power, but also the end-use of electricity and heat.

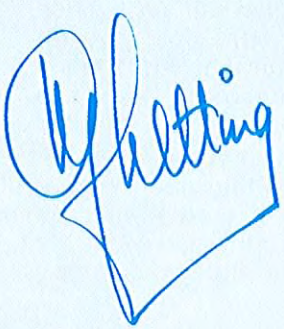
As illustrated in the articles of this issue, well designed heat pumps can offer many possibilities for improving the efficiency of energy supply through demand side management. For countries with a cooling demand, reversible heat pumps with thermal storage technologies seem to offer many opportunities for peak shifting and load levelling. And for countries where resistance heating is significant, heat pumps can help reduce the electrical demand in the heating season.

But for the Netherlands, with little cooling demand and where much of the heat demand is currently met by gas-fired equipment, the issue of demand side management of is viewed from the wider aspect of optimizing the country's power and heat supply system.

The generation of electricity by combined heat and power (CHP or cogeneration) and the supply of heat through district heating is an important method for making more effective use of fuel resources. But CHP has its limitations.

At present, the heat to power ratio in the Netherlands is between 4:1 and 5:1. This seriously constrains the further penetration of CHP. At the same time, large quantities of primary energy are used directly for low-temperature heat production.

In this situation, heat pumps in combination with CHP can provide an excellent contribution to increase the overall efficiency of energy consumption. We therefore see the promotion of heat pumps as an important measure in the search for a more optimal energy supply system.



Niek Ketting
Chairman, Dutch Electricity Generating Board, N.V. Sep.

News & Views

US DOE recommends heat pump water heaters

USA - The Department of Energy (DOE) Office of Codes and Standards has proposed that heat pump water heaters be the minimum standard for electric water heating.

From a comparison of resistance heaters, various levels of insulation, and both stand-alone and integrated heat pumps, the DOE has concluded that a minimum standard of an add-on heat pump and R-25 insulation is "technologically feasible and economically justified".

In stating that technical solutions exist to retrofit existing equipment, the notice refers to the proceedings of the workshop "Heat Pump Water Heaters" held in July 1993 and organized by the IEA Heat Pump Centre and the US National Team.

A "Notice of Proposed Rule Making and Public Hearing" on this topic was published in the *Federal Register* (Vol. 59, No. 43, March 4, 1994) and is available for public comment. The proposed standard is a minimum power factor (similar to a seasonal performance factor) of 1.89. This could be achieved with an air-source heat pump using heat from indoor air.

The notice states that the imposition of this minimum standard would save 36.8 EJ of primary energy, and reduce emissions of CO_2, SO_2 and NO_2. Looking at the economics, the notice states that the equipment with the recommended minimum standard has the lowest life cycle cost of all the options considered and gives a payback period of just two years to the consumer. However, the proposed rule is controversial and many issues have been raised by public interest and environmental groups, utilities and appliance manufacturers.

The notice is made in conjunction with the National Appliance Energy Conservation Act and includes many other recommendations on amendments to energy conservation standards on other household equipment. The DOE will consider all public comments received by 18 May 1994 before taking final action on the proposed regulation.

20 years of research at Melbourne

Australia - A programme on heat pump design and performance testing has been in progress at the University of Melbourne for almost 20 years.

During this period, work has been carried out on conventional and advanced heat pump designs, including solar boosted and solar assisted heat pump systems.

Application areas have included space conditioning, household, commercial and industrial water heating, swimming pools, greenhouses, dairy industry and other industrial process heat systems. Work has covered both electric and gas-engine heat pumps and includes research on alternative refrigerants.

Some preliminary feasibility studies have been carried out on hydride heat pump systems, following on from work on metal hydride storage tanks for fuel storage.

The programme is governed by the Dean of Engineering, Prof. W.W.S. Charters, who is currently a Vice President of Commission E2 of the International Institute of Refrigeration.

(Source: Mr Mirek Piechowski, University of Melbourne, Australia. Fax: +61-3-347-8784)

Three cheers for ammonia

USA - A record breaking 850 industry professionals attended the annual meeting of the International Institute of Ammonia Refrigeration (IIAR).

The atmosphere was buoyant, with a strong feeling that with CFCs banned, HCFCs on the way out, and HFCs being treated with reservation, ammonia has unprecedented market opportunities.

The participants heard that "most opinions on ammonia are founded on myth, misunderstanding or ignorance" (Lindborg, Frigoscandia), that "with the right design and appropriate safety precautions, air conditioning with ammonia is the ideal solution" (Toth, Integrated Refrigeration Corp.), and that "the ammonia industry has an excellent opportunity to increase its market share" (Millais, Greenpeace).

Heartened by these notions, the participants heard a total of 18 technical papers on a wide range of topics. For a full set of papers please contact the IIAR , Tel.: +1-202-857-1110. And to top it all there were "NH_3 - the Right Stuff" souvenir buttons available.

(Source: The Air Conditioning, Heating and Refrigeration News, 28 March 1994)

Standards harmonized

USA - The Air Conditioning and Refrigeration Institute (ARI) and the Canadian Standards Association (CSA) have published joint standards on "Packaged Terminal Air Conditioners and Heat Pumps" and on "Ground Water-Source Heat Pumps".

More recently, ARI's standard on "Ground Source Closed-Loop Heat Pumps" has been revised.

Meanwhile in Canada, a study by Caneta Research has recommended that the CSA does not go ahead with a proposal to set minimum efficiency standards for hermetic compressors for unitary heat pumps and air conditioners.

Further harmonization of North American standards can be expected after an agreement was reached in Mexico to promote tri-national (Canada, Mexico and USA) standards and test procedures for electrical safety and performance ratings of both ducted and non-ducted heat pumps.

At the International Organisation for Standardisation (ISO), ISO 5151 on "Non-ducted Air-Conditioners and Heat Pumps" has been approved for printing. Furthermore, the new ISO TC86/SC6 Working Group on Water-Source, Ground Water-Source and Ground Source Closed-Loop Heat Pumps has agreed to develop a single standard covering all three types of heat pumps. The heat pumps will be described as "water-to-air heat pumps" and "brine-to-air heat pumps".

(Source: Koldfax, Jan/Feb/Mar 1994, ARI, USA)

Heat pumps take to water

Austria - Tied to the banks of the River Danube in Vienna, the 188 m "schoolboat "shown below is not only a perfect venue for educational facilities but also a perfect application for a water-source heat pump.

Two 43.5 kW electric heat pumps provide heating, cooling and hot water using river water heat. The bivalent system includes a 650 kW oil-fired boiler and a 5000 litre water storage tank. The 9300 m² of floor space is heated using a 50/35°C central (hydronic) heating system. A hydraulic control system optimizes energy consumption.

(Source: Phänomen, 1/94, Leistungsgemeinschaft Wärmepumpe, Austria)

The Austrian "schoolboat" on the banks of the Danube, Vienna.



Stringent criteria for heat pump subsidies

The Netherlands - Heat pumps must meet stringent energy efficiency criteria to qualify for a subsidy in the Netherlands since 1 January this year.

In general, gas-fired heat pumps need to achieve a primary energy ratio of at least 1.2 and electric heat pumps a heating seasonal performance factor (SPF) of 3.0.

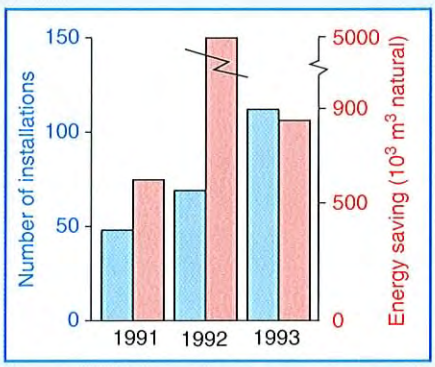


Figure 1: SET supported heat pump installations and their energy savings.

Subsidies for heat pumps are given under the so-called SET scheme, and are available since 1991. A grant of 25% of the investment costs can be given, with a maximum of NLG 300,000 (US$ 160,000) per installation. The SET scheme is a support programme to stimulate the use of energy conservation technologies. It is run by the Netherlands agency, SENTER, which executes government incentive programmes. In recent years, a small but growing number of heat pumps has been installed with support from SET as illustrated in Figure 1.

Figure 2 illustrates the performance of electrically driven heat pump systems supported up until December last year. It is clear that a number of systems would not have received a grant under the new terms. These systems were predominantly heat pump air-conditioners for offices. However, specific projects for which the new criteria are not relevant may still be subsidized. For example, heat pumps to recover waste heat from refrigeration or essential space cooling, dehumidification units in swimming pools, industrial waste heat recovery installations etc. do not have to qualify.

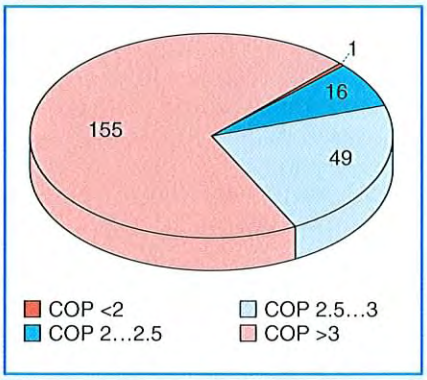


Figure 2: COPs of heat pumps installed with SET support.

(Source: Dutch National Team)

Heat pump working fluids in Turkey

Turkey - A survey on heat pump working fluids conducted for the IEA Heat Pump Centre estimates the consumption of CFC-12 and HCFC-22 in heat pumps to be around 20 tonnes per year. This compares with Turkey's annual import of 3600 tonnes of which the heating and air conditioning (HVAC) industry consumes around 3%.

Although fundamental research has been going on for many decades, primarily at the leading universities, heat pump applications in space conditioning are relatively new and limited. Nearly all heat pumps for commercial and industrial applications are imported, although there is some local manufacturing of window-type equipment. The current market share for heat pumps in the HVAC industry is estimated at around 7%, with some private projections suggesting a rise to around 15% over the next decade.

As a signatory to the Montreal protocol, Turkey will comply with the regulations on CFCs and HCFCs. Last year the Turkish government introduced strict measures to control the use and import of CFC and HCFC. Some manufacturers (both HVAC and industrial) have already implemented the use of recycling equipment and techniques, as have some of the major equipment users.

Equipment manufacturers plan to switch to alternative working fluids when compelled by the regulations set by the Turkish Ministry of Environment. Basic and prototype research on alternative working fluids is going on at various universities and the Gebze Research Centre of the Turkish Scientific and Technical Research Council. However, the eventual choice of alternative working fluids will be largely dependent on those developed and marketed by institutions and companies outside Turkey.

(Source: Dr Ibrahim Kilkis, Director of Heatway, USA, and Professor at the Middle East Technical University, Turkey. Fax: +1-417-864-8161)

Developing countries consider hydrocarbons

Asia - The two most populous developing countries, China and India, are warming to the idea of using hydrocarbons as refrigerants - initially for domestic cooling equipment.

In a significant move, the German Institute for Technical Cooperation, GTZ, has given grants to support the production of hydrocarbon filled equipment in China and India.

In China, the refrigerator manufacturer Haier is using German funds and expertise to retrofit one of its plants to produce equipment with hydrocarbons as refrigerant. The retrofitted facility will serve as a demonstration plant for the 19 other production sites of Haier, which together serve over 80% of the Chinese cooling market.

In India, the German "greenfreeze" refrigerator is being adapted for the Indian market. A pilot plant is being realized with GTZ support at the Indian Institute of Technology.

In spite of the obvious safety issues which must be addressed, developing countries are very interested in hydrocarbons as working fluids. Hydrocarbons are much cheaper than HFCs and do not require expensive lubricants. They are widely available and are not burdened with licensing issues. They are also certain to be a long-term solution as they have neither an ozone depletion nor a global warming potential. Environmental pressure groups such as Greenpeace believe that hydrocarbon technology should therefore be the main technology to be supported by the Montreal Protocol multi-lateral fund, executed by the Worldbank.

However, the US trade paper *The Air Conditioning, Heating and Refrigeration News* claimed in a strongly worded comment (13 Dec 1993) that the safety issues of using hydrocarbons in developing countries are far from resolved.

This view was to some extent seconded by Prof. Helmut Lotz, of the Siemens-Bosch Group, as he commented on the issue in the German trade paper *CCI*. The Siemens-Bosch Group is the major German manufacturer of refrigeration equipment, and a leader in the use of hydrocarbons as working fluids. Prof. Lotz stressed that the use of hydrocarbons in domestic refrigeration equipment is most certainly sound, but only when the equipment is made to high standards. Manufacturers in developing countries must be able to reach these standards before the technology can safely be transferred. After having stated that the Siemens-Bosch Group has long viewed HFC-134a as an intermediary solution only, Prof. Lotz went on to say that it will not be simple to transfer the environmentally benign hydrocarbon technology for domestic refrigerators to other applications, especially on a global scale.

(Sources: The Air Conditioning, Heating and Refrigeration News, December 1993; CCI, March 1994; CCI, April 1994)

Technology & Applications

Heat pump competition for Nordic countries

Sweden - The Swedish National Board for Industrial and Technical Development (NUTEK) is organizing a competition to design a heat pump system for a single-family home. Designers in Denmark, Finland, Norway and Sweden are invited to develop and present a package design for all aspects of a space heating system. This includes the heat pump, the heat source and the heat distribution system.

The aim is to stimulate the development of more efficient, more reliable and cheaper heat pumps and heating systems for use in detached houses previously heated by some form of electric heating. With about 1.2 million electrically heated detached houses in Sweden alone, it is estimated that heat pump systems have the potential to save about 5-6 TWh per year in all four countries.

Contestants have until 1 August 1994 to submit a written design. From these designs, a jury will select the 10 best entries who will each receive a premium of SEK 50,000 (US$ 6300). Up to six entrants will be invited to submit a prototype of their entry for testing in trial houses and in laboratories. Entries will be judged on both the heat pump and the system performance, including energy saving, economic performance and noise. Preference will be given to designs with environmentally benign refrigerants. For the three winners, in the categories air-source system, liquid-source system and heat pump unit, a total of SEK 900,000 (US$ 113,000) is available in subsidies, to help sales of the new heat pumps to reach at least 2000 units. For more information contact Arne Lögdberg, NUTEK, Tel/Fax: +46-8-396763.

(Source: Stefan Camitz, NUTEK)

Propane used in direct-expansion unit

Austria - NeuraTherm in Regau, Upper Austria, has developed a direct-expansion ground-source heat pump (DXHP) that uses propane as refrigerant.

The new model is a modification of a currently marketed HCFC-22 unit for use with horizontal ground coils. In combination with a low-temperature floor heating system with maximum operating temperatures of 32°C (also supplied by the company) this two-speed HCFC-22 unit has demonstrated SPFs higher than 4.

Considering the flammability of propane, the new model is designed for outdoor installation (see photo). The only connections into the building are the supply and the return pipe to the hydronic distribution system and some wires.

A second new feature of this DXHP unit is that the connection of the ground coil to the heat pump is made in the factory. The complete unit - heat pump and collector circuits - is delivered fully operable to the site.



DXHP using propane.

The SPFs of this new model are expected in the range of 4 to 4.4 due to the better performance of units using propane compared with those using HCFC-22.

(Source: Mr Hermann Halozan, Austrian National Team)

EPRI examines advanced hydronic distribution

USA - The typical air duct distribution system used in the residential sector has losses in the order of 25 to 30%. Realizing the significance of these losses on power consumption and peak demand, the Electric Power Research Institute (EPRI) has developed and demonstrated a hydronic (water or water with antifreeze) thermal distribution system for both heating and cooling.

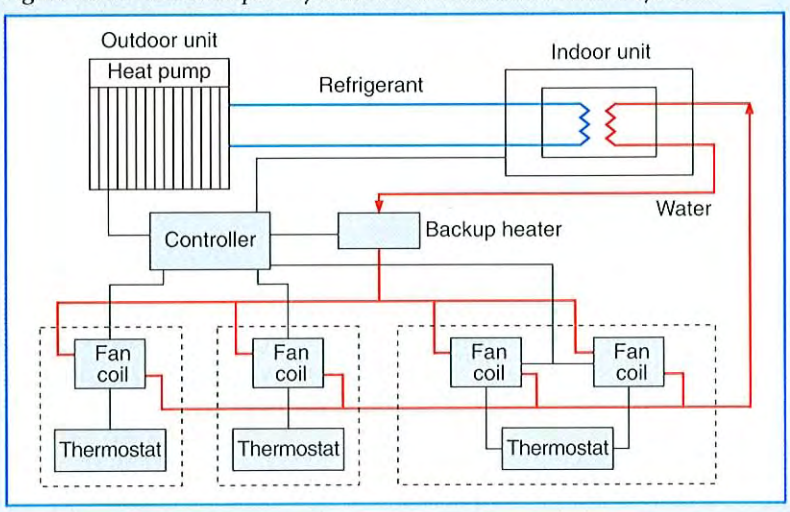
As outlined in Figure 3, the system is driven by an air-source heat pump, although a water or ground-source unit could just as well be used. Thermostatically controlled fan-coil units provide individual temperature control of different "zones" of the home. A centralized microprocessor ensures that the heat pump and fan-coil units work in harmony, and provides overall control of the multi-zone system.

A key feature of this system is the design of the hydronic circulation system. Installation is simplified by using flexible hydronic cable which carries the supply, return and, possibly, the condensate drain piping along with control wiring in a single tube of about 10 cm diameter. Heat is distributed at supply/return temperatures of 70/60°C.

The system has been tested at an unoccupied test house in Gaithersburg and further field tests in different climatic areas are planned. Results to date demonstrate that the system provides greater comfort than a comparable air-duct system, but show that further optimization is needed before the potential energy savings can be realized.

(Source: Mr John Kesselring, EPRI, USA. Fax: +1-415-855-2954)

Figure 3: EPRI developed hydronic thermal distribution system.



Markets

Signs of recovery

USA - With the recession over, sales of consumer goods are on the rise and heat pumps are no exception.

Year-to-year sales of air-to-air unitary heat pumps rose 10% in 1993, slightly ahead of the rise in unitary air-conditioning systems as a whole. Of the unitary air-conditioning systems sold last year, around 22% were heat pumps. Figure 4 plots the trend in unitary heat pump sales over the past four years. As shown in Figure 5, water source heat pumps had only a modest sales rise of 3% last year. This figure also shows a sharp rise of 18% for packaged terminal air conditioners and heat pumps (ptacs and pthps).

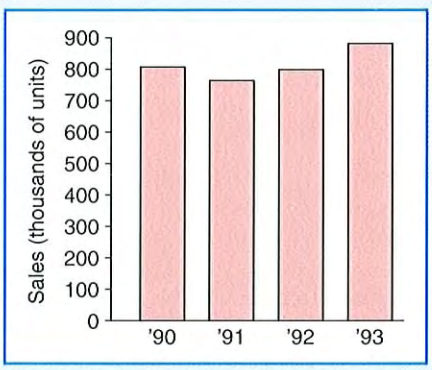


Figure 4: Air-to-air unitary heat pump sales.

But compared with more conventional heating systems, heat pumps have not fared so well in the revived economy. Sales of gas furnaces rose 20% to US$ 2.54 million. The much smaller electric furnace market also rose 20% to 348,000 units. Gas boilers for hydronic heating had a modest sales rise of 4.7% to around 347,000 units.

The trend to switch from fuel oil to gas continues, with about 300,000 homes connecting to gas networks last year.

Heat pumps continue to play a significant role in new single-family homes. Of the 1 million homes built last year, 246,000 were equipped with heat pumps.

Overall, the current installation of heat pumps is estimated at around 8.7 million. This compares with 54 million warm air furnaces and 15 million hydronic heating systems.

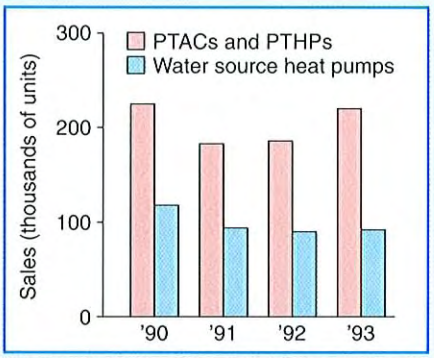


Figure 5: Sales of packaged terminal equipment and water source heat pumps.

(Source: The Air Conditioning, Heating and Refrigeration News, 11 April 1994)

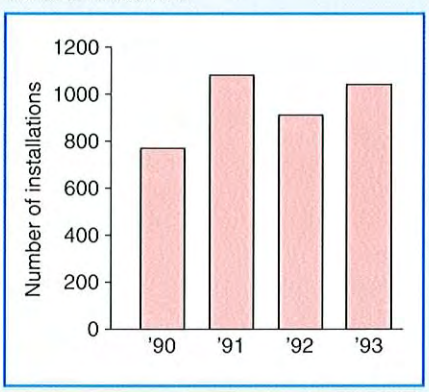
Space heating heat pump sales rising

Austria - Sales figures for space heating heat pumps rose again above the 1000 unit mark last year after a fall in 1992 (see Figure 6).

However, sales remain moderate compared with the boom year of 1981 when sales reached 3300 units. The much larger market for hot water heat pumps showed no significant change on 1992, with sales figures of around 6000 units.

(Source: Phänomen 1/94, Leistungsgemeinschaft Wärmepumpe, Austria)

Figure 6: Space heating heat pump sales in Austria.



Air source heat pump market declines

Canada - Newly published data by the Canadian Heating, Refrigeration and Air Conditioning Institute (HRAI) show that the market for residential air-source heat pumps continued to shrink in 1992, in spite of a slight turn up in the residential air-cooled air conditioning market (sales of cooling only equipment rose by 10,000 to just over 70,000. In 1989 190,000 units were sold). Less than 10,000 residential air source heat pumps were sold in 1992, a decline from a high of over 18,000 units in 1989. The commercial air-source heat pump market has also slowed down in 1992.

It must be emphasized that these data concern air-source equipment only, and that other information suggests that the total heat pump market has been more steady over the last few years.

(Source: Canadian National Team)

IEA Heat Pump Programme

Users of large absorption heat pumps and heat transformers meeting

Germany - One of the IEA Heat Pump Centre's main activities to support the application of absorption heat pump technology is the organization of an annual meeting of the "Users Club of Absorption Heat Pumps". This year's meeting was held on 11 February and hosted by ZAE Bayern, the Bavarian Centre for Applied Energy Research. Users from Denmark, Germany, the Netherlands and Sweden were present along with representatives from the manufacturers Rinheat Oy of Finland and Entropie of France.



Participants of the meeting of the "Users Club of Absorption Heat Pumps".

A report was given at the meeting on a Swedish company, GRAAB that processes refuse, amongst other things, by incineration. Their plant in Gothenburg comprises of three incinerators equipped with a two-stage wet scrubbing system to clean and condense the flue gasses. The steam produced drives four absorption heat pumps which recover the heat from the flue gas cleaning system, and produce heat for Gothenburg's district heating system. The system will be extended with two new incinerators and an 8 MW absorption heat pump. The extension is scheduled for operation in October 1994.

A Dutch company, Hoogovens, reported that their heat transformer operates satisfactorily. The system produces 130°C steam from 90°C cooling water at the company's strip mill in IJmuiden.

An absorption heat pump in Hundested, Denmark, operates as expected, except for the highly advanced gas engine which provides the waste heat to drive the heat pump. Due to technical problems in the engine, the system's availability is hampered. This heat pump supplies the heat to a local district heating system.

A report was given on a heat pump replacement in Neu Brandenburg, Germany. The old compression-type heat pump installation consisted of four screw compressor units that performed poorly and leaked refrigerant. The new absorption heat pump operates on geothermal heat (50 - 54 °C water) and is integrated in the local refuse incineration plant. Plans for two similar installations in Poland were also unveiled.

The firm Entropie announced that it is designing a new installation in Erdingen, Germany. This system will use geothermal heat (65°C) and deliver heat to the district heating system at different temperatures in winter and summer. A unique feature of this system is that the well water is used as potable water after it has been cooled. The heat pump will also feature double mode operation; in winter it works as a single effect machine delivering 9 MW heat, and in summer as a double-effect machine delivering 4 MW heat. Operation is scheduled to begin in 1996.

Meeting participants visited the absorption heat pump in the Deutsches Museum in Oberschleissheim, which was built under the license of the Technical University of Munich. This installation can work in three modes: as a double effect machine (COP=2); in intermediate mode (COP=1.6); and as a double-lift machine (COP=1.2). The system uses ground water as the heat source and delivers heat at two different temperature levels in winter and provides cooling in summer. The driving heat of the heat pump comes from a boiler. The system has been in operation for more than a year and operates satisfactorily.

Those attending the User's Club meeting benefitted from a valuable exchange of experiences once again. The contribution from manufacturers was particularly effective as it gave valuable insight into new developments and helped to answer some of the operating difficulties experienced by users.

(Source: Mr Jos Bouma, IEA Heat Pump Centre)

HPC finalizes analysis report

The Netherlands - "International Heat Pump Status and Policy Review" is the title of a major analysis work by the IEA Heat Pump Centre (HPC).

The first two volumes of this review are now being finalized and will be available this summer. These volumes examine the heat pump situation in the HPC's member countries plus Belgium, Denmark, France, Germany, Greece, Spain, Sweden and the United Kingdom.

Information is currently being compiled for a third volume which will cover several more countries, including Australia, China, the Republic of Korea, New Zealand and Poland.

The Analysis Report brings together many statistics not previously available and offers a unique way to compare the application of heat pump technology in different countries.

Workshops

The Heat Pump Centre has set dates for two workshops this autumn: "Consequences of (H)CFC Replacement in HVAC Applications" will be held in Gothenburg, Sweden, on 7-8 September and "Heat Pumps as Retrofit Alternatives for Resistance and Hydronic Heating Systems" will be held in Baden, Switzerland on 26-27 September.

(Source: IEA Heat Pump Centre)

US National Team

USA - Dr Arvo Lannus of the Electric Power Research Institute hosted the most recent US National Team Meeting held on 15-16 February in Palo Alto, California. The meeting launched several new initiatives including a drive to upgrade and expand the membership of the US National Team. The future membership will have a wider base and include representation from equipment manufacturers, builders, trade associations, universities, laboratories and regional heat pump associations. Several proposals for new Annexes for the Heat Pump Programme were discussed and an action plan to develop a strategy for the promotion of heat pumps was introduced. The next meeting is scheduled for 11-12 August 1994.

(Source: US National Team)

Feedback

The previous issue of the IEA Heat Pump Centre Newsletter featured an international overview of heat pump working fluids, by Bert Stuij of the HPC. In the discussion, a comparison was made of the global warming impact of using different working fluids in heat pumps in various countries, using the concept TEWI (total equivalent warming factor). In making this comparison a choice had to be made on the integration time horizon (ITH) - the time over which the global warming impact is considered. Both the 20 and 100 year time horizon featured in the article, but in one of the illustrations the short term 20 year horizon was chosen to calculate TEWIs. This choice drew a response from Mr A. McCulloch, of ICI Chemicals and Polymers Ltd., and Chairman of the Science Committee of the Alternative Fluorocarbons Environmental Acceptability Study. Most of his comments are printed below.

I read the article, cited above, with interest and must congratulate you on such a thorough summary of the current status of the selection of alternatives to CFCs and the environmental considerations inherent in the choices. There is, however, one aspect of the paper with which I must take issue; your use of GWPs calculated at the 20 year time horizon to calculate total equivalent warming impacts.

As you correctly showed, the TEWI of an installation is the sum of the contributions to global warming arising directly from leakage of the fluid used and indirectly from the carbon dioxide by-product of the power to run it. Carbon dioxide has a very long atmospheric lifetime, so long that the whole contribution of carbon dioxide to global warming is not accounted even at a 500 year ITH. The absolute global warming potentials of carbon dioxide [in $Wm^{-2}yrppmv^{-1}$] are:

- between 0.23 and 0.28 at a 20 year ITH
- between 0.69 and 0.96 at a 100 year ITH
- between 1.96 and 2.85 at a 500 year ITH

The range depends on the model used and on assumptions about the composition of the atmosphere up to the ITH. The absolute GWPs tell us that at the 20 year ITH, somewhat less than 10% of the potential effect of carbon dioxide has been counted, and even at 100 year ITH only some 35% is counted.

Failure of the shorter integration time horizons to capture the whole effect of gas emissions is particularly severe for gases with long atmospheric lifetimes, such as carbon dioxide and the CFCs. For gases with shorter atmospheric lifetimes, such as HCFC-22 or HFC-134a, there is little difference between the absolute GWP at 20 and 100 year ITHs and no difference between 100 and 500 years.

Mr A. McCulloch
Group Research Associate
ICI Chemicals & Polymers Ltd, UK.

Heat Pumps and DSM

An International Overview

Mike Steadman, IEA Heat Pump Centre

The term Demand Side Management, or DSM, is applied to programmes run by utilities which aim at improving the performance of energy supply by influencing the way it is used by the consumer. While DSM applies to both electric and gas supply, this article focuses on DSM as applied to electricity consumption, and its particular relevance to electric heat pumps.

The reason why utilities carry out DSM programmes is discussed and the use of heat pumps is put in context. The blue boxes provide an insight into heat pump related DSM programmes in the HPC member countries, as well as in Germany and Sweden. Information is also given on a new IEA initiative.

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The activities of power utilities, whether privately or publicly owned, are motivated by three criteria;

- the need to provide a reliable electricity supply at the lowest possible cost;
- the need to attract and retain customers by providing a satisfactory service (in free market situations this need may be driven by the desire to maximize income from electricity sales or related services);
- the desire to address society's concerns for energy conservation and environmental protection - sometimes made compulsory by governmental regulations.

Traditionally, as utilities strived to reduce the cost of power, their activities focused on improving the efficiency of the supply side, such as the use of more efficient power generation technology. However, in the early eighties, utilities began to realise that the cost of power supply could also be reduced by acting on the way electricity is used by the consumer. This kind of activity became known as DSM.

Load Management

Initially, DSM programmes focused on load management measures, aimed primarily at reducing daily and annual load fluctuations. Such fluctuations are a major problem to utilities since they mean that a substantial proportion of power generation equipment is idle for long periods, and other equipment must be kept in readiness to meet peaks. Most types of power generation equipment work more efficiently and with lower costs when the load is steady. A renewable energy source such as hydropower is often an exception to this rule. Here the power capacity depends on seasonal conditions.

The amount of fluctuation over a given period is often expressed as the load factor - this is the ratio of average load to peak load, expressed as a percentage. DSM programmes can improve both annual and daily load factors, bringing the following benefits to the utility:

- better financial performance from generating equipment;
- more efficient use of primary energy resources as low-efficiency generation equipment for meeting peak demands is used less often;
- avoidance of or delay in the need to build new generating capacity.

Load management measures reduce load factors by addressing both power consumption and instantaneous demand.

Energy Conservation

More recently, DSM programmes have come to include measures to limit the consumption of primary energy resources by changing the way energy is used by the consumer. Such measures can either reduce or increase electricity consumption, and, with it, revenue to the utility.

Encouraging users to switch from fossil fuel equipment to more energy-efficient electrical technologies can reduce energy consumption whilst increasing revenue for the electric utility. In contrast, improving the efficiency of electrical equipment, such as with energy-efficient lighting, will reduce electricity consumption. In this case, the needs and wishes of society, for lowering fuel consumption and reducing emissions, appear to be in conflict with those of the utility.

However, there are several incentives for utilities to promote measures to reduce electricity consumption. Firstly, by slowing down the growth in consumption,

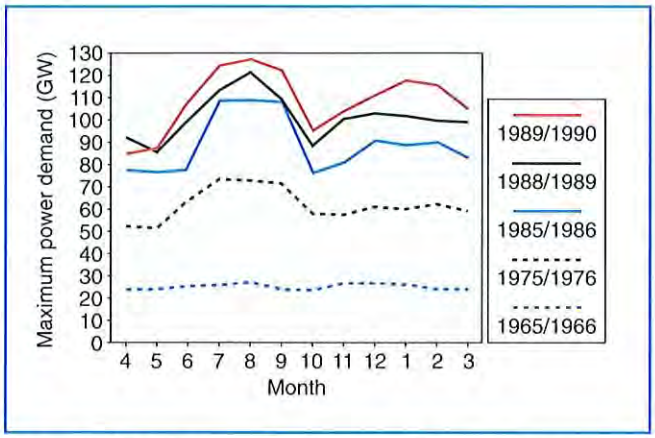


Figure 1: Development in the annual power demand pattern in Japan.

the need to invest in new power generation capacity is delayed. Secondly, in a competitive market, utilities must attract customers by meeting their energy needs at the lowest cost. While income per customer may be reduced, market share is retained. And for larger buildings, the provision of advisory services, such as energy auditing, has become a new source of revenue for utilities. Finally, utilities may be obliged or encouraged to promote measures to reduce energy consumption through government regulations or incentive schemes.

Heat Pumps and DSM

From a utility's point of view, the connection of electrical heat pumps to the grid can influence the electrical load in many ways. Depending on the alternative heating system they displace, heat pumps can either increase or decrease annual electrical consumption. Furthermore, the amount of electricity demanded and consumed by heat pumps varies with the time of year (according to the outside temperature) and the time of day (according to the habits of the user). On a shorter time scale, heat pumps generally have a cyclic operation, with a frequency related to the outside temperature. And with variable-speed heat pumps, the instantaneous power demand can also vary.

DSM programmes with heat pumps can help to control these influences for the benefit of society.

Balancing the Annual Load

Using Japan as perhaps the most extreme example, Figure 1 shows how the increased use of air conditioning can lead to the development of a large summer peak. By demanding power in both the heating and cooling seasons, reversible heat pumps can help to reduce the impact of this trend by balancing the load over the year. The most recent curve in Figure 1 appears to indicate this effect.

In colder climates, DSM programmes to encourage the replacement of resistance heating with heat pumps can help to reduce the winter peak.

Heat pump water heaters can also help to balance the annual load. They offer a fairly steady load throughout the year and, in regions with a cooling demand, they can reduce summer peaks by utilizing condenser heat from air conditioning.

The replacement of fossil-fuel heating systems by heating-only electric heat pumps can have a detrimental effect on the load factor. Winter peaking utilities sometimes recommend the use of bivalent, or dual-fuel heat pumps whereby the back up fossil fuel heating equipment helps to reduce peak demand.

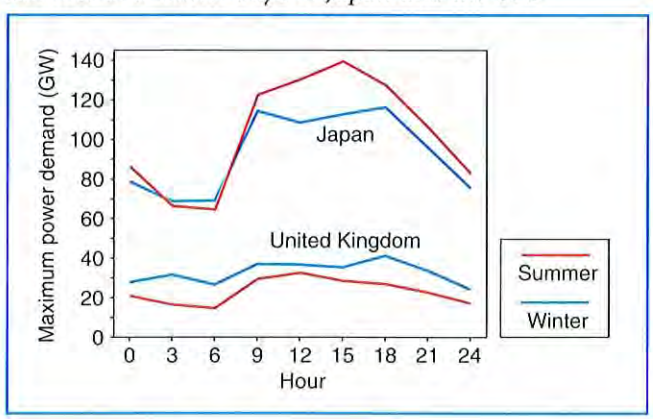
Shifting the Daily Load

Figure 2 compares the fluctuation in load on typical summer days in Japan, where reversible heat pumps are widespread, with that in the United Kingdom, where they have far less penetration. The widespread use of reversible heat pumps leads to a high daily load factor, especially in summer. By offering lower tariffs at night, many utilities encourage measures to shift the load away from peak periods, to give a more balanced daily demand.

For heating and cooling systems, load shifting requires some form of thermal storage. Much work has been done in this field in recent years, some of which was presented at the IEA Heat Pump Centre Workshop "Heat Pumps and Thermal Storage" in May 1993 (the proceedings are listed on the inside back cover).

Water and ice thermal storage systems are being applied increasingly in Japan and the United States. Most systems are used to shift the cooling load, although a study by the Tokyo Electric Power Company has shown that a water thermal storage system could shift up to 70% of cooling and 90% of heating to night-time power. Ice thermal storage systems reduce the size of the thermal storage tank at

Figure 2: Power demand characteristics on typical summer and winter days in Japan and the UK.



IEA

Recognizing the growing importance of DSM, the International Energy Agency has recently begun a programme of international cooperation known as the "Implementing Agreement on Technologies and Programmes for Demand Side Management." Initial work revolves around five projects (Annexes):

1. provision of a database on DSM projects;
2. a study of communications technologies for DSM;
3. establishment of a procedure for co-operative, multinational procurement of innovative DSM technologies;
4. a study of methods for integrating DSM options into the integrated resource planning (IRP) programmes of utilities and governments;
5. a study of DSM marketing approaches.

Austria

With a large number of storage hydroelectric power stations, peak load supply is not a problem. The main concern to utilities is the dependence of the base load capacity on river water content. The 260 Austrian power utilities are applying a range of measures to try to increase the load factor and to avoid the construction of new power stations.

Night-time tariffs have long been offered for hot water production and storage heating systems. Now utilities are motivating energy consumption by making demand charges instead of making a fixed charge based on the number of rooms and the installed equipment, as was done previously. Special tariffs are offered for interruptible power supplies to heat pump systems. These may allow short-term interruptions (e.g. maximum of three, two-hour interruptions per day) or long-term interruptions (e.g. maximum of 950 hours per year). The latter is for use with bivalent systems where heat pump operation is not allowed at low outdoor temperatures.

Computer technology is playing an increasing role in controlling power consumption. Information systems help consumers select the operation of home appliances according to various criteria including energy consumption. In industry and commercial/institutional buildings direct digital control systems (DDCs) are being increasingly used to reduce peak demand.

(Source: Mr Hermann Halozan, Austrian National Team)

the expense of reduced efficiency. Other storage technologies such as clathrate and chemical storage have been successfully demonstrated but further progress is needed to make them economically viable.

Reducing Instantaneous Demand

Because conventional heat pumps and air conditioners operate by cycling on and off, their instantaneous power demand is considerably more than would be suggested by their power consumption. To limit the impact of coincidental demand from many systems, more frequent operation at less power is preferred. Variable-speed and two-speed technology is helpful in this respect.

Integrated heat pumps give a similar effect by avoiding coincidental demand for space heating and hot water heating. In summer, much or all of the hot water need is met by using condenser heat. In winter, the heat pump is controlled so that space heating and hot water heating demand is met at separate times.

Remote Switching

Heat pumps with thermal storage, and bivalent or dual-fuel heat pump systems can be switched off for limited periods without any reduction in comfort level. These types of systems provide an excellent opportunity for utilities to reduce peak loads by remote switching. Some utilities (e.g. in Austria and

Canada

The power supply system is characterized by the predominance of hydropower and relatively low electricity prices. The penetration of resistance heating causes peak demands in winter. Several electric utilities are actively promoting heat pumps. The recent experience of Ontario Hydro is discussed below.

A three year marketing programme, which finished in 1993, achieved 34 MW of peak demand reduction by encouraging the use of heat pumps. By offering cash incentives, a subsidized loan plan, and through promotional efforts, heat pumps were installed in over 11,000 new and existing homes (see Figure 3), primarily in areas where natural gas is not available.

The utility imposed strict standards on the performance of the installed heat pumps. For example, air-source heat pumps had to exhibit a COP of at least 1.6 (later revised to 1.7) at -20°C. Installation contractors also had to meet strict requirements. Training and qualification of contractors and inspection of installations was provided, at a fee, by the Ground Source Industry Heat Pump Association.

It is hoped that the success of this programme will lead to a greater penetration of heat pumps among Ontario's 500,000 houses (around 20% of the total) currently using resistance heating.

(Source: Mr Frank Lenarduzzi, Canadian National Team, based on a paper by Mr Brian L. Killins and Mr Randall B. Lee of Ontario Hydro)

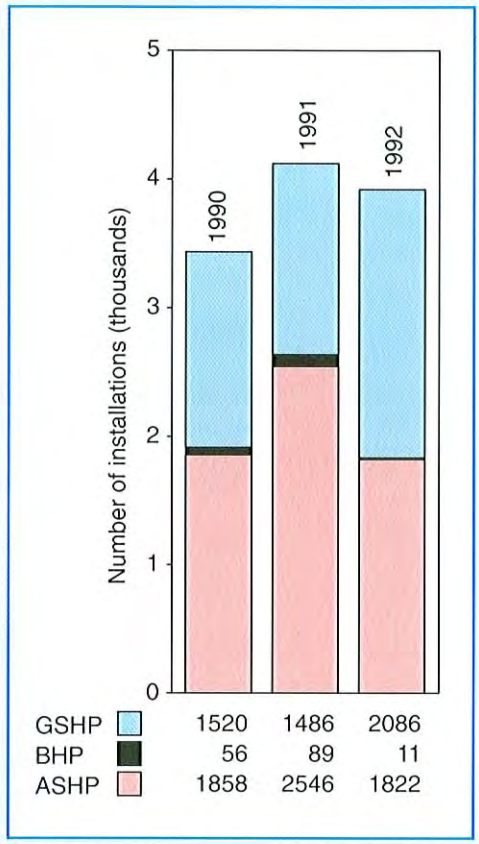


Figure 3: Number of ground-source heat pumps (GSHP), bivalent (BHP) and air-source heat pumps (ASHP) installed under Ontario Hydro's marketing programme.

Germany

Most homes are heated by either oil or gas-fired systems. Utilities see electric heat pumps as an opportunity for increasing revenue whilst reducing primary energy consumption. Their prime target is the promotion of bivalent systems for existing houses whereby an air-source heat pump is added to a conventional hydronic system with an oil or gas-fired boiler. Since 1985, electric utility RWE Energie has supported the installation of bivalent heat pumps by offering favourable electricity prices and other incentives such as financing, extended guarantees and consultation services. However, the fall in energy prices has meant that the take-up of this offer has been extremely low.

The company has now turned its attention to the much smaller, new housing market (1 to 2% of the total housing stock). For new houses, the preferred system is a monovalent ground-source heat pump and a low-temperature hydronic heating system. For this type of installation a 25% tariff reduction is available for 10 years, along with a favourable system for determining the standing (connection) charge. It is hoped that the four year promotion programme will lead to renewed opportunities in the existing housing market.

(Source: Mr P. Göricke, RWE Energie. Tel: +49-201-185-2445; Fax: +49-201-185-4543)

Italy

With space heating predominantly from gas-fired equipment, and a significant penetration of air conditioning, the Italian electricity system peaks in the summer. These conditions suggest that the wider use of reversible heat pumps would help to balance the annual load. Despite this, there are no DSM programmes to promote heat pumps although the government does subsidize some heat pump installations under general measures to encourage rational energy use and energy saving. About 50% of hot water heating is provided by resistance heaters, suggesting a huge potential for the promotion of heat pump water heaters.

Most electricity is supplied by publicly owned utilities, dominated by the national utility ENEL. Power generation from the private sector is mainly from cogeneration. The electricity market cannot be described as free.

(Source: Mrs Laura Manduzio, Italian National Team)

Japan

Electricity supply is characterized by huge summer peaks due to air conditioning. Power utilities are active in encouraging the use of thermal storage systems for large buildings and district heating and cooling systems. Because of size considerations, ice thermal storage is being applied increasingly.

Heat pump technology is supported by the government in view of its wide implications to energy supply. Energy demand has grown at an alarming rate in recent years (see Table 1), well ahead of the official long-term estimate of 1.3% per year. Given Japan's dependence on importing energy, it is feared that future fluctuations in energy prices could seriously affect industrial activities and the standard of living.

The use of heat pumps is encouraged through a tax incentive scheme which allows 7% of the initial investment cost to be written off against tax. This applies to industrial heat pumps and to space conditioning and heat pump water heaters with a heating capacity above 75.6 kW and a COP greater than 2.83.

The energy consumption of heat pumps is now governed by the following minimum efficiency standards: COP cooling of 2.19, COP heating of 2.38 and an average COP of 2.3.

Year (April-March)	1987-88	1988-89	1989-90
Increase in energy demand on previous year	4.8%	5.7%	8.4%

Table 1: Growth in energy demand.

(Source: Mr Yoshio Igarashi, Japanese National Team)

Switzerland) offer special tariffs to customers who agree to allow their heat pump to be switched off once or twice a day for a limited period.

Bivalent or dual-fuel heat pump systems can be switched off for long periods so that periods of excessive heating demand can be met by fossil fuels instead of electricity. In North America, dual-fuel heat pumps are sold as single units including both the heat pump and a gas furnace (see *IEA Heat Pump Centre Newsletter* Vol. 8, No. 1, pp 20-23). An integrated control system ensures optimum operation according to the heating needs and economic factors. This generally means that the heat pump will not be used during periods of peak electrical demand.

Reducing Energy Consumption

With electricity consumption continuing to grow worldwide, albeit at a slower rate, DSM tends to be associated with measures to reduce electricity demand and consumption. The irony of the heat pump is that,

Netherlands

The energy conservation measures of utilities are governed by contracts known as environmental action plans (MAPs). These set targets for energy saving over a specified period. It is expected that measures to support heat pump applications will be included in these schemes in the near future. However, there are currently no utility programmes for the promotion of heat pumps in place, although a number of important projects have utility support.

Support for heat pumps from the government is available as part of a general subsidy programme for energy-saving technologies. This amounts to a 25% subsidy, up to a maximum of NLG 300,000 (US$ 160,000). Recently, this subsidy has been restricted to heat pumps with an SPF (heating) of at least 3. More government support can be expected once a proposed plan to save 5-10 PJ of primary energy with heat pumps by the year 2000 is finalized.

(Source: Mr Onno Kleefkens, Dutch National Team)

Norway

On 1 January 1991, the Norwegian electricity industry underwent a dramatic change with the implementation of the Norwegian Energy Act. This completely deregulated the market, allowing customers to buy electricity from any utility - there are more than 200 in Norway. In this highly competitive market, the activities of utilities have focused on sales measures such as special tariffs and contracts, rather than on energy conservation measures such as the promotion of heat pumps. One exception is a utility sponsored project to monitor the performance and user attitude to heat pump installations in 10 homes. This is the first such project to be supported by a utility in Norway.

A particular feature of Norway's 100% hydroelectric power system is that surplus power becomes available in wet seasons at a very low tariff. Recently, the price of surplus power has been fluctuating wildly, from a low of 2 øre/kWh (0.3 US$ cents/kWh) to as much as 47 øre/kWh (7 US$ cents/kWh) in February 1994. This tends to favour heat pumps which, unlike electrically heated boilers, do not rely on low cost surplus power to keep down operating costs.

(Source: Mr Ulf Rivenæs, Norwegian National Team)

when used in place of a fossil fuel-fired heating system, it actually increases electricity demand and consumption whilst reducing the consumption of primary energy resources. In this case, utilities have a clear incentive to encourage the use of heat pumps.

Using heat pumps in place of resistance heating is also beneficial to society but can be less attractive to utilities as it may result in reduced revenue.

Motivating the Consumer

There are many ways in which utilities encourage the use of heat pumps and the application of DSM measures. The most obvious way is through the provision of special tariffs, such as those based on time-of-use, peak demand or the acceptance of remote switching. Subsidies and rebates may also be offered to help reduce the cost of heat pump equipment to the consumer. Some utilities take on the full costs of the heat pump and then charge the consumer a tariff based on heat consumption. Others offer free servicing and help in selecting and installing the system.

The Role of Government

In some situations there are financial incentives for utilities to initiate DSM programmes with heat pumps. However, they do not always offer the utility the desired profitability, and in some cases the promotion of heat pumps can lead to a reduced revenue. There is therefore a role for governments to play in encouraging the application of DSM programmes with heat pumps, primarily by offering financial incentives to the heat pump user. Countries where financial incentives for heat pumps are available through national or regional government programmes include Austria, Denmark, Germany, Italy, Japan, the Netherlands and Switzerland.

Switzerland

Around 1200 companies supply electricity, most of which is from hydroelectric power generators. On average, 73% of the share capital of utilities is owned by the public. There is only a limited free market regarding the setting of tariffs. Heating demand is dominated by oil-fired boilers, with only 6% attributed to electric systems (see Figure 4).

The Swiss government encourages the installation of electric heat pumps with a subsidy of SFR 270/kW (US$ 180/kW). To qualify for this subsidy, the heat pump model used must be certified by the Heat Pump Test and Training Centre at Winterthur-Töss. This centre was set up in 1993 by the utilities NOK and EKZ and issues quality certificates for air/water, water/water, brine/water and air/air heat pumps.

The heat pump subsidy clearly provides an excellent opportunity for utilities to sell more power. A key part of the Swiss government's heat pump policy is that the additional power generation must be met from replacing resistance heating with heat pumps or from CHP (combined heat and power) plants.

Some utilities are offering additional incentives for heat pump installations such as subsidies and special guarantees, or by taking care of all the installation costs and charging the consumer for the heat delivered. Special tariffs reduce the price of electricity by about 25% when the consumer agrees to allow an interruption in supply of a maximum of two, two-hour periods per day, with a minimum period in between. The cut off is announced two hours in advance by means of a special signal.

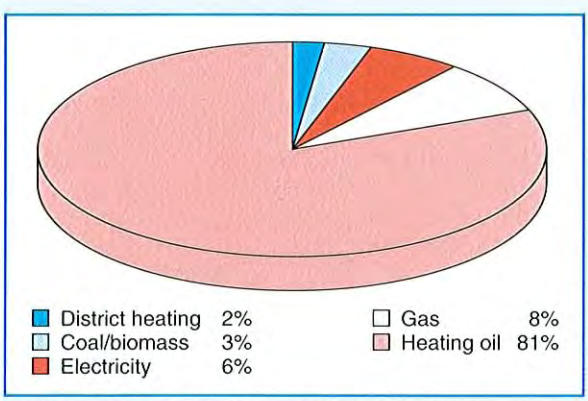


Figure 4: Share of energy sources for home heating in Switzerland.

A less direct form of DSM is through communication. Utilities organize open days when successful heat pump installations are presented to home owners to try to convince them that heat pumps are a proven, reliable technology. If things go wrong, unsatisfied heat pump users can contact free "hot lines" offered by utilities who will send experts to check installations when necessary.

(Source: Mr Thomas Afjei, and Mr Karl-Heinz Handl, Swiss National Team)

These programmes often include regulations to ensure that the promotion of heat pumps has a positive effect in terms of energy saving and environmental protection. In Switzerland, for example, heat pumps must reach a minimum performance, and in some regions the use of air conditioning is restricted to buildings of special need. Furthermore, heat pumps must be driven by power derived from the avoided electricity demand which follows from the reduction in resistance heating, or from newly built CHP (combined heat and power) equipment.

A Complex Issue

Electric heat pumps can no doubt save significant primary energy resources when properly applied. When considering a heat pump supplied by a single power station, it is simple to compare the primary energy ratio with other forms of heating. But when the realistic situation of connecting a heat pump to a national grid is considered, the effect of the heat pump on both primary energy consumption and on CO_2 emissions can be far more complex.

DSM programmes can certainly help to encourage the more widespread use of heat pumps. And there are a number of load management techniques associated with heat pumps which can lessen the impact of variations in electricity demand. It is important that all these factors are taken into account when considering policies to increase the use of heat pumps.

Sweden

Out of an annual consumption of around 140 TWh, about 32 TWh is used for residential space heating. This causes high peaks in January and February. DSM programmes for heat pumps date back to 1970 when a government subsidy of 25% of the heat pump cost was available. Despite the subsidy, heat pump sales remained low until the beginning of the 1980s, when the oil price was high and the electricity price low. The subsidy was stopped in 1985 when the oil price decreased. Figure 5 shows the rapid decline in heat pump sales since that year.

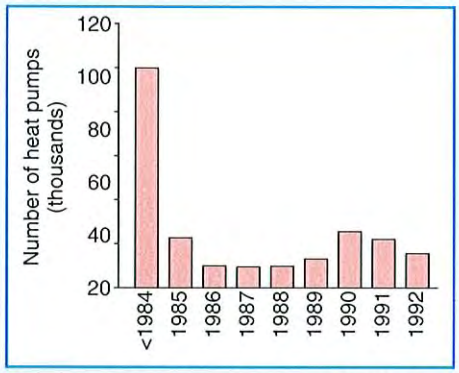


Figure 5: Annual sales of residential heat pumps in Sweden.

The Swedish power market is dominated by the publicly owned utility, Vattenfall Utveckling AB, which meets almost half the demand. The electricity market is expected to be deregulated in the near future.

(Source: Mr Gunnar Bröms, Vattenfall Utveckling AB. Tel: +46-26-88255; Fax: +46-26-72820)

United States

The annual coincidental peak demand is about 550 GW and occurs in summer, although some utilities experience peaks in winter. The increased saturation of residential air conditioning has caused the national average annual load factor to erode from 60% in the mid-eighties to about 58% at present. Some major electric systems are as low as 50%.

About 85% of annual demand is met by over 200 investor-owned utilities with the remainder supplied by hundreds of publicly owned utilities and rural electric cooperatives of various sizes. System reliability is accomplished through nine regional grids coordinated by the North American Electric Reliability Council. This organization also includes Canada and northern Baja California in Mexico.

The Energy Policy Act of 1992 places responsibility for DSM with the US Department of Energy and the Public Utility Commissions of each of the 48 states. In some states, such as California, energy use regulations have been established.

The significance of air conditioning on peak demand means that technologies such as ground-source heat pumps, integrated air-source heat pumps and ice thermal storage are commanding increasing attention. EPRI (the Electric Power Research Institute) has recently launched a project to study the effects of high-efficiency residential air conditioners and heat pumps on peak demands and load factors [1]. By performing field tests, the project hopes to get a clearer picture on the actual performance of single, dual and variable speed equipment under different climatic conditions, especially high-temperature conditions. For winter peaking utilities, dual-fuel heat pumps with gas furnace back up, are particularly attractive since peak demand can be met by the natural gas utility.

In 1993, the North American Electric Heat Pump Alliance was set up to coordinate the promotion of heat pumps by electric utilities [1]. The Alliance will provide an information service on heat pump programmes and will organize regional and national conferences and seminars. For more information contact Mr Steven Koep, The Electrification Council; Tel: +1-202-508-5900.

(Source: Mr Ted Gilles, US National Team, and [1] EPRI Heat Pump News Exchange, Fall 1993)

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The Impact of Heat Pump Air Conditioning on Electricity Supply

Takashi Uchida, Japan

In Japan, most natural resources for energy, for example petroleum and natural gas, are imported. Therefore, air conditioning in Japan is influenced by the demand and supply of energy resources. One of the energy policies which was adopted after the oil crisis encouraged the use of the heat pump air-conditioning system. But now the widespread use of heat pumps causes problems in peak demand of electricity. This article discusses the history of the air-conditioning system and demand side management in Japan. The energy balances of two buildings with air-conditioning systems are also looked at as typical examples of demand side management.

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After the oil crisis in the 1970s, energy policies in Japan changed the system of energy demand and supply which had previously depended upon petroleum. New energy policies were adopted, two of which influenced air conditioning. One aimed to raise the share of nuclear power generation and the other to introduce the heat pump. Recently, the share of nuclear power generation reached about 30% in Japan. When electric power supply depends upon nuclear power, it is desirable to limit the variation in power demand over the year. The diffusion of heat pumps was a suitable energy policy after the oil crisis because it was effective in not only levelling the electricity demand in winter and in summer, but also saving energy, especially petroleum.

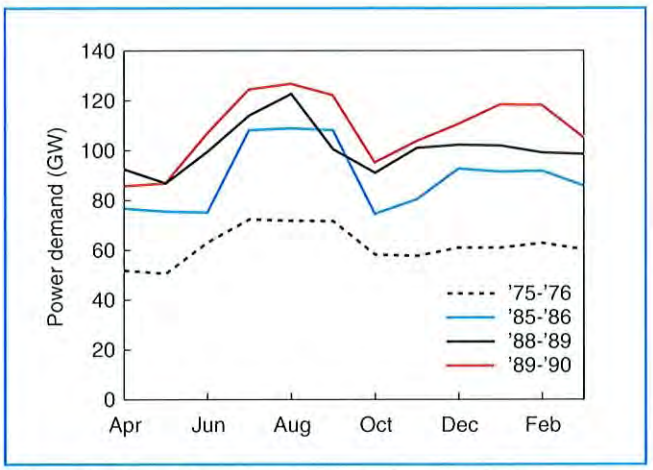


Figure 1: Trend in annual power demand in Japan.

Photo 1: Kajima Corporation Headquarters.



Decentralized

With this background the decentralized, heat pump air-conditioning system was developed and commercialized. This system has been called a "split-type heat pump air conditioner for buildings". Japan is a small and overpopulated country so almost all buildings are small or medium-sized. The decentralized, heat pump air-conditioning system was widely applied within a short time because the system had the following useful features:

- No machine room is needed so rental space in the buildings increases;
- It is easy to measure and charge for energy consumed for air conditioning;
- The energy consumption of this system is less than a conventional centralized air-conditioning system;
- Each indoor unit can be individually turned on/off and controlled by its own thermostat.

At first, the decentralized, heat pump air-conditioning system mainly served small and medium-sized buildings, but recently its use in large buildings has become more significant.

The Present

The diffusion of heat pump air-conditioning systems has contributed to the levelling of electricity demand in summer and winter. Moreover, the energy consumption of each building has been lowered in winter as the consumption of heating fuel oil is reduced. However, the widespread use of heat pump air-conditioning systems has caused an increase in the demand for peak electricity in summer. Figures 1 and 2 show the annual and daily electricity demand in Japan. Electricity companies have made a great effort to encourage the use of thermal storage air-conditioning systems that use night-time electricity in an attempt to even out electricity demand. But until recently this system has been mainly used in large buildings.

It was very difficult for small and medium-sized buildings to introduce a thermal storage air-conditioning system, since there was usually no space or money to install a water thermal storage tank and other equipment needed. But high capacity thermal storage technology, for example ice thermal storage, has now been developed. Ice thermal storage air-conditioning systems have been introduced not only in large buildings but also in small and medium-sized buildings.

Electricity companies have implemented policies to encourage the installation of thermal storage air-conditioning systems. An allowance of about 70% is now made for the night-time power rate against the daytime rate. This allowance was about 30% in 1980. The Tokyo Electric Power Co. has set up a "trust system" for thermal storage air-conditioning. Under this system, the installation cost for the storage tank and other related equipment is borne by the utility, and the cost is recuperated by charging the user an extra fee for electricity. Thermal storage air-conditioning systems are also treated favourably under the tax system. All these factors have led to a rapid growth in the installation of both water and, to a lesser extent, ice thermal storage air-conditioning systems.

Figure 2: Daily power demand in Japan.

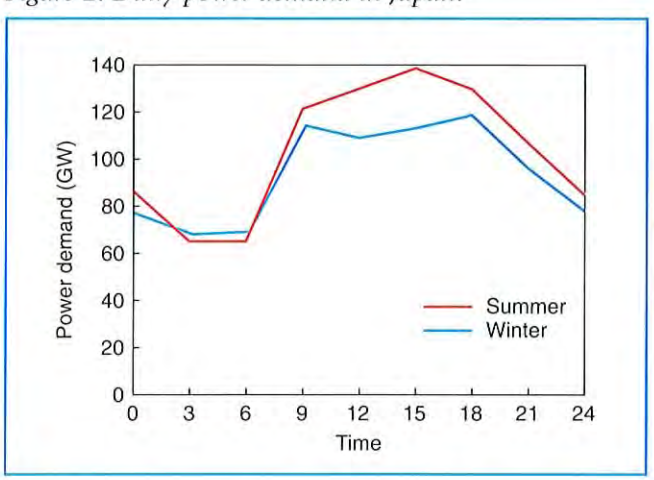




Photo 2: The 37-floor Crystal Tower in Osaka.

Examples of Energy Balance

Since 1991 the Heat Pump Technology Center of Japan has given special awards to superior heat pump systems worthy of recommendation. Two examples of energy balance that won awards in 1992 are shown below.

The first example is the renovation of an office building (see Photo 1). The air-conditioning system in this building was a conventional, centralized system based on a centrifugal chiller and an oil-fired boiler. During renovation, a decentralized system was added based on an air-source heat pump. The cooling design load for light fixtures and office automation equipment was increased during the renovation as more computer terminals would be installed. Despite the increased cooling load, the power consumption of the chiller, heat pump, pumps and fans remained the same after renovation and oil consumption was reduced. More details are given in Table 1.

The second example is a high-rise building called the Crystal Tower, which has an ice thermal storage air-conditioning system (see Photo 2). When a water thermal storage air-conditioning system is applied in a high-rise building, it is difficult to install a storage tank with a big enough volume. The floor area of the basement is too small compared with the total building area and, therefore, the volume of the water thermal storage tank in the basement is limited. In this building sufficient volume in the storage tank

Description
Twin tower building with 32,000 m² floor space

Original System
Centrifugal chiller
Oil boier

After Renovation
Secondary decentralized air conditioning is provided using a water-source heat pumps. Original equipment was retained to serve certain areas and for fresh air treatment.

Energy savings
Total primary energy consumption reduced by 7%
Oil consumption reduced by 33%

Table 1: Details of renovation work at the Kajima Corporation Headquarters.

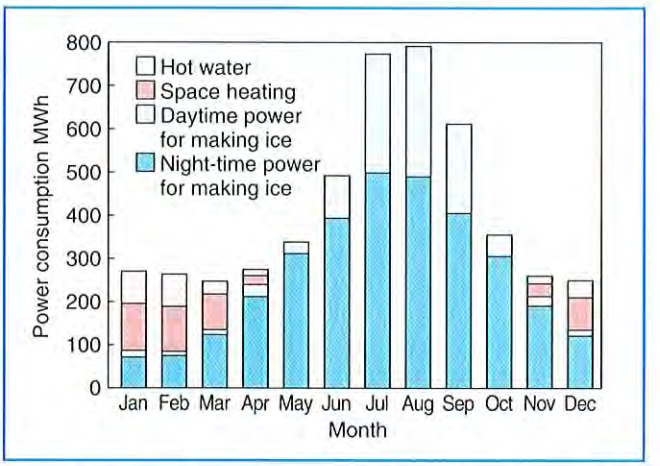
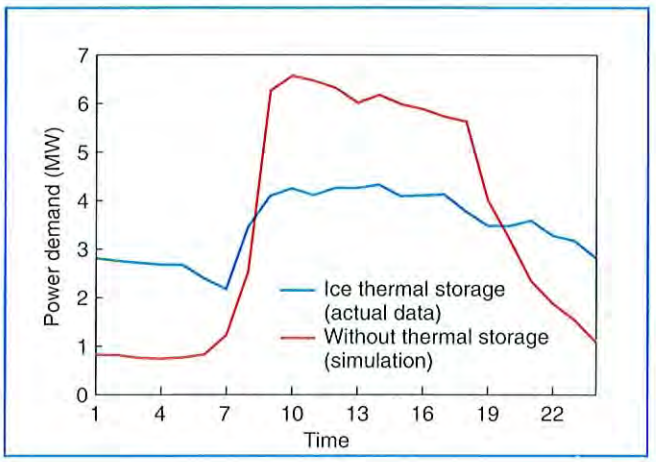


Figure 3: Annual power consumption of heat pumps in the Crystal Tower.

was achieved by adopting ice thermal storage. As a result, about 75% of the annual cooling load was served by night-time power. With the new system, the Crystal Tower's 86,000 m² of floor space is served by 32 ice thermal storage heat pumps. Each unit has a capacity of 112 kW for ice making, 174 kW for chilled water and 198 kW for water heating. The COP of an ice heat pump chiller is lower than that of a conventional water chiller so the energy consumption of the new system would be expected to be higher. However, energy consumption was reduced by using a more efficient thermal distribution system. In Japan, systems such as low-temperature blow-out or chilled water circulation, with a large temperature difference between supply and return water, are commonly used in the secondary circuit of an air-conditioning system. In the secondary air-conditioning system of this building a natural circulation system was applied, using the fluid HCFC-22. This eliminated the need for secondary circulation pumps with their own power demand. This system is called the Vapor Crystal System (VCS). Although the installation costs of ice thermal storage and VCS in this building were almost the same as the decentralized heat pump air-conditioning system, the operation cost was almost half. Figure 3 shows the annual power consumption. Figure 4 illustrates how ice thermal storage helps to level the daily power demand.

Figure 4: Effect of ice thermal storage on power demand for air conditioning in the Crystal Tower.



Future

The Heat Pump Technology Center of Japan studied the status of thermal storage air-conditioning systems for almost the whole of last year. According to this study, we estimate the effect of thermal storage air-conditioning systems to be a reduction of between 380 MW or 510 MW of peak electricity demand. This value is very small compared with total electricity demand in Japan, but thermal storage air-conditioning systems are one of the few means of reducing the use of electricity in peak hours. [Total electrical capacity in Japan was about 200 GW in 1991 according to IEA statistics. - Ed.] It is very important that this system is introduced in all types of buildings. Fortunately, last year many products with ice thermal storage were developed and commercialized, including the decentralized, heat pump air-conditioning system. Moreover, these systems are suitable not only for large buildings and district heating/cooling plants, but also for small and medium-sized buildings. The use of thermal storage air-conditioning systems is now expected to increase substantially.

Reference:
[1] March 1993. "Superior heat pump system in 1992". Heat Pump Technology Center of Japan

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DSM Applications with Residential Heat Pumps

Two-Speed Systems Widen the Opportunities

Ted C. Gilles, USA

In the United States, the increased saturation of residential air conditioning has caused the national average annual load factor to erode from 62% in the mid-1980's, to about 58% at present (meaning that the average power requirements are just 58% of the highest demand). For most power utilities, demand is highest in the summer, resulting in a national peak figure of 550,000 MW.

In residential applications, technologies such as two-speed compressors, ice storage and zone control are cost-effective demand side management (DSM) tools for reducing this summer peak. And when these technologies are applied in reversible heat pumps, utilities will also benefit from efficient electric power consumption during the heating season.

* * *

Residential space conditioning heat pumps are attractive to US electric utilities for several reasons. Firstly, since over 80% of new residential dwellings have air conditioning systems, the majority of which are electric powered, the serving utility sees their load factor continuing to decline when an alternative fuel is used for space heating. Heat pumps provide important winter season revenue from space heating kWh consumption, whilst demanding little or no additional capital investment for a summer peaking system.

Secondly, when it replaces a conventional electric resistance heating system, a heat pump will typically consume 50 to 70% less kWh, conserving power plant fuel and reducing atmospheric emissions. On the other hand, when replacing fossil-fuel heating equipment, heat pumps will increase power demand in winter. However, "dual fuel" heat pumps [termed bivalent systems in Europe - ED.] can avoid winter peaks by using fossil fuel forced-air furnaces for supplementary heat.

Effective Tools

Many utilities see heat pumps as effective demand side management tools and encourage their use through subsidies and other measures. Heat pumps are even more effective for demand side management when they incorporate technologies such as two-speed compressors, ice storage and zone control systems.

Balance-Point Control

If economically justified, the heat pump capacity can be selected to meet cooling season loads with efficient low-speed operation. This provides the ability to shift the heating balance point of the residence from typically -1.1°C or 1.7°C (30°F or 35°F) down to -9.4°C or -6.7°C (15°F or 20°F) with high-speed compressor operation on the coldest days in the heating season.

Zone Control

Two-speed compressor heat pumps with a single variable-output indoor air handling unit can serve up to four independent damper-controlled zones. During either the heating or the cooling season, unoccupied zones can have their thermostat control point set to the energy conserving setback mode, reducing total demand to that required to meet only the occupied zone comfort needs.

Peak Levelling

Summer peaking utilities can signal the two-speed unit to operate at low-speed (with approximately 50% kW input) during an on-peak period, rather than causing a single-speed compressor unit to cycle at a higher power level. Normal setpoint conditions can be maintained through the use of zone control.

Thermal Energy Storage

Two-speed heat pumps (or cooling-only units) can provide highly flexible, multiple control strategies when used in combination with ice thermal storage.

Two-Speed Equipment

Two-speed compressors have been used in residential-class air-source unitary equipment in North America since 1976. And residential single-phase heat pumps with two-speed compressors have been listed in the Air Conditioning and Refrigeration Institute (ARI) Directory since 1980.

The popularity of two-speed compressor equipment continues to grow because it is less expensive to manufacture and simpler and easier to maintain than other types of variable-speed heating and cooling systems. Figure 1 shows the cooling capacity and COP of a 17.6 kW cooling (five-ton cooling) unit rated at

This heat pump and ice thermal storage module serves a residence in Ohio with minimal on-peak demand.



SPF_C of 4 (13.6 SEER) with a nominal evaporator air quantity for each of the two speeds as compared to the sensible load being served. As indicated, the COP in low-speed operation is greater than for high speed at a given outdoor air temperature. At low speed, the entire condenser and evaporator coils are being used for less refrigerant mass flow and thus the equipment provides the greatest operating economy. Typically, a two-speed compressor unit will operate at low speed 70 to 80% of the time in a mid-America location like Kansas City.

By varying the delivered indoor air quantity according to the speed of the compressor, a two-speed heat pump can make a near-perfect track of the sensible cooling demand over a wide range of outdoor temperatures. Low-speed compressor operation, with various indoor air quantities, are typically used below 32°C outdoor temperature. Above this temperature, high-speed compressor operation with appropriate indoor air quantities is used to track the load.

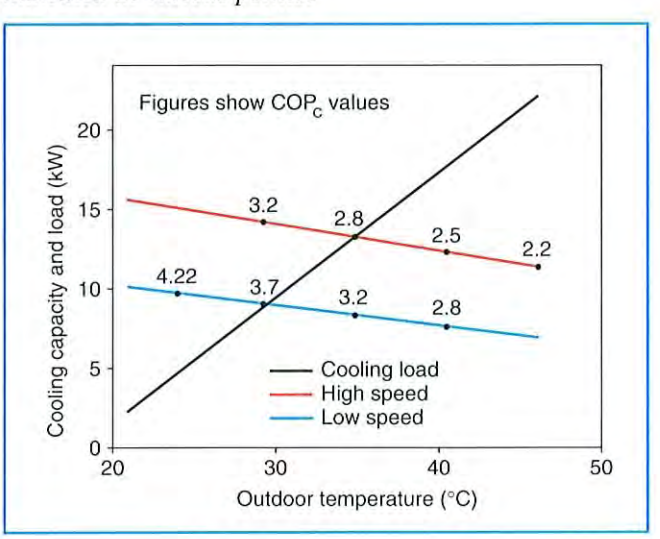
Dehumidification

The combination of various indoor air quantities and compressor speeds can also be used to solve the sometimes troublesome issue of dehumidification control with high-efficiency residential cooling systems. Some systems have an auxiliary humidity control to allow the level of dehumidification to be set. Residents are informed of the relative level of energy use by function lights on the controller. The greater the number of function lights illuminated, the further the humidity set point is below the actual space condition. To save energy, the resident can raise the humidity set point to more quickly return the unit to low-speed compressor operation. When the space humidity is at or below the set point, no lights are illuminated.

Heating

Where it is cost effective, the two-speed compressor heat pump can be used to lower the heating balance point. Figure 2 shows how to assess this for a 14.1 kW heating (four-ton heating) unit. In the cooling mode, this unit would usually provide very high efficiency, low-speed compressor operation. The high-speed heating output of the unit would move the balance point from about 0.5°C down to -8°C with a two-speed compressor application. The amount and cost of supplemental electric heat determines whether this is practical. It could be particularly applicable in high humidity areas of the US where supplementary electric

Figure 1: Cooling capacity versus outdoor temperature for a 17.6 kW cooling two-speed heat pump. COP is indicated at various points.



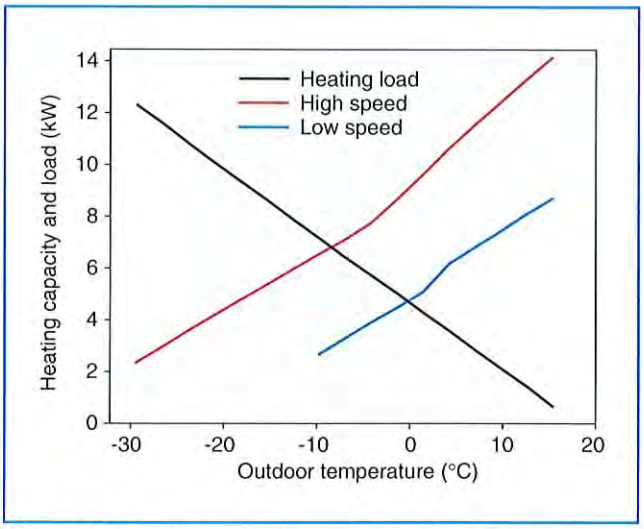


Figure 2: Heating capacity versus outdoor temperature for a 14.1 kW cooling two-speed heat pump.

heat use would probably be eliminated during the heating season, with the same system providing superior mild season dehumidification if equipped with an auxiliary humidity control.

Zone Control

A system of ducts and dampers can be used to provide a range of comfort levels in different zones of a building. The use of two-speed compressor heat pumps to provide up to four zones of temperature control from a single indoor unit has been demonstrated across North America in National Association of Home Builder's Smart Houses. Zoning provides individual occupant comfort, while offering significant potential energy conservation and lower operating cost by reducing the amount of energy delivered to unoccupied areas of the home.

Ice Thermal Storage

The two-speed compressor heat pump may find its greatest advantage when combined with ice thermal storage in areas where the serving utility experiences an annual peak demand during the hottest months when air conditioning is used. The photograph shows a test installation of a 10.6 kW cooling (three-ton cooling) air-source unitary heat pump and an 84 kWh ice storage module serving a residence in Ohio. The ice storage module is installed in the refrigeration circuit between the outdoor and indoor units. No secondary circulating fluids are used.

During off-peak periods, the outdoor condensing unit can be connected for ice making. During on-peak periods, a 100 watt liquid refrigerant pump provides cooling with low energy demand by circulating refrigerant through the ice storage module. The system can also bypass the ice storage module to provide direct cooling.

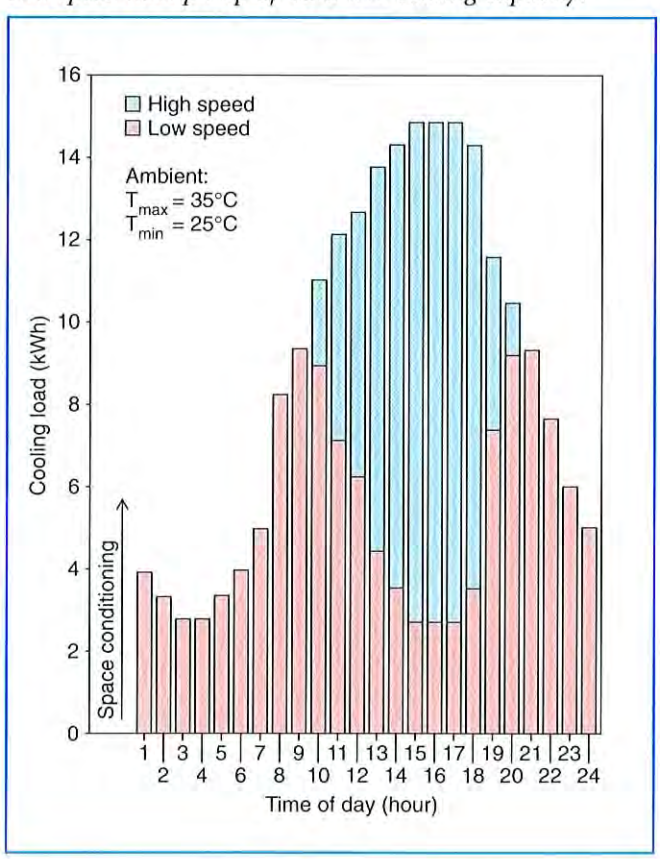
Although the system uses more kWh during ice making than a conventional system, due to the low suction temperature (no viable alternative to water has been found to increase the phase-change temperature), it seasonally saves significant primary source energy. By shifting normally on-peak kWhs to off-peak, the use of less efficient peak generation capacity is reduced, and the use of high-efficiency intermediate or base load generating units is increased.

Shifting and Levelling

Figure 3 depicts the cooling demand on the peak typical meteorological year (TMY) day of cooling in Kansas City which has a maximum temperature of 35°C and a night-time low of 25°C; this is the statistical worst day of the summer (from a utility's perspective). The operation of an ARI rated 16.7 kW cooling (4.7 ton cooling) two-speed compressor unit is indicated. As shown, periodic high-speed compressor operation is required between 10:00 and 21:00. This is also the peak demand time for many electric utilities.

Ice thermal storage can provide several different load shifting or levelling strategies for this scenario. Figure 4 (a) shows how the system could provide six hours of full load shift operation during the worst peak load hours. Only the 100 watt liquid refrigerant pump and

Figure 3: Meeting the cooling load with a conventional two-speed heat pump of 16.5 kW cooling capacity.



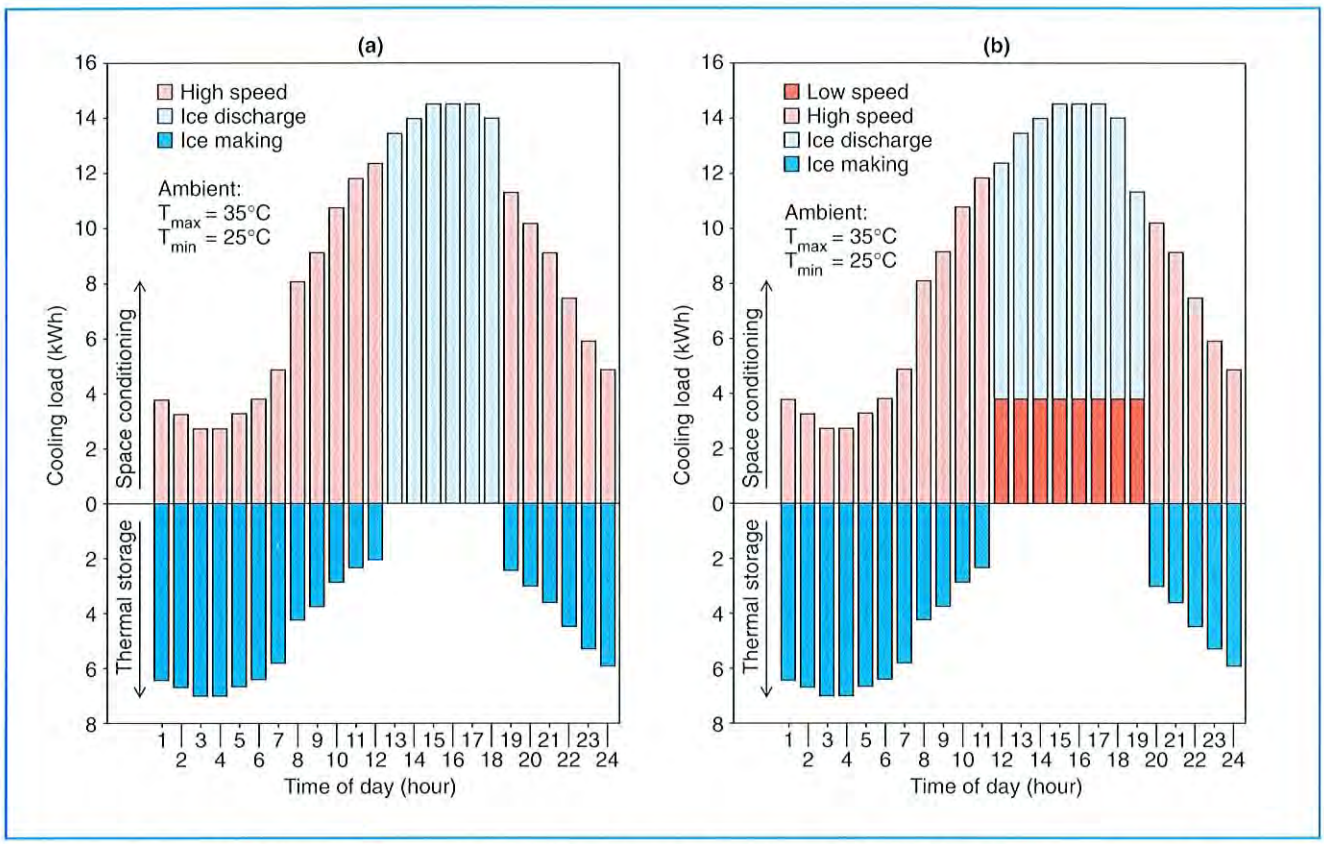


Figure 4: (a) Use of ice thermal storage to provide six hours of full load shift. (b) Combining ice thermal storage and speed selection to provide eight hours of load levelling at minimal energy consumption.

the indoor air handler are operating, resulting in about an 80% peak demand reduction. High-speed compressor operation is used during off-peak hours to meet both the space cooling and ice making demands. The low suction temperature of the ice-making operation causes the capacity of the system, even at high speed, to drop 50%. On milder days, when less time is required to recharge a smaller quantity of consumed ice, the system would use low-speed compressor operation whenever there was a demand for cooling after the ice was fully recharged.

Figure 4 (b) shows a scenario for an eight hour on-peak window. Since the off-peak period is now only 16 hours, the amount of ice that can be produced is not enough for full load shifting. Instead, the system provides load levelling during the on-peak period. However, the small amount of low-speed compressor operation during on-peak hours would still result in a peak demand reduction of about 70%. The strategy can be adapted to provide load levelling during longer peak-periods at the expense of increased energy consumption. Further flexibility can be provided through the use of zone control.

Cost-Effective DSM

Heat pump systems can provide summer peaking utilities with the best demand side management (DSM) capability for residential air conditioning and also provide heating kWh use to improve their system annual load factor. Two-speed heat pumps with ice thermal storage provide many opportunities for demand side management. And while they cost more to install than conventional systems, they can be cost-effective to a residential customer if the serving utility offers a revenue-neutral time-of-use (TOU) rate. Users benefit from improved comfort and operating economy, and the electric utility gets cost-effective demand side management results.

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Heat Pumps and Energy Management in the Netherlands

Pieter van der Ploeg and Toine van Wunnik, the Netherlands

When considering the options available to meet a community's demand for heat and power, it is important to look first at the available methods before comparing the available technologies. This article illustrates the significance of district heating and CHP (combined heat and power) in combination with electric heat pumps as an energy efficient heating system for residential heating.

* * *

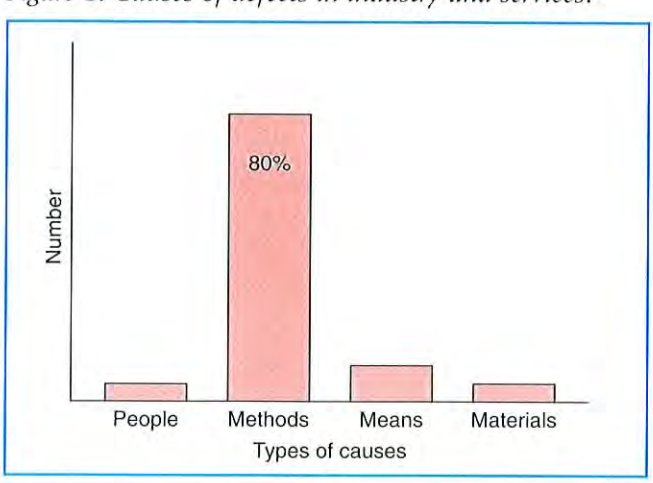
In supplying energy to villages, cities, districts and countries it is important to make the right choice in the methods of energy supply to be used. As energy supply infrastructures already exist, choices are of course limited. But it is also good to realize the importance of energy supply methods when, for instance, existing infrastructures are extended or replaced, or when new goals in energy savings or environmental improvements have to be met.

Quality

Quality is a factor that continues to concern many people in industry and services worldwide. The global experience in surveying quality in industry and services is illustrated in Figure 1, which shows types of defects and causes.

The message of the figure is clear. The causes of defects leading to a reduction in quality are only slightly affected by people, means or materials. Poor quality is mainly a consequence of choosing the wrong methods.

Figure 1: Causes of defects in industry and services.



What can be learned from this for energy supply? Do people in the field of energy supply working on energy saving, energy efficiency and environmental impacts, pay enough attention to the "method"?

To illustrate the importance of the "method" in energy supply, Table 1 compares two supply systems for space heating. System A is the actual energy supply system for a large area mainly based upon district heating, while system B is the system for a Dutch town, partly with district heating and mainly with individual gas-fired boilers. The technical standard in

Table 1: Energy consumed in space heating for systems with different CHP contributions and standards of energy efficiency.

	System A	System B
CHP contribution	80%	20%
Heat losses in distribution	25%	15%
Fuel consumption rate CHP	0.3 PJ/PJ	0.2 PJ/PJ
Heating boiler efficiency	75%	90%
Heat demand	100 PJ	100 PJ
District heating from CHP		
Contribution	80 PJ	20 PJ
Heat losses	27 PJ	4 PJ
+	------- +	--------
CHP heat generation	107 PJ	24 PJ
Fuel consumption rate	0.3 PJ	0.2 PJ
x	-------- x	--------
Fuel consumption	32 PJ	5 PJ
Heating Boilers		
Contribution	20 PJ	80 PJ
Efficiency	75%	90%
Fuel consumption	27 PJ	89 PJ
Total fuel consumption	59 PJ	93 PJ

Note:
"Fuel consumption rate" indicates the efficiency of heat extraction from CHP plants. This represents the additional fuel consumption needed to make up the reduced electricity output when extracting one unit of heat.

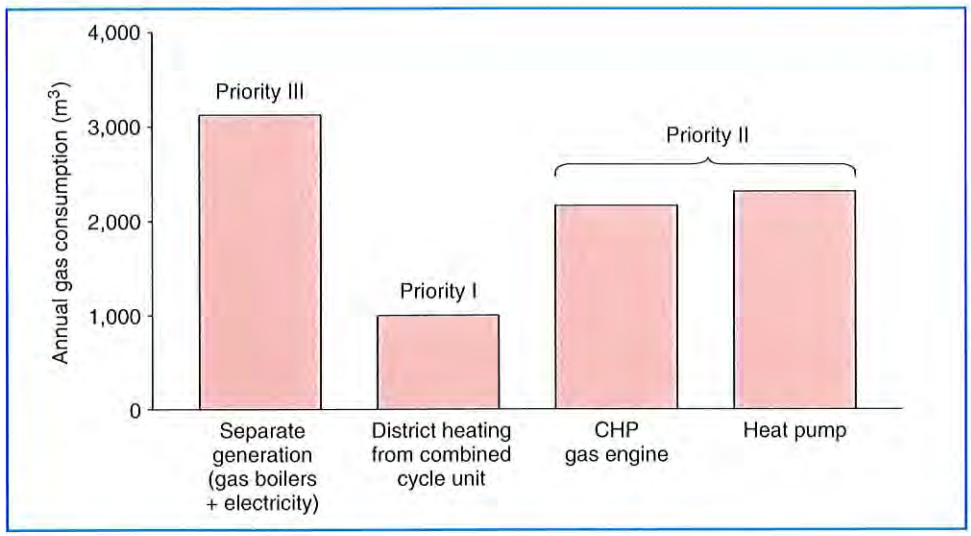


Figure 2: Annual gas consumption when using different energy methods to meet the heat and power needs of a house.

system B is far better than in system A. However, the primary energy consumption is smaller in system A because of the better "method" for energy supply.

The result is indeed striking. The system with the higher technical standard, system B, consumes more than 1.5 times the fuel needed by system A. This illustrates that the "method", CHP in this case, is far more important than the technical standard (means and materials) of the system.

Priorities

Having established the importance of the "method", priorities must be set for the different methods that can be used in energy supply.

For countries such as the Netherlands, four different natural gas-based methods of energy supply to dwellings can be considered:

1. Separate Generation

Small heating boilers installed on a consumer level (in homes), and combined cycle units for power generation installed on a national level. This method requires two distribution systems for gas and electricity.

2. District Heating

CHP combined-cycle power generation units installed on a regional level with two distribution systems for heat and electricity.

3. CHP Gas Engine

Small-scale CHP units (gas engines) on a local level and two distribution systems for gas and electricity. The distribution of heat is restricted to the inside of a building and is not a utility distribution system.

4. Heat Pump

Small-scale electric heat pumps installed on a consumer level using electricity from large combined-cycle units. This option requires only one distribution system for electricity (mono-supply) with the distribution of heat restricted to the inside of each house.

In Figure 2 a comparison of these methods is shown, when applied to houses in the Netherlands. The figure shows the annual gas consumption required to meet the needs of a typical house which demands 2500 m^3 of natural gas (or its equivalent) for space heating and 2500 kWh of electricity annually. As shown, the method of separate generation requires just over 2000 m^3 more gas than the method of district heating.

The priorities in the methods of energy supply are absolutely clear regarding the gas consumption. As shown in Table 2, the differences are not marginal at all - the differences are to be expressed in factors not in percentages.

Ideal Concept

The ratio of heat and power demand, however, sets a fundamental limit on the amount of heat which can be generated from CHP. Furthermore, it is not economically attractive to distribute heat from power generation over large distances, nor is it attractive to use district heating in residential areas with a low heating demand.

Taking a theoretical case, it is interesting to consider an energy supply concept where choices are made using the best priorities, and so as to allow the highest flexibility for practical implementation.

The ideal concept of energy supply appears to be the combination of district heating and heat pumps. It is reasonable to assume a share of 20% for district

Priority	Method	Fuel consump.
I	District heating	100%
II	CHP gas engine or heat pump	200%
III	Separate generation	300%

Table 2: Priorities in methods of energy supply.

heating of residential areas in the Netherlands. In this concept, all electricity generated by CHP/DH (district heating) plants is used to drive heat pumps. This would mean that only 5% of the heat demand in residential areas has to be served by gas-fired heating boilers. Table 3 compares the fuel consumed under this concept with that consumed without heat pumps. Clearly, the combination of CHP/DH and heat pumps results in the largest energy savings. Other advantages are:

- biggest possible market share;
- more flexibility and lower investment costs for distribution systems;
- improving the possibilities of CHP.

Impact

To get a better feeling of the impact of the large-scale introduction of electric heat pumps on power generation, some indicative figures are given below for the Dutch situation.

In 20 years it could be possible to serve about 1.2 million dwellings with heat pumps, which equals nearly 20% of the total housing stock. Using an advanced integrated heat pump boiler, which is currently being tested, and using electric cooking as necessary in a mono supply situation, the extra annual electricity consumption will be about 3 TWh, which is 3 to 4% of the national power generation. To serve that extra annual demand it is necessary to build in the order of magnitude of 500 MW of new power generating capacity thus increasing the opportunities for CHP.

Because of heat storage in the boiler, the heat pump can be remotely switched off by the utility to enable peak demand control without adverse effect to the user. This provides an interruptible capacity of around 600 MW that can be switched off at once - about 6% of the peak demand of the national power system. For the assumed situation the impact would be:

- ~6% more interruptible capacity;
- ~4% more demand;
- ~5% more installed capacity (more CHP opportunities).

The Importance of Method

All parties involved in the energy world, on both the demand and the supply side, should realize the importance of the method, when planning and selecting energy systems. For even the best energy technology can lead to low overall energy efficiency if not applied in the right manner. Government organizations, local authorities, utilities and organizations in the buildings and industrial sectors can together realize tremendous savings in energy and subsequently huge reductions in environmental impact. And in search of the best energy supply option, it must be recognized that the method "heat pumps" can play a remarkably large role, especially when combined with the method "CHP/DH".

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Note: N.V. Sep is the Dutch Electricity Generating Board. KEMA N.V., Testing, Research and Development, Engineering Consultants.

Table 3: Energy consumption for residential space heating with CHP/DH only and CHP/DH + heat pump.

	CHP/DH	CHP/DH + heat pump
CHP efficiency - heat	40%	40%
CHP efficiency - power	45%	45%
Standard efficiency - power	50%	50%
DH heat transmission losses	10%	10%
Boiler efficiency	90%	90%
COP of heat pump	-	3
Heat demand	100 PJ	100 PJ
CHP/DH contribution	20 PJ	20 PJ
CHP heat generation	22 PJ	22 PJ
CHP power generation	25 PJ	25 PJ
Boiler and/or HP contribution	80 PJ	80 PJ
HP heat generation	-	75 PJ
Boiler contribution	80 PJ	5 PJ
Fuel Consumption		
CHP	55 PJ	55 PJ
Standard fuel for power	50 PJ	-
Additional fuel for heat	5 PJ	-
Boiler fuel consumption	89 PJ	6 PJ +
Total fuel consumption	94 PJ	61 PJ
Consumption when all heat is provided by gas boilers	111 PJ	111 PJ
Overall savings (compared to all-gas boiler system)	15%	45%

A Power Utility's Strategy for Heat Pump Promotion

Alfred Bürkler, Switzerland

The Swiss utility, St Gallen-Appenzell Power Company Ltd (SAK) sees the expansion of the heat pump market as a key element in demand side management. But to do this, a number of barriers, affecting building owners, equipment designers and installers, must be overcome.

SAK's strategy for the promotion of heat pumps is based on information dissemination, a services performance package and heat pump tariffs. With these measures, SAK aims to help meet the targets for heat pump use set in 1990 by the Swiss Confederation under its Energy 2000 programme.

* * *

Photo 1: The first heat pump installation in line with the new SAK marketing concept.



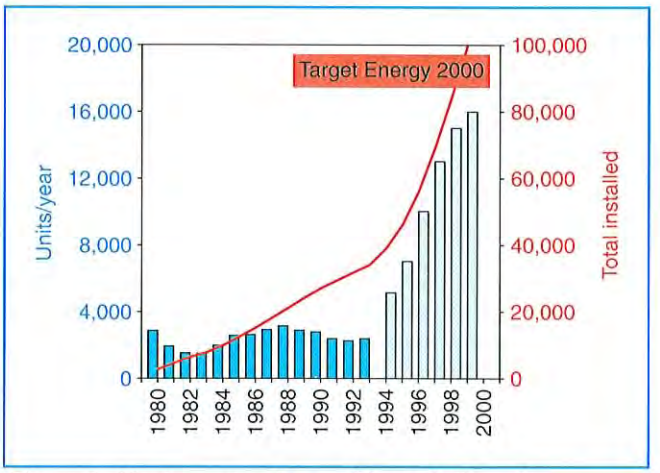


Figure 1: Heat pump sales and installations in Switzerland.

Without doubt, the heat pump offers one of the most attractive options for the use of renewable energy. It is for this reason that it has a special place in the Energy 2000 programme. This promotion programme was launched in 1990 by the Swiss Federal Council with the target that by the year 2000, in addition to the amount produced in 1990, a further 3% of fossil-derived heat would be replaced by renewable energy. In accordance with the objectives of the Federal Bureau of Energy, 40% of this replacement of fossil energy should come through the use of environmental heat by heat pumps. If this target is to be achieved then a total of 100,000 heat pumps need to be installed throughout Switzerland by the year 2000.

Reversing the Trend

According to figures from the Swiss Electrical Power Association, the number of heat pumps in Switzerland more than doubled between 1986 and 1992, increasing from 13,100 to 27,300 units. However, the market survey of the Heat Pump Working Group shows that the trend in heat pump installation is regressing (see Figure 1).

In order to reach the given target, considerable efforts are required. And measures to promote the installation of heat pumps by the Swiss Confederation, the Heat Pump Working Group and power companies must be coordinated and implemented energetically. SAK has developed a strategy to promote the use of heat pumps in its region. In formulating its strategy, SAK

Survey of Designers and Installers

What are your greatest objections to heat pumps?

- Too many suppliers without adequate knowledge
- The quality of the consultation is often poor
- Poor service from some individual suppliers
- High investment costs
- Low reliability and high service costs
- Low oil and gas prices; high electricity costs
- Inadequate cost-effectiveness
- Worse operating effectiveness at low external temperatures (air-water-heat pump)
- Ground probes require deep holes
- Seasonal performance factor is sometimes less than 3.0
- Problems with working fluid losses
- Uncertainty of the building owners and house owners
- Declining support by the authorities for electric heat pumps
- Bureaucratic hurdles such as permits

Survey by the Association of Swiss Heating and Ventilating Companies (VSHL), published in July 1993.

considered the views of the building owners, and the equipment designers and installers.

The Owner's View

The building owner is influenced by a number of different criteria when choosing a heating system. For most owners the main considerations are the investment and operating costs, the reliability, the proven nature of the heating system, and the safety aspects of the fuel. Some of the problems are itemized below:

Prejudice

Although nearly 30,000 pump systems are already in operation, the heat pump still suffers from prejudice springing from excessive expectations of energy efficiency and poorly functioning installations.

Coordination

The successful implementation of heat pumps depends on consultation, planning, installation and control in order to satisfy expectations. The coordination of the work of various specialists can overtax the user.

Costs

The investment costs are higher compared to a conventional oil or gas heating installation. Furthermore, the operating costs of the heat pump are also often disadvantageous.

Many building owners recognize the major advantages of the heat pump: use of renewable energy, no space needed for tanks or chimneys, no danger of explosion, less or no maintenance. However, all too often they decide in favour of a conventional heating system that is cheaper in the short term, despite paying lip service to the need for active protection of the environment.

Designers and Installers

It is not only building owners that face problems connected with the installation of heat pumps: uncertainty and doubt are also evident to a similar extent among designers and installers. The results of a recent survey which identified the main problems of designers and installers concerning the installation of heat pumps are shown in the box (left). These concerns, however, are in contrast to the interest and overall positive attitude of the installation industry.

SAK's Promotion Strategy

The promotion strategy of SAK for heat pumps rests on three pillars. The first is to inform building owners and those responsible for the design of heating systems (architects, engineers and installers) of the advantages of heat pumps. Secondly, an extensive service package is offered to reduce the risk to the building owner when the wrong decision is made. Thirdly, measures are taken to improve the cost-effectiveness of heat pumps.

SAK's strategy targets the promotion of the heat pump for the heating of new single-family houses and

St. Gallen-Appenzell Power Company Ltd (SAK)

Region

Cantons of St. Gallen, Appenzell Ausserhoden and Appenzell Innerrhoden (400,000 inhabitants)

Ownership

Completely owned by the above cantons

Electricity Source

96% of the total consumption comes from the North-East Switzerland Power Company Ltd. (NOK), in which SAK has a 12.5% interest, 2% from its own installations and 2% from third parties.

Annual Business (October 1993 September 1993)

Supplied 2.34 TWh electricity at a peak load of 415 MW to 98 local power companies, 186 large industrial users and 53,000 small customers.

small multi-family buildings. Because of the high annual workload, the first heat pump to be considered for installation should be the monovalent ground-water heat pump with ground probe. This type of heat pump is very suitable for our market area which is mostly more than 600 m above sea level. Another application area is the replacement of conventional heating installations due to the increasingly strict regulations on air pollution.

Information

Participation in regional and local fairs and exhibitions has proven to be a very effective and efficient type of information dissemination. Organized together with a local heat pump supplier and the Canton Office for the Environment, such events have attracted an extraordinarily high interest in heat pump technology from the public.

In order to speak directly with architects, engineers and installers, a specialist's meeting on heat pumps was organized within the framework of the large East Switzerland fairs. This meeting, with representatives from the Confederation, universities, suppliers and the electric power industry, was attended by more than 200 participants. SAK's promotion measures were presented at this meeting and received a positive reaction.

SAK's Services Package

SAK takes total responsibility for the heat pump system offered to a customer by providing an inclusive services package including:

- the determination of the heating requirements with the building owner;
- the design of an optimum heat pump system;
- system planning and the production of the necessary drawings;
- provision of all necessary permits;
- installation and commissioning;
- user training for the servicing of the installation;
- guaranteed round-the-clock service support;
- evaluation of the energy consumption during the first two years of operation.

SAK works with consulting engineers and heat pump suppliers, with installation generally carried out by the trade. The service package works in cooperation with the local trade and not in competition. Most importantly, by taking over complete responsibility for the system, SAK reduces the risk to the building owner of making a bad investment.

Table 2: Normal tariffs.

Daytime tariff (US$ cents/kWH)	16.13
Night-time tariff (US$ cents/KWh)	7.37
Monthly standing charge (US$)	8.30 to 18.26

	Summer	Winter
Daytime tariff (US$ cents/kWh)	8.43	11.68
Night-time tariff (US$ cents/kWh)	4.65	7.37
Power demand tariff per kW per month (US$)	6.31	9.96

Table 1: Switchable equipment tariffs.

Investment

As a form of encouragement, SAK will subsidize investment in a heat pump with an advance of SFR 270 per kW of thermal power (SFR = Swiss Franks, SFR 270 = US$ 180). This subsidy is in addition to a similar amount offered by the Swiss Confederation under its "Energy 2000" programme.

The SAK subsidy is limited to SFR 6750 (US$ 4480) and applies to both new and renovated buildings, but only for low voltage customers in the area directly supplied by SAK. SAK has allocated SFR 100,000 (US$ 66,000) for this limited promotion.

Operating Costs

The operating costs of an electric heat pump depend to a large extent on the tariff applied by the electric power company. One way to reduce the tariff is to design the heat pump system so that it can be switched off remotely during periods of peak load. By switching off equipment during peak times, power companies are able to lower the costs of energy production, and this can be reflected in lower tariffs.

Table 3: Annual energy costs for a single-family house.

Energy costs (US$)	Heating	General	Hot water	Assoc. costs	Total
Gas heating with hot water	1042	789	116	332	2279
Oil heating with hot water	516	789	74	398	1777
Electric storage heating with electric boiler	2350	402	181	66	2999
Heat pump (water/water) with heat pump boiler	896	402	90	133	1521

Energy Requirements: 21,000 kWh thermal heating, 4000 kWh general electricity and 3000 kWh thermal hot water.

SAK offers a special tariff for switchable equipment on condition that the equipment can be switched off twice a day for a maximum of two hours, with at least one hour in between periods of non-operation.

As shown in Table 1, the switchable equipment tariff has both a power demand and a consumption component. The power demand is based on the highest power demand over the season, and is charged differently according to the summer and winter seasons. The consumption tariff varies according to the season and the time of day.

For heat pumps rated at less than 10 kW electric power, the power demand is not measured but set at 3 kW. For an average single-family house, therefore, the electricity rating can be measured as before, with a normal house meter. Other measurement equipment is unnecessary.

If the rated power of the heat pump exceeds 10 kW, a tariff meter with power measurement is installed to monitor the actual power. The power demand charge then corresponds to the highest actual value reduced by a free power allowance of 7 kW. Table 2 indicates the normal tariffs for comparison. Table 3 shows the effect of these tariffs on the energy costs of a single-family home using various heating and hot water equipment.

Keeping it Simple

In order to widen the use of heat pumps, the planning and installation must be made as simple for the user as that of an oil or gas heating system. Furthermore, operating costs must be competitive.

By providing consultancy and information dissemination, the benefits of heat pumps can be made known more widely and directly. By assuming total responsibility for consultancy, planning, installation, commissioning, servicing and follow-up monitoring, the utility reduces the risks for the building owner and guarantees trouble-free heating operation.

Photo 2: Specialist meetings for designers and architects are a means of informing an important group of purchasers/decision-makers.



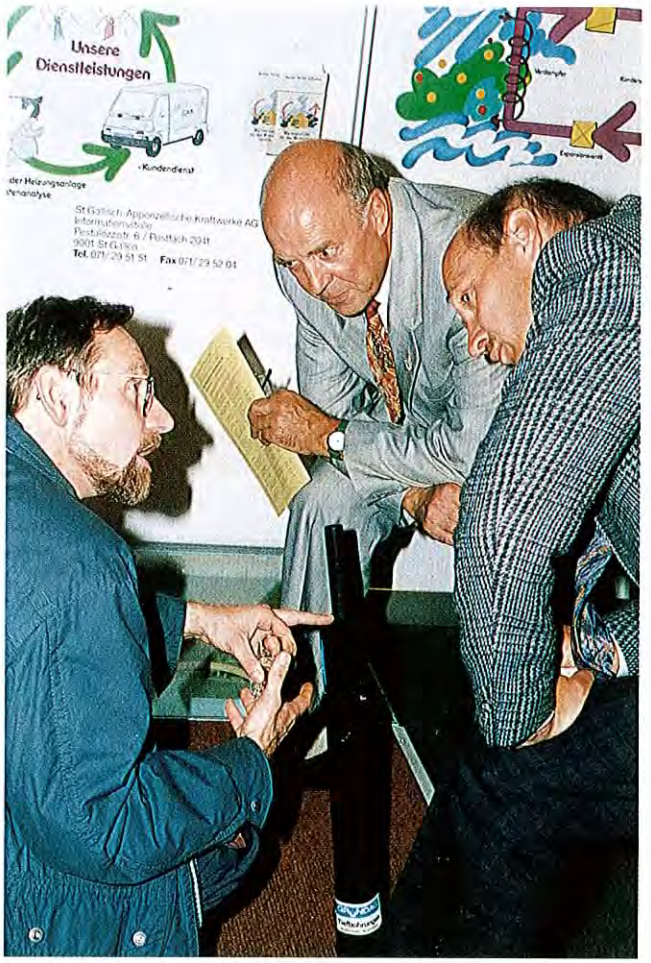


Photo 3: Presence at exhibitions and dissemination of information to potential customers is an important element in the promotion of heat pumps.

Investment subsidies serve to stimulate action and can favourably influence the installation of a heat pump. And with special tariffs, the operating costs of heat pumps are competitive with those of conventional heating systems.

The heat pump promotion measures of SAK should reinforce the measures undertaken by the Swiss Confederation in the Energy 2000 programme and the Swiss Heat Pump Working Group. With the achievement of the target of 100,000 heat pumps by the year 2000, 200,000 tonnes of fossil fuels could be saved per year. The measures presented here by SAK will contribute towards the achievement of this target.

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Power Demand Reduction with Integrated Heat Pumps

Wayne R. Reedy, USA

Electric utilities would like to reduce the power demand characteristics of residential equipment, such as for heating, cooling and hot water supply, in order to lower the power requirements needed to meet a significant coincidental demand. While the energy saving aspects of electric heat pumps have been widely discussed and are well known, the power demand aspects are just beginning to be considered, and are not at all well known. This article shows how heat pumps can have a wide range of power demand characteristics, and that the integration of hot water heating with the space heating heat pump offers several options to reduce and control the total electrical power demand.

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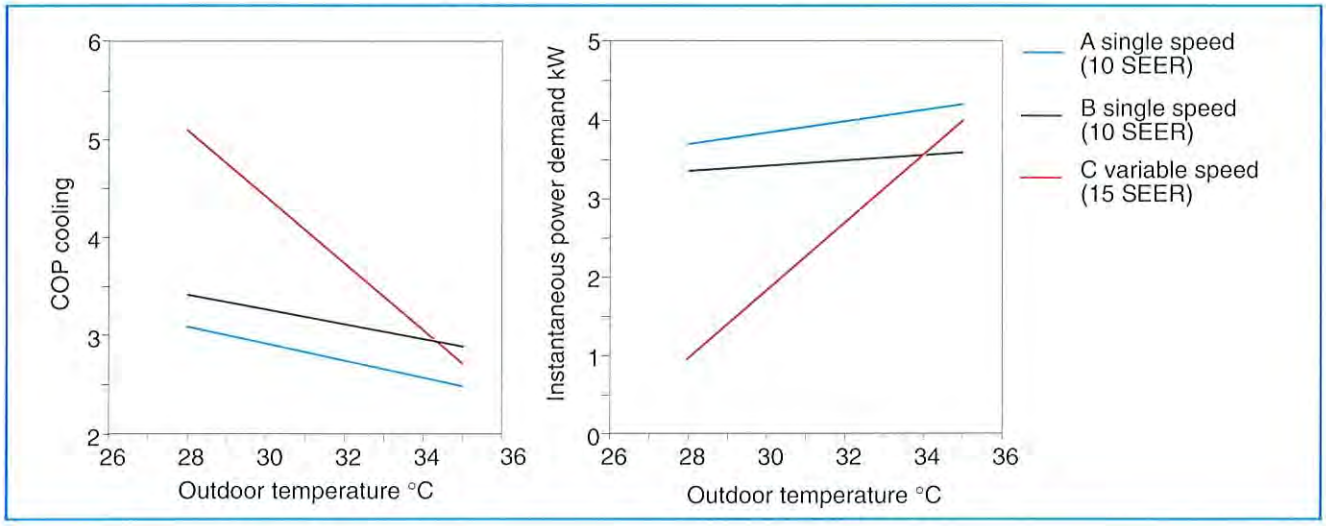
The power demand of a residential electric heat pump is a function of several variables, including capacity, design technology and operating condition. Some of these relationships are straightforward, such as with capacity, where the power demand can be expected to change in direct proportion to capacity if all other variables are held constant. Power demand would also be expected to decrease with increasing efficiency. This is not the case however, if the efficiency measure is a seasonal average value. In addition, the total power demand for a household consists of the heat pump plus other appliances such as the electric water heater. The water heater can represent as large or larger demand than the heat pump. When operating simultaneously, the heat pump and water heater represent a very large demand, but if integrated and controlled, the result is a smoothed and reduced demand.

Cooling Performance

Given the capacity and steady-state COP (coefficient of performance) for the cooling performance of a heat pump, the power demand for that operating condition can be easily calculated by dividing the capacity by the COP. When the system performance is rated in terms of the Seasonal Energy Efficiency Ratio (SEER), as is presently the case in the United States, the COP and/or power demand determination is not straight forward. Table 1 gives a brief outline of the definition of United States performance ratings.

Figure 1 presents curves of COP and power demand as a function of outdoor temperature for three different air-to-air heat pumps, all rated at 10.5 kW (36,000 Btu/hr) at 35°C (95°F). Two of the units are also rated as 10 SEER (2.9 in dimensionless units) in

Figure 1: COP and power demand versus outdoor temperature for three different heat pumps in the cooling mode. US ratings for cooling performance are 10 SEER (2.9 in dimensionless units) for heat pumps A and B, and 15 SEER (4.4 in dimensionless units) for heat pump C.



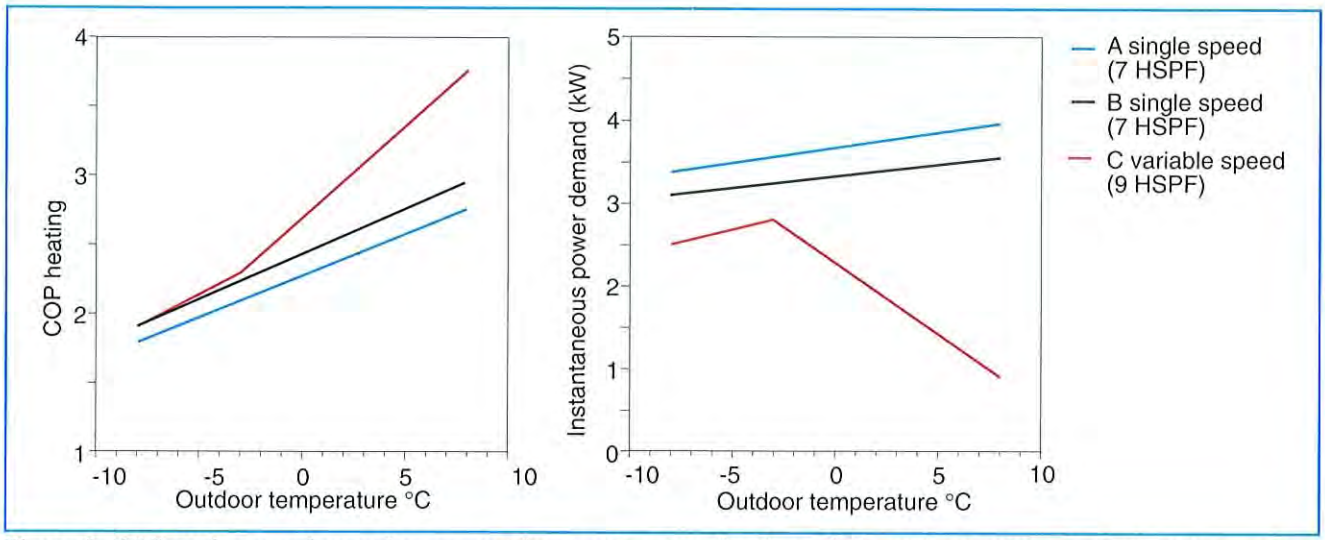


Figure 2: COP and power demand versus outdoor temperature for three different heat pumps in the heating mode. US ratings for heating performance are 7 HSPF (2.1 in dimensionless units) for heat pumps A and B, and 9 HSPF (2.6 in dimensionless units) for heat pump C.

the US and the third as 15 SEER (4.4 in dimensionless units). The two 10 SEER units are rated for seasonal efficiency based on their steady-state efficiency and cyclic performance at 28°C (82°F).

Because of differences in their cyclic performance, the two 10 SEER example units have a 16% difference in steady-state efficiency at 35°C (95°F) or 0.6 kW difference in power demand. The 15 SEER unit is variable speed and thus its rating is based on a combination of its 35°C (95°F) and 28°C (82°F) performance.

Table 1: United States performance ratings.

SEER

The US performance rating SEER (Seasonal Energy Efficiency Ratio) for a single-speed heat pump, or air-conditioner is defined as:

$$SEER = EER_b (1 - 0.5(C_d))$$

where EER_b is the steady-state energy efficiency ratio, and C_d is a measure of the cyclic performance. C_d relates to the difference in capacity between six minutes of operation at steady-state, and six minutes of operation from start-up. Both these measurements are made at 28°C (82°F) outdoor temperature

For variable-speed equipment, SEER is determined by a combination of performances at low, intermediate and high speeds, at 19°C (67°F), 28°C (82°F) and 35°C (95°F) outdoor temperatures.

HSPF

HSPF is determined by a combination of measurements which take account of the building load at different temperatures and the input energy to the heat pump and the supplementary resistance heating. In addition, the calculation includes measurements of the steady-state, frosting/defrosting and cyclic performance.

This unit would follow a typical house cooling load, running at low speed and low capacity at warm outdoor temperatures and increasing to high speed and high capacity at hot outdoor temperatures. As the unit changes speed and capacity, its efficiency can change by 85% and 3.1 kW of power demand. Note that while the 15 SEER unit is rated 50% higher in US seasonal efficiency, its power demand on a 35°C (95°F) day can actually be higher than that of a 10 SEER single-speed unit.

Heating Performance

Seasonal heating efficiency ratings also tend to mask the actual power demand of the heat pump in its heating mode. Figure 2 presents the curves for heating COP and power demand as a function of outdoor temperature for the same three example heat pumps used above. The 10 SEER units would carry ratings of 7 HSPF (heating seasonal performance factor: 2.1 in dimensionless units) and the 15 SEER unit carries a 9 HSPF (2.6 in dimensionless units).

As with the cooling performance, it can be seen from Figure 2 that there is a wide spread in steady-state performance between the two 7 HSPF units due to cyclic performance and design differences. The efficiency and power demand of the 9 HSPF unit varies over a wide range, and at certain conditions it is close to that of the 7 HSPF units. The unit will run at low speed and low capacity to heat the house when the outdoor temperature is cool, and will increase its speed and capacity as the outdoor temperature gets colder.

For a complete picture, one would also have to account for any supplemental heating used at very cold outdoor temperatures, but that analysis is beyond the scope of this article.



The "Powerniser" integrated heat pump, a joint development of Nordyne and EPRI (The Electric Power Research Institute, USA).

Integrated Performance

The next consideration is the addition of an electric water heater, which, if it cycles coincidentally with the heat pump, would more than double the power demand, assuming a heat pump with a heating and cooling capacity of 10.5 kW (36,000 Btu/hr) and a 4.5 kW water heater element, typical of US units. Figure 3 (a) presents the curve of the combined heat pump and water heater power demand, showing instantaneous demand for a single system. The average power demand of a water heater depends on the homeowner's total hot water usage and the use pattern. US electric utilities generally consider an individual water heater element to represent about 0.6 kW on a diversified basis.

Regardless of the assumed kW demand of a water heater element, if the water heating function is integrated with the space conditioning heat pump, then during the cooling season the heat pump can provide both space cooling and water heating simultaneously with a total power demand equal to that of the heat pump, as shown in Figure 3 (b). By providing the two functions simultaneously, the electric utility benefits from a reduction in peak power demand and the homeowner benefits with significant energy savings. This is possible because the water heating is a waste or by-product of the cooling function.

When the integrated heat pump is in the space heating mode, it will again provide both space and water heating with a total power demand equal to that of the heat pump, but will run longer as shown in Figure 3 (c) to meet the combined capacity requirement of space and water heating. The photograph shows an example of an integrated heat pump.

Significant Opportunity

Heat pumps can make energy savings and reduce power demand if the particular unit technology is understood and properly selected. While "SEER" and "HSPF" may be useful in comparing relative energy savings over a season, it can be misleading to electric utilities in predicting power demand. There is a very significant opportunity for both energy savings, and power demand reduction through the use of an integrated heat pump system which provides both space conditioning and water heating.

References:
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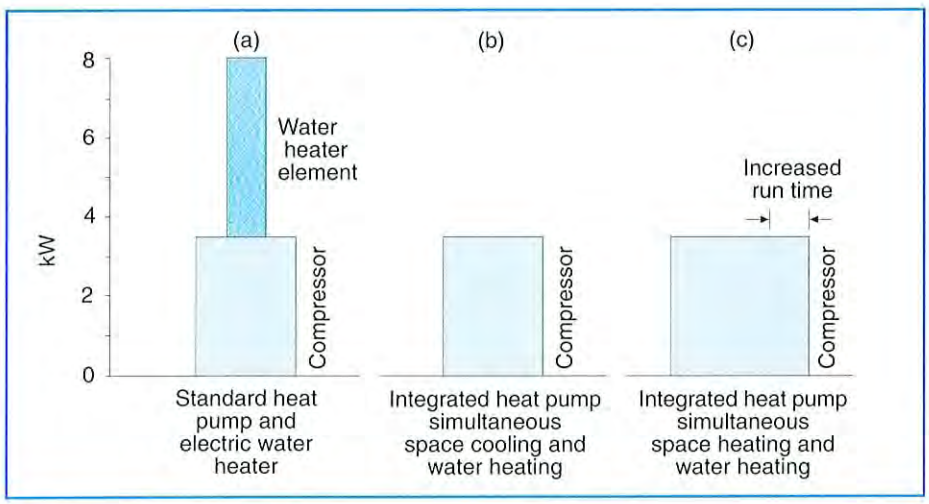


Figure 3: Power demand profiles for combined space conditioning and water heating.

Bibliography

Measurements of Diffusion Absorption Heat Pumps
Federal Office of Energy, Switzerland; January 1994; 95 pp; German.

The report summarizes a study of a diffusion absorption heat pump (DAHP) that was designed for heating houses using ambient air as a heat source. The Swiss company, DAWP Creatherm AG, began developing the heat pump in 1985. In order to verify laboratory data, two 3.5 kW DAHP units, driven by natural gas, were installed in houses in the Zürich region for heating purposes. One DAHP reference unit was tested at the Swiss Federal Institute of Technology in Zürich. The field tests, lasting more than one year, showed very positive results. As this heat pump is noiseless and maintenance free it can be installed in the living area of a house.

Heat Pumps in Cold Climates
Proceedings of the Second International Technical Conference, Caneta Research Inc., 6981 Millcreek Drive, Unit 28, Mississauga, Ontario, Canada, L5N 6B8; Tel: +1-905-542 2890; Fax: +1-905-542 3160; 1994; 560 pp; English; US$ 50 plus US$ 5 for postage.

The Second International Technical Conference was held on 16-17 August 1993 in Moncton, New Brunswick, Canada; A total of 44 papers were presented at Moncton on a variety of topics including, environmental benefits of heat pumps, demand side management programmes, alternative refrigerants, compressor developments, ground-source heat pumps, integrated-function heat pump systems, control developments and advanced cycles.

After R-22, What?
Published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 1791 Tullie Circle NE, Atlanta, Georgia 30329-2305, USA; Tel: +1-404-636 8400; Fax: +1-404-321 5478; 1994; 94 pp; English; US$ 33.

This book contains nine papers reviewing the latest research on alternative refrigerants to replace HCFC-22. Split-system air conditioners, unitary equipment and air-to-air heat pumps are covered along with residential systems and other air-conditioning applications.

The Behaviour of HFC-134a, HFC-152a and HCFC-22 in Evaporators
Published by the IEA Heat Pump Programme; available from the IEA Heat Pump Centre (address on back cover); July 1994; English.

This report is the result of the IEA Heat Pump Programme's activity within Annex 17: "Experiences with New Refrigerants in Evaporators". Its objective is to increase the knowledge of heat transfer coefficients and pressure drops on the working-fluid side in the evaporator part of a heat pump.

Trends of Heat Pumps in Japan
Published by Heat Pump Technology Center of Japan, (address on back cover); 1993; 128 pp; English.

This extremely useful book informs readers in detail of the technology and products of Japanese heat pumps. Translated into English, this book is one chapter of the book "Heat Pumps in Japan - third edition", which was published in Japanese by the Heat Pump Technology Center of Japan. The Center has been translating and publishing chapters of this valuable book one by one since it was first published in March 1992.

Demand-Side Management: Opportunities and Perspectives in the Asia-Pacific Region
Available from IEA/OECD Publications Service, 2 rue André Pascal, 75775 Paris Cedex 16, France; Fax: +33-1-4524 8171; ISBN: 92-64-14060-3; 1993; pp. 303; English; FRF 250.

Proceedings of the International Conference on Demand-Side Management held on 4-5 November 1993 in Seoul, the Republic of Korea.

Demand side management is gaining greater attention among developing countries in the Asia-Pacific region as a tool for coping with the challenges of the region's rapid growth in energy demand. The conference proceedings include design and implementation of demand side management programmes; barriers to increased efficiency; potential for adapting experiences of industrialized countries to the region's developing countries.

Conferences

*Call for Papers

International Refrigeration Conference
12th International Compressor Engineering Conference and 5th International Refrigeration Conference
19-22 July 1994 / Purdue University Indiana, USA.
Short courses are arranged for 17-19 July 1994.
Contact: Phylis Hurst, Conference Secretary, Purdue University, 1077 Ray W. Herrick Laboratories, West Lafayette, IN 47907-1077, USA. Tel: +1-317-494-0117.

Calorstock '94
6th International Conference on Thermal Energy Storage
22-25 August 1994 / Otaniemi, Espoo, Finland.
Contact: Mr Markku Kangas, Helsinki University of Technology, Dept. of Technical Physics, Otakaari 3, 02150 Espoo, Finland. Tel: +358-0-451-3212.

CFCs - The Day After
(IIR Commissions B1, B2, E1 and E2)
21-23 September 1994 / Padua, Italy.
Contact: Organizing Committee, IIR-AICARR Conference, c/o AICARR - viale Monte Grappa, 2, I-20124 Milano MI, Italy.
Fax: +39-2-2900-0004.

49th National Congress of the Italian Thermotechnical Association
26-30 September 1994 / Perugia, Italy.
Contact (for heat pump topics): Eng. Carlo Nazareno Grimaldi, Instituto di Energetica, Str. S. Lucia-Canetola, 06125 Perugia, Italy. Tel: +39-75-5852735

New Techniques in Combined Heat and Power Generation
26-27 September 1994 / Prague, Czech Republic.
The conference languages are Czech, German and English. Simultaneous translation available.
Contact: VDI-Gesellschaft Energietechnik (Assoc. of German Engineers - Society for Energy Technology), Postfach 10 11 39, 40002 Düsseldorf, Germany. Tel: +49+211-6214-219.

15th AIVC Conference - The Role of Ventilation
27-30 September 1994 / Buxton, UK.
Contact: Mrs Rhona Vickers, IEA Air Infiltration and Ventilation Centre, University of Warwick Science Park, Sovereign Court, Sir William Lyons Road, Coventry CV4 7EZ, UK. Tel: +44-203-692050; Fax: +44-203-416306.

Heat Transfer Enhancement by Additives
10-11 October 1994 / Munich, Germany.
A discussion meeting concerning sorption heat pumps.
Contact: Dr Felix Ziegler, Institute E19 - Physics Dept., Technische Universität München, James Franck Strasse 1, D-85748 Garching, Germany. Tel: +49-89-3209-2535.

Ground-Coupled Heat Pumps Symposium
17-19 October 1994 / Giessen, Germany.
The symposium language is German.
Contact: Dr Burkhard Sanner, Institute for Applied Geosciences, University of Giessen, D-6300 Giessen Germany.
Tel: +49-641-702-8248; Fax: +49-641-702-4711.

Applications of Adsorption for Energy Transport and Storage
13-18 November 1994 / San Francisco, USA.
Contact: Dr Orhan Talu, Dept. of Chemical Engineering, Cleveland State University, Cleveland, Ohio 44115, USA.
Tel: +1-216-687-3539; Fax: +1-216-687-9220.

Design and Application of Ground-Coupled Heat Pump Systems
19-24 March 1995 / Hawaii, USA.
Held in conjunction with the 1995 ASME/JSME JSES International Solar Energy Conference.
Contact: Prof. Dennis L. O'Neal (Session Co-chair), Mechanical Engineering Dept., Texas A&M University, College Station, Texas 77843-31123, USA.
Tel: +1-409-845-8039; Fax: +1-409-862-2762.

**19th International Congress of Refrigeration - For a Better Quality of Life*
20-25 August 1995 / The Hague (The Netherlands)
Organized under the auspices of the International Institute of Refrigeration (IIR).
Deadline for abstracts: 1 September 1994.
Contact: Van Namen & Westerlaken Congress Organisation Services. Tel: +31-80-234471; Fax: +31-80-601159

**International Symposium on Two-Phase Flow Modelling and Experimentation*
9-11 October 1995 / Rome (Italy)
Organized by the Assembly of World Conferences on Experimental Heat Transfer, Fluid Mechanics and Thermodynamics.
Deadline for abstracts: 5 September 1994
Contact the Symposium Scientific Secretary: Dr Tommaso Setaro, ENEA Casaccia, Energy Department, Via Anguillarese 301, I-00060 SM Galeria, Rome, Italy.
Tel: +39-6-3048-6466; Fax: +39-6-3048-3026.

**1995 International Gas Research Conference IGRC95*
6-9 November 1995 / Cannes, France.
Deadline for abstracts: 31 July 1994.
Contact: Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, Illinois 60631, USA.
Tel: +1-312-399-8300; Fax: +1-312-399-8170.

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