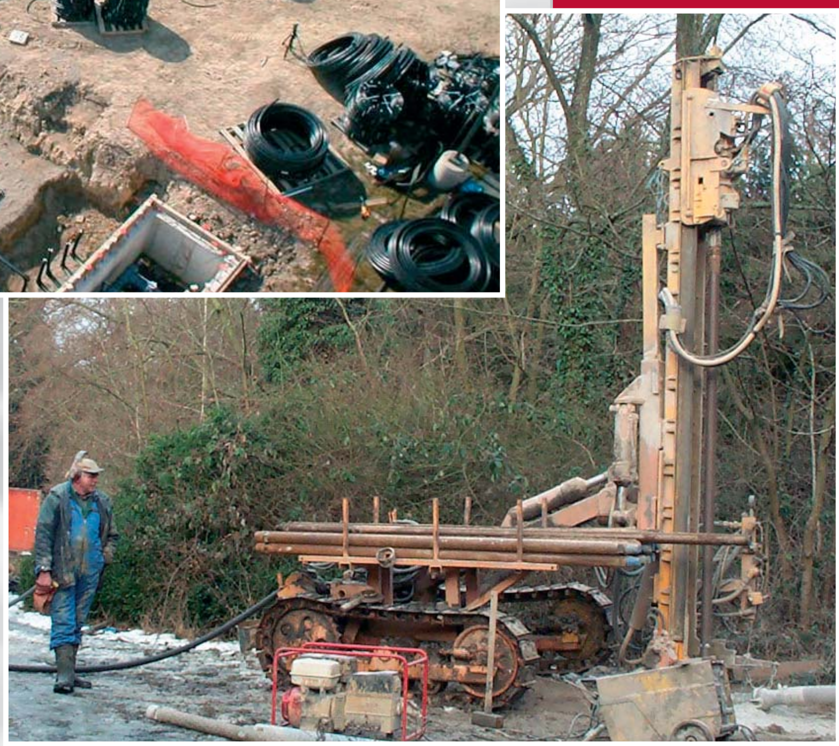
IEA Heat Pump CENTRE
NEWSLETTER
Volume 23
No. 4/2005

The advance of geothermal heat pumps – worldwide

Ground-source heat pump activity and its future

Very efficient school with ground source heat pump system in a cold climate

Ground-source heat pump systems



IEA OECD heat pump centre

IEA **Heat Pump** CENTRE
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In this issue

Ground-source heat pump systems

Ground-source heat pump systems are gaining increasing interest all over the world. In Sweden, this type of heat pump is the dominating type used in single-family houses, but interest is now also increasing in central Europe, in Germany, Austria and Switzerland. Activities are also ongoing in Japan, the US and in Europe for using ground-source heat pump systems in large commercial buildings, where they can provide both heating and cooling. This issue of the Newsletter features articles dealing with both small and large systems in Europe, Japan and North America.

Finally, the Heat Pump Centre staff would like to wish all HPC Newsletter readers a Merry Christmas and a Happy New Year.

Heat pump news

Features

Topical article

COLOPHON

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Foreword

Ground-source heat pump systems will play a major role in reducing demands on the environment

James Bose
Director
International Ground Source Heat Pump Association

A person only needed to attend the 8th IEA Heat Pump Conference in Las Vegas (2005) to come away with the feeling that the international market for ground source heat pumps (GSHP) will take its rightful place among those technologies that will play a major role in reducing demands on our environment. Increasing energy costs, increasing worldwide demand for energy, pressures to limit global warming and an increasing acceptance of heat pumps are but a few of the reasons for its successful future.

Substantial energy savings in both residential and commercial are proven. Current gas and electric pricing in the US has resulted in payback periods of less than 5 years. With new residential construction, the mortgage costs are less than savings resulting in an instant positive cash flow to the owner.

The industry or technology does not need a technological breakthrough or further reductions in first cost to be economically viable. This is not to say that further and continued research is not needed in heat pumps and design methods and procedures for large thermal loads and long-term imbalanced heating and cooling loads. Community-type systems that integrate buildings with time-varying loads of excess energy to buildings that need energy supplement need to be implemented. Hybrid system development has resulted in a number of installations that would not have been constructed if it were not for the type of application to control initial costs of the ground heat exchanger. Seasonal designs that use hybrid methods to refresh and reduce long-term effects will become the norm in large commercial systems.

New creative thinking in the applications of ground source technology to the existing residential market must be initiated. GSHPs in an assist mode to an existing HVAC system should be evaluated. A ground source mini-split heat pump system (through-the-wall) could be designed to provide base loading without the normal added expense of reworking the existing thermal energy distribution system or the residential electric service sizing. The existing HVAC system would become the peaking or back-up unit.

The rate of improvement of GSHP technology in the last ten years has been phenomenal. The application is worldwide and the range of applications continues to grow in residential, commercial, institutional and agricultural markets. Heat pumps now consume half the energy than those installed fifteen years ago. The IEA Heat Pump Program has been a major factor in this success.

The number of international member associations pursuing this technology is growing. There is still some reluctance to engage the technology since it is not considered power production. GSHPs are power reduction systems. It must be understood by energy evaluators that any power producing technology benefits substantially by being coupled with a GSHP.

James Bose

Columnist

Annex 29 - Ground Source Heat Pumps – Overcoming Market and Technical Barriers

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Three Annexes on ground-coupled heat pumps have been carried out within the framework of the IEA Heat Pump Program: Annex 2, Vertical Earth Heat Pump Systems; Annex 8, Advanced In-ground Heat Exchanger Technology for Heat Pump Systems; and Annex 15, Heat Pump Systems with Direct-Expansion Ground Coils. Annex 13, Design, Construction and Maintenance of UTES Wells and Boreholes, has been carried out by the Energy Conservation Through Energy Storage Implementing Agreement.

The ground source heat pumps topic has become increasingly important with respect to energy efficiency, demand side management activities and the reduction of greenhouse gas emissions. Additionally, demand for cooling and air conditioning is increasing significantly, especially in the developing countries, as well as in Europe.

The first Meeting of Annex 29 was an Experts' Meeting in September 2003 at Arsenal Research, Vienna, Austria. The result of this meeting was strong interest, but not sufficient definitive participation. So, promotion work went on.

Annex 29, which started officially in March 2004 and will end in September 2006, will investigate the present state of ground source heat pump systems, which is very different all over the world, and will identify systems – depending on climate and application – that could improve the performance and market attractiveness of ground-source heat pump systems. The objective is to demonstrate the economic and environmental benefits of ground-coupled heat pump systems.

The kick-off meeting, attended by 17 participants from eight countries, was also held at Arsenal Research in Vienna, Austria, in September 2004, at which an overview of the activities in the different countries was presented. The work programme was finally decided in the discussion, with the following main topics:

- State of the art and a market analysis (this part is almost finished)
- Matrix of ground source systems under different conditions of climate and site
- Improvement of components and systems
- Overcoming legal barriers
- Increasing acceptance
- Overcoming economic barriers by promotion, subsidy and contracting models

The products of Annex 29 will be a Website (almost finished), the Final Report and - more importantly - National Dissemination, Workshops (not only in Las Vegas), National Courses, Seminars and Conferences.

A workshop on Annex 29 was held at the IEA Heat Pump Conference in Las Vegas, with the participants presenting findings and solutions from their country to more than 90 attendees.

Participating countries: Canada, Japan, Norway, (Sweden), the United States, and Austria (Operating Agent). There is great interest of some additional countries to participate, i.e. Belgium, China, the Czech Republic and the UK. I hope they will really join.

Hermann Halozan

General

Australia focuses on energy efficiency

Australia – Despite twelve years of mandatory labelling, the average efficiency of air conditioners sold in Australia has not increased significantly. It is slightly better than the average efficiency of similar products made in China, but below that of products of other Asian countries. As a result of this, the Australian Government has renewed its interest in Minimum Energy Performance Standards (MEPS), and is working together with industry to come up with ideas for implementation. The Air Conditioning and Refrigeration Institute (ARI) in the USA is cooperating with the Australian Government in order to develop such MEPS for the Australian market.

Source: Koldfax, September/October 2005

Third German heat pump forum

Germany - The third German Heat Pump Forum (3. Forum Wärmepumpe) was organised in Berlin on 13th/14th October 2005 by Solarpraxis AG, in conjunction with German heat pump associations, institutes, societies and companies.

The Forum was attended by 230 participants, a 25 % increase over the previous year's Forum. A total of 50 papers was presented, covering markets, financing, marketing and distribution. Each paper was followed by intensive discussions.

The fast-growing heat pump market in Germany was the most important subject of the event. Whereas less than 5000 heat pumps were sold in 1999, the market had increased to more than 12 000 units in 2004, with a total of about 90 000 units installed by then. The market is dominated by small and medium-sized systems for new single-family and two-family houses, while the retrofit market, with a potential of several orders of magnitude larger, is still in an early stage of development, although of increasing importance for heat pump manufacturers and installers.

Increasing oil and gas prices, and the present energy policy of the Government, are the main reasons for this growth. Under favourable conditions, a total of 200 000 units could be in use by 2020, with an annual reduction of about 590 000 tonnes of CO2 emissions.

In a special session, IZW e.V., the German National Team of the IEA Heat Pump Programme and co-organiser of the Forum, presented three papers under the general title of "Provenance, Global Role and Future of the Heat Pump". These three papers (in German) are available as pdf files.

Source: Professor H. J. Laue
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The 22nd IIR International Congress of Refrigeration

China – The International Congress of Refrigeration is held every four years, and the next congress will be held in Beijing, China, on 21st - 26th August 2007. The conference theme will be "Refrigeration creates the future". The first call for papers has now been published, with information on the content and structure of the congress. More information is available from the congress web site, www.icr2007.org

Source: First Call for Papers, IIR

IZW-IEA Symposium - Innovations in Refrigeration, Air Conditioning and Heat Pump Technologies for the Reduction of CO_2 Emissions

Germany - Stopping climate change is of ever-increasing importance in several international and European energy policy programmes. Within the EU programme, Germany has agreed to reduce its greenhouse gas emissions until 2012 by 21 % as compared with its 1990 emissions.

It is well known that most of the greenhouse effect is caused by anthropogenic carbon dioxide emissions from fuel combustion. In Germany, 6 % of primary energy and 14 % of final energy is used for the production of artificial cooling. Energy demand for space heating is around 33 % of final energy and 25 % of primary energy. There are no questions that heat pump technology is playing an important role in more efficient heating and cooling and the related reduction of CO_2 emissions.

The Information Centre on Heat Pumps and Refrigeration (IZW) and the National Team of the International Energy Agency (IEA) Heat Pump Programme organised a symposium in Hanover in cooperation with the VDKF in conjunction with the 26th International Trade Fair of Refrigeration, Air Conditioning and, Ventilation - IKK 2005 on 1. November 2005. Highlights were all matters relating to the reduction of carbon dioxide emissions in connectin with cooling, air conditioning and heating.

The symposium was attended by more than 140 participants from all over the world. Leading representatives from the PTJ Research Centre Jülich, GTZ, Deutsche Gesellschaft für technische Zusammenarbeit and dena, Deutsche Energieagentur, introduced the subject. Prof. Dr.-Ing. Dr. h.c. Horst Kruse from the Heat Pump and Refrigeration Information Centre (IZW) described the importance of energy saving for the reduction of CO_2 emissions in refrigeration and air conditioning. He explained how heat pumps account for a major share of the reduction of energy-based emissions by reducing the heating energy necessary for heating buildings.

International experts for each of the individual segments of refrigeration, air conditioning and heat pump technology provided an overview of innovative developments for reducing CO_2 emissions. Each of the assigned presentations has been intended to show the progress of increased energy efficiency in the use of these technologies.

Summarizing the results of the Symposium: Research, Development and Demonstration activities for the development of technologies with improved energy efficiency and advanced refrigerants are of specific importance to limit global warming to a maximum 2 K average temperature increase above pre-industrial levels, which requires global greenhouse gas emissions to be cut by approximately half by the middle of the century.

Source:
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Increased attention paid to energy efficiency

Energy efficiency measures have been on the agenda on several international high-level meetings this year. It was discussed by the energy ministers of the IEA countries at their meeting at the beginning of May, where energy efficiency measures were considered as the most important action to solve the environmental problems and create a more stable and secure energy system. The EU Commissioner for Energy has launched a Green Book on energy efficiency with the title of "Doing more with less", calling for both economic growth and reduced use of resources.

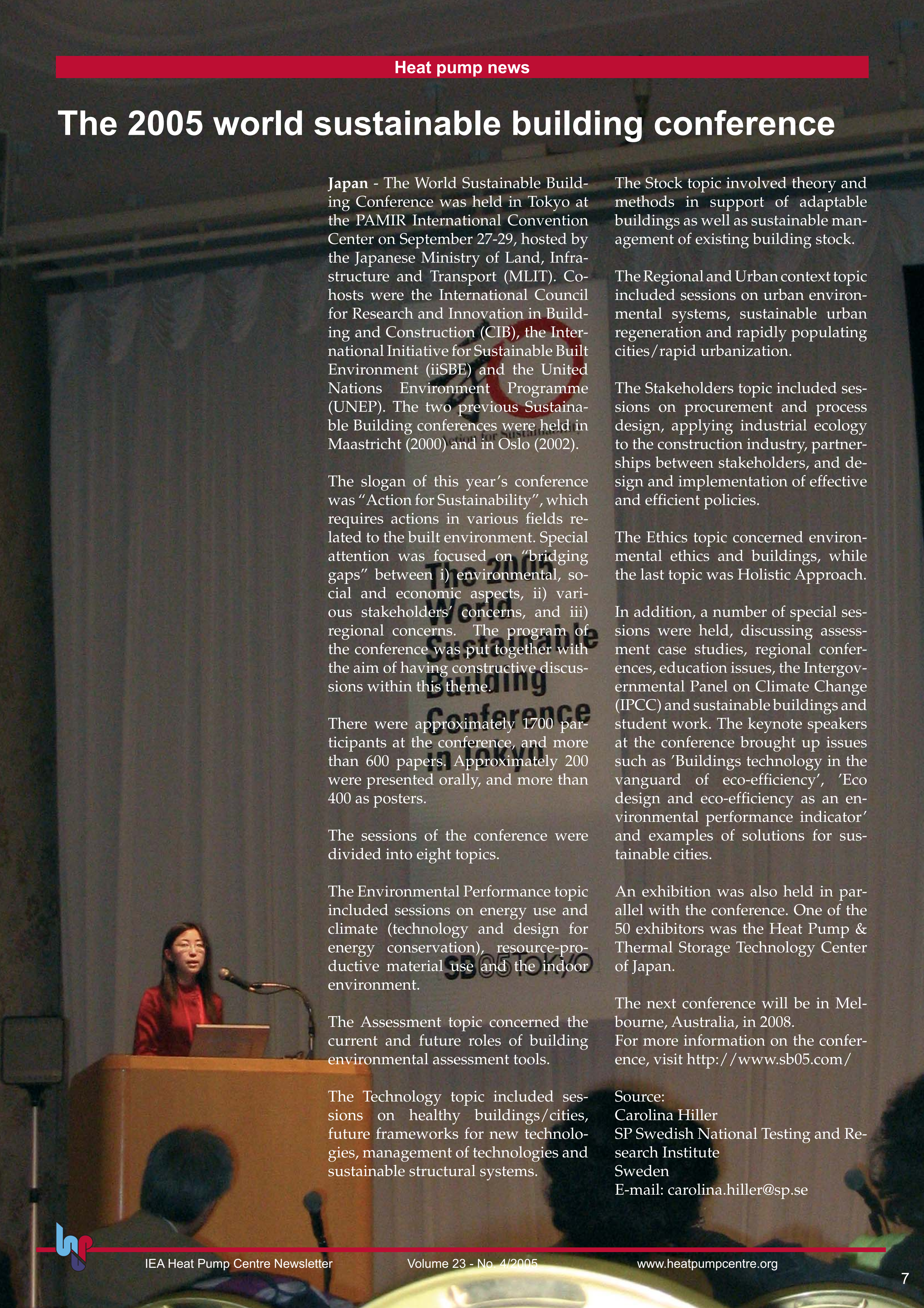
In July, the G8 countries issued their "Plan of action", under which member countries are encouraged to tighten up their building regulations and to put more effort into encouraging the design and marketing of more energy-efficient products etc.

These issues are of concern outside the OECD as well. China has released a very ambitious energy saving plan, under which it wants to increase the GNP by four times by 2020, but with only a doubling of energy use.

Conclusion: there seem to be substantial business opportunities for companies working with energy efficiency implementation.

Source: Energi & Miljö, no. 8, 2005 (in Swedish)

The 2005 world sustainable building conference



Japan - The World Sustainable Building Conference was held in Tokyo at the PAMIR International Convention Center on September 27-29, hosted by the Japanese Ministry of Land, Infrastructure and Transport (MLIT). Co-hosts were the International Council for Research and Innovation in Building and Construction (CIB), the International Initiative for Sustainable Built Environment (iiSBE) and the United Nations Environment Programme (UNEP). The two previous Sustainable Building conferences were held in Maastricht (2000) and in Oslo (2002).

The slogan of this year's conference was "Action for Sustainability", which requires actions in various fields related to the built environment. Special attention was focused on "bridging gaps" between i) environmental, social and economic aspects, ii) various stakeholders' concerns, and iii) regional concerns. The program of the conference was put together with the aim of having constructive discussions within this theme.

There were approximately 1700 participants at the conference, and more than 600 papers. Approximately 200 were presented orally, and more than 400 as posters.

The sessions of the conference were divided into eight topics.

The Environmental Performance topic included sessions on energy use and climate (technology and design for energy conservation), resource-productive material use and the indoor environment.

The Assessment topic concerned the current and future roles of building environmental assessment tools.

The Technology topic included sessions on healthy buildings/cities, future frameworks for new technologies, management of technologies and sustainable structural systems.

The Stock topic involved theory and methods in support of adaptable buildings as well as sustainable management of existing building stock.

The Regional and Urban context topic included sessions on urban environmental systems, sustainable urban regeneration and rapidly populating cities/rapid urbanization.

The Stakeholders topic included sessions on procurement and process design, applying industrial ecology to the construction industry, partnerships between stakeholders, and design and implementation of effective and efficient policies.

The Ethics topic concerned environmental ethics and buildings, while the last topic was Holistic Approach.

In addition, a number of special sessions were held, discussing assessment case studies, regional conferences, education issues, the Intergovernmental Panel on Climate Change (IPCC) and sustainable buildings and student work. The keynote speakers at the conference brought up issues such as 'Buildings technology in the vanguard of eco-efficiency', 'Eco design and eco-efficiency as an environmental performance indicator' and examples of solutions for sustainable cities.

An exhibition was also held in parallel with the conference. One of the 50 exhibitors was the Heat Pump & Thermal Storage Technology Center of Japan.

The next conference will be in Melbourne, Australia, in 2008.
For more information on the conference, visit http://www.sb05.com/

Source:
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Real-estate owners choose heat pumps

Sweden – Sweden is at present in a debate on the price of district heating. District heating is commonly used in cities and towns in Sweden, but prices in some areas have increased considerably in recent years. In response to this, real-estate owners are tending to choose heat pumps instead of district heating, even in the centre of Stockholm. An investigation has 'moved' a typical building to different cities in Sweden, calculating the resulting costs of heating in different areas. The results show that, in about 50 % of the cases where district heating is available, it would be less expensive to use a heat pump or a pellets-fuelled boiler system. The problem is that of the cost of converting from district heating to the alternative system. However, it is strange that heat pumps are used in large cities, where the heat demand is very high and thus should favour district heating systems.

An enquiry sent out to district heating customers revealed that district heating was considered as more reliable than a heat pump, mainly because of concerns for a power failure. However, heat pumps were considered best value in terms of price, with concern for future cost increases being lowest for heat pumps when compared with district heating and bio-mass systems.

Source: Energi & Miljö, no. 11, 2005 (in Swedish)

VAT reductions for heat pumps

UK – A 5 % reduction of VAT is now granted for heat pump installations in the UK. It applies to both ground-source and air-source heat pumps for residential use. It applies only for products with the primary purpose of heating, i.e. it does not apply for cooling-only units.

Source: Heat Pump News, no. 4, 2005

Photo Johan Tegnelius

Heat pumps make their entry to IKK

Germany - One of the most important trade fairs for the international refrigeration sector is IKK, which this year was held in Hanover in Germany from 2nd to 4th November. For the first time, the heat pump was given a more important part in the fair. This was mainly in the form of a symposium, held on the day before the fair opened, and a specialist forum of presentations and an exhibition that put the heat pump on the map this year. 29 companies and organisations had stands under the category of heat pumps.

Unfortunately, it had to be noted that several international companies were conspicuous by their absence this year. These were mainly companies in the traditional refrigeration market: as far as heat pump manufacturers were concerned, the number of exhibitors was larger than previously. There was a special exhibition of heat pumps in parallel with the Knowhow Forum, and there were also companies and organisations who were exhibiting elsewhere in the show. The highest profile was that of system solutions for the residential single-family house market. As far as air/air heat pumps were concerned, there was a clear input of Chinese manufacturers. The prices for their units were such that they could be expected to increase their sales on the European market, but the actual technology, construction and quality were not always up to those from the large, established brands. (For the time being, we should perhaps add.)

It was more interesting to look at the carbon dioxide designs that were on show, whether as commercial products or as ground heat concept designs. Products from Ochsner could be found on several stands, where they were shown in conjunction with the CO_2 ground-source heat pump systems that are slowly starting to be installed in Germany. The evaporator, made of stainless steel, is drilled into the ground, with heat exchange on the thermo-siphon principle. This achieves a high efficiency as a result of carbon dioxide's better heat transfer performance and the elimination of any need for a brine circulation pump. The next step must be link this commercially available technology to the design study for a heat pump using CO_2 as its refrigerant that was displayed by FKW (Forschungszentrum für Kältetechnik und Wärmepumpen).

IKK 2006, to be held in Nürnberg, will doubtless unveil a lot more new hardware products. Hopefully, the heat pump manufacturers will be there, and in still larger numbers.

Source: Johan Tegnelius, KYLA, Sweden, johan.tegnelius@kyl.se

Technology & Applications

Solar refrigerators

Denmark – The "SolarChill" project has developed solar-assisted vaccine and food refrigerators, intended for use in parts of the world where there is no electricity supply or where the grid is unreliable. A SolarChill refrigerator is powered by 3x60 W photovoltaic solar panels, with the refrigerator itself using a DC compressor and R600 refrigerant. The insulation foam is blown using cyclopentane. No batteries are used for energy storage; instead, the energy produced during the day-time is stored in ice which keeps the compartment cool during the night. Solar-assisted refrigerators are available today but the estimated price of USD 1500-2000 for a SolarChill refrigerator (including solar panels) is claimed to be 50-60 % lower than that of presently available units.

The current technology for this application is kerosene refrigerators. These refrigerators use approximately 0.8-1 kg of kerosene per day. They emit an unpleasant smell, they occasionally catch fire, and they need to be regularly fuelled. In addition, of course, they contribute to global warming.

The SolarChill refrigerator has been developed by the following group: Danish Technological Institute, Greenpeace, PATH, WHO, UNEP, UNICEF, GTZ Proklima, Danfoss and Vestfrost. The results from this project will be publicly available from the web site, www.solarchill.org, and from research papers. Field tests are at present under way in Cuba, Indonesia and Senegal. When the tests have been concluded, and the technology can be considered as reliable, further information will be posted on the web site.

Source: IIR Newsletter, October 2005, and www.solarchill.org

Dehumidification with heat pump water heater

USA – Many users of heat pump water heaters (HPWH) recognise their ability also to dehumidify the air. This has been recognised also by the US Department of Energy and Oak Ridge National Laboratories, which recently finalised a market study on an integrated water heater and dehumidifier. Based on the results from the study, they have initiated development and field testing of an integrated HPWH and dehumidifier (hereinafter referred to as WHD).

The market study showed that the major obstacles for a WHD are:

- Location. (If installed in the garage, there will be no benefit.)
- Installer. (In new construction, the installer chooses the system, but has no incentive to choose a highly efficient system.)
- Replacement. (When installing a replacement system, it is often the plumber, again with no incentive for choosing a highly efficient system, who chooses the product.)
- Familiarity.

Major advantages are:

- Tackling of humidity problems. (60 % of US homes with basements have moisture problems.)
- Mould. (Homes with mould problems can benefit.)
- Competitive with gas.
- Useful in utility rooms.
- Dehumidifier sales. (Over one million dehumidifiers are sold per year in the US.)

The WHD prototype will have two condensers; one in the water tank, and one in the air stream. If there is no demand for hot water, the unit can continue to dehumidify the air if needed. The system is able to change from water heating to dehumidification without using any valves in the refrigerant circuit. Two different prototypes have been tested: in Phase 2 of the work, major components of the system will be further evaluated and optimised. Eight prototypes will be evaluated in field tests during a later phase of the work.

Source: In Hot Water, no. 3 2005

Promotion of efficient electric motor systems

EU –A SAVE project has developed a support tool for the design of electric motor systems. The aim is to help end users to explore the possibility of energy savings in motor systems of industrial or other installations. The intended users are seen as those having basic technical expertise.

The background to this project is that motor systems in industry and in the building sector are the largest users of electricity, thus presenting a very considerable energy-saving potential. The Europe-wide potentials have been estimated at 100 TWh for each sector.

The tool supports four basic electrically driven systems:

- Motors and drives
- Compressed air systems
- Water pumps
- Chiller (heat pump) systems

The module for motor and drive systems provides information on the benefits of using high-efficiency motors and drive systems. Guidance is also given for motor sizing and reduction of transmission losses. The module for compressed air systems provides an overview of existing systems and identifies the most important actions for energy savings. The pumping system module examines the potentials for energy savings in pumping equipment and associated controls, such as through the use of variable-speed drive systems.

The chiller module provides basic information on the components of an HVAC system (chillers, pumps and fans, pipes and ducts, air handling units etc). The tool is linked to the Eurovent/Cecomaf site for updated product information. The calculations support air-cooled and water-cooled chillers.

More information is available at the web site, http://www.motorchallenge.ch:8181/promot

Source: Eurovent/Cecomaf Review, October 2005

Markets

An overview of the Turkish air-conditioning market

Turkey – With an immature market for air conditioners, and a good economy, the Turkish market for room air conditioners and packaged air conditioners has grown by 15 % per year over the last few years, and is expected to become a solid air-conditioner market. The market size exceeded 500 000 units in 2004, and is expected to reach around 1 million units in 2008. Ductless split units are the most common type, with 70 % of them being reversible and thus capable of operating as heat pumps as well. Window units are not popular, and only the replacement market will keep that segment alive. R22 is still the dominating refrigerant, and is used in 95 % of the equipment; the remaining part is covered by R407C and R410A.

Major manufacturers are Arcelik-LG, Vestel, Teba and Akfel. Imports are mainly from China (Haier and Midea), although also from Korea, Italy, Taiwan, Malaysia and Thailand.

Source: JARN, October 2005

The Russian air-conditioning market

Russia – Russia has a well-established market for packaged air-conditioning equipment, according to the UK research centre BSRIA. Total sales in 2004 were worth EUR 514 million, and expected sales for 2005 worth EUR 635 million. Split systems are the largest market segment, having sold 125 000 units in 2004, representing 85 % of the market in terms of value. Almost all of these are of the reversible type, and can thus operate as heat pumps. The future seems bright for the Russian air-conditioning market – it is expected to grow at a rate of 23 % per year up to 2009.

Source: JARN, October 2005

Status of the Italian air-conditioning market

Italy – 2003 and 2004 were excellent years for the Italian air-conditioning market. Sales in 2003 increased due to the hot summer, with the effect lasting through 2004. However, there are concerns about the Italian manufacturers. In competition with Chinese manufacturers, Italian manufacturers seem to be losing market share for the residential and light commercial sectors. In 2004, only 10 % of the split-system market of 1.9 million units was Italian-made. 70 % of the remaining portion was supplied by Chinese imports. This trend continues in 2005. As the market seems to have declined by about 10 % since 2004, the major part is taken by low-price imports from China, or from Chinese brands with factories in Italy.

Source: JARN, October 2005

Working Fluids

Second reading of the F-gas regulation

EU – After the second reading of the proposed F-gas regulation, the European Parliament again voted for containment measures to be imposed on the global warming F-gases in refrigeration and air-conditioning. Parliament did not, in other words, follow the call from its environment committee that wanted to impose bans on the use of F-gases.

The background to this regulation is that F-gases represent only 2 % of EU-15's greenhouse gas emissions, but their estimated global warming potential (GWP) is up to 23 900 times that of CO2 (in the case of SF6). To ease the impact of F-gases on global warming, the EU Parliament wants to introduce a regulation that will force users and manufacturers to implement measures that will ensure that the gases are contained inside the equipment and do not leak out in the atmosphere.

It also seems that the same rules will apply for the whole EU, which means that the stricter rules imposed by Denmark and Austria will be harder to implement. However, there is one exception – if stricter F-gas controls are needed for a country to fulfil its Kyoto Protocol targets, such measures are allowed.

The directive that was proposed earlier this year will be applied for car air-conditioning systems. With effect from 2011, there will be a ban on F-gases with a GWP > 150 in new cars. From 2017, this ban will be extended to all cars.

Source: www.euractiv.com, 2005-11-21

Second international seminar on natural refrigerants

Japan - The 2nd International Seminar on Natural Refrigerants will be held in Tokyo on February 10, 2006. The Seminar will be chaired by Prof. Eiji Hihara (Univ. of Tokyo), with English as the official language. It will focus on international standards and regulation, the latest technology, marketing trends, and further prospects for natural refrigerants world-wide.

The seminar will start at 9:45 in the morning. The morning presentation will consist of the following two papers:

1. Refrigerant regulation in the United States, by Stephen O. Andersen, US Environmental Protection Agency, USA.
2. F-gas regulation in the European Community, by Friedrich Busch, European Partnership for Energy and the Environment, Germany.

After the lunch break, the seminar will continue with six lectures by Japanese researchers (Japanese-English simultaneous translation will be provided).

The venue of the seminar is the "Tokyo Big Sight" Tokyo International Exhibition Center. It is planned as an event in conjunction with the HVAC&R JAPAN, which will be held at the same location from Feb. 7th to 10th, 2006. The registration fee is 10 000 Japanese yen per person for advanced registration by Jan. 20th, and 12 000 yen after Jan. 21st.

The seminar is organised and sponsored by the Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ), and by the Japan Refrigeration and Air Conditioning Industry Association (JRAIA).

For further information, please see http://www.hptcj.or.jp/about_e/index.html, or contact the seminar secretariat (isnr@hptcj.or.jp).

Source: Japanese National Team (HPTCJ)

IEA Heat Pump Programme

Two new annexes start and one is closed

Two new annexes were approved at the autumn Executive Committee (ExCo) meeting held in Vienna on November 9-10th.

Annex 31 – Advanced modelling and tools for analysis of energy use in supermarkets, with participation from Sweden (Royal Institute of Technology [Operating Agent], Swedish National Testing and Research Institute), Canada (Natural Resources Canada) and Germany (IZW). France, Norway, the USA, the UK and Switzerland also showed interest for this research project, which means that additional parties may join.

Annex 32 – Economical heating and cooling systems for low-energy houses, with participation from Switzerland (University of Applied Sciences Basel – Operating Agent), Canada (LTE Hydro Quebec), USA (Department of Energy), Germany (Fraunhofer) and Sweden (Swedish National Testing and Research Institute). Japan, Norway and Austria also showed interest in this Annex.

More information about these Annexes and contact data for the Operating Agents will be published on the web site, www.heatpumpcentre.org. Click on 'Projects'.

Annex 28 - Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating - was finalised and closed at the ExCo meeting. The ExCo found the Annex very well organised and congratulated the operating agent (University of Applied Sciences, Basel) and the participants on excellent work. The final report from Annex 28 will soon be available, and can then be ordered from the web site, www.heatpumpcentre.org. Click on 'Publications'. Information on the work of Annex 28 can also be found on www.annex28.net.

Source: Heat Pump Centre

New features of the Heat Pump Centre web site

There's a new button in the menu of the Heat Pump Centre web site, www.heatpumpcentre.org. It's called 'Workshops', and links to presentations from workshops arranged at ExCo-meetings and other Heat Pump Programme events. Just now, it accesses presentations from a workshop held in Vienna in conjunction with the ExCo-meeting in November. In due course, it will be updated with presentations from the Annex 28 and 29 workshops held at the IEA Heat Pump Conference in Las Vegas, and ExCo-workshops from Paris and Montreal held in 2004.

In addition, the web site now also contains information on five of the national teams – Germany, Sweden, Switzerland, USA and Japan. This is in the form of contact information for the National Team, activities within the team and areas of interest. Click on 'Organisation', and then scroll down to 'National Teams'.

Source: Heat Pump Centre

Topics for Newsletters 2006

The topics for the Heat Pump Centre Newsletter in 2006 have been decided.

1. Thermally activated heat pump systems (March).
2. New regulations and directives – how will they affect heat pumping technologies? (June).
3. The latest developments on the use of CO_2 as refrigerant.
4. Retrofit heat pumps for buildings.

The HPC Newsletter can be downloaded from the web site, www.heatpumpcentre.org. You can also subscribe to an e-Newsletter that will tell you when a new issue is available, with brief information on the content of the new issue.

Source: Heat Pump Centre

Ongoing Annexes

Bold text indicates Operating Agent.

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

The advance of geothermal heat pumps – world-wide

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Introduction

Geothermal (ground-source) heat pumps (GHP) are one of the fastest growing applications of renewable energy in the world, now in 31 countries, with annual increases of 10 % over the past ten years. GHPs are based on a ubiquitous and largely unexploited energy resource: the heat content of the ground right beneath our feet. The world-wide increase of geothermal direct use is mainly due to the advance of GHPs.

Ground source heat pumps are an established technology, utilizing the immense renewable storage capacity of the ground. GHPs use the relatively constant temperature of the ground to provide space heating, cooling and domestic hot water for homes, schools, factories, public buildings and commercial buildings. They come in two basic configurations: ground-coupled (closed loop) and groundwater (open loop) systems, which may be constructed horizontally or vertically, or in wells and lakes. The type chosen depends upon the soil and rock type at the site, the land available and/or if a water well can be drilled economically or is already on site. In the ground-coupled system, a closed loop of pipe, placed either horizontally (1 to 2 m deep) or vertically (50 to 200 m deep) is placed in the ground and a water-antifreeze solution is circulated through the plastic pipes to either collect heat from the ground in the winter or to reject heat to the ground in the summer. The open loop system uses ground water or lake water directly in the heat exchanger and then discharges it into another well, into the same well [1], into a stream or lake, or on to the ground (say for irrigation), depending upon local laws [2].

Sustainability of the resource

In the case of GHPs, sustainability concerns the various heat sources. In horizontal systems, the heat exchanger pipes are buried at shallow depth; long trouble-free operation is guaranteed by the constant heat supply from the atmosphere by solar radiation on the one hand and from below on the other. In the case of combined heating/cooling by GHPs, the heat balance (in/out) is determined by the system design itself. In the case of groundwater-coupled GHPs, the re-supply of fluid is provided by the hydrologic cycle (infiltration of precipitation) and the heat comes either "from above" (atmosphere) and/or "from below" (geothermal heat flow), with the relative proportions depending on the aquifer depth. This leads to a ± constant aquifer temperature all through the year without any significant seasonal variation. Any deficit created by heat/fluid extraction is replenished by the (lateral) groundwater flow.

The situation with borehole heat exchanger (BHE)-coupled GHP systems in the heat-only mode is different. During heat extraction operation, the BHE becomes more and more of a heat sink. Poor design, especially with forced extraction rates (several tens of W per meter BHE length, in low thermal conductivity materials such as dry gravel) can lead to freezing of the surrounding ground and thus to system collapse. The conditions by which reliable operation can be assured in the long term (i.e. sustainable operation) can be established by proper design [3].

The operating BHE creates a heat sink in the ground, which has cylindrical shape. When equilibrium conditions are reached, the isotherms are concentrated near the BHE. Figure 1 shows a typical situation depicting ground temperatures around a BHE in mid winter. The heat sink leads to heat inflow to replenish the deficit; this heat flow density reaches quite high values, of up to several W/m^2, which should be compared with natural terrestrial heat flows of about 80 – 100 mW/m^2. Thus an efficient heat re-supply takes place.

After shutdown of BHE operation, thermal recovery begins, strong at first and then decreasing asymptotically. Model simulations with different operational recovery periods show that recovery duration roughly equals that of operation: e.g. 30 years of BHE operation require 30 years for the ground to recover in thermal terms [3]. BHE arrays exhibit a similar behaviour [4].

In the following, the worldwide status of GHP development will be presented, on the basis of information provided by the national reports submitted to the World Geothermal Congress 2005. The individual papers can be found in the Conference Proceedings [5].

World-wide data

The International Geothermal Association (IGA) organizes, jointly with a host country, a World Geothermal Congress every five years. The last three congresses were held in Italy (WGC1995, Florence), Japan (WGC2000, Beppu and Morioka), and Turkey (WGC2005, Antalya). Each time, appointed national correspondents provided statistical data from their countries. The numbers for geothermal direct use are presented first.

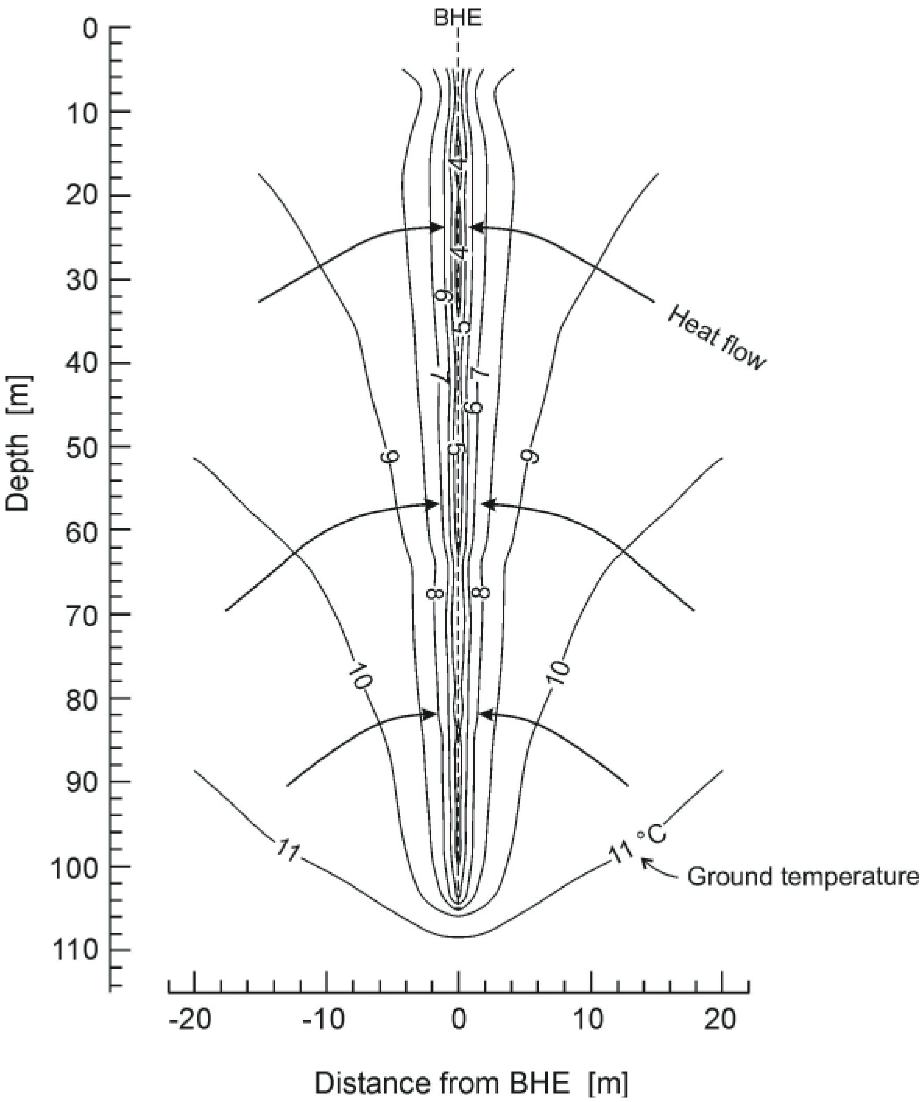

Figure 1. Temperature isolines in the ground around a 105 m deep BHE, during the coldest period of the heating season 1997 in Elgg/ZH, Switzerland. The radial heat flow in the BHE vicinity is around 3 W/m2. From [3].

Table 1. Summary of the various worldwide direct-use categories, 1995-2005 (from [6])

Usage type	Capacity (MW_{th})			Utilization (TJ/yr)		
	2005	2000	1995	2005	2000	1995
Geothermal heat pumps	15 384	5 275	1 854	87 503	23 275	14 617
Space heating	4 366	3 263	2 579	55 256	42 926	38 230
Greenhouse heating	1 404	1 246	1 085	20 661	17 864	15 742
Aquaculture pond heating	616	605	1 097	10 976	11 733	13 493
Agricultural drying	157	74	67	2 013	1 038	1 124
Industrial uses	484	474	544	10 868	10 220	10 120
Bathing and swimming	5 401	3 957	1 085	75 289	79 546	15 742
Cooling/snow melting	371	114	115	2 032	1 063	1 124
Others	86	137	238	1 045	3 034	2 249
Total	**28 269**	**15 145**	**8 664**	**273 372**	**190 699**	**112 441**

At WGC2005, a total of 71 countries have reported their numbers [6]. Table 1 is a summary of the installed capacity (MWth) and annual energy use (TJ/yr). The total installed capacity, reported in May 2005, for the world's geothermal direct utilization is 28 269 MWth, almost a two-fold increase over the 2000 data, growing at a compound rate of 13.3 % annually. Total annual energy use is 273 372 TJ (75 943 GWh), almost a 45 % increase over 2000, growing at a compound rate of 7.5 % annually. Compared to ten years ago, capacity increased by 12.6 %/yr and use by 9.3 %/yr. Thus, it appears that the growth rate has increased in recent years, despite the low cost of fossil fuels in the past few years, economic down-turns and other factors.

It is obvious from Table 1 that GHPs are the greatest contributors to geothermal direct use; they contribute decisively also to the growth over time. In the following, the GHP situation in individual countries will be presented and analysed.

The rapid growth in worldwide installation and use of geothermal heat pumps for both heating and cooling for the past 15 years is illustrated in Figures 2 and 3. They clearly show the dramatic growth in geothermal heat pump use due to the growing awareness of their capabilities, popularity and ability to use them anywhere in the world.

At the country level, there are great differences. In addition to some pioneering countries, there are several countries and regions in which there are only a few or even no GHPs in operation. There are various reasons for this difference, such as climate, level of development or lack of information. The latter turns out to have a major influence: the awareness of many architects, developers and building services systems designers is still limited and will need considerable improvement before they become fully aware of the advantages and benefits of GHP systems.

Reports of GHP systems in operation

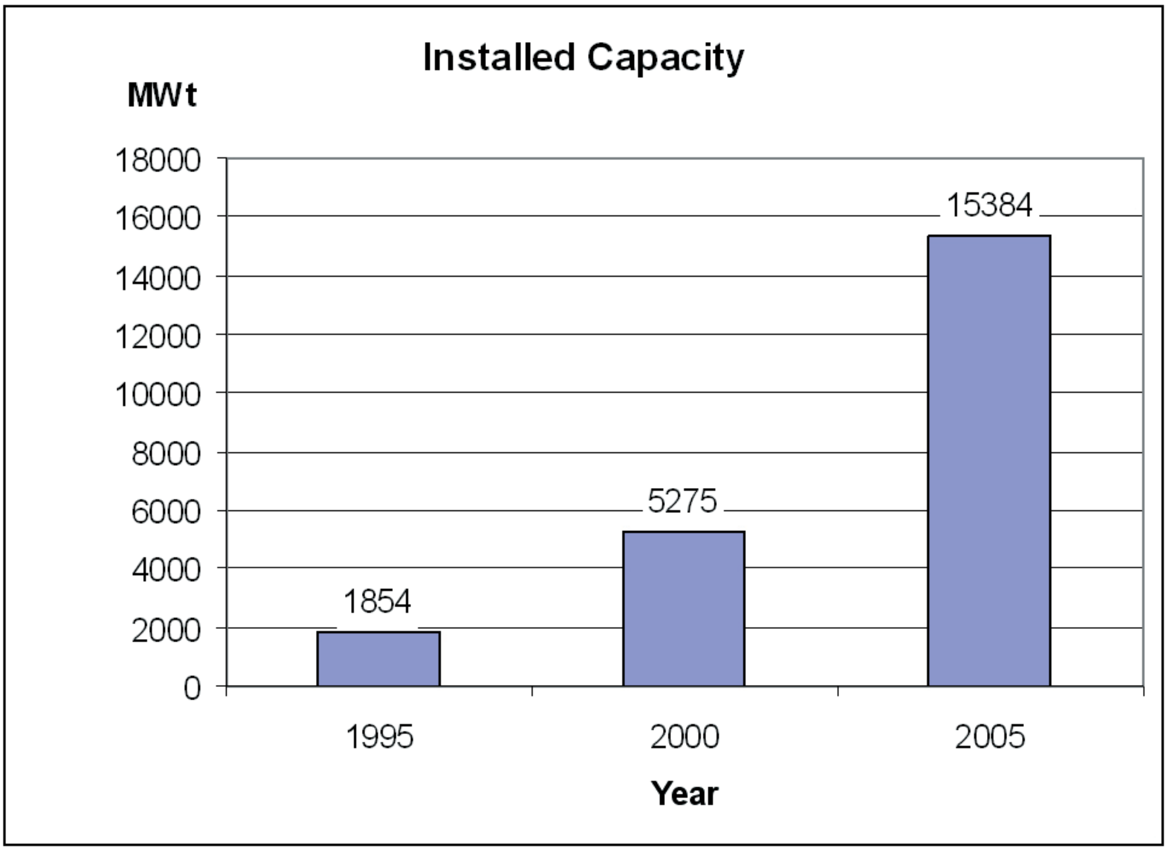

Figure 2. Growth of installed GHP capacity

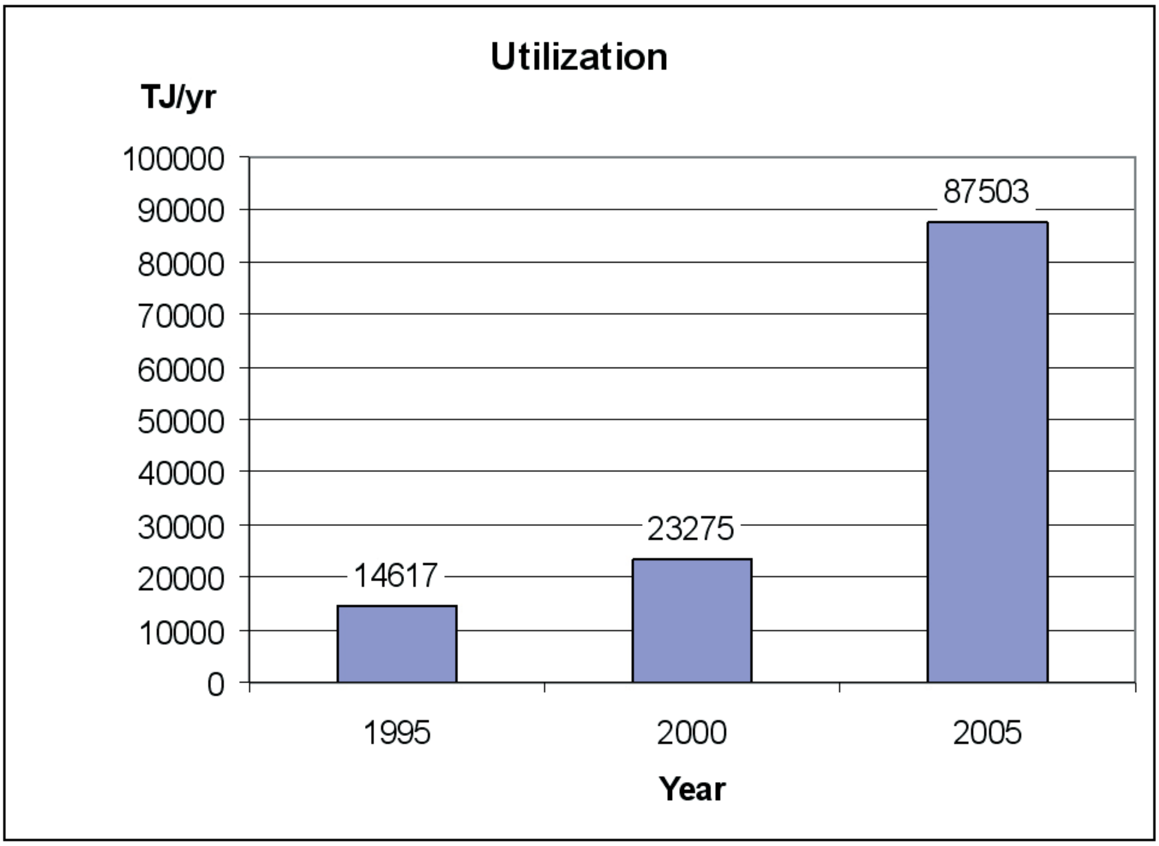

Figure 3. Growth of GHP utilization

have been submitted by 32 countries, i.e. less than half of the 71 countries with direct use (direct use means the utilization of geothermal heat as such, rather than for generating electricity). No or negligible GHP operation is reported from Albania, Algeria, Argentina, Armenia, Brazil, Caribbean Islands, Chile, Columbia, Costa Rica, Croatia, Ecuador, Egypt, Ethiopia, Georgia, Guatemala, Honduras, India, Indonesia, Iran, Israel, Jordan, Kenya, Macedonia, Mexico, Mongolia, Nepal, Papua New Guinea, Peru, The Philippines, Romania, Thailand, Turkey, Ukraine, Venezuela, Vietnam and Yemen.

Table 2 presents the data reported from the 32 countries about GHPs, valid at the end of 2004. It is surprising that in countries such as Japan, although having a strong heat pump manufacturing industry, GHPs have still not established a market.

The figures in Table 2 range from very small to very large. They reflect, to a considerable extent, the country size. For example, China and USA quoted impressive numbers, however these numbers refer to large countries. Some form of weighting is therefore necessary in order to account for country size. In the following, this is applied by taking into account country size and population. Table 3 shows the results in terms of installed capacity per total land area (W/km2), capacity per capita (W/capita), energy per area (GJ/yr, km2), energy per capita (GJ/yr, capita), and GHP units per area (12 kW units/km2). Table 4 gives the ranking from this weighting.

In terms of fictitious medals, the results are as follows:

- Gold to Sweden 3x, Switzerland 2x, Denmark 1x, USA 1x
- Silver to Sweden 4x, Denmark 1x, Norway 1x, USA 1x
- Bronze to China 2x, Denmark 2x, Switzerland 2x; Norway 1x

In terms of the weighted figures (capacity or energy per country area or population), the lead is clearly held by Nordic/Scandinavian countries, with Sweden being the champion.

Table 2. Geothermal heat pump usage in different countries, as reported at and after WGC 2005 (from [6])

Country	Installed capacity (MW_{th})	Annual energy use (TJ/yr)	Equivalent 12 kW units*
Australia	5.5	30.0	458
Austria	300.0	1’450.0	25 000
Belarus	1.0	3.3	83
Belgium	60.0	324.0	5 000
Bulgaria	0.3	4.4	25
Canada	435.0	2 160.0	36 250
China	631.0	6 569.0	52 583
Czech Republic	200.0	1 130.0	16 667
Denmark	309.0	3 940.0	25 750
Finland	260.0	1 950.0	21 667
France	16.1	468.8	1 342
Germany	400.0	2 200.0	33 333
Greece	4.0	39.1	333
Hungary	4.0	22.6	333
Iceland	4.0	20.0	333
Ireland	19.6	83.6	1 633
Italy	120.0	500.0	10 000
Japan	4.0	22.4	333
S. Korea	3.4	11.9	283
Lithuania	3.3	29.0	275
Netherlands	253.5	685.0	21 125
Norway	600.0	3 085.0	50 000
Poland	103.6	574.4	8 633
Portugal**	0.2	0.0	17
Russia	1.2	11.5	100
Serbia	6.0	40.0	500
Slovak Republic	1.4	12.1	117
Slovenia	3.3	69.9	275
Sweden	3 840.0	36 000.0	320 000
Switzerland	532.4	2 854.0	44 367
United Kingdom	10.2	45.6	850
United States	7 200.0	22 215.0	600 000
TOTAL	**15 332.0**	**86 550.6**	**1 277 665**

**) 12 kW is the typical size for a residential unit*
***) the one unit in Portugal is not operational – thus zero value for annual energy.*

Table 3: Worldwide geothermal heat pump statistics 2005, compiled from Table 2

Country	Installed MW_{th}	Energy p.a. TJ/yr	Equivalent 12 kW units	Population 10^6*)	Area 10^3 km^2	Capacity per area MW/km^2	Rank	Capacity per capita W/capita	Rank	Energy per area GJ/yr per km^2	Rank	Energy per capita GJ/yr p.c.	Rank	Units** per km^2 area	Rank
Austria	300.0	1 450.0	25 000	8.05	84	3.6E-3	5	37.3		17.3	4	0.18		0.30	5
Canada	435.0	2 160.0	36 250	31.41	9 958	4.5E-5		13.8		0.22		0.07		0.004	
China	631.0	6 569.0	52 583	1 280	9 571	6.6E-5		0.49		0.67		0.005		0.005	
Czech Republic	200.0	1 130.0	16 667	10.21	79	2.5E-3		19.6		14.3		0.11		0.21	
Denmark	309.0	3 940.0	25 750	5.38	43	7.2E-2	3	57.4	4	91.6	1	0.73	2	0.60	3
Finland	260.0	1 950.0	21 667	5.20	338	7.7E-4		50.0	5	5.77		0.38	5	0.06	
Germany	400.0	2 200.0	33 333	82.48	357	1.1E-3		4.8		6.16		0.03		0.09	
Netherlands	253.5	685.0	21 125	16.15	42	6.0E-3	4	15.7		16.3	5	0.042	4	0.50	4
Norway	600.0	3085.0	50 000	4.54	324	1.4E-3		132.0	2	9.52		0.68	3	0.15	
Sweden	3'840.0	36 000.0	320 000	8.93	450	8.5E-3	2	430.0	1	80.0	2	4.03	1	0.71	2
Switzerland	532.4	2 854.0	44 367	7.29	41	1.3E-2	1	73.0	3	69.6	3	0.39		1.08	1
USA	7'200.0	22 214.0	600 000	287.5	9 809	7.3E-4		25.0		2.26		0.08		0.06	

*) from IEA 2004 Key World Energy Statistics
**) 12 kW equivalent units

Table 4. Worldwide ranking results (in order) of geothermal heat pump utilization in 2005, compiled and evaluated from Table 3.

Capacity installed (MW_{th})	Energy use (TJ/yr)	Capacity per area (MWt/km^2)	Capacity per capita (Wt/capita)	Energy per area (TJ/yr per km^2)	Energy per capita (GJ/yr per capita)	Units per area (12 kW equivalent units per km^2)
1. USA	1. Sweden	1. Switzerland	1. Sweden	1. Denmark	1. Sweden	1. Switzerland
2. Sweden	2. USA	2. Sweden	2. Norway	2. Sweden	2. Denmark	2. Sweden
3. China	3. China	3. Denmark	3. Switzerland	3. Switzerland	3. Norway	3. Denmark
4. Switzerland	4. Denmark	4. Netherlands	4. Denmark	4. Austria	4. Netherlands	4. Netherlands
5. Norway	5. Norway	5. Austria	5. Finland	5. Netherlands	5. Switzerland	5. Austria

Conclusions, outlook

Geothermal heat pumps contribute the largest share to geothermal direct use world-wide. The number of new GHP installations will continue to increase in countries where such systems are already well known; in addition to space heating, they are now increasingly used for cooling as well, even in moderate climates, due to global warming. It can be anticipated that GHP systems will penetrate the market also in countries where they not so far done so.

It is evident that GHP systems replace fossil fuels, which has – in view of the currently soaring oil prices – economic benefits. The world-wide saving of fossil fuels (in tons of oil equivalent, TOE), as well as the reduction in CO2 emissions, resulting from global annual energy production by GHP systems can be calculated. This requires several assumptions to be made. If the annual GHP energy use is 86 600 TJ (24 000 GWh), and this is compared to electrical energy generation using fuel oil at 30 % efficiency, then the savings are 37.8 million barrels of oil or 5.6 million TOE. This corresponds to an annual saving of about 17.2 million tonnes of CO2. If we assume savings in the cooling mode for about the same number of operating hours per year, these figures would double.

The main message is that geothermal heat pumps are the most powerful systems in geothermal direct use world-wide and represent the only really booming sector in geothermal development. However, the absolute numbers and growth rates are very different from country to country, even if allowance is made for the country size and/or population. Considerable efforts are still needed to disseminate the message about the technical feasibility and reliability, sustainability, economic advantages and environmental benefits of GHP systems to developers, decision-makers and even to the general public.

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Ground-source heat pump activity and its future

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Introduction

Increasing energy costs and the almost one million installed ground source heat pump systems (GSHP) in the US are indications of a strong future for the growth of this highly efficient technology. The IEA Heat Pump Centre, with its sponsorship of research and publication of worldwide activity, provides the basis for those proponents of the technology to be armed with facts when presenting their cases to governments who by and large play the major role in future energy decisions. Broad application (schools, government buildings, residences, etc) of the GSHP technology speaks to its long-term viability. Compound rates of growth (12.4 % to 12.9 %) worldwide over the last 10 years are reported by Lund et al [1], with water source heat pump manufacturing companies in the US reporting "their best year ever." The future activity will be an expansion of what is presently being accomplished but at a higher rate due to energy costs, environmental concerns and the more active participation in government leadership.

Federal sector growth

Up until recently, GSHP market growth in the federal sector had been driven by retrofit projects in military family housing, but housing privatization has reduced the pool of candidate sites. Most new federal projects now involve larger buildings such as offices, laboratories, maintenance facilities and barracks. It is estimated that the U.S. federal government has invested over $200 million in GSHP, installing more than 40,000 tons of equipment worldwide [2].

The National Aeronautics and Space Administration (NASA) is tasked to consider the use of geothermal heat pumps in all new buildings and any building of substantial renovation. NASA is only one example of federal facilities considering GSHP usage [3].

The requirement to consider life cycle cost in energy conservation projects has been one factor in the increased use of GSHP by the U.S. federal government. Multiple sites have been renovated such as the military housing at Fort Polk, Louisiana USA where 4,003 military gas/electric residential HVAC units were converted to GSHPs. "Summer electrical peak demand were reduced by 7.5 MW, a 43 % reduction equivalent to a decrease of nearly 2 kW per residence" [4].

Residential markets

Residential markets in the US will grow as a result of increased energy costs and tax incentives. U.S. average winter fuel expenditures are projected by the U.S. Energy Information Agency to increase from 16 % to 50 % depending on fuel choice and severity of the weather. Tax incentives are being offered in some states in the U.S. where rebates are given to developers if demonstrated energy reductions in the 30 % to 50 % range are made as measured by 2003 International Energy Conservation Code®. Zero Energy Buildings (ZEB) that have been constructed in the US use GSHPs for the HVAC system [5].

Legislative issues

The GSHP industry needs to be given whatever incentives and/or credits that have been written into legislation for the other renewable technologies. The GSHP technology needs to be included by the US Federal government as a renewable form of energy. Without this acknowledgement, a whole host of opportunities are denied this vital technology.

Training

In the past, electric utilities provided training support though the IGSHPA. With electric deregulation (or the threat of), training is now the responsibility of the professional engineer for commercial work and the distributor/dealer/contractor for residences and small commercial units where the owner does not require or seek the services of a professional engineer.

Training for additional installers and designers must be made available. The existing **IGSHPA Accredited Installer** course must be made available in such a manner that those interested in entering this field can be made aware of the opportunities without a large upfront expense. The present 20 hour course has been offered formally over the past 15 years in the US and more recently in Canada, Asia and Europe. To date over 8,000 installers in 22 countries have been trained as accredited installers.

A **Certified GeoExchanger (Geothermal) Designer** course has been developed and offered for professional engineers, architects, installers and contractors who need an extensive knowledge and certification for design of GSHP commercial and residential buildings and systems. The certification is a partnership with the Geothermal Heat Pump Consortium (GHPC) and the Association of Energy Engineers (AEE). Currently, IGSHPA has trained 299 engineering and architect designers.

A **Train-the-Trainer** program was developed to train professionals with industry experience, vocational HVAC adult instructors and university professionals to teach the installation of GSHP systems. At present, the IGSHPA has trained 196 trainers internationally.

The above training curriculum is to supplement and not replace any existing training programs. These GSHP training programs will need to be deployed in conjunction with the existing infrastructure. In the US, the existing energy outreach (extension) service, vocational schools and universities will be engaged to achieve the appropriate deployment of trained professionals in concert with the anticipated market development. Training materials must be shared internationally and training must become locally available by local, native-speaking and technology-experienced trainers. Professional organizations from around the world must develop reciprocal agreements in the development of installation standards and design methodologies. Training will make use of electronic media facilitating repaid and inexpensive deployment.

GSHP applications

The range of applications and thermal capacities has become large. School buildings with thermal cooling loads ranging from 372 to 3517 kW have been installed in Texas [6] with reduced operating costs of 60% when compared with conventional HVAC systems. This study compared six GSHPs with seven conventional systems. First cost comparisons for all thirteen systems are presented with some geothermal systems having a lower installed cost.

Thermal load networking using GSHPs increases overall system efficiency by combining or adding thermal loads. For example in a service center (Figure 1), heat from refrigerated display cases, ice makers, building HVAC loads are networked into a common ground heat exchanger that ultimately provide heated water for the automobile car wash and pavement ice melting. In another application [7] connecting several large building HVAC loads, food preservation refrigeration loads from a grocery store provides heat via a ground heat exchanger to a nearby gambling casino and an array of greenhouses used for food production. Excess heat in the system is discharged in lake loops with heat exchanger of the type shown in Figure 2. Lake loops as large as 3,500 kW have been fabricated and are especially important in rejecting large cooling loads efficiently.

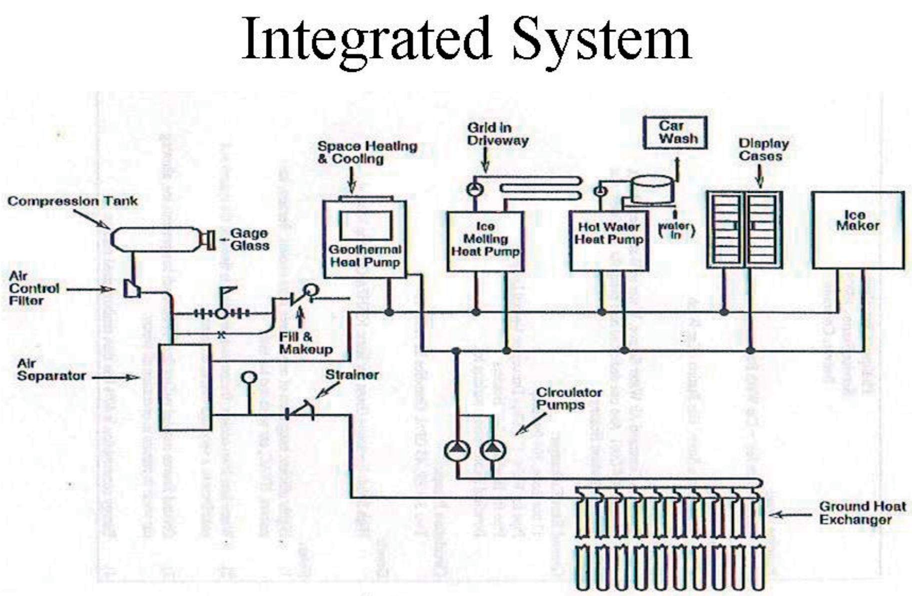

Figure 1: Integrated or Load Networking Using GSHP System

Ground heat exchanger piping systems

Figure 3 shows a large ground heat exchanger header vault which allows parallel piping systems to be connected exterior to a building. The pipe system consists of thermally- heat-fused high-density polyethylene, shut off valves, pressure and temperature sensing ports and air vents. The illustration shows the quality and professionalism which contractors have brought to this technology.

Photo: courtesy of Lane Brown, Geothermal Designs Associates, Inc. Fort Wayne, Indiana – Plastic pipe coils fabricated as a pond loop

Copper pond loop constructed and installed on the golf course in Oklahoma - 2005

Stainless Steel Plate Heat Exchanger Photograph supplied by AWEB Supply – Baton Rouge, Louisiana
140 kW preassembled pond/lake heat exchanger bank

Figure 2: Three photos

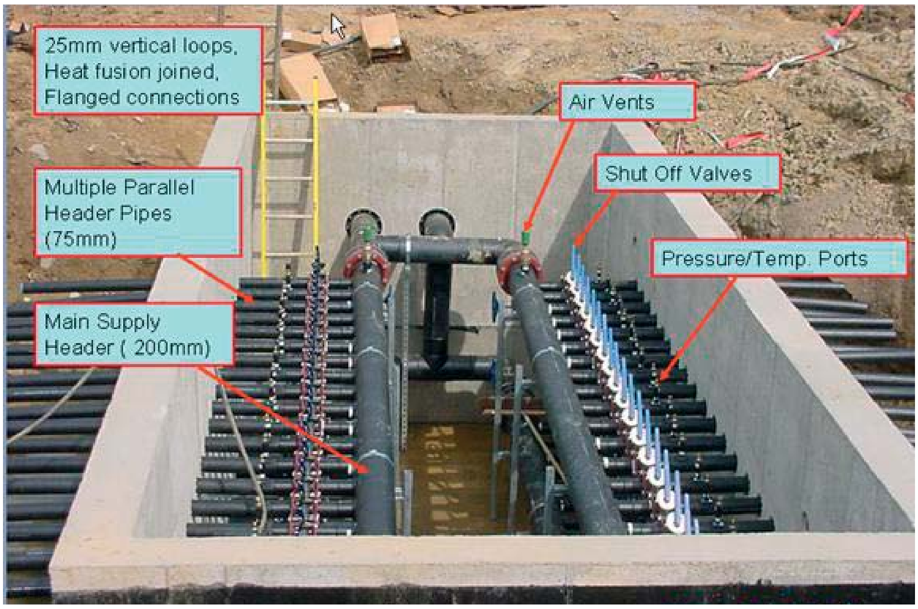

Figure 3: Piping Systems of a Field Fabricated Header Vault. Photo courtesy of Greg Wells

Financing issues and market development

Financing issues are being addressed to determine if these issues are impeding increased growth. The simple payback period is from three to five years for residences and in some commercial school systems [6] the GSHP has installed costs equal to or less than a conventional cooling tower/boiler system. Government guaranteed loans and tax credits comparable to other renewable technology benefits are being considered.

The role of electric utilities has changed dramatically in the past ten years and adjustments to technology promotion and utility financing are being evaluated. Promotion programs are highly dependent on specific utilities. Deregulation of the electric utilities in the US has curtailed some very active promotion programs of the past. Some electric utilities give special rates to GSHP systems if they can show their shareholders a positive balance sheet.

Federal government role
Through the use of Energy Savings Performance Contracts (ESPC) and Utility Energy Service Contracts (UESC), agencies of the U.S. Federal government can use private funding to implement GSHP projects at their sites. Such alternative funding has been used to install GSHPs in a wide variety of federal facilities both within the United States and around the world.

One question seems to be how aggressive should the federal government be in demonstrating the technology to the public. The general public must be made aware of the favorable attributes of GSHPs without appearing to be favoring one technology over another. The only way out of this dilemma is to rate technologies on a performance basis.

Conclusions

The ground source industry in the US has grown steadily, with a 2005 anticipated rate approaching 20%. The strength of the industry can be gauged by the following:

- Research in heat pump technology is progressing worldwide and improvements are certain.
- Plastic pipe technology for ground heat exchangers is well-developed and proven. Pipe joining methods using thermal welding is a major attribute.
- Drilling and excavating is a well-developed industry around the world
- Training programs are in place and are being implemented worldwide and collaboration among countries is excellent.
- The international community is in agreement on the validity of the GSHP technology and its contribution to world energy needs. See Halozan [8]
- Energy pricing is uncertain, but it is going up and conservation must be aggressively pursued.

GSHPs have had many technical leaders and enough entrepreneurial leaders to bring this technology to a recognized level, but far from its potential. Government leadership takes different paths among those countries involved in the GSHP industry.

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Very efficient school with ground source heat pump system in a cold climate

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In 2003, one of the largest School Boards located on the south shore of Montreal, in collaboration with a well known consulting engineering firm and Hydro-Quebec's Energy Utilization Service and LTE Laboratory, constructed a new all-electric school with the intent of becoming a "green" and very energy-efficient building in the context of a cold climate. An indirect, closed-loop ground source heat pump system with a vertical ground heat exchanger, exhaust air and solar energy heat recovery and advanced control strategies was constructed at the DU TOURNANT school. The main characteristic of this GSHP system is its simplicity in terms of design, which minimizes construction and maintenance costs in addition to providing some of the well-known advantages of institutional GSHP systems such as a smaller plant room, indoor location of equipment, lack of noise and outdoor disturbances, and longer technical life of the heat pumps versus traditional roof-top units.

Introduction

As for most renewable energy concepts, ground-source heat pump (GSHP) systems make use of the solar energy stored in the Earth's crust, and are attractive alternatives for heating and cooling buildings in cold climates. These systems offer opportunities to save additional energy since the heat recovered from zones requiring cooling can be transferred to zones with simultaneous heating demands; they also offer the possibility of using other free, inexhaustible and ecological energy such as solar and exhaust air heat [1]. Nowadays, the main issue in regards to such concepts concerns optimising their mechanical design and control strategies in order to overcome any technical barriers, reduce capital costs and thus increase their acceptance on the market.

System Configuration

The new two-storey school (2 682 m^2 total floor area) with 220 students has a decentralized, indirect GSHP system. It is an all-electric HVAC system that uses electricity at reasonable costs - costs that are more stable and foreseeable in Canada than the cost

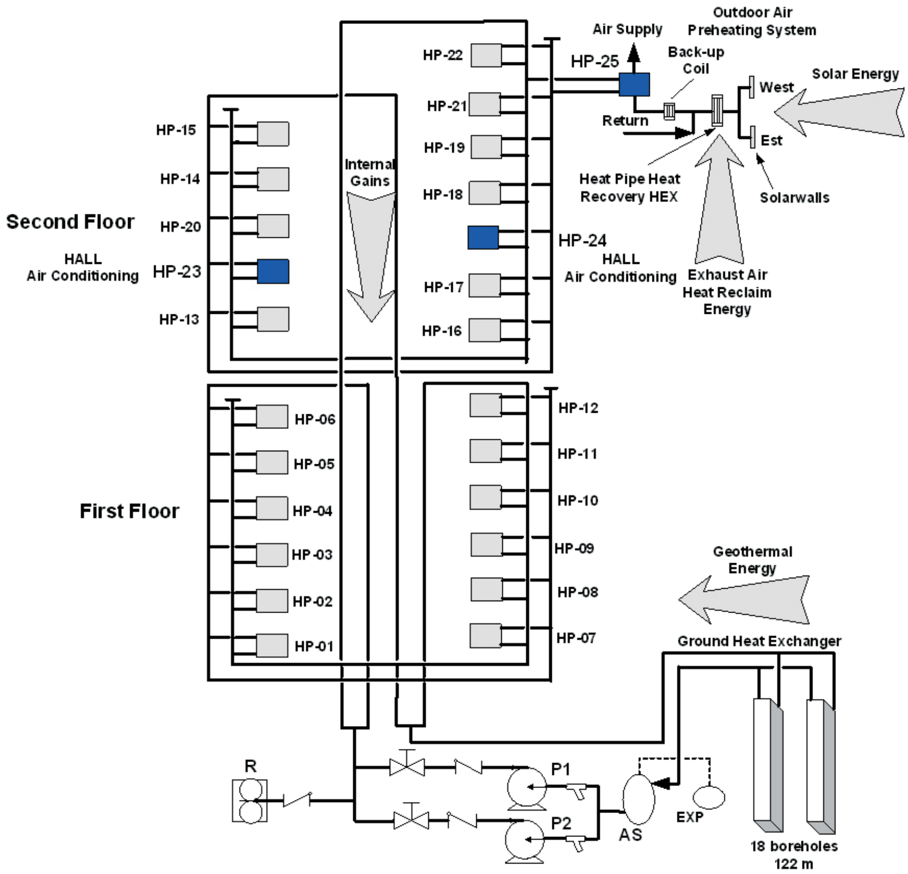

Figure 1 – Configuration of the simple GSHP system at DU TOURNANT School HP: heat pump; R: refilling receiver; P: circulating pump; AS – air separator; EXP – expansion tank

of fossil fuels. This particular situation reduces CO_2 emissions because no combustion equipment is used. Moreover, an improved centralized control strategy, including network controls, barometric pressure sensors, lower settings depending on building occupancy, occupancy detectors and natural light and indoor CO_2 concentration sensors contribute to the success of this application. The system makes use of solar energy by direct recovery through passive solar walls for preheating the make-up fresh air. A 110 kW back-up electrical coil covers the building's heating demand peaks, but the system has no means of rejecting any excess heat (e.g. such as a cooling tower or some other means). A pump station circulates the geothermal fluid (25% by weight methanol-water brine) through the inversed closed loop, which is connected to 25 water-to-air heat pumps (2.6 to 35 kW), to provide a nominal cooling capacity of 204 kW (Figure 1). Two 17.5 kW heat pumps (HP-23 and HP-24) supply the main entrance hall of the building, while a 35 kW heat pump (HP-25) acts as the last stage of the outdoor fresh air conditioning. The ground HEX is comprised of 18 vertical 11/4'' ID U-tubes installed in 150 mm boreholes of 122 m in depth each. A central Direct Digital Control system is equipped with 28 controllers mounted in a network in keeping with BACnet Standards, accessed by the operator on the Internet using ORCAview communications software.

Make-Up Air Conditioning

In the first phase, a passive solar wall located on the east side of the building (51 m^2) and another on the west side (40 m^2) preheat the outdoor fresh air. A heat pipe heat exchanger then preheats the fresh air in the second stage with the energy recovered from the exhaust air. After being mixed with the building's return air, the make-up fresh air is heated again, if necessary, by the electrical back-up coil (Figure 1). The fourth and last preheating phase involves a brine-to-air heat pump with two identical 17.5 kW compressors and associated blowers. Finally, a 30 kW electric humidifier ensures the air setting humidity in the winter.

Operating Profile

The simplicity of the GSHP configuration has stimulated the system's operators to adopt a simple and comprehensive control strategy. Thus the room temperature in occupied spaces is normally maintained at 22 °C in the daytime during the week and at 18 °C on weekends. During the night, these temperatures are reduced by 1 °C to 3 °C, depending on the outdoor temperature [3]. The fresh air make-up is modulated according to the barometric pressure and is shut off during the night and at weekends. In the morning, the control system opts for the solar wall on the east side of the building and, in the afternoon, for the solar wall on the west side. If there is no need for heating, the system chooses the solar wall located where the sun isn't shining. The exhaust fans operate upon demand to maintain an acceptable level of CO_2, and are shut down during the night and at weekends. The brine circulating pump operates at constant speed and on a continuous basis during the normal hours when the school is occupied, and only if at least one of the heat pumps is in operation during the night or on the weekend.

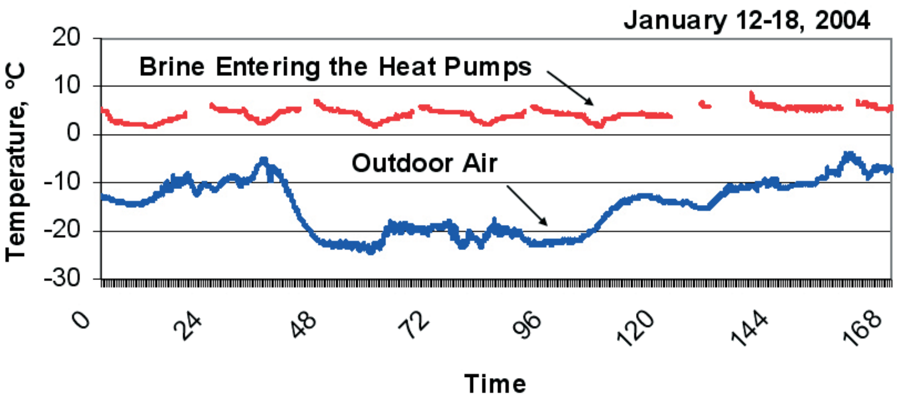

Figure 2 – Daily Average Temperatures of the Brine Entering Heat Pumps vs. Simultaneous Outdoor Air Temperatures – typical very cold week

The annual use rate of the geothermal system (43.2%) was a direct result of the hours during which the building is occupied (from 9am to 5pm), including vacation periods and statutory holidays, and of the control strategy, which generally shuts down the system during the night and at weekends. The geothermal system therefore has run in the heating mode for 28.7 % of the time, and for only 14.5 % of the time in the cooling mode. The average temperature of the brine entering the heat pumps (heat source) varied between 15 °C in the summer and a minimum of 0 °C in the winter, where the corresponding average ambient temperatures were 32 °C and -25°C respectively. Figure 2 shows the brine temperature entering the closed loop versus the simultaneous outdoor temperatures during a typical very cold winter week. These data prove that the ground HEX was properly designed in relation to the system's nominal cooling charge (10.7 m/kW). In these conditions, the heat pump's seasonal coefficient of performance, defined as the ratio between the total heating capacity expressed in kWh and the total electrical energy input also expressed in kWh (SCOP) was approximately 4 (heating mode), while the seasonal energy efficiency ratio, defined as the ratio between the total seasonal cooling capacity expressed in BTU/H and the total seasonal electrical energy consumed

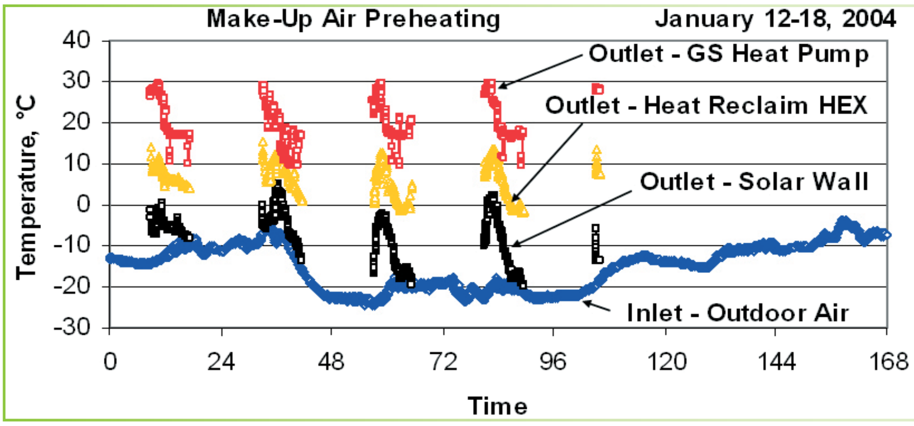

Figure 3 – Example of Make-Up Air Preheating Temperature Profiles during a Typical Cold Week HEX – heat exchanger; GS – ground-source

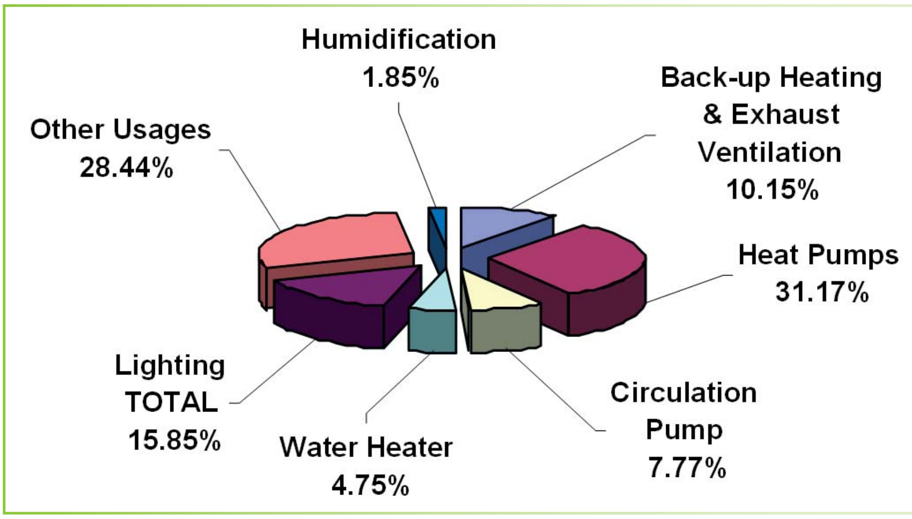

Figure 4 – The building's annual energy consumption distribution

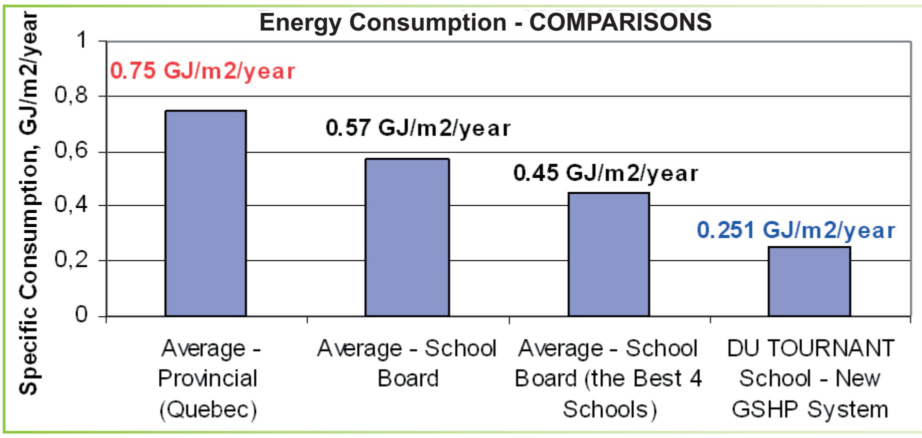

Figure 5 – Comparison of annual specific energy consumptions

expressed in kWh (SEER) was 18.3 (cooling mode).

Another interesting result consists of the fact that fresh air preheating was met almost completely by heat recovery during the winter in the context of a cold climate (Figure 3). The solar walls provided an average of 6 kW in thermal power, with temperature increasing of up to 22 °C during the winter's maximum solar gains. The heat pipe heat recovery HEX then provided around 7 kW (seasonal average), and the fresh air temperature increased, on average, by an additional 10 °C during the winter. The electrical back-up coil was energized at only 5% of its maximum capacity for only 1.45% of the time (123 hours/year).

Lastly, the fresh air heat pump (HP-25) was in operation 5.4 % of the time (471 hours/year), often at only 50 % of its installed capacity. This heat pump, as well as the heat pipe heat exchanger, also operated in the cooling mode during the summer.

Construction Costs

The construction cost of the geothermal system including solar walls, controls, labour, administration fees and the general contractor's profits (5.2 %) was US\$175/m^2, while the specific drilling costs, including the ground HEX, as well as the geothermal fluid and accessories, were US\$42/m2, which represents the average provincial costs (Quebec). The cost of building an equivalent conventional CVC system (roof-top heating and cooling units) was also extensively evaluated, and would have been 26.8 % lower than the cost of the actual geothermal system [2, 4]. However, this difference in construction costs is largely compensated by the significant annual energy savings.

Energy Performances and Savings

During the first 12-month period of operation (2002 – 2003), the 25 geothermal heat pumps consumed 31.2 % of the building's total annual electrical energy (Figure 4). Indoor and outdoor lighting (15.8 %) was in second place, and the back-up heating (fresh air preheating coil and peripheral electrical skirting boards) and the waste air ventilation system came in third (10.15 %). Lastly, the brine system's circulation pump represented only 7.8 % of the total energy consumed by the building, in spite of the fact that this pump was over-designed by about 20 %.

These energy performances are rather exceptional, since the school's annual specific energy consumption was 0.251 $GJ/m^2/year$, against the average annual specific energy consumption of schools in Quebec (Canada) of 0.75 $GJ/m^2/year$ (source: Quebec Ministry of Education). This represents a reduction of 67 % (Figure 5). Compared to four of the best schools in the same School Board area, equipped with traditional closed-loop water heat pumps, electrical back-up boilers and evaporative cooling towers, the new system has demonstrated a 44% decrease in annual specific energy consumption.

Taking into consideration that approximately 75% of the energy saved by the new GSHP system is generally supplied by natural gas (0.36 US$/$m^3$ – 2004), which is commonly used for heating in conventional schools in Canada, the total savings in energy costs were established at US$17 680/year (2004). Consequently, the simple pay-back period of the additional investment in the actual geothermal HVAC system, as compared to the provincial average, is estimated to be 7.4 years.

Conclusions

The vertical GSHP system in the new school near Montreal distinguishes itself by its exceptional simplicity and very efficient controls based on a day/night and week/weekend strategy, and by the fact that it ensures a uniform level of comfort and a high level of consistency in the building's power demand. With a specific annual energy consumption of 0.251 $GJ/m^2/year$, which is 67 % lower than Quebec's provincial average, and a simple pay-back period of 7.4 years (without subsidies), DU TOURNANT school certainly owns the most efficient secondary school HVAC system in Canada.

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Results of a two-year field trial in Germany confirm high efficiency of heat pumps

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Introduction

The field trial was conducted by E.ON Energie and a number of partner companies during the 2001/2002 and 2002/2003 winter heating seasons and involved 29 heat pumps – mainly of the ground-source type – and one low-temperature gas-fired boiler [1]. Because data capture and system installation was not performed correctly for all of the heat pumps, the following diagrams refer to only some of the systems in the trial. The data from the second, somewhat colder, heating season that are presented in this paper confirm the findings from the first heating season. The average number of heating degree-days across all tested sites was approximately 3,600 Kelvin-days per annum (Kd/a). However, despite this, the average heat consumption actually measured was significantly higher than the theoretical value calculated using the methods of calculation specified in Germany for new building projects by the Energy Conservation Law (EnEV).

The objectives of the field trial were as follows:

- To assess the current state of the art in heat pump technology and its reliability.
- To achieve cost savings by simplifying heat pump system design.
- To determine energy efficiency and CO2 savings.
- To calculate the economic efficiency of the technology using test measurements.

Measurement setup

The measurement setup (see Fig. 1) was designed to allow as comprehensive a measurement of the energy flows as possible, thereby providing a sound basis for verifying the readings recorded. The heat absorbed from the surrounding area, power consumption, and the heat transferred to the building's hot water and space heating systems were measured simultaneously. The total power consumption of the heat pump and circulation pumps were measured separately from the power consumption of the refrigerant compressor and the electric supplementary heating system. This enabled us to gauge the efficiency of the actual primary heating system (compressor) on its own, i.e. without auxiliary energy and supplementary heating; and to determine the percentage of total heating energy consumption constituted by the electric supplementary heating system. The readings were recorded at 10-minute intervals, allowing a limited form of dynamic analysis.

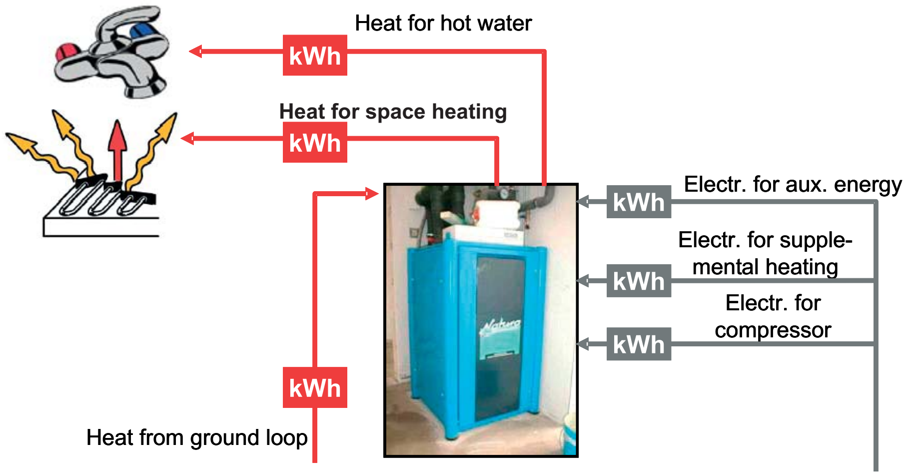


Figure 1: Measurement set-up for ground-source heat pumps, showing the various energy flows on both the heat and the electricity side

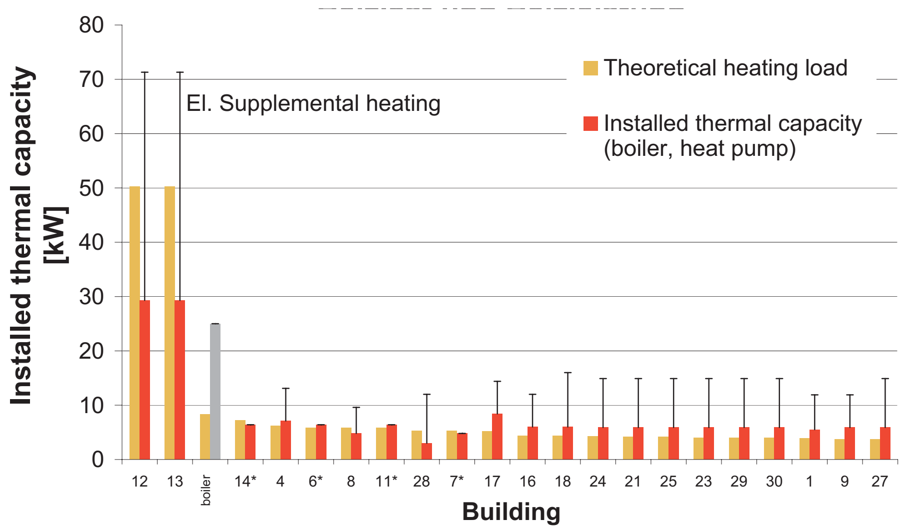
Interpretation

The trial showed that the 5 – 6 kW installed thermal capacity of the heat pumps used is sufficient to supply the entire theoretical heating loads of the single-family houses in the trial, which, using the DIN calculation methods as required by the building regulations, was determined as being approximately 5 kW (see Fig. 2 and Table 1). With an installed capacity of around 6 kW, the electric supplementary heating system effectively increases the available thermal capacity to twice the theoretical heating load. Almost all of the heat pumps in use in single-family homes in the trial were sufficient to supply both water heating and space heating requirements. In the apartment buildings included in the test (buildings 12 and 13 in the diagrams), the heat pumps' installed capacity was about 40 % less than the theoretical heating load as calculated in accordance with the DIN methods. Of particular interest in this regard were the recorded peak-load electricity requirements of the supplementary heating system. At 25 kW, the installed thermal capacity of the low-temperature boiler unit in the test is roughly three times the theoretical heating load.

The diagrams that follow show the findings for the second heating season, the winter of 2002/2003. These confirm the findings of the first heating season. An analysis of the second, colder, heating season showed that most of the heat pumps were operated at full load for between 2,000 and 3,000 hours (see Fig. 3). In the apartment buildings (buildings 12 and 13 in the diagrams), the heat pumps even ran for as many as 4,000 – 4,500 full-load operating hours. However, despite the high number of full-load operating hours recorded in these buildings, and indeed all the others, the energy consumed by the electrical supplementary heating system constituted only a very small percentage of the total heating energy consumption. For example, during the 2002/2003 heating season, the ratio remained below 5 %, even when the heat pump system design capacity was only 60 % of the theoretical heating load (as in buildings 12 and 13, figure 4). In other words, in apartment buildings, a heat pump design capacity of 60 % of the theoretical heating load results in only minimal use of electrical supplementary heating, and this despite the fact that the total heating consumption measured for these buildings over the heating season was as much as 60 % - 80 % higher than the theoretical value calculated in accordance with the Energy Conservation Law (EnEV).

Environmental impact

A comparison between the heat pumps used in the trial and state-of-the-art boiler plants [3] shows that heat pumps consume between 25 % and 50 % less primary energy per kWh of useful heat supplied (see Figs. 5 and 6). This is because heat pumps have a high annual coefficient of performance. The primary energy is the sum of non renewable energy demand from the ground source well to the household to produce 1 kWh of heat. In Germany, the ratio of primary energy demand per kWh heat produced by new low-temperature or condensing boilers from oil or natural gas is 1.2 - 1.4. On average, the heat pump plants in the trial require 0.77 units of primary energy (including auxiliary energy for control systems and circulation pumps) to produce one unit of usable thermal energy. Under



* No electrical supplemental heating

Figure 2: Comparison of the theoretical heating load (calculated in accordance with the DIN methods mandated by statute in Germany) with the installed thermal capacity of the heat pumps and of the electrical supplementary heating system

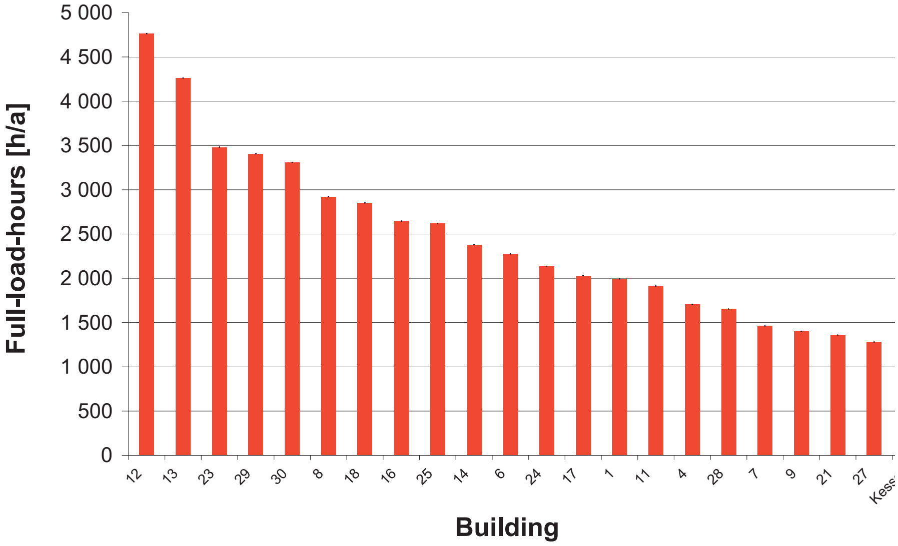


Figure 3: Full-load operating hours of the heat pumps

Table 1: Energy data for the buildings and plants in the trial, measurement results as annual mean values

		Brine Heat Pumps														Other Systems		
Buildings		6	7	8	9	11	14	16	17	21	23	25	27	29	30	1	12	13
Type		SE	SM	SE	SE	SE	Flat	SE	S	SE	SE	SE	SE	S	SE	S	M	M
Heated Area	m²	141	136	141	131	141	165	140	173	137	129	137	131	153	129	128	1 463	1 463
Calculated Heat Demand	kWh/a	7 353	5 787	7 353	7 411	7 353	13 194	6 620	9 223	8 618	6 418	8 618	7 411	8 656	6 418	6 348	64 900	64 900
Calculated Tap Water Demand	kWh/a	1 768	1 696	1 768	1 633	1 768	2 058	1 752	2 157	1 715	1 612	1 715	1 633	1 907	1 612	1 606	18 288	18 288
Calculated Heating and Tap Water Demand	kWh/a	9 121	7 483	9 121	9 044	9 121	15 252	8 372	19 915	10 333	8 030	10 333	9 044	10 563	8 030	7 954	83 188	83 188
Specific Calculated Demand	kWh/m² a	65	55	65	69	65	93	60	115	75	62	75	69	69	62	62	57	57
Heat Pump System																		
Utilisation (H=Heating, T=Tap Water)		H+T	H+T	H+T	H+T	H+T	H	H+T	H+T	H+T	H+T	H+T	H+T	H+T	H+T	H+T	H	H
Heat Pump Type		B	B	B	B	B	B	B	B	B	B	B	B	B	B	A	W	W
Theoretical Heating Load	kW	5,9	5,3	5,9	3,7	5,9	7,2	4,4	5,2	4,2	4,0	4,2	3,7	4,0	4,0	3,9	50,3	50,3
Capacity Heat Pump Installed	kW_{th}	6,4	4,8	4,8	5,9	6,4	6,4	6,0	8,4	5,9	5,9	5,9	5,9	5,9	5,9	5,5	29,3	29,3
El. Supplemental Heating Installed	kW_{th}	-	-	4,8	9,0	-	-	6,0	6,0	9,0	9,0	9,0	9,0	9,0	9,0	6,4	6,0	6,0
Measurements																		
Measured Heating Demand	kWh/a	11 391	5 209	9 688	7 053	7 052	6)14 671	14 653	14 858	6 106	16 604	12 345	5 645	16 221	15 755	8 125	127 620	111 520
Measured Tap Water Demand	kWh/a	2 051	1 610	2 854	713	4 654	-	578	1 416	644	1 436	1 927	762	2 501	2 513	2 843	-	-
Measured Total Demand	kWh/a	13 442	6 819	12 542	7 766	11 706	14 671	15 231	16 274	6 750	18 040	14 272	6 407	18 722	18 268	10 968	127 620	111 520
COP_{HP}	-	3,91	4,23	4,01	-	3,87	4,82	4,66	4,08	-	-	-	-	-	-	3,55	4,72	4,71
$COP_{HP,Aux}$	-	3,05	3,21	3,26	4,27	3,41	3,79	3,92	3,28	3,58	3,92	3,70	3,33	3,74	3,73	1) 2,93	3,51	3,48
$COP_{HP,Aux,Suppl.}$	-	3,05	3,21	3,26	4,27	3,41	3,79	3,92	3,28	3,56	3,92	3,70	3,27	3,74	3,62	1) 2,73	3,14	3,17
e_p 2)	-	0,87	0,82	0,81	0,62	0,78	0,70	0,68	0,81	0,74	0,68	0,72	0,81	0,71	0,73	0,97	0,84	0,84

1) Without electricity for ventilation system and heat exchanger (Conservative assumption)
2) Primary energy factor Germany without renewable 2,65 kWhPE/kWhel
S: Single house, SE: Single houses at the end of a row;
SM: Single houses in the middle of a row; M: Multi family houses

B Brine heat pump
W Ground water heat pump
A Compact air heat pump with ventilation sys.

COP_{HP} COP of compressor only
$COP_{HP,Aux}$ COP of compressor and auxiliary energy (control system, pumps)
$COP_{HP,Aux,Suppl}$ Total COP of compressor, auxiliary energy and el. supplement heating system

Germany's Energy Conservation Law (EnEV), this measure of efficiency is known as the plant-specific primary energy factor, and is used to compare the efficiency of different heating systems. The equivalent factors for state-of-the-art low-temperature and condensing boilers are approximately 1.4 and 1.25 respectively (including electricity required for auxiliary energy).

The results for CO_2 emission savings were similarly positive. Compared with the latest oil-fired boiler units, heat pumps offer CO_2 savings of as much as 50 %. This is because oil-fired systems have a higher specific CO_2 output.

Costs

Of particular interest here are the total costs of the heat pump plants tested. A basic requirement for inclusion in the trial was that the heat pumps tested should be as cost-effective as possible. For this reason, none of the systems tested featured a buffer tank; the only water storage elements used in the systems tested were the hot water tanks used for household hot water supply.

The trial compared a number of price quotations from heating systems installers in order to arrive at a reliable assessment of the difference in acquisition cost between the heat pump plants installed and state-of-the-art boiler plants. This revealed that the heat pump plants cost between €4,000 and €5,000 more. This difference, which was reimbursed by a grant to the households participating in the trial, should be regarded as the absolute upper limit of the cost difference between the two types of systems. However, because the heat pump plants consume around 50 % less energy than the boiler plants, their total costs – that is, including operating costs over the plants' 15–20 year service life – were generally shown to be lower. Heat pumps that are installed in new buildings can therefore deliver significant CO_2 savings without incurring additional costs.

At present, building owners and developers in Germany are still wary of using heat pumps owing to the higher capital expenditure involved. Unfortunately, this ignores the fact that, in Germany, the energy efficiency gains

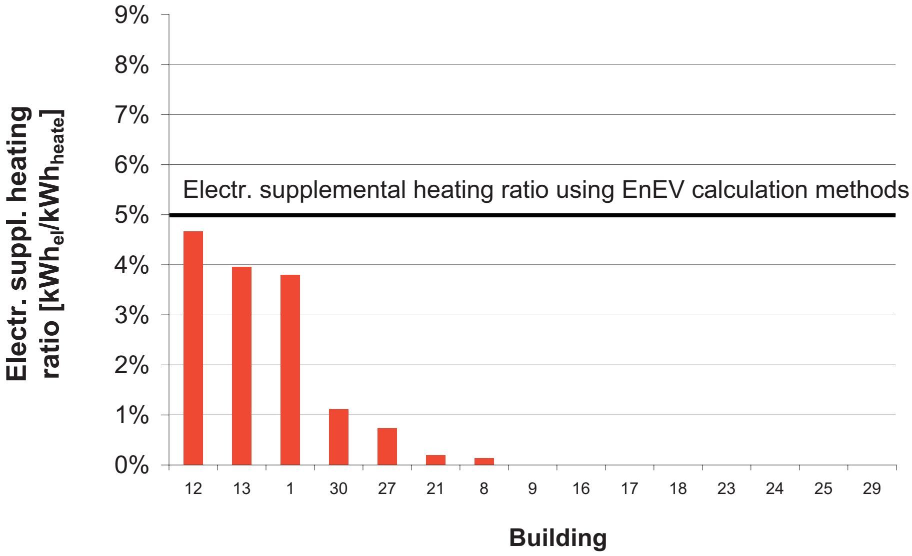


Figure 4: Electrical supplementary heating as a percentage of total annual heating requirements, with theoretical percentage calculated in accordance with Germany's statute-mandated (EnEV) methods

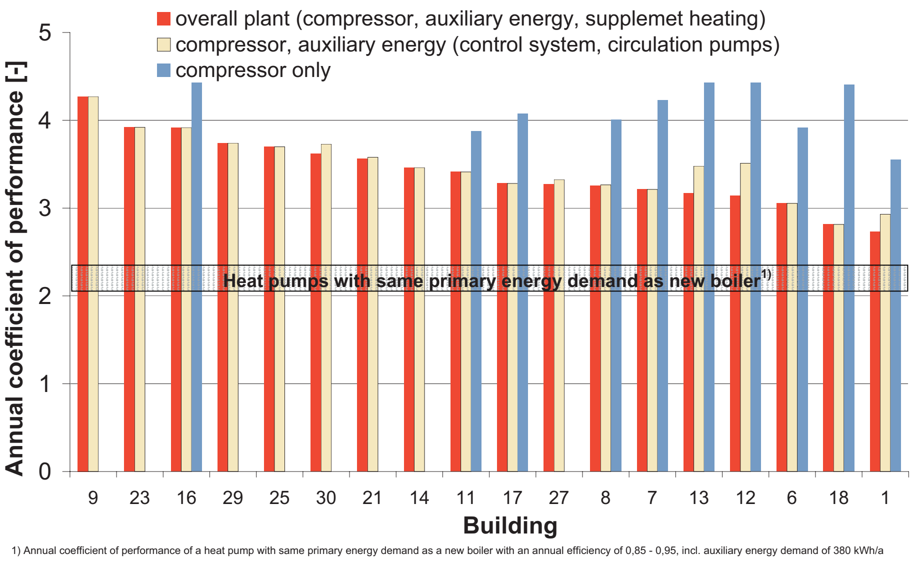


Figure 5: Annual heat pump coefficient of performance (COP) measurements compared to theoretical heat pump system with same primary energy consumption as a modern new boiler (low-temperature and condensing)

of heat pumps result in less stringent thermal insulation requirements and hence a reduction in insulation costs that can compensate for the extra capital expenditure on the heat pumps. Heating costs can therefore be reduced without the need for additional investment.

Summary

The operating characteristics of the heat pump plants trialed show that, in apartment buildings, units with an installed capacity of no more than 60 % of the theoretical heating load are still cost-effective, because the energy consumption for the supplemental heater amounts to less than 5 % of the total heating energy consumption in a year. In the case of detached, single-family housing, an installed capacity that matches the building's heating load will cover both space heating and hot water heating requirements.

The heat pump plants trialled are very energy-efficient (with coefficients of performance ranging from 3.0 to 3.8 (including auxiliary energy for the heat pump plant, heat circulation pumps, and supplementary heating). This means that they consume between 25 % and 50 % less primary energy than even the latest, state-of-the-art boiler plants.

Measured at today's rates, the energy costs associated with heat pumps are around 50 % less than those of boiler plants. This means that, although the capital cost is somewhere between €4,000 and €5,000 higher, the total cost for new residential construction projects is generally lower than that of boiler plants. Furthermore, because of their higher energy efficiency, in Germany the additional capital expenditure can be compensated by cost savings in building insulation.

Heat pump technology is a particularly attractive solution for those sparsely-populated regions in Germany that are not connected to district heating or natural gas pipeline networks, thanks to the country's blanket electricity grid and the technology's lower CO_2 emissions as compared with the oil-fired boiler systems that are currently being used.

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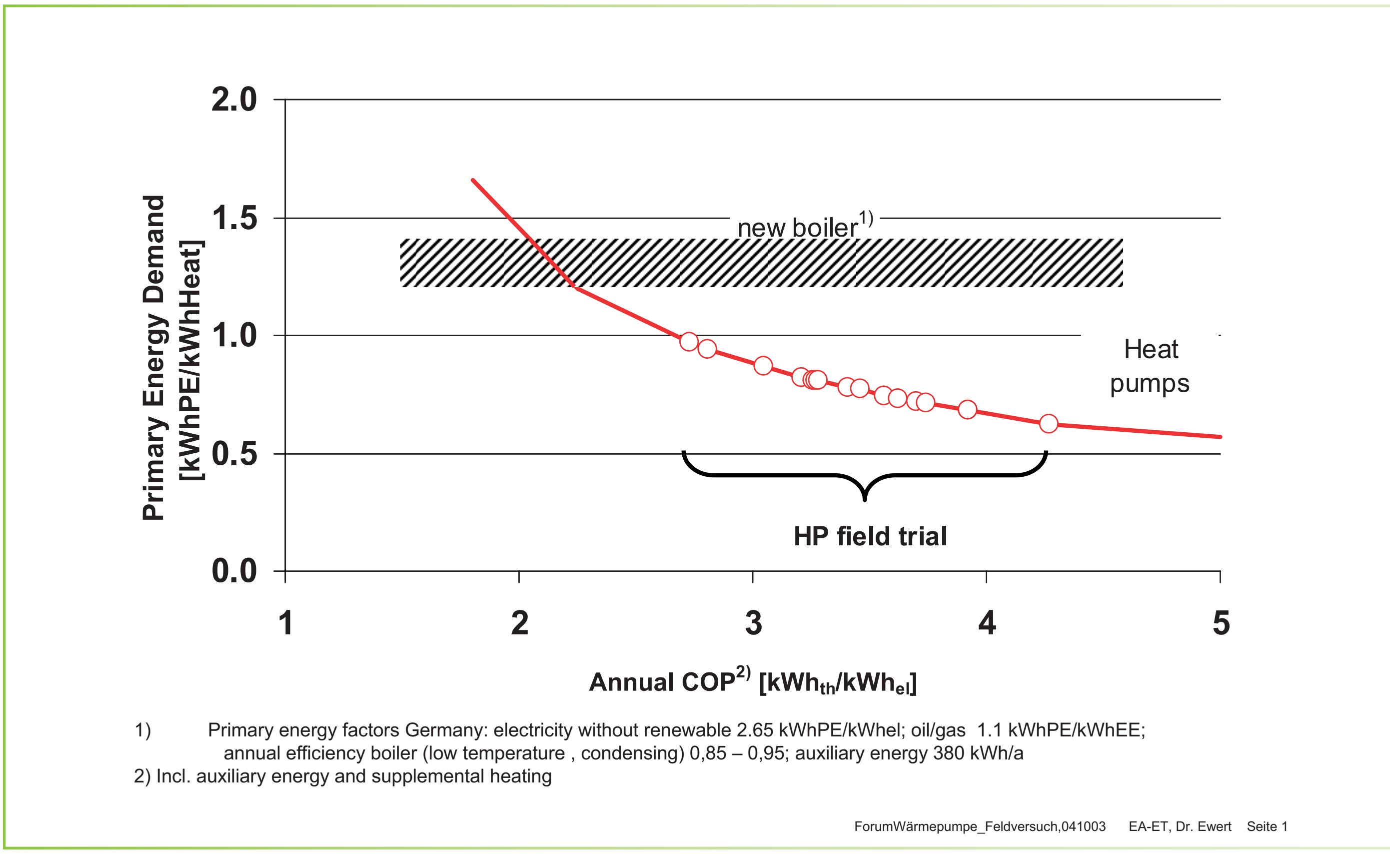

Figure 6: Comparison of heat pump plant primary energy factors at various COPs (incl. auxiliary energy, heat circulation pumps and electrical supplementary heating) with those of state-of-the-art boilers

Direct-expansion ground-coupled heat pumps

Hermann Halozan, René Rieberer, Austria

Introduction

After the second oil price shock in 1979, heat pumps installed in Austria were either groundwater heat pumps for monovalent systems or outdoor air heat pumps for bivalent systems (Fig. 1). The rapid drop of the oil price in 1985, in combination with the significant reduction of Government subsidies, reduced the sales of heat pumps. Bivalent outdoor air heat pumps, in particular, were no longer competitive, while groundwater heat pumps often encountered problems with the availability of groundwater or with licensing to use groundwater. Another heat source had to be found, and this was the ground itself. (Fig. 2)

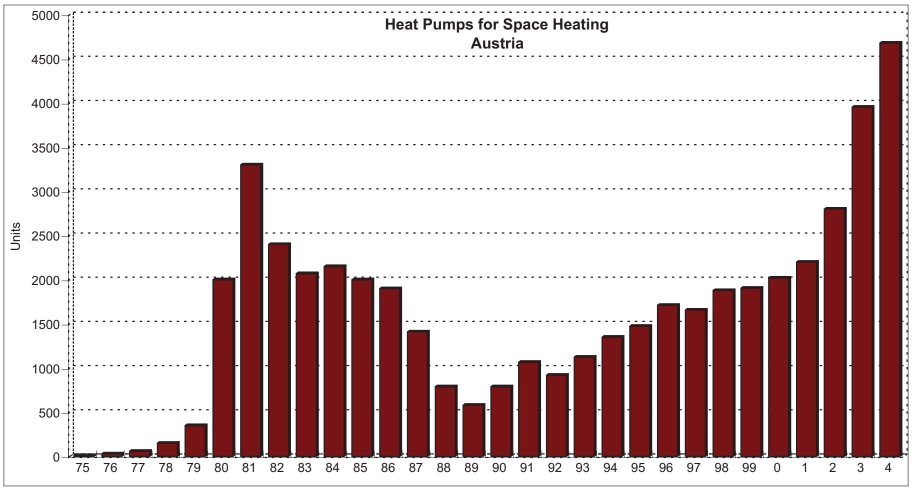

Fig. 1: Heat-only heat pump sales in Austria

The ground as a heat source/heat sink

The ground acts as a seasonal heat store. The ground coil has to be sized for both the seasonal heat extraction rate and for the specific heat extraction capacity (compare VDI 4640 [1]). These values depend on the climate, the geometry of the ground coil and the properties of the ground.

Horizontal ground coils are most commonly installed at a depth of 0.2 m below frost depth, i.e. at a depth of about 0.8 - 1.2 m. At this depth, the ground temperature changes during the year, being much higher at the end of summer than at the beginning of spring. However, as far as heat extraction is concerned, this depth offers some advantages: At the beginning of the heating season the ground has a higher temperature than the undisturbed ground temperature. During the heating season, heat extraction causes the temperature to drop below 0 °C. Frost formation around the coil increases the thermal conductivity. At the end of the heating season, when the ambient air temperature rises, natural recharging starts and heat is delivered from the surface to the coil. During the summer, the temperature at the extraction level is completely restored, with vegetation above the ground coil is hardly affected at all. The only disadvantage of such a system is the ground surface area required: up to three times the heated area.

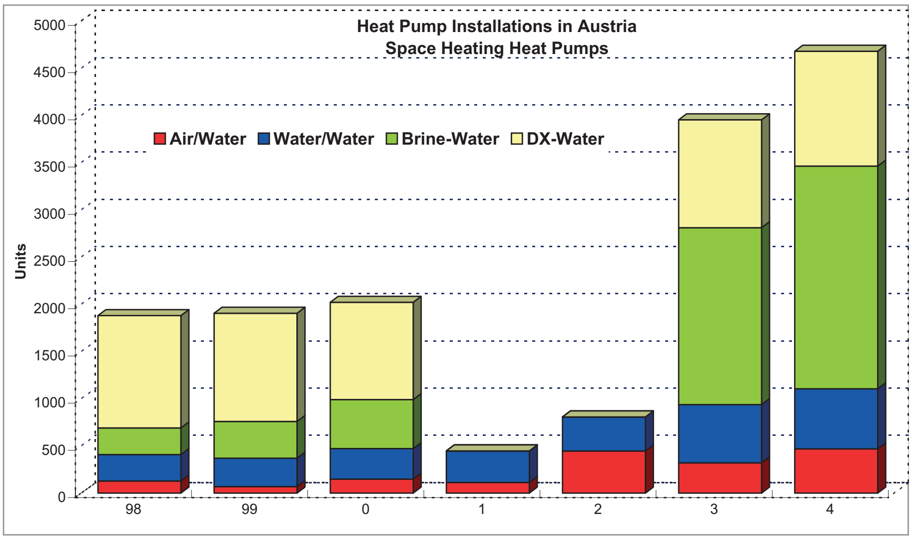

Fig. 2: Heat sources used in Austria

Vertical wells are required if the surface area available is insufficient for horizontal systems. In the case of vertical wells, two designs are possible: either shallow wells down to a depth of 20 m, or deep wells down to 200 m or more. The depth depends on the ground conditions as well as on the drilling equipment available. In the case of small systems, recharging will again happen naturally. That means that, in principle, the same surface area is necessary as for horizontal systems. An exception exists if the vertical well is installed below the groundwater table. In this case, recharging of the ground coil will mainly be done by the groundwater.

Secondary loop vs. direct expansion systems

Heat extraction/removal can be carried out in two ways, either

- by using a separate loop for heat extraction from the ground, with a secondary loop system with a circulation pump and brine as the heat carrier, or

- by installing the evaporator/condenser of the heat pump directly in the ground, known as a direct expansion (evaporation) system.

In general, secondary fluid ground source heat pumps, i.e. brine/water heat pumps, are the field of larger heat pump manufacturers, who sell their products to distributors and installers, and very often they do not know what happens with their units. Failures, which are sometimes the result of poor work by inexperienced installers, are such as undersized ground collectors, or heat distribution systems with too high supply temperatures, which are also an obstacle to achieving a high SPF.

Direct expansion systems – where the evaporator of the heat pump is buried in the ground or installed in a borehole – are a speciality of the Austrian heat pump market [2; 3]. One reason is the structure of the manufacturers: small companies that have looked for market niches in which they can be competitive, and who have developed this technology into highly efficient and reliable systems. Direct evaporation systems have some advantages over secondary circulating fluid systems:

- The elimination of a heat exchange, from the secondary fluid to the refrigerant, and also elimination of the power requirement for a circulating pump, which may become significant especially at low heat source temperatures, due to the properties of the anti-freeze solution (brine). These two effects reduce the COP and the SPF respectively.

- Additionally, heat transfer conditions of copper tubes (coated with a thin plastic film to avoid corrosion) used in direct-expansion coils are better than those of the plastic tubes used for indirect systems.

But there are also some problems to be considered:

- The refrigerant velocity in the evaporator has to be kept as low as possible in order to achieve a low pressure drop, which also reduces the evaporation temperature, but it has to be high enough to ensure oil return. To achieve this velocity and to make a sufficient mass of ground accessible, the diameter of the evaporator tubes has to be smaller than that of indirect systems; which means that the temperature drop from the ground to the tube surface is higher.

- Coils for vertical systems must be designed very carefully, in order to compensate the pressure gain in the down-comer and to guarantee oil return through the riser.

- Brazing at the site is usually necessary to connect the ground collector and the heat pump unit, thus introducing the possibility of refrigerant losses and pollution of the groundwater.

- The ground coil evaporator is much larger than the evaporator of a compact heat pump unit. The length means long run-through times and problems with the refrigerant cycle control, while the size means that the refrigerant charge increases.

These challenges have been solved by manufacturers and installers of direct evaporation systems. In new well-insulated buildings with specific heat loads below 60 W/m^2, with low-temperature floor heating systems, SPFs are between 4 and 5! The success can be recognised in the sales figures for direct expansion systems. Over the last years, while the percentage of DX systems dropped, the absolute sales figures are still rising.

Development continues. The refrigerant cycle control has been solved in different ways by keeping the evaporator coil as wet as possible and utilising the total length of the coil for evaporation, and even the problem of the smaller tube diameters has been overcome by operating the compressor on part-load, i.e. decreasing the heat flow from the ground to the coil. To ensure oil return, the unit is operated from time to time for about ten minutes with full-load, even if not be required by the heat load of the building.

An Austrian heat pump manufacturer has developed a packaged direct-evaporation heat pump using propane as the refrigerant, and intended for outdoor installation. The heat pump is prefabricated, i.e. the ground evaporator is connected, filled with the refrigerant charge required, and tested in the factory. The connection to the heating system in the building consists of the supply and the return pipe and cables for power supply and control.

An interesting development has been carried out by K. Mittermayr, who developed a heat-pipe based ground probe with CO_2 as the working fluid for vertical wells down to about 60 (100) m [4]. This self-circulating system is environmentally fully acceptable – the probe is oil-free – and it has the advantage of not requiring a circulation pump. SPFs of test installations are in the range of about 5 and higher.

Future applications of heat pumps

The building sector is characterised by two facts, i.e. new buildings have better thermal insulation, thus the heat loads are reduced significantly. The next step has to be the introduction of controlled ventilation combined with an exhaust air heat recovery system. The optimum is the combination of both: a heat exchanger and a heat pump. The exhaust air is firstly cooled down in the heat exchanger and than used as a heat source for the heat pump. Fresh air is preheated in the heat exchanger and then further heated by the heat pump. Such houses can be heated down to low outside temperatures by the ventilation system alone. The remaining heat demand can be covered by preheating the fresh air in the ground (Fig. 3). A suitable ground/air collector for a single-family house consists of about 60 m of pipe with a diameter of 0.25 m buried in the ground at a depth of about 1.5 m. Using such a collector, the air temperature will be always higher than –5 °C, even when the outdoor temperature drops below –20 °C. This preheating effect is sufficient to heat the building with the heat recovery system alone. A further improvement can be achieved by using a ground coil for avoiding frosting/defrosting losses (Fig 4).

The system SPFs achievable are in the range of 6 [5]. Due to the high thermal insulation standard and the controlled ventilation system, they provide excellent hygienic conditions as well as high comfort combined with a low energy bill.

As mentioned above, in addition to the market for new buildings, the retrofit market has to be taken into consideration, which is more difficult due to the higher supply temperatures required. But heat pumps with maximum heat pump outlet temperatures of 65 °C are already possible, using present technology with propane as the refrigerant. Designs using an economiser circuit with a scroll compressor with additional suction ports and using the ground as heat source, offer high SPFs that are competitive with conventional heating systems. Retrofitting, which was common at the beginning of the heat pump market in the 1980s, could widen the heat pump market considerably.

Conclusions

The heat pump has undergone, and is undergoing, several changes. The changes in working fluids have entailed a number of design changes. However, the efficiency today is generally better than before the changes, and it keeps rising.

The DX-system remains an interesting solution for single-family houses, provided that they are carefully designed and installed. Such systems are cost-effective and highly efficient.

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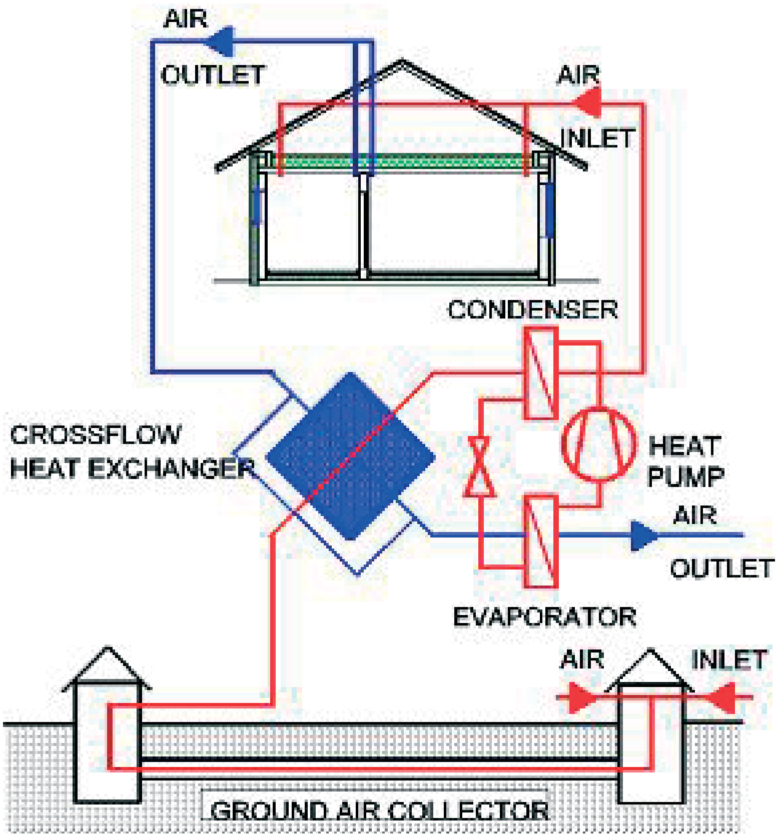

Fig. 3: Fresh air heating system with ground/air collector, heat exchanger and heat pump

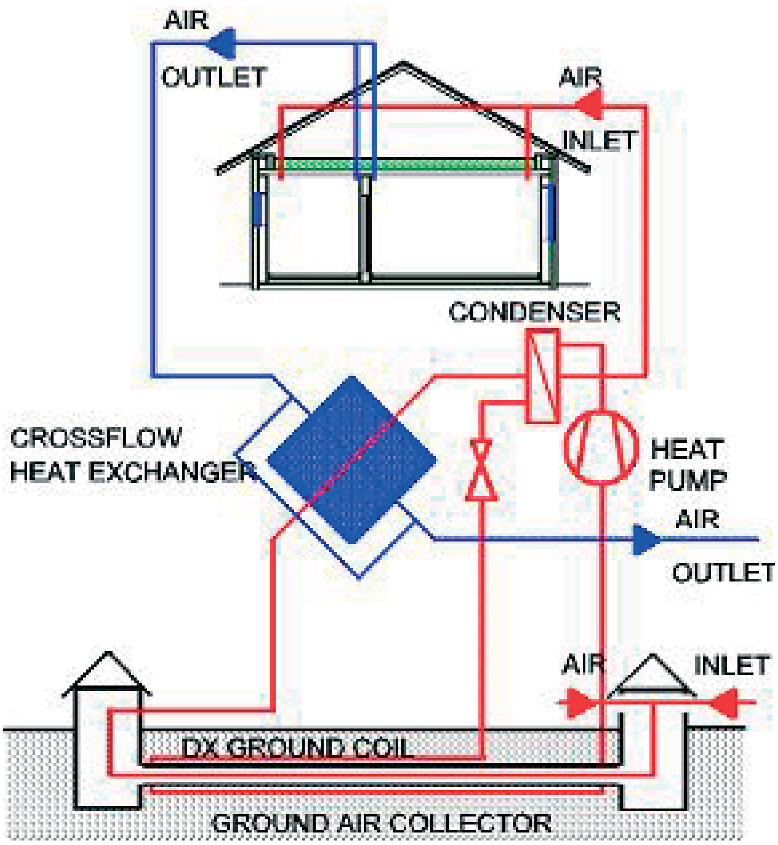

Fig. 4: Fresh air heating system with ground/air collector, heat exchanger and DX heat pump

Investigation of a ground source heat pump system for use in large and dense city areas in Japan

Ryozo Ooka, Japan

In Europe and North America, ground source heat pump (GSHP) systems have provided heat mainly for buildings or, in the early stages, for snow melting. This has not occurred in Japan, due to high excavation costs. If such systems are to be used in Japanese cities, three problem areas need to be considered: 1) reduction of the initial construction cost, (2) improvement of the performance of water source heat pumps, and (3) development of simulation methods for heat transfer in the ground. Since 2003, the authors have working on these areas, with support from the New Energy and Industrial Technology Development Organization of Japan (NEDO). This article describes the results of two years' work.

Introduction

Heat abstracted from the ground by ground source heat pump (GSHP) systems has been mainly used for the heating of buildings in Europe and North America, or a heat source for snow melting in the early stages. However, in Japan, such air-conditioning systems have not become widely established, due to such reasons as the high cost of boring for subsurface installations etc. For example, the cost of boring in Japan is about USD 100/m, as against about USD 20-30/m in the USA or northern Europe. As a result, the cost payback time of GSHP for ordinary office buildings is over 50 years.

Three working areas are important if GSHP systems are to be constructed in Japanese cities:

(1) reduction of the initial construction cost,
(2) improvement of the performance of water source heat pumps, and
(3) development of simulation methods for heat transfer in the ground.

The authors have been supported by New Energy and Industrial Technology Development Organization of Japan (NEDO) to deal with these subjects. This is a collaborative project between the University of Tokyo, Taisei Corporation and Zeneral Heat Pump Industry Co. Ltd

Foundation pile heat exchangers

In order to reduce the construction cost, the foundation piles of a building have been used as underground heat exchangers in several buildings in Japan (for example Sapporo, Fukui etc.). However, in Japan, this method has been used mainly in connection with prefabricated piles for small-scale buildings. Cast-in-situ concrete pile foundations are widely used in densely developed areas in Japan due to their cost advantage and ease of construction. The authors' work is therefore concentrated on GSHP systems using such concrete pile foundations as geothermal heat exchangers, in order to improve the take-up of GSHP systems for large-scale construction in densely built-up city areas in Japan. The system involves installing U-tube heat exchangers around the outer surface of the cast-in-situ concrete pile foundation in order to extract/reject heat from/into the ground as efficiently as possible (see Figure 1).

The authors have carried out experimental work for this system at Chiba Experimental Station of the University of Tokyo. Two cast-in-situ concrete piles (1500 millimetres in diameter, 20 meters in depth) were used, with eight pairs of U-tube heat exchanger arranged around the surface of each pile (see Figure 2). The heat pump connected to them was rated for 4.6 kW of cooling and 5.7 kW of heating, supplying heating and cooling to two examination rooms.

The results indicated a maximum ground heat exchange of 260 ~ 280 W/m, with an average rating of 180~200 W/m. As there were eight tube sets, this meant that rating for one tube set was 32 ~ 35 W/m. The average cooling COP for the system was 4.9, which was therefore 1.4 times more efficient than a conventional air source heat pump system.

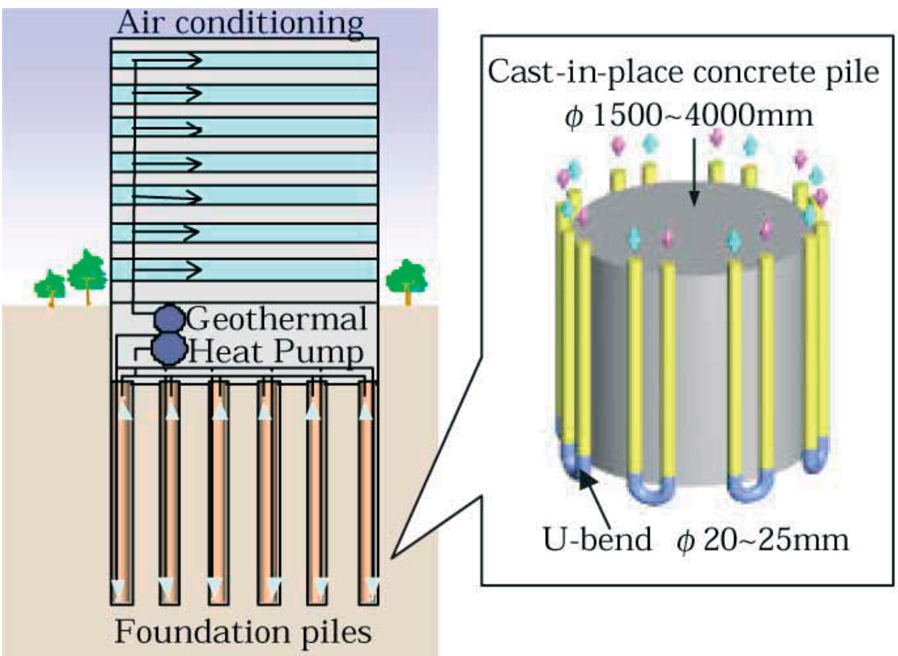

Figure 1 Conceptual figure of heat exchange system using cast-in place concrete piles

Water source heat pump

The author has also developed a new water/water heat pump with high performance in this project in cooperation with Zeneral Heat Pump Industry Co. Ltd. The experimental machine developed in this project is shown in Figure 3. To achieve high performance, the improved points are as follows.

(a) A new plate-type heat exchanger has been used for the condenser and evaporator of a heat pump instead of the conventional copper pipe heat exchanger. This plate-type heat exchanger has twice the heating or cooling surface area as a conventional heat exchanger, while being much smaller in overall size than the conventional one. The result is improved performance in combination with a reduced size of heat pump. COP has been improved by about 32 % as a result of adopting this plate-type heat exchanger.

(b) A new type of scroll compressor has been used. The axial bearing load of this compressor is as low as possible (to reduce friction loss), while the compressor has larger radial bearings with sealing by centrifugal force to improve the performance. COP has been improved by about 12% by the new compressor.

(c) In addition to the above modifications, accumulator and oil separators were removed. Further, by installing two three-way valves and reversing the water flow, the refrigerant and water in the evaporator flow counter to the usual pattern. This improves capacity and COP, since the logarithmic mean temperature difference of the refrigerant and heat-source water is reduced and the evaporating pressure rises.

By adopting all methods described above, the cooling COP of the experimental machine reached 5.75 when producing chilled water at 7-12 °C and with a heat source water temperature of 25-30 °C. This COP is about 1.7 times higher than that of the ordinary water-water heat pump.

Simulation model

For the design of ground-source heat pump (GSHP) systems, it is necessary accurately to predict the heat extraction and injection rates of the heat exchanger. An effective method is to combine a model of groundwater flow and heat transfer in the soil with a model of heat transfer in and around a ground heat exchanger, and many models have been developed and used. However, most of these models use a cylinder coordinate method for heat transfer in the soil, modelling ground heat exchangers as cylinders of an equivalent diameter. However, these models have weaknesses that do not allow for the influence of groundwater flow in the soil or heat interference effect caused by the shape of the heat exchanger. On the other hand, simulation models of groundwater flow, mass and heat transfer in the soil have been developed for applications in hydrology, geology and geotechnical engineering. However, the purpose of these models is to analyse macroscopic groundwater flow, mass and heat transfer in the soil, and so modelling of ground heat exchangers is not supported.

In this project, the authors have developed a numerical model that converts a heat

Figure 2 Experimental facility at Chiba Experimental Station of the University of Tokyo

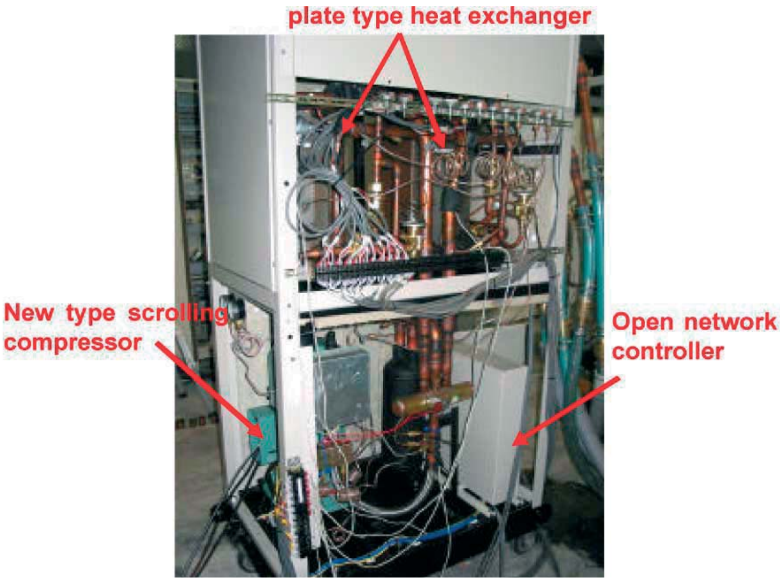

Figure 3 The experimental machine of water-water heat pump developed in this project

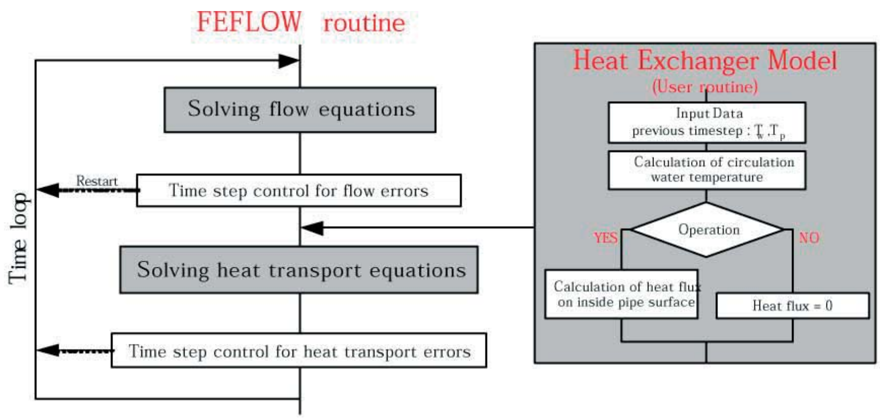

Figure 4 Flow chart of simulation coupling FEFLOW and heat exchanger model

transfer model in and around a ground heat exchanger into simulation code of groundwater flow and heat transfer in the soil. For simulation of groundwater flow and heat transport, the authors employed FEFLOW, which was developed in Germany in order to simulate groundwater flow and heat transfer in the soil. We also used the circulation water model with 1-dimensional advection-diffusion equation in the ground heat exchanger. A flow chart of this simulation model is shown in Figure 4.

A comparison between simulation results and experimental data performed in the Chiba Experimental Station was made in order to verify the numerical model developed here. The mesh system and simulation conditions and the simulation results are shown in Figures 5 and 6 respectively. The simulation results showed good agreement with the experimental data.

A feasibility study for LCC (Life Cycle Cost) investigation has been carried out for the medium-scale office building. This proposed system was adopted for a new building of the University of Tokyo, which will be completed next March (see Figure 7). The actual construction cost of this system has been examined in this building. The cost payback time when using the system developed here was 17.7 years, while that of a conventional GSHP system is over 50 years in Japan.

Conclusions

The report describes the results of two years' work, supported by NEDO. The GSHP system using cast-in-situ concrete pile foundations as geothermal heat exchangers is proposed, in order to reduce the initial construction cost. A new water/water heat pump with high performance has been developed, having a cooling COP of 5.75. In addition, a numerical simulation model which combines a ground heat transfer model with groundwater flow and heat exchanger models has been developed to predict exact heat extraction/injection rates from/into the ground. Finally, LCC (Life Cycle Cost) is examined for the medium-scale office building. The cost payback time when using the system developed here was 17.7 years.

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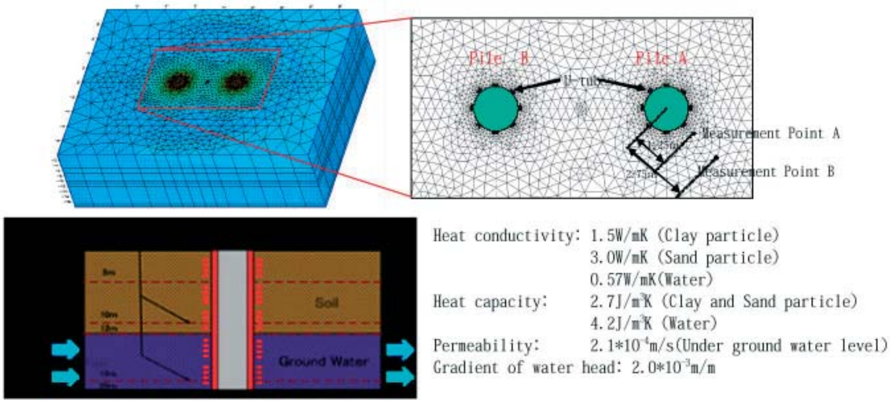

Figure 5 Mesh dividing and simulation conditions

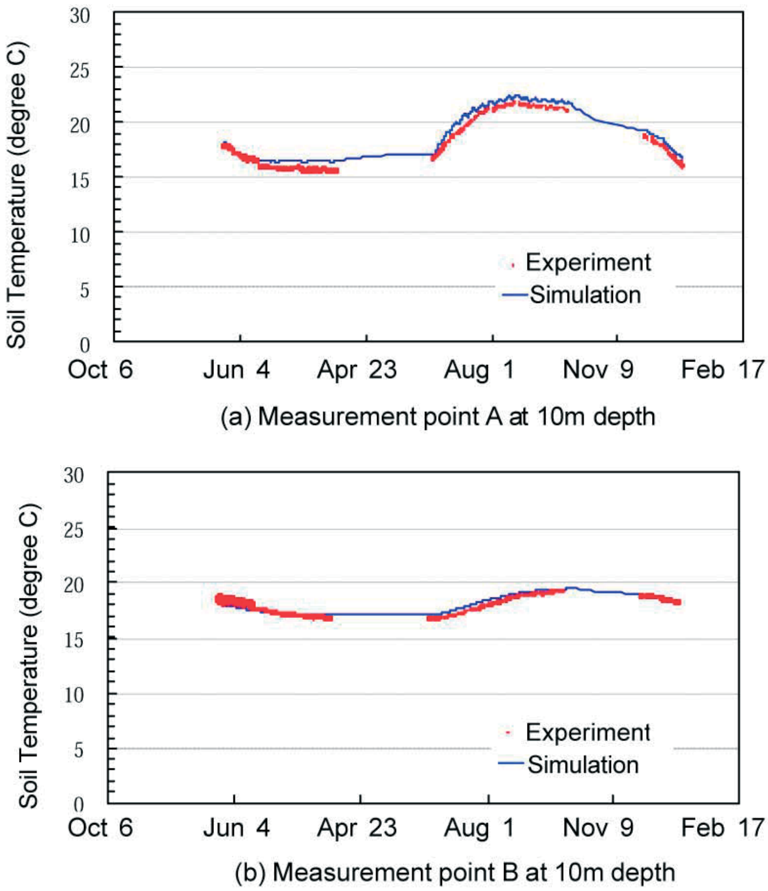

Figure 6 Comparison of soil temperature between the experiment and the simulation

Figure 7 A new building of the University of Tokyo adopting the proposal system

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In the next Issue

Thermally activated heat pump systems

Volume 24 - No. 1/2006

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

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