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IEA HEAT PUMP CENTRE

NEWSLETTER
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Ground source heat pumps

Heat Pumps - A key technology for the future

IEA **Heat Pump** CENTRE
NEWSLETTER

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In this issue

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Heat Pump Centre Newsletter, 3/2015
Ground source heat pumps generally give the largest energy savings of all heat pump types. However, they also generally require the largest initial investments; thus, for any GSHP installation this trade-off has to be taken into account.

The topic of this issue is Ground Source Heat Pumps. As usual, the Foreword provides a (green) overview. The Column, which is slightly extended in this issue, compares North American and European GSHP systems. The Strategic Outlook gives us a broad overview of the role of heating and cooling in the energy system. Topical articles include a GSHP market progress report from Japan, a case study from the US, an account of DX systems, and a report on a solar-GSHP combination.

Enjoy your reading!
Johan Berg, Editor

Heat pump news

Regulars

Topical articles

COLOPHON

Published by IEA Heat Pump Centre
c/o SP Technical Research Institute of Sweden, Box 857, SE-501 15 Borås, Sweden
Phone: +46 10 516 55 12

Publisher:
IEA Heat Pump Centre
PO Box 857, S-501 15 BORAS
SWEDEN
Tel: +46-10-516 55 12
hpc@heatpumpcentre.org
http://www.heatpumpcentre.org

Editor in chief: Monica Axell
Technical editors: Johan Larsson, Markus Lindahl, Olleper Hemlin - SP Technical Research Institute of Sweden. Caroline Haglund Stignor, Johan Berg, Roger Nordman, Caroline Stenvall - IEA Heat Pump Centre
Language editing: Teknotrans AB

IEA OECD heat pump centre

Foreword

Signhild Gehlin
Ph.D., Technical expert
Swedish Centre for Shallow Geothermal Energy
Sweden

Feel green – not blue

Feeling glum? Bad economy got you down? Are funds scarce and challenges abundant? It's time you pick up the Direct Utilization of Geothermal Energy 2015 Worldwide Review to get a new perspective!

Every five years at the World Geothermal Congress (WGC), worldwide statistics on geothermal energy use are compiled and reported. In April of this year, the WGC2015 was held in Melbourne. In the 70 individual country reports and the worldwide review[1] by J.W. Lund and T. L. Boyd, there is a wealth of figures on market development and potential for ground-source heat pumps. Although the WGC has a decided historic partiality for deep geothermal resources, including geothermal power production, the worldwide review shows with some clarity that the incredible market growth of geothermal energy use in recent years (installed capacity has grown by 45 % during the period 2010–2015), is largely due to the growth of ground-source heat pumps.

The total installed capacity of direct geothermal energy (shallow or deep geothermal heat with or without the aid of heat pumps, but no power production included) worldwide is today 70 GW, of which ground-source heat pumps account for 50 GW (71 %). In comparison, the total installed wind power capacity in the world by the end of 2013 was 320 GW. On an annual basis, ground-source heat pumps provide 55 % of the 163 TWh of thermal energy produced by geothermal systems, which is just about as much as Sweden's total annual electricity production. The annual growth rate of installed ground-source heat pump capacity since 2010 is more than 8 %, and the annual growth rate for ground-source heat pump energy use has, in the past, reached levels of over 10 %.

Ground-source heat pump technology use is now reported to the WGC in 48 countries, compared to 26 countries in 2000. It is likely that even more countries use ground-source heat pumps, as not all countries report to the WGC. We are not surprised to read that the highest numbers of installations are found in North America, Europe and China. The leading countries in terms of number of installed units are: the USA, China, Sweden, Germany and France. If calculated as an equivalent number of installed 12 kW units in the world, the number of units would be approximately 4.2 million, more than a 50 % increase since 2010.

There are several highlights in this report: how much renewable energy our technology provides, how the market has grown and is still growing, how the number of countries using ground-source heat pumps has increased, and how individual countries are – admittedly with some missteps at times – developing their markets and know-how. Another highlight is the great potential yet to be realised in immature markets.

Ground-source heat pumps are a fantastic green technology that can be used in most regions of the world. It is a natural, renewable and local energy resource that would otherwise not be used – the heat under our feet. As if this was not enough, this ingenious machine recovers the heat from the electricity used to run the compressor, by adding it to the output heat. Beautiful.

Still feeling blue?

1 Available at http://www.geothermal-energy.org under Conference paper database

Column

Observations on ground-source heat pump systems in North America and Scandinavia

Jeffrey D. Spitler
Regents Professor and OG&E Energy Technology Chair
Oklahoma State University
USA

Ground-source heat pump (GSHP) systems are commonly used to provide energy-efficient heating and cooling for residential, commercial, and institutional buildings in both North America and Scandinavia. Since the 1970s, there have been active research programs in both Sweden and the USA. Over time, there has been significant knowledge exchange going on between the two countries in such areas as methods for analysing and modelling GSHP systems and measuring ground thermal properties. Nevertheless, as an American researcher who has been traveling back and forth between the two countries for twenty years and who recently spent a year in Sweden, I find that there is a remarkable lack of knowledge about the differences in how the technology is applied between the two countries. This works two ways – not only do researchers from one continent not understand how the technology is applied in another continent, we often don't understand what is unique or different about our own technological solutions. In hopes of mitigating, at least slightly, these misunderstandings, I offer the following observations about ground source heat pump systems in North America and Scandinavia.

Perhaps it is a trivial observation, but residential buildings in Scandinavia seldom use mechanical cooling while in much of North America both residential and commercial/institutional buildings require both heating and cooling. This certainly explains some of the differences, such as American use of reversible heat pumps. Perhaps it also indirectly explains the near-universal preference of Scandinavians for quiet hydronic heating systems while Americans tend to accept more noise from their heating and cooling systems.

Whatever the cause, residential ground source heat pumps are predominantly water-to-air in North America and water-to-water in Scandinavia. In both regions, ground source heat pumps use a water/antifreeze mixture circulated through ground heat exchangers as the source for a vapor compression heat pump cycle. Beyond that commonality, there are quite a few differences, some of which are summarized in Table 1 for typical residential GSHPs. To be sure, advances in technology are ongoing – e.g. GSHPs that have dedicated domestic water heating have recently become available in North America.

For commercial heat pump applications, it appears that distributed heat pump systems predominate in North America and central heat pump systems are predominant in Scandinavia.

When I started looking into Scandinavian residential heat pumps, it took some digging to understand how domestic hot water heating is done – with a water-to-water heat exchanger rather than a refrigerant-to-water heat exchanger. But the most surprising difference from my perspective is not the technology per se, but the availability of data from manufacturers. For design of ground heat exchangers, it is necessary to quantify the heat transferred to and from the ground and in North America, simple equation-fit models of heat pumps are often used to translate the heating and cooling loads met by the heat pump to heat extraction and rejection rates imposed on the ground. In North America, development of such

Characteristics	North America	Scandinavia
Source medium	Water/antifreeze mixture	Water/antifreeze mixture
Load medium	Air	Water
Domestic water heating capability	Limited to water heating with desuperheater; coincident with compressor operation.	Integrated domestic hot water (DHW) tank.
Internal valves	Refrigerant-reversing valve switches between heating and cooling mode.	Diverting valve switches hot water from heat pump condenser between radiators (for house heating) and outer shell of DHW tank.
Data availability	Manufacturers provide tabulated data sets and correction factors sufficient for developing equation fits of performance that can be used in ground heat exchanger design.	Only one or a few data points are provided by manufacturer.

Table 1. Some characteristics of typical ground-source heat pumps used in North America and Scandinavia.

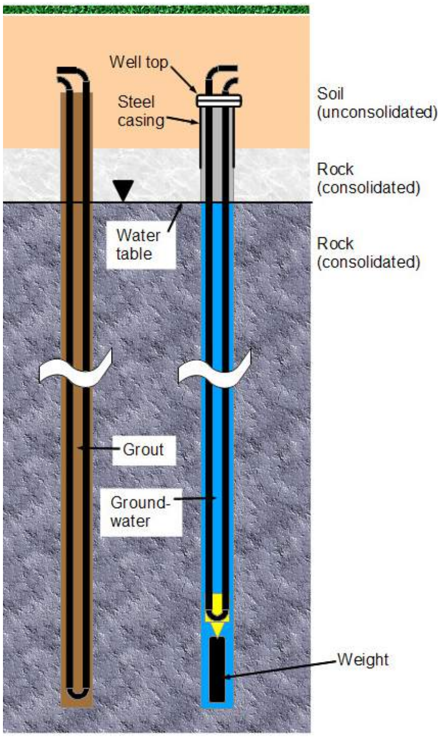


Figure 1. Different types of boreholes.

equation-fit models is supported by the availability of rich data sets (typically 60-150 combinations of flow rates and entering fluid temperatures) provided by manufacturers for each heat pump model. In Scandinavia, manufacturers provide only one or a few data points, rendering development of such an equation-fit model impossible. From my perspective, this is a hindrance to ground heat exchanger design.

For the most part, boreholes in North America (Figure 1, left) are backfilled with grout in order to protect any groundwater at lower depths from surface pollutants. Because of the often shallow bedrock and high groundwater levels in Scandinavia, boreholes are generally constructed like water wells, with steel casing lining the borehole down into the bedrock. Then the U-tube is weighted and suspended in the borehole. (Figure 1, right.)

Groundwater-filled boreholes tend to perform well, with low thermal resistance, though the thermal resistance varies with heat transfer rate and annulus temperature. While it is difficult to make comparisons of different technologies in different countries, groundwater-filled boreholes in Scandinavia are significantly more expensive to install than grouted boreholes in the USA. In some Scandinavian locations (e.g. the west coast and south of Sweden) where the distance to bedrock is high, the cost of groundwater-filled boreholes can be prohibitive and grouted boreholes might be considered.

Borehole heat exchangers tend to be deeper in Scandinavia, with the average borehole depth being 171 m in 2013[1]. I'm not aware of anyone compiling such statistics for North America, but my impression is that the average would be closer to 80 m, though in recent years we've started to hear more about much deeper boreholes.

One other observation is that in North America where geological conditions are similar to Sweden, standing column wells are often used. These may have potential for Scandinavian application. Likewise, in those regions in North America, it may also be feasible to use groundwater-filled boreholes with suspended U-tubes for some applications.

The differences in heat pump technology and ground heat exchanger design as utilized in North America and Scandinavia are substantial. Some differences are inherent, due to climate and geology, but others deserve further investigation.

References

[1] Gehlin, S., Andersson, O., Bjelm, L., P.G. Alm, and J.E. Rosberg. 2015. *Country Update for Sweden*. Proceedings World Geothermal Congress 2015, Melbourne, Australia, April 19-24, 2015.

IEA HPT News

Belgium joins the HPT!

We at the IEA Heat Pumping Technologies (HPT) are very happy to welcome Belgium as our latest member country!

The IEA HPT now has 16 member countries. As a member country, all Belgian people can now access our full newsletters free of charge. Organisations, such as industry, research institutes and universities in Belgium can also join current Annexes or start new ones.

12th IEA Heat Pump Conference: Rethink Energy, Act NOW!

The 12th IEA Heat Pump Conference will be held from 15th to 18th May 2017, at the World Trade Centre in Rotterdam. The Conference will begin with a series of workshops on 15th May and a welcoming reception on the evening of 15th May.

Rethink Energy

The era of renewables is inevitable, while energy conservation is a must. The main solutions and choices will not be made on economics only, but more on expectations of future energy systems. Infrastructures are becoming dependent on insecure suppliers and on electricity from renewable sources. As result, ecological concerns are becoming key drivers for policy makers and consumers alike, and their choices are fundamentally altering the energy business landscape.

Governments and high level decision makers worldwide should give more attention to heating and cooling and look at the best available options. Heating and Cooling is the Elephant in the room, often overlooked. Heat is, at 171 EJ, over 50 % of global final energy demand and more than three quarters of this demand is met by fossil fuels. The IEA mentions a significant untapped potential for energy efficiency in the building and industrial sectors, where low-carbon and zero-carbon technologies for heating and cooling systems are essential to achieve the CO_2 emissions reduction.

Heat pumps are the already available and proven key technology to achieve the goals of a secure, sustainable and competitive energy system.

Act NOW!

In the market of heating and cooling systems, there is a great urgency to act now. Almost all current investments made in this sector will have a long-term effect on overall energy use. The implementation of a new heating system or a renovation has an impact on energy usage for the next 15 to 20 years.

CONFERENCE PROGRAM

The 12th IEA Heat Pump Conference will, after the main plenary opening, session consist of three main bodies running in the parallel tracks.

The Conference will have invited speakers, speakers from the key stake holders in the market and the Annexes, as well as speakers in a call for papers, where researchers are encouraged to give their opinions and show their latest developments. There will be both oral and poster presentations.

Before and after the Conference there will be workshops on the Annexes (before) and special events. Sponsors will be offered special side events and rooms to have meetings.

Who should attend

- Policy makers, government officials, and local city councils
- Executives and representatives from industry, utilities and the public sector
- Manufacturers, distributors, and technology supporters.
- Designers and R&D managers of manufacturers and suppliers
- Researchers, developers and equipment designers
- Academics, students.

Call for Papers

A call for papers will be published in October 2015. Watch for more information on how to send in an abstract for a paper, how to participate and other information on the Conference website: *www.hpc2017.org*.

Report from International Congress of Refrigeration, ICR2015, Yokohama, Japan

View over Yokohama.

The 24th International Congress of Refrigeration, ICR 2015, took place in Yokohama, Japan, August 16-22. The congress was organized by the International Institute of Refrigeration (IIR) and the Japan Society of Refrigerating and Air Conditioning Engineers (JSRAE). The special title given to this 24th congress was "Improving Quality of Life, Preserving the Earth". The event was very well organized in the venue Pacifico Yokohama and everything worked very smoothly for all participants, speakers as well as exhibitors.

The weeks before the event, the outdoor temperatures in Yokohama had reached high levels, around 35 °C, but during the week of the congress, the visitors were blessed with temperatures below 30 °C most of the days. After having experienced a rather chilly summer in Sweden, I personally enjoyed the warmth, and I think many of the other Scandinavian visitors did as well. Nevertheless, in a climate like the one we experienced in Yokohama, the necessity of air-conditioning and refrigeration is very obvious for a good quality of life. However, it needs to be implemented as efficiently as possible, with as low environmental influence as possible in order to preserve the earth.

In total, there were 1 186 registered participants at the congress, of which 439 came from Japan and 194 from China. However, in place number three, four and five were Germany, France and the United States with 60, 59 and 56 participants, respectively. The congress participants represented 55 countries. A total of 643 papers were accepted and presented, of which the main author came from China for 149 and from Japan for 116. 40 of the papers were written by authors from United States, 40 by French authors and 26 by German authors. In total, the main authors represented 43 countries.

The congress officially started with an opening ceremony and a plenary lecture held by Ken Koyoma, chief Economist and Managing Director, Institute of Energy Economics, Japan with the title "World Energy Situation and Japan's Energy Strategy", where he drew the big picture and talked about the global, Asian and Japanese perspectives. He told the audience that after March 11, 2011, Japan reduced the energy consumption by 20 %. All the nuclear plants were shut down. However, the decline in nuclear power was partially offset by consumption of fossil fuel, which resulted in high costs for the country. Now, the challenge for Japan is to change crisis mode into standard mode, while at the same time achieving safety and the 3E's (Energy Security, Economic Efficiency and Environment). Thus, the main principle of the basic energy strategy is to reduce dependence on nuclear power, to increase renewables maximally, to achieve safety, and to realize a balanced energy portfolio for the 3E's.

There were nine parallel sessions with oral presentations and different themes. In addition, 120 posters were displayed and presented by their authors. Dr Piotr Domanski made a thorough survey of the papers of the congress, which he presented at the closing ceremony. According to his survey, the theme of many papers were systems of the future, which should be more efficient, more reliable and smarter than current ones. One challenge dealt with by many presenting researchers was the phase-out of high-GWP refrigerants, for which the options are limited. There are hardly any new fluids, only blends of existing

Some of the workshop participants from IEA HPT Annex 44 Performance Indicators for Energy Efficient Supermarket Buildings.

The IEA Heat Pumpring Technologies (HPT) and Heat Pump Centre (HPC) was on location at ICR2015.

ones. Also, significant focus was on the use of natural refrigerants. Although very few papers were about propane as refrigerants, and a few about ammonia, very many presented results from research on CO_2 as refrigerant, for instance about the potential of using of multiple ejectors for increased energy efficiency in supermarket refrigeration with transcritical CO_2 also in warm countries. Further, and still according to Dr Domanski's survey, other papers dealt with cycle modifications such as economizers, liquid injection with for example R32, and other ejector cycles. A number of papers discussed the performance of heat exchangers, for example one keynote lecture held by professor Pega Hrnjak on microchannel heat exchangers. There were in total ten papers about frost formation and five papers dealing with increased air side heat transfer coefficients. Some papers dealt with smart systems such as controls, fault detection diagnosis and smart heat pumps for smart electric grids. In total 23 papers, mainly from the Asian countries, dealt with absorption and adsorption heat pumping technologies. There were also papers on liquid and solid desiccants, evaporative cooling, and sessions on cryobiology; one keynote on the pharmaceutical cold chain, two sessions on magnetocaloric refrigeration, and one on thermoacoustic refrigeration.

In addition to the technical sessions, eight technical summary lectures and fourteen workshops (two of them arranged by IEA HPT Annexes) were held, so it is not an exaggeration to state that A LOT OF INFORMATION WAS EXCHANGED! There was also an exhibition, that could be visited in-between sessions, where various companies and organizations within the field of refrigeration and heat pumping technologies were represented. Among them the IEA Heat Pumping Technologies IA.

Attending this congress was very fruitful in many ways and I went home several impressions and ideas richer. Great thanks to everyone who had put effort in arranging this event! I am already looking forward to the next International Congress of Refrigeration which will be held in Montreal, Canada, in 2019.

Caroline Haglund Stignor,
Heat Pump Centre (HPC) and
SP Technical Research Institute of Sweden

IEA HPT Conference articles now available online!

As a part of HPT's work to disseminate the benefits with heat pumps, the Executive Committee decided in may 2015 that all previous conference proceedings should be made available for free at the website *www.heatpumpcentre.org*.

We have now uploaded all articles (Conference Proceedings Papers) from the IEA Heat Pump Conferences in 2005, 2008 and 2011 in our database. All articles can be downloaded for free as single PDF files. Please browse to our *publications database* to digest and enjoy a great variety of knowledge!

General

New BSRIA publication focuses on achieving carbon targets

BSRIA has published a White Paper on Achieving Carbon Targets, which looks at what the UK industry needs from the government to deliver and achieve carbon targets over the next 10 years. It considers the long-term strategy – stability, benchmarking, and legislation and regulation. It recommends that government can help, and the main tools at its disposal are legislation, regulation, incentives and sponsorship.

Chief executive of BSRIA, Julia Evans, said: “Our industry will be aided through the establishment of clear policy, clear and uncomplicated legislation, and more regulation. However, there are currently too many different government departments dictating policy, therefore, industry supports the creation of a single government department with which it can interface. This will help to reduce contradiction and confusion.”

Ms Evans continued: “Regulation is currently viewed as the minimum standard people need to achieve. Government should tax poor performance and provide subsidies to encourage best performance and the use of best low-carbon technologies.

Source: www.acr-news.com and www.bsria.co.uk

IBM wants to cool data centers with their own waste heat

Several years ago, IBM pioneered a *hot-water cooling system* for use in supercomputing. Dubbed Aquasar, the system relied on hot water rather than refrigerant or huge banks of air conditioners, and it managed to significantly cut power consumption in server rooms. IBM is now working on a more advanced type of cooling solution, dubbed Thrive, which could dramatically slash power consumption.

Most estimates put data center cooling costs between 30-50 % of the total, depending how many machines are deployed and the type of cooling required for the building. IBM thinks it could cut cooling-related power consumption by up to 65 %. That’s 65 % of ~35 %, but it could still reduce the total cost of data center operation by as much as 23 %. Those are the sorts of figures that get companies interested.

What IBM has built is a heat pump that can run largely on a data center’s own waste heat. That’s not something data centers are short on, since even the most efficient cooling solutions on low-power servers still produce a great deal of heat energy. Instead of a compressor, the IBM design has an adsorption heat exchanger.

Sources: www.extremetech.com

27 000 square meters of chocolate factory now on geothermal

An office building for a chocolate factory just outside of Stockholm, Sweden, will upgrade its heating and cooling system, completely switching to geothermal energy. In doing this, purchased energy for the building, workplace for 1 000 people, is expected to drop by up to 70 %. It also paves the way for environmental certification of the building.

Source: www.kylavarme.se (in Swedish)

Policy

China implements Top Runner Program

The details about China's Top Runner Program have been unveiled by Zhang Xin, deputy director of the Environment and Resource Institute, China National Institute of Standardization. The new program covers three categories of products including inverter air conditioners, refrigerators, and panel TVs. Drawing on the experiences of the developed countries, especially the first Top Runner Program implemented by Japan in 1999, China's Top Runner Program is an innovation based on China's specific situation.

Regarding the qualifications to participate in the China's Top Runner Program, which is mostly concerned with industry actors, Zhang Xin provided three standards. The first is advanced energy efficiency technology, meaning the energy efficiency of the products should not be lower than the grade I national energy efficiency standard. The second is high level of energy-saving contribution to the society, indicating the products should reach certain sales volume in the market, rather than being sample products only. The third is excellent comprehensive performance, including product quality. Products included in the China's Top Runner Program will be selected not only by energy efficiency performance but also by general features such as functional effects, product designs, and user-friendly operations.

Source: JARN, July 25, 2015

An NGO comment to Juncker’s plan to boost EU investment (in summary)

The Juncker Commission’s investment plan is an unprecedented opportunity to improve the EU’s energy productivity and efficiency, writes Ingrid Holmes, director of environmental NGO E3G.

The EU’s response to ongoing challenges (low growth, international development, volatility in commodity and energy prices, etc.) – notably the ‘Investment Plan for Europe’ – is the right one. The focus on driving investment in a very practical way in the short-term –

through the European Strategic Fund for Investment (EFSI) and technical assistance for project developers - is important. But equally important will be the longer term reforms the Commission enacts (the second part of the Investment Plan) to deepen the single market and sustain growth in the longer term through innovation and improved efficiencies across capital, energy and digital markets in the EU.

This is a smart way to drive a return to competitiveness and growth in the EU. And yet there is currently a yawning and obvious gap in how the Plan is being implemented. In focusing on facilitating investment in traditional big infrastructure such as gas pipelines, fibre optic cable and airports, we will miss the opportunity to deliver the equally important but smaller and more widely distributed energy investments that could play such a big role in driving growth. This includes investment in increased levels of energy efficiency and smarter management of energy demand that can deliver significant competiveness gains through increasing Europe's energy productivity.

More on the "Investment Plan for Europe", "Juncker's plan": *www.euronews.com/2015/07/22/juncker-s-plan-to-boost-eu-investment/*

Source: www.euractiv.com

EHPA: Long awaited strategy must build on best available solutions

During the European Sustainable Energy Week, the European Heat Pump Association (EHPA) published a position paper on the European Heating & Cooling Strategy. This Strategy will be a guidance document the European Commission has announced to publish in Fall 2015.

The European heat pump industry stresses the need for such a strategy to realise the huge potential of the heating and cooling sector. The Strategy should be a major tool to fulfill all the objectives of the Energy Union (climate goals, energy security and competitiveness). EHPA calls for the commission to be ambitious in creating the framework around an ever more efficient and renewable - based thermal system fully integrated in smart energy grids.

To get there, the Strategy should activate the end-consumer and ensure maximum synergies between energy efficiency solutions, various renewable technologies and the aims of a circular economy. In order to be effective, the Strategy should leave the "technology neutral" approach behind and instead be based on encouraging the use of best available solutions.

Link to EHPA's position paper

Source: www.ehpa.org

Energy Efficiency is key to Europe's Energy Union

The Energy Efficiency Industrial Forum (EEIF) has published its recommendations on the EU's Energy Union, emphasising the importance of the "Energy Efficiency First" proposal.

In the *document*, the EEIF states that energy efficiency is the core element of the Energy Union framework and that Member States should be encouraged to give it primary consideration in their policies.

The document also addresses how to create upfront investment for energy efficiency, raise consumer awareness of the importance of energy savings, and put in place incentive mechanisms for end-users.

The EEIF also welcomes the future review of the Energy Performance of Buildings Directive, given the significant potential for energy savings in this sector, as well as the Commission's Strategy on Heating and Cooling which is due for publication later this year.
The document concludes: "Putting energy efficiency first... provides the best way forward to achieving the Union's energy security and climate objectives, to fostering innovation, to creating new jobs and to enabling end-users to benefit economically from the smarter management of energy."

Source: www.epeeglobal.org

Working fluids

AHRI and UNEP agree on program for refrigerant supply chain

The US Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and the United Nations Environmental Programme (UNEP) have reached an agreement, which includes the development of a global qualification program for refrigerant supply chain networks, entitled "refrigerant driving license" (RDL), aimed at ensuring the sound and safe management of refrigerants.

"Working with UNEP and developing the RDL is one very important aspect of the industry's focus on ensuring the proper, safe, and environmentally sound management of refrigerants," said AHRI President and CEO, Stephen Yurek. "AHRI's relationship with UNEP will provide an excellent platform for working with other associations and institutes, creating a global network to support the safe handling of refrigerants," he said.

The agreement will support the accelerated global transition to new refrigerants brought on by the Montreal Protocol's ozone layer protection targets by addressing challenges in soundly and safely managing refrigerants. It will also complement existing programs to upgrade the skills and knowledge of field specialists as new technologies become available.

Source: www.ahrinet.org

Alternative refrigerants for low-temp applications

The hydrofluorocarbon (HFC) R404A, which has zero ozone depletion potential (ODP), is widely used as refrigerant in low-temperature applications. R404A's global warming potential (GWP), however, is quite high (3,922). Ammonia (NH_3) has a long history of being used as refrigerant for industrial refrigeration units, but it is toxic and mildly flammable. Another refrigerant that has a long history of use is carbon dioxide (CO_2).

In a final rule issued last summer, the U.S. Environmental Protection Agency (EPA) announced that it would remove HFCs R404A and R507A (GWP of 3,990) from the Significant New Alternatives Policy (SNAP) list in 2016, but the timing has been pushed back after industry made a number of appeals. Now the EPA has announced that these refrigerants would be banned in supermarket refrigeration equipment from January 2017. Other HFCs will also be prohibited in certain applications in the near future.

U.S. regulations also have no small effect on regulations in other countries. The HFC phase-down and ultimately the HFC phase-out, or moves to restrict HFC use, are also being seen in Europe, Canada, and Japan in addition to the United States. The F-gas Regulation already in place in Europe sets dates for bans on the use of several HFC refrigerants in specific applications.

Read more in JARN.

Source: JARN, August 25, 2015

When will R290 RACs be available?

In the phase-out of R22 refrigerant in China, the room air conditioner (RAC) industry has chosen R290 (propane) to replace R22. Chinese manufacturers are prepared to undertake batch production of R290 RACs, which has attracted a fair amount of industry attention. However, are R290 RACs available on the market?

The answer is no, at least for now. There are no R290 RACs at home appliance chain stores, RAC franchise stores, or supermarkets in the key cities visited in China, nor are there any advertisements promoting R290 RACs. Salespeople do not know what R290 RACs are. Moreover, replies from sales managers of some leading RAC manufacturers also indicate that they have no current plans to sell R290 RACs. Therefore, it is reasonable to assume that there is a long way to go before R290 RACs are available in the Chinese market.

Read more in JARN.

Source: JARN, July 25, 2015

Natural refrigerants electronic newsletter, now also in Europe

Shecco has had a news magazine for the Americas, focusing on natural refrigerants, for some time; the Accelerate America. They will now launch the European version, Accelerate Europe.

Source: www.accelerate.shecco.com

Worldwide free access to patents for equipment using HFC-32

Daikin Industries, Ltd., has announced that it is offering companies worldwide free access to 93 patents, to encourage companies to develop and commercialize air conditioning, cooling and heat pump equipment that use HFC-32 as a single component refrigerant. This action is aimed at encouraging manufacturers worldwide to adopt comfort cooling and heating technologies that use HFC-32.

Source: www.ehpa.org

Technology

Potential of hybrid heating technology not fulfilled – yet

A new report from Delta Energy & Environment (Delta-ee) has identified some significant opportunities for hybrid heat pumps, which combine a gas boiler with a heat pump, in the largest European heating markets. Yet, several barriers identified in the report are keeping the technology from realising its full market potential.

These include:

- System complexity and size – This remains a major barrier, but we see that new products are decreasing in both size and installation complexity. Thus the challenge is now to educate installers and customers about the technology.
- Pricing of hybrids – While prices have become more competitive, the total installed costs of a boiler remain significantly lower than for a hybrid.
- Running cost savings are uncertain – The current reality is that electricity is too expensive in most markets (except France) meaning that running cost savings from hybrids are too low. Additionally, falling oil prices have marginalised the economic proposition for oil hybrids in recent months.

Source: www.acr-heat-pumps-today.co.uk and www.delta-ee.com

The global magnetic refrigeration market

The magnetic refrigeration market is expected to reach USD 315.7 Million by 2022, growing at a compound annual growth rate (CAGR) of 98.7 % between 2017 and 2022, according to a new market research report published by Research and Markets.

Increasing concerns regarding the use of refrigerants that are ozone depleting and have a high global warming potential (GWP) in refrigeration and air conditioning systems are expected to provide growth opportunities for the magnetic refrigeration market. According to the report, a magnetic refrigeration system's simple design, low maintenance cost, green technology, and higher energy efficiency are some of the attributes that are likely to fuel the growth of magnetic refrigeration in the coming years.

Source: www.iifiir.org and www.researchhandmarkets.com

Optimisation of a heat pump for satellite cooling

Satellites are deployed into near earth orbit in order to provide a platform for a wide range of missions, including telecommunications systems, surveillance systems and astronomical systems.

These systems have seen a large increase in electrical component power density. It is currently common practice to use heat pipes to conduct the heat generated by the electrical components to the radiators of the satellite, but tomorrow's electrical components will have heat fluxes high enough to render this system unfeasible. As a result, it is necessary to develop heat pump systems that can operate in low-gravity environments with high reliability and efficiency to cool electrical components in the satellite.

A recent paper considers a conventional heat pump that uses an oil-free scroll compressor, since oil-refrigerant separation is difficult in low-gravity environment. There are a number of other unique features to this system, including the fact that all the heat rejection occurs through radiative heat transfer and the heat load is fixed (rather than being a function of source and sink temperatures).

The authors conclude that this heat-pump system, using R152A as a refrigerant, can achieve a relatively good coefficient of performance (> 4 for reasonable conditions). The component temperatures in the evaporator are quite high in the refrigerant dryout region; so, when designing satellite heat pump systems (and electronic cooling systems in general), it is critical to have a sufficient factor of safety on the thermal design in the dryout and superheated zones.

This *paper* can be downloaded via IIR Fridoc database (please log in or register first).

Source: www.iifiir.org

Sun-powered refrigerator 1

Due to the high cost and unreliability of electricity, food refrigeration is an important problem in developing countries. In parts of Africa, food spoilage can represent up to 40 % of produce.

Quang Truong, a student of MIT in Boston has developed The Evaptainers, an electricity-free and mobile fridge, using evaporative cooling technology.

The system needs sun and 6 liters of water for 12 hours of use. The heat is drawn out of the unit's interior onto a conductive aluminum plate. Wet sand filling in the gap between pots (called zeer pot and made of terra cotta) keeps cool inside. It is designed without a fan or pump to make it light and mobile. It should cost between $10 to $20 and would increase end-user profits by about 25 %.

Source: www.iifiir.org

Sun-powered refrigerator 2

A group of final-year Mechanical Engineering students of the Sree Chithra Tirunal College of Engineering (SCTCE), Pappanamcode, India, have developed a prototype of a refrigeration system using direct sunlight panels.

According to the students, the system uses a parabolic-shaped solar concentrator, instead of a solar panel made of stainless steel, to concentrate the heat.

According to K. Krishna Raj, one of the members of the team, this method is cheaper than a solar panel. In conventional systems, a compressor driven by electricity is used to pump the refrigerant and then a solar panel converts solar energy into electrical energy. This drives a compressor that has relatively low efficiency, owing to loss of power during conversion. To overcome the maximum possible heat loss, they integrated a heat pipe that provides effective heat transfer from the parabolic concentrator. Another component, an adsorbent bed, receives the heat from the heat pipe. The carbon inside the bed absorbs the refrigerant (methanol) when it is at low temperature and releases it at high temperature. This pressure is used to run the system.

The students said that the results of the experiment showed that its cooling efficiency was the same as any normal refrigerator.

Source: www.thehindu.com

Markets

Global geothermal heat pump market 2015-2019

The global geothermal heat pump market is predicted to grow at a CAGR (Compound Annual Growth Rate) of about 15 % over the period 2015-2019, according to a report from Research and Markets.

Commenting on the report, an analyst said: "Organizations and individuals across sectors such as residential, commercial and industrial look for technologically progressive geothermal heat pumps with improved display and control systems. Vendors are therefore adding greater functionality to their geothermal heat pumps such as two-speed compressors, dual-speed motors, de-super heaters, scroll compressors, and backup burners. This motivates end-users to opt for modern technology-equipped geothermal heat pumps rather than conventional heating and cooling equipment."

Source: www.iifiir.org and www.researchhandmarkets.com

Global demand for HVAC equipment on the rise

Global demand for HVAC equipment is projected to increase 6.1 % per year through 2016 to USD 107 billion. Rapid growth in building construction expenditure along with rising industrialization and per capita incomes, the ongoing modernization of the housing stock and opportunities arising from the relatively low penetration rates will aid advances. HVAC demand growth in the Asia Pacific region will outpace the global average, increasing 6.4 % per year through 2016.

Source: www.iifiir.org

Heat pump KEYMARK: a single certificate for a single European market

European certification of heat pumps quality will be simpler in the future. This is the result of a cooperate effort between the European heat pump industry and European certification bodies.

The cooperating parties have announced the introduction of new European heat-pump certificate based on the CEN KEYMARK scheme.

Martin Forsén, president of the European Heat Pump Association: "Heat pumps provide efficient solutions to meet Europe's climate and energy targets, and more broadly all the goals outlined in the European Energy Union initiative. In this context, the heat pump KEYMARK is an appropriate tool to ensure the highest quality of systems in the market place."

While every manufacturer and importer of heat pumps has to fulfil the requirements of CE marking, those opting for the heat-pump KEYMARK go one step further by choosing a voluntary third party check of product quality.

Products bearing the heat-pump KEYMARK show to end-users that they have been tested by recognized third-party testing laboratories according to European standards and fulfil the requirements of the scheme. The requirements of the new heat-pump KEYMARK include:

- a set of performance test requirements carried out by third party tests based on EN 14511, EN 15879 and EN 16147
- a robust model range approach
- a product related Factory Production Control (FPC)
- an initial inspection of the FPC
- regularly surveillance of the certified products and FPC.

The scheme will be available to final consumers in Q4, 2015. It is compatible with the requirements of Ecodesign and the Energylabel. Once installed, it will also be supportive to market surveillance authorities.

Source: www.ehpa.org

China: new Food Safety Law to stimulate refrigerated car market

A new version draft of the Food Safety Law has been approved, and will be enforced on October 1, 2015. The revised version requires stringent full-process control over food safety, from production, transportation, storage, to sales and catering services. Responsibility of food producers will be emphasized, with strengthened monitoring and punishing measures.

Source: JARN, July 25, 2015

Heat pumps are more cost-efficient than district heating in Finnish NZEB

Finnish nearly zero energy level for buildings can be achieved more cost-efficiently with concepts utilizing heat pumps than with district heating. This was one of the main results of the development project "HP4NZEB – Heat Pump Concepts for Nearly Zero Energy Buildings", where the main objective was to outline the role of heat pumps in energy- and cost-efficient nearly zero energy building solutions.

When comparing the energy classification and life cycle costs of concepts utilizing heat pumps with district heating, the heat pump concepts were more cost efficient in both larger apartment buildings and in smaller detached houses. In addition to offering lower life cycle costs, heat pumps can also cool the building and no extra investment for cooling is needed.

Source: www.ehpa.org

Ongoing Annexes

IEA HPT Annex 40 Heat pump concepts for Nearly Zero Energy Buildings

Annex 40 working meeting in the Helsinki region, Finland

IEA HPP Annex 40's aim is to investigate and improve heat pump systems applied in Nearly or Net Zero Energy Buildings (nZEB). The nine countries CA, CH, DE, FI, JP, NL, NO, SE and US are collaborating in Annex 40.

Annex 40: Group photo of Annex 40 members at the largest ground-source heat pump installation in Finland.

The sixth working meeting of IEA HPT Annex 40 was held in the Helsinki region at Aalto University, Espoo, and Green Net Finland, Vantaa on June 16–17, 2015. The main objectives were the presentation and discussion of the final results of the contributions of the participants and the integration of the results into the country and final reports.

Contributions to Task 2, the system comparison and improvement regarding performance and cost, are different simulation studies performed by the different countries. In the Nordic countries, both in Finland and in Sweden, heat pumps were confirmed as one of the most efficient and cost-effective systems for nZEB. In Sweden, ground-coupled heat pumps are also a viable solution, and even in Finland, with a dense district heating grid, heat pumps are an economic and efficient solution for nZEB. Results were also confirmed for Swiss boundary conditions, where, both in residential and in office buildings, heat pumps are the most energy-efficient and cost-effective systems. In larger buildings, district heating and CHP are also options. In Japanese office buildings, with more pronounced air-conditioning needs, nZEB can be reached with efficiently integrated heat pump solutions for space heating and cooling and with significant reduction of internal loads through efficient lighting (daylighting and LED) and efficient appliances. In Canada, techno-economical analyses of different system solutions have been carried out. Depending on the region, heat pump systems are among the best solutions.

Furthermore, design tools have been developed in Task 2. In Norway an optimisation tool for heat pump design, based on cost and CO_2-emissions is being developed, using Matlab-Simulink as a basis. In the USA, at the Center for Environmental Energy Engineering (CEEE) of the University of Maryland, a tool for carrying out detailed comfort evaluation for different room types equipped with heating or cooling panels, as well as convective heating and cooling systems, has been developed. By utilising low emission temperatures in the room, the performance of the heat pump can be further increased without a decrease in comfort.

In Task 3, technology developments and field monitoring have been carried out. In the USA, a residential testing facility for nZEB system technology (NZERTF) has been constructed and commissioned at the campus of the National Institute of Standards and Technologies (NIST). In the test house, with tunable thermal and moisture loads in order to emulate real user operation, different nZEB technologies have been measured and tested. Overall, the building achieved a positive annual energy balance in the first year of operation. At Oak Ridge National Laboratory (ORNL) different highly integrated heat pump variants have been developed, lab-tested and are undergoing field monitoring. In Canada, the combinations of heat pumps with solar collectors and ice-slurry storage have been lab-tested. Furthermore, in Switzerland, the combination of solar collectors and heat pumps for office use and the operation modes space heating, DHW and space cooling have been investigated through lab-testing and simulations.

Both in the Netherlands and in Germany, larger field tests are ongoing. In the Netherlands the field test 'Energy Leap' has been carried out in residential nZEB, and in Germany long-term monitoring of nZEB used as office buildings and equipped with heat pumps and thermally-activated building systems (TABS) is ongoing. Additionally, some of the first Norwegian nZEB have been monitored and evaluated within the framework of Annex 40 by SINTEF, the NTNU and COWI AS. In Japan, several best practice installations have been documented. Canada will contribute detailed monitoring results of an EQuilibriumTM house.

Task 4 investigates options for local load management with respect to self-consumption of PV-electricity generated on-site and evaluates the load match characteristics of different technologies. In the German field test, options for a load shift in order to realise a grid-oriented operation are being evaluated. In two monitored nZEB in Switzerland, one a multi-family house and one a building with mixed residential/office use, options for load shift by the heat pump and e-mobility have been investigated.

The meeting was framed by a workshop presenting the results of the Finnish project in Annex 40, which took place at the Finlandia Hall with Finnish nZEB stakeholders and Annex 40 members, on 15 June 2015. The workshop presentation, as well as other Annex 40 publications, can be downloaded from the Annex 40 website at http://www.annex40.net under 'Publications'. Moreover, a technical tour to the largest ground-coupled heat pump installation in Finland was included in the meeting. Annex 40 is scheduled to be concluded by the end of 2015. The final documents of the Annex work are expected to be published in 2016.

Contact: Carsten Wemhöner,
carsten.wemhoener@hsr.ch

IEA HPT Annex 41 Cold Climate Heat Pumps (CCHP)

Annex 41 began in July 2012 to revisit research and development work in different countries to examine technology improvements leading to successful heat pump experience in cold regions.

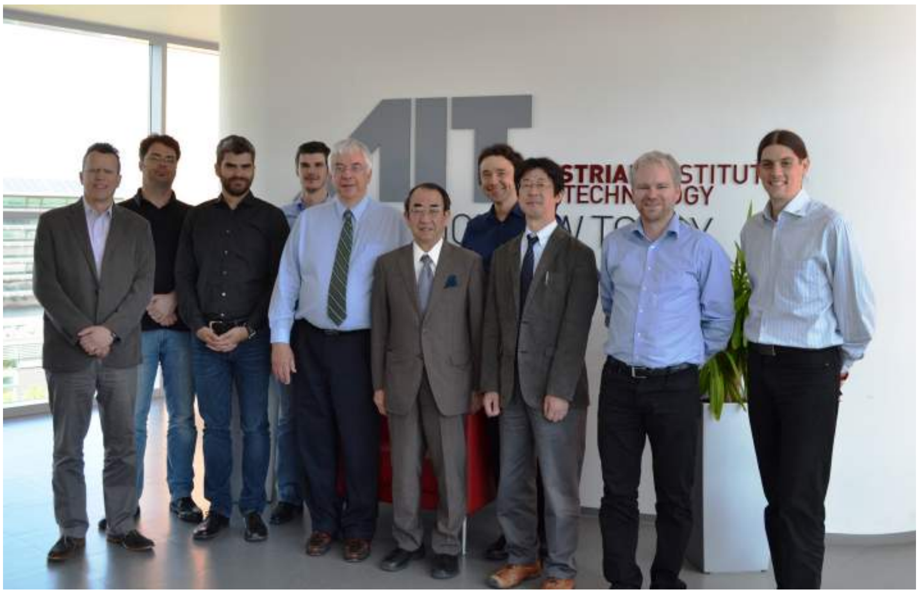
The primary focus is on electrically driven air-source heat pumps (ASHP) with air (air-to-air HP) or hydronic (air-to-water HP) heating systems, since these products suffer severe loss of heating capacity and efficiency at lower outdoor temperatures. The main outcome of this Annex is expected to be information-sharing on viable means to improve ASHP performance under cold (≤ -7 °C) ambient temperatures.

In the past quarter the Annex 41 3rd working meeting was held May 8, 2015 in Vienna at the Austrian Institute of Technology (AIT). The 2nd Annex 41 workshop was held August 19, 2015 in Yokohama, Japan during the 24th International Congress of Refrigeration (ICR). The final workshop program (as presented) is listed on next page. All Participants are continuing to make progress on their country projects.

A 4th working meeting is being tentatively planned for January 22, 2016 in Orlando, FL, USA, just before the start of the 2016 ASHRAE Winter Conference. The final report is planned to be submitted to the ExCo around July 2016.

The Annex web site is http://web.ornl.gov/sci/ees/etsd/btric/usnt/QiQmAnnex/indexAnnex41.shtml

Contact: Van D. Baxter,
baxtervd@ornl.gov



Annex 41: Group photo of Annex 41 members - May 8, 2015, Vienna, Austria

Table: Annex 41 – Yokohama Workshop Program, as presented

Title	Presenter
Introduction to Annex 41	V. Baxter, Oak Ridge National Laboratory, USA
Welcome from host country	Dr. M. Katsuta, Waseda University, Japan
Frosting phenomena between concavity and convexity plate under forced convection & Development of CO_2 thermo syphon for ground heat source assisted heat pump system	Dr. M. Katsuta, Waseda University, Japan
Dynamics of heat pump system with frost formation process	Dr. K. Ohno, Waseda University, Japan
A new method for preventing air-source heat pump water heaters from frosting	Dr. L. Zhang, Central Research Institute of the Electric Power Industry of Japan
Investigation on icing effects of lab scale heat exchangers	Dr. T. Fleckl, Austrian Institute of Technology, Austria
Field performance of cold climate heat pump	Dr. B. Le Lostic, Hydro-Quebec (presented by Dr. D. Giguère, Canmet Energy), Canada
Update on cold climate heat pump research at the Ray W. Herrick Laboratories at Purdue University	Dr. E. Groll, Herrick Labs, Purdue University, USA
Cold climate air-source heat pumps using refrigerant mixtures with thermal glide	Dr. D. Giguère, Canmet Energy, Canada
Liquid Injection – a suitable solution for cold climate heat pumps?	Dr. R. Rieberer, Technical University of Graz, Austria
Tandem, single-speed compressor air-source heat pump system laboratory and preliminary field test results	Dr. B. Shen, Oak Ridge National Laboratory, USA
Closing remarks - Annex 41 final report plan and schedule	V. Baxter, Oak Ridge National Laboratory, USA

IEA HPT Annex 44 Performance indicators for energy efficient supermarket buildings

At the International Conference of Refrigeration 2015, which was held in August in Yokohama (Japan), a scientific paper was presented concerning the results of Annex 44 over the first two years. The paper is primarily based on data concerning supermarket energy consumption collected in the Netherlands. The (preliminary) conclusion presented in the paper is that non-technical issues, such as personnel training, maintenance and management focus, also contribute to the overall energy efficiency. Besides presenting the paper, the members of the Annex team also held a workshop at the conference on the subject for interested parties. Both paper presentation and workshop showed that the work is received with much interest, both amongst academics and industry. In the past two years, it has been difficult to 'translate" this interest in participation in the Annex, mostly due to reasons of financing.

This summer we have welcomed a new participant to Annex 44: Denmark will also participate (alongside the current participants The Netherlands and Sweden). The Danish participation is supported by research and industrial partners from Denmark – who also were present at the recent workshop in Japan. The decision to participate has been taken, and the formalities have now been concluded. One of the consequences of this broadening of the participation in the Annex is that a request will be made to extend the Annex from three to four years, to allow for the inclusion of data and results from Denmark.

Contact: Sietze van der Sluis,
s.m.vandersluis@gmail.com

Ongoing Annexes

Bold text indicates Operating Agent.

Annex 37 Demonstration of Field measurements of Heat Pump Systems in Buildings – Good examples with modern technology	37	CH, NO, **SE**, UK
Annex 39 A common method for testing and rating of residential HP and AC annual/seasonal performance	39	AT, CH, DE, FI, FR, JP, KR, NL, **SE**, US
Annex 40 Heat Pump Concepts for Nearly Zero-Energy Buildings	40	CA, **CH**, DE, FI, JP, NL, NO, SE, US
Annex 41 Cold Climate Heat Pumps (Improving Low Ambient Temperature Performance of Air-Source Heat Pumps)	41	AT, CA, JP, **US**
Annex 42 Heat Pumps in Smart Grids	42	AT, CH, DE, DK, FR, KR, **NL**, UK, US
Annex 43 Fuel Driven Sorption Heat Pumps	43	AT, **DE**, FR, IT, UK, US
Annex 44 Performance Indicators for Energy Efficient Supermarket Buildings	44	DK, **NL**, SE
Annex 45 Hybrid Heat Pumps	45	FR, **NL**, DE, UK
Annex 46 Heat Pumps for Domestic Hot Water	46	**NL**
Annex 47 Heat pumps in District Heating and Cooling systems	47	**DK**

IEA Heat Pumping Technologies participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), Finland (FI), France (FR), Germany (DE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), South Korea (KR), Sweden (SE), Switzerland (CH), the United Kingdom (UK), and the United States (US).
All countries are members of the IEA Heat Pump Centre (HPC). Sweden is the host country for the Heat Pump Centre.

Heating and cooling in Energy systems

Onno Kleefkens, the Netherlands

In energy discussions, heating is the 'Elephant in the Room' – a subject so large that it's often overlooked. Across the globe, it is estimated that thermal energy comprises approximately 50 % of total global final energy demand (across the residential, commercial and industrial sectors). Many analysts estimate that it will not be possible to achieve long-term climate security and energy goals for a low carbon society without two key steps: reducing the demand for heating and cooling and increasing the use of renewable heating and cooling. Heat Pumping Technologies are a key technology in this approach.

What can awaken this sleeping giant? What can policy makers do to accelerate market growth of Heat Pumping Technologies?

At the international policy level, there is broad agreement that we should all move towards low carbon emissions. However, there is notable disagreement about how to achieve this objective. Information about energy alternatives is not always available for, or embraced by, policy decision makers. The shared goal of low carbon emissions will be difficult to realize without exercising control over future infrastructure development worldwide. There is increasing urgency to act, with the fast changing geo-political realities of today. New business models guided by policy must be developed. Promising directions are already being explored; we have to act now.

Urgency to act

Imagine how your life would be without electricity to power the devices you use at home and in the office, without reliable drinking water from the tap, without the convenience of cars, trains and air traffic, without your mobile phone and without Internet access. In many parts of the world, we take these services for granted.

It takes 1.6 Earths to support humanity's demand on nature. But we only have one planet [1].

By Earth Overshoot Day, August 13th 2015, we had spent it all. By August 13th, humanity's annual demand on nature exceeded the total amount of resources that the earth is able to regenerate by year's end. In seven and a half months we had used up the Earth's annual ability to produce wood and food, fresh water and fish, meat and so much more. Even our annual capacity to capture and convert emitted CO_2 had been used with over four months to go. Quite a chilling notion. Earth Overshoot Day moves backwards by about five days per year.

The short-term economic outlook of energy markets seems to justify a delay in energy system transformation. The recent drop in fossil fuel prices ensures that cheap energy is now available. However, short-term economic gains and delayed investment in clean energy technologies will most certainly be outweighed by longer-term costs. Shifting to clean energy and achieving more efficient energy production and consumption can provide an energy security hedge against future market uncertainty [9]. This moves the discussion beyond the traditional topics of energy efficiency, renewables and the environment. The main solutions will not be made based solely on economics, but based on ensuring future energy situations in which the energy infrastructure is more and more independent from insecure suppliers. Fuel savings more than compensate for the higher investment needs in the move to the low-carbon energy sector [10].

For the energy supply chain, long-term policy must include a commitment that the necessary investments will be made. Long-term policy is based upon a number of scenarios. In the decision-making process at the policy level, we have to ask ourselves if the information before us is still uncertain and open to debate. Uncertainties are often inspired by false preachers and lobbyists defending outmoded ideas and conventional solutions for reasons of economic self-interest. Uncertainties will always exist, and to solve this problem, a change in the paradigm shaping our vision has to be established where other than traditional aspects prevail.

The Elephant in the Room

Heating and cooling is the 'Elephant in the Room,' and often overlooked by many. Policy makers worldwide should give primary consideration to heating and cooling usage and look at the best available options. Here heat pumps play a key role as an already available and proven technology.

The IEA Energy Technology Perspectives 2012 [10] mentions a significant untapped potential for energy efficiency in the building and industrial sectors, where low-carbon and zero-carbon technologies for heating and cooling systems are essential to achieve the CO_2 emissions reduction. Within the IEA framework, heat pumps can be seen as a key technology to achieve these goals.

Among energy end users, heating and cooling systems offer substantial potential for decarbonisation that so far has been largely untapped. Today, heating and cooling in buildings and other industry accounts for approximately 40 % of final energy consumption – a larger share than transportation (27 %). With 70 % of heating and cooling demand relying on fossil energy sources, these end uses are estimated to have been responsible for 30 % of global carbon dioxide (CO_2) emissions in 2012. Broad application of more energy efficient practices and the switch to low-carbon final energy carriers (including decarbonised electricity) can push the fossil share to below 50 % by 2050, with renewables (including renewable electricity) covering more than 40 % of heating and cooling needs. Direct and indirect CO_2 emissions linked to heating and cooling would fall by more than one-third by 2050.

It is expected that electricity generation itself will be drastically decarbonised in future energy generation, and according to the ETP 2014 [9] the biggest challenge by far lies in making a massive shift towards clean electricity production and electrification of the overall energy infrastructure. The use of low-carbon electricity with heat pumps for heating and cooling in buildings and industry will thus be a valuable option to reduce emissions in the end-use sectors. Given the storage capacity of these systems, as well as the anticipated building and industrial expansion, heat pump technology can be a game changer in the future development of energy infrastructure. The combination of decarbonized electricity generation and increased electrification of end uses is an important strategy to reduce emissions and improve energy efficiency overall.

In the area of heating and cooling systems, there is a great urgency to act now. Almost all current investments made in this sector will have a long-term effect on overall energy use. The renovation of a heating system will impact energy usage for the next 15 to 20 years. At the same time, almost all these measures to reduce energy emissions, whether implemented within the industrial, commercial or residential market, can be categorized as "no-regret options" and should be prioritized in a systematic policy approach.

The intended lifespan of larger heating systems, such as district heating, reflect an investment of even longer duration. These are heating systems whose traditional designs, based upon high temperature waste heat, cannot be considered a "no-regret option". In most cases the waste heat from industrial processes and electricity generation, which are the momentary heat sources considered, will not be available as feed in over a longer period of time. Substantial energy and cost savings can often be achieved by applying heat pumps in these larger systems [7] and by developing renewable heat sources as low temperature feed in.

The challenge ahead

Fewer than one in ten Europeans think that fossil fuels should be prioritized; 70 % of Europeans think renewable energy sources should be the priority energy option [4]. Unsurprisingly, the Customer Choice scenario for Renewable Heating fails to meet the 2050 carbon reduction targets that we have set as a common goal [3].

The market alone cannot generate the overall solution, as the market continues to react to economic drivers. Large-scale socio-technical systems, such as infrastructures for energy and telecommunication, are not designed and constructed according to a masterplan but are developed incrementally over a long period of time. Most of these changes are designed to satisfy local or national markets' needs and are less often the result of comprehensive governmental policies. When considered in a larger international framework, this approach often results in suboptimal development.

The complex barriers for the wide application of heat pumps are present at various levels:

- Availability of capital – high upfront costs for many heat pump applications compared to conventional alternatives.
- Policy stability – market growth for heat pumps is still often dependent on market design and/or incentives, particularly in mature OECD markets and in renovations.
- Technological and societal challenges – including reliability, system and network stability, cost, size, and benefit distribution.
- Incumbent resistance and system inertia – the vast amounts of capital, power, hardware and physical infrastructure linked to the current energy system.
- The spectacular ability of the current energy system to meet societies' thirst for energy, comfort and growth, while not being able to meet the sustainability goals.

Governments can play a critical role in supporting or even starting up the market for heat pumps by ensuring stable, long term support in all stages – from basic and applied research through to development, demonstration and deployment phases [2]. In the case of heat pumps it is not so much a question of technological innovation but more of market innovation, especially in mature OECD markets.

Rethinking energy

In line with the main policy developments to create a secure, sustainable and competitive energy system heat pumps can support and serve as a key technology for these policy objectives [3]:

- Energy security - Heat pumps eliminate the need for fossil fuel imports coming from politically unstable regions and support the larger goal of reducing overall energy demand/need.
- Integrated energy market - Heat pump systems bridge electric grids and thermal networks. Serving as thermal batteries, they provide demand-response capacity. Heat

pumps enable a higher share of renewables in complex energy systems.
- Research, innovation and competitiveness - Heat pump applications offer a variety of solutions to keep the industry competitive. In future smart cities/regions, they will be at the heart of energy-optimized buildings and infrastructure that integrates different energy technologies.
- Incentives to increase employment and creation of new business models that replace the traditional model of 'selling as much energy as possible.' Energy companies must find ways to profit from saving energy.
- A reduction in energy poverty, i.e. when the total cost of household energy bills exceeds the threshold relative to household income. In many OECD countries this is a growing problem. Heat pumps combined with conservation measures reduce the end user costs for energy and the likelihood of energy poverty [7].

Energy efficiency [5, 8] and renewable energy [6] are the two basic factors, where heat pumps increase energy efficiency in the residential, commercial and industrial sector and decarbonize by using sustainable energy from air, water and ground, and renewable electricity as an energy source.

Conclusion

There is a link between the rather grand Earth Overshoot Day and the more mundane obsolescence of current energy business models. It is already noticeable that ecological concerns are more and more becoming key drivers for policy makers, large industries and consumers alike, and their choices are fundamentally going to alter the energy business landscape. However these first signs of change are not sufficient yet. New business models guided by policy must be developed. Promising directions are already being explored; we have to act now.

The International Energy Agency analysis demonstrates that it is both realistic and economically sensible to pursue a clean energy agenda, and that the tools and mechanisms exist to support innovative and transformative change to create an affordable, secure and environmentally sustainable energy future.

To achieve all that, it is necessary that we go beyond the traditional approach with regard to energy efficiency and renewables; re-thinking these twin elements remains critical. Climate change and energy scarcity problems are two of the most complex sustainability challenges facing not only scientists but also policy makers. Attempts at tackling these issues should be approached from two fronts: by increasing the energy efficiency (demand side) and by promoting the usage of renewables and non-greenhouse gases-emitting energy sources (supply side). The energy supply until 2050 and beyond needs to be structured in another way than our experience in 2014.

Heat pump solutions are reliable, mature and ready to deliver.

Author contact information
Onno Klefkens (M.Sc., Consultant on Renewable Heating and Cooling), Phetradico Communication and Publishing, the Netherlands,
onno@phetradico.com

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The Progress of GSHP in Japan

Katsunori Nagano, Japan

Since the March 11 crisis, Japanese citizens have taken a great interest in energy issues, and the Japanese government has taken various actions to promote the introduction of a renewable energy system. One such action is the focus on ground source heat pump systems. The GSHP market is growing by 20 % a year and GSHPs have been planned in many NZEB projects in recent years. This paper reports on the current status of the Japanese GSHP market and shows an example of NZEB integrated with renewable energy resources, including a GSHP for the floor heating system in a cold region.

Background

Use of a ground heat source has some benefits: everybody can use it everywhere at any time, and it results in reduced CO_2 emissions. It is also a very effective way to reduce the heat island effects when we use the ground as a heat sink for the air conditioning system.

From these points of view, the introduction of a renewable thermal energy system including effective use of the ground heat source has been described in Japan's Fourth Strategic Energy Plan, endorsed by the Cabinet in April 2014. After this endorsement, various supporting programs, including subsidies for promoting ground source thermal energy systems have been carried out by the Ministry of the Environment; the Ministry of Economy, Trade and Industry; the Ministry of Land, Infrastructure, Transport and Tourism; the Ministry of Agriculture, Forestry and Fisheries, and other ministries.

In addition to governmental actions, various local governments, such as Tokyo metropolitan government, and those of other, small towns also have their own programs to promote ground source heat pump systems (GSHP).

The total number of GSHPs installed in the 2013 fiscal year was 273, as shown in Figure 1, as the result of an investigation carried out by the Ministry of the Environment [1]. Of the systems, 90 % are closed type, and borehole systems are the most

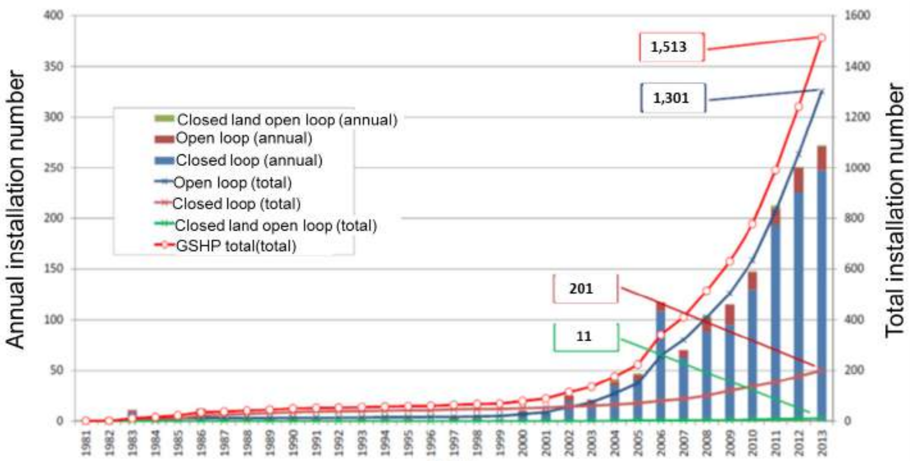

Figure 1. Trends in developments in the Japanese GSHP market [1]

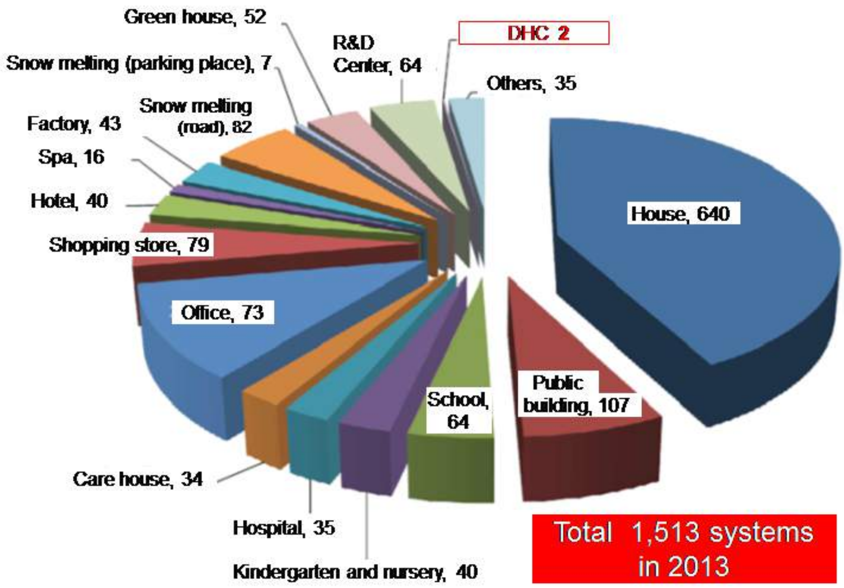

Figure 2. Application of GSHPs in Japan (2013) [1]

popular in Japan. The total number has almost doubled between 2010 and 2013 and is increasing along the parabola. The average heating capacity reaches to 56 kW, which is much higher than in the EU and US. This shows that the GSHP market in Japan is led by the commercial building sector, as shown in Figure 2. Representative examples can be found in the Tokyo Sky Tree district cooling and heating system, the Tokyo Haneda international airport terminal building, the IKEA Fukuoka store and the IKEA Tachikawa store, as well as public offices, schools buildings, hospitals and nursing homes. When recounting the numbers based on 12 kWt per building, according to the EU market analysis, the total number installed reaches approximately 1 300.

Although the largest numbers appear in the Hokkaido region, due to the climate conditions and large heating demand similar to the Nordic countries, the numbers installed in Tohoku, Tokyo, Chubu and Chugoku area are also growing as its higher seasonal efficiency and stable operation during summer is gradually recognized. This fact shows that the motivation behind using GSHP equipment is not only for heating purposes but also for cooling and air conditioning purposes, according to the statistical data, with major installers in each area playing an important role in developing the local market. In fact, an investigative report commissioned by the Ministry of the Environment concluded that GSHP systems showed a 10 % to 30 % energy saving effect, compared to the conventional air source heat pump (ASHP) systems. In addition to this, anecdotal evidence suggests that building owners who have equipped their buildings with GSHP systems are generally satisfied with the stable operation and low maintenance and low energy consumption. Such reliable impressions may promote the decision to adopt such systems in emerging GSHP projects.

Electric energy consumption	Thermal energy production (45 °C)	COP of HP units
71.8 MWh	225 MWh	3.55

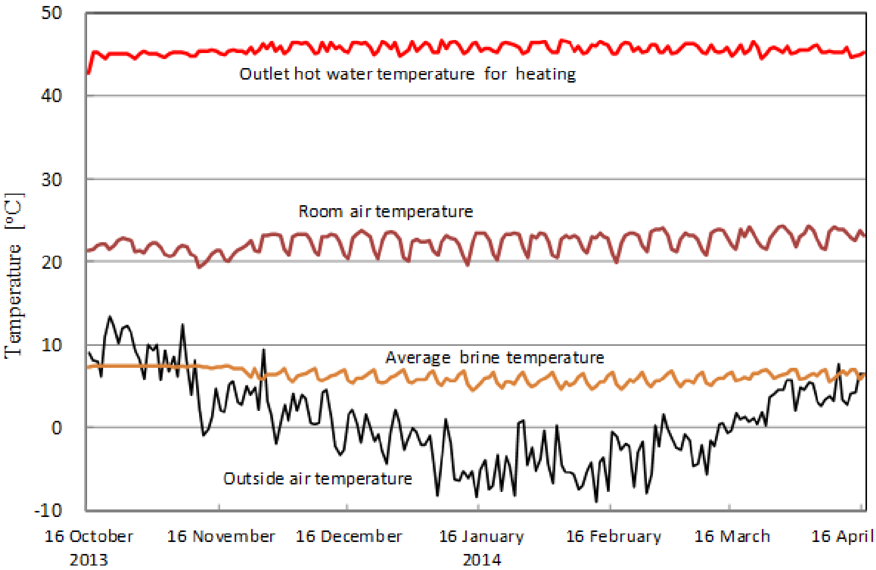

Figure 3. GSHP heating system for the primary school building in Kuromatsunai town

Success story in the Niseko area, Hokkaido

The author would like to introduce the success story in Niseko town and the 'Ripple Effect' in Hokkaido. Niseko town, which is located approximately 120 km west of Sapporo city, is now very famous as a ski resort, especially for Australian and Asian tourists. The town is very eager to promote environmental protection and the use of local renewable energy resources. The author chaired a green decentralization of power reform promotion committee in this town in 2010. At that time, an officer in charge at the energy and environmental department asked me for advice on the renovation of the heating and cooling system in the small museum in this town. The author recommended replacement of the current electrical heater heating and package air conditioning systems with a GSHP system. This turned out to be a success. The town has adopted six GSHP systems overall; one in the village center (2,500 m^2, 2012), one in a greenhouse in a high school (200 m^2, 2012), one in a community radio station (150 m^2, 2012), one in a group home for elderly persons with dementia (800 m^2, 2014) and one at an after-school day care facility (300 m^2, 2015). Furthermore, the mayors and officers of the neighborhood municipalities who visited and observed these facilities recognized that GSHP is the best heating system in the cold and snowy region, and thus decided to introduce GSHP systems at their own municipalities' facilities, such as a social welfare home, special elderly nursing homes, public housing, primary schools, nursery schools and after-school day care centers. This is a good example of the 'Ripple Effect', and it extends to various regions even in the central part in Japan.

Figure 3 shows the outside view of the primary school building in Kuromatsunai town, Hokkaido. This building was completely renovated, for better thermal performance. In addition, GSHP was installed for floor heating, with heating tubes placed on the original floor and subsequently new wooden floor material was put on it without mortar, so water is circulated at 45 °C. Two 115 kWt HP units with 36 single U-tube borehole exchangers of 80 m length have been installed. The measured seasonal COP of the HP units were 3.55. In this case, the room air temperature was kept at around 22 °C and the average brine temperature circulated in the ground loops fluctuated between 5 and 7 °C.

We now understand how important enthusiasm and word-of-mouth communication from reliable persons in charge to visitors is in spreading new technology.

Figure 4. Images of the façade and interior hall space in Rusutsu Village Children's Center

An example of the 'Ripple Effect'; Low energy building in Rusutsu village

Rusutsu Village Children's Center

Rusutsu village is neighbor of Niseko town. This children's center was built in April 2015. Rusutsu village is well known for having a cold climate and heavy snow, with the minimum air temperature often reaching -25 °C. The center has several functions, serving as a nursery, child care support center and after school facility for children. It is a single story wooden paneled building with good thermal insulation and a total floor area of 1 500 m^2 (Figure 4). The overall heat loss coefficient is 0.93 W/(m$^2_{\text{floor area}}$·K).

HVAC system and low energy techniques

Low temperature floor heating with three invertor-driven GSHP units (each with a regular thermal output of 28 kW) was adopted. For the ground heat exchangers, a total of fifteen vertical boreholes of a depth of 85 m with a single U-tube (ID 25 mm Ø) were constructed and connected to the heat pump units in parallel. The geological condition of this site was mainly silt consisting of volcanic ash. The result of the thermal response test (TRT) indicated that the average effective thermal conductivity of the ground was 1.45 W/(m·K).

A combination of an evacuated tube solar collector (3.0 m^2) and an air-source CO_2 heat pump water heater (heating capacity 7.2 kW) store hot water and supply the kitchen. In order to reduce the heat demand for the ventilation, four earth tubes were installed in order to preheat and precool the outside air, and high efficient heat recovery ventilation units were also installed. Each earth tube was 40 m long with a diameter of 400 mm, and they were buried at a depth of 2.5 m under the basement of the building. In addition to this, passive humidity and odor control was installed in the ventilation chamber, using underground pit spaces piled up with bags filled with natural mesoporous rock and charcoal. LED lighting and toplights on the roof were provided.

ZEB simulator to evaluate energy consumption and performance

The ZEB simulator developed by the author's laboratory was applied to analyze the energy demand and the energy consumption [2]. This ZEB simulator consists of six calculation modules, as shown in Figure 5:

1. Heating and cooling of the Building
2. Heating and cooling machines
3. Ground heat exchanger and heat transfer into the ground
4. Domestic hot water supply (DHW)
5. Ventilation and earth tube
6. Lighting and other facilities.

AMEDAS weather data is used for the annual calculation. The heating period is set from October 6 to May 28. In essence, GSHP units will operate continuously to maintain a room air temperature at least 22 °C from 8 am to 6 pm.

Calculation results and discussion

It is clear that maximum supply water temperature needed for the floor heating is only 33 °C, which will maintain a room air temperature of 22 °C during the daytime, even in the severe midwinter. The seasonal performance factor for the GSHP floor heating system, including energy consumption for pumping, is 3.8. The total energy demand and heating demand are 144 and 92 MWh respectively, and 51.4 % can be supplied from renewable energy resources. The total power consumption is 67.6 MWh and 41 % is used for heating purpose. This means that when this building provides a generating capacity of 80 kW with the PV system on the

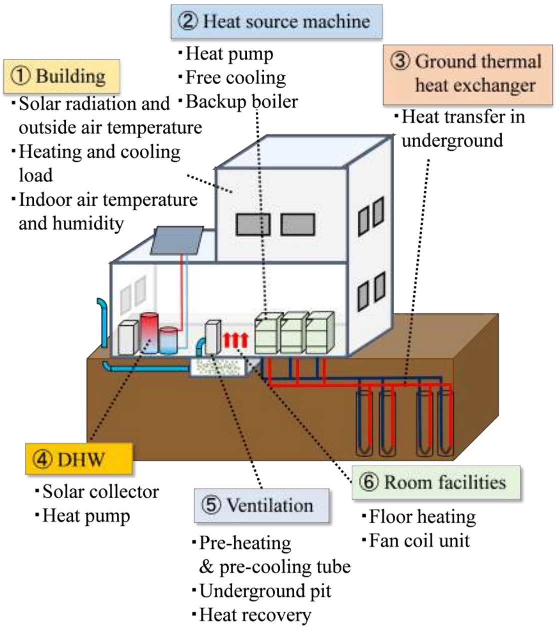

Figure 5. Structure of the ZEB simulator

	Overall heat loss coefficient	Heating	Hot water supply	Heating and cooling tube	Light
Standard	1.6 W/(m²K)	Oil	Oil	No	Fluorescent light
Current	0.93 W/(m²K)	GSHP	ASHP	Yes	LED

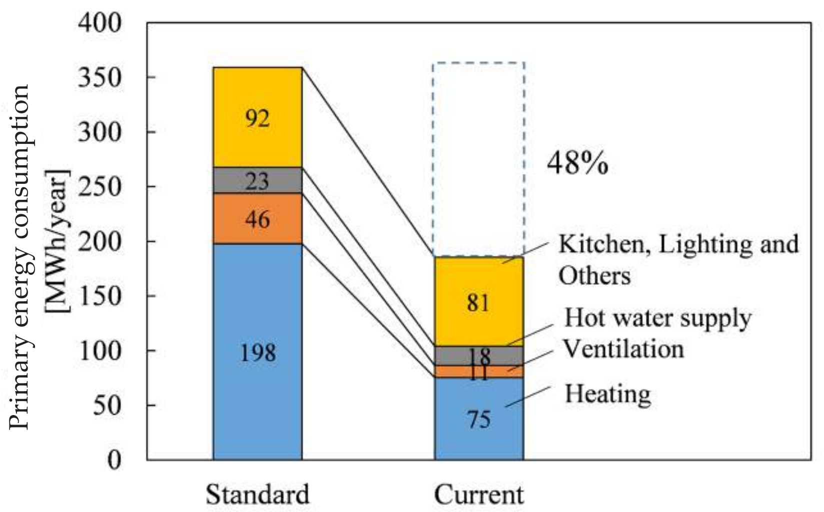

Figure 6. Estimated levels of reduced primary energy consumption

roof, net zero energy through the year can be achieved.

The primary energy saving of this building is evaluated compared to a conventional building, where the heat loss coefficient of the building is 1.6 W/(m^2·K), kerosene boilers are used for heating and DHW, and a total heat exchanger for the ventilation system is provided without earth tubes. As shown in Figure 6, primary energy consumption is reduced by 50 %. In particular, the energy consumption for heating is dramatically decreased to 38 %. Here, the contribution of each item to the energy saving was examined. The results show that the reduction effect of enhanced insulation is 22 %, use of renewable energy is 24.6 % and use of LEDs is 2.8 %.

GSHP market prospects in Japan

It is said that developing the GSHP market in Japan is the result of our continuous efforts related to this technology. On the other hand, it is a fact that the growth depends on governmental support. It is well known that subsidies are very effective in accelerating dissemination at the initial stage. This must then be carried on into the autonomous development stage. Industry, government and academia must work in cooperation to create standard design methods, energy-saving effect calculation methodology, quality management, cost reductions in construction, and a highly efficient GSHP system integrated with other renewables.

The national R&D program on the utilization of renewable thermal energy resources began in 2014 and runs until 2018. Its objectives are a 20 % reduction in both the initial cost and the operating cost of renewable thermal energy systems, to harvest the autonomous market. 12 projects have been adopted, including that of the author's team. Although the initial cost of constructing a GSHP system is still higher than that of many other systems, the author believes that this is one of few renewable energy systems which are guaranteed to bring payback, as well as having a great growing potential equivalent to the Nordic market. In fact, opportunities for adopting GSHPs increased in many ZEB projects, as introduced here. In addition to this, GSHP could also form the core of a smart community, with its flexible storage effect. Future market expansion can be expected.

Author contact information
Katsunori Nagano, PhD, Presidential Advisor, Professor,
Graduate School of Engineering, Hokkaido University
nagano@eng.hokudai.ac.jp

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Direct exchange ground source heat pumps

Hermann Halozan, Austria

Direct-exchange ground-source – DX - heat pumps with horizontally installed ground collectors had a market share of 65 % in Austria in the mid nineties. They were the most efficient heat pump type achieving SPFs between 4 and 5. Currently, air source heat pumps dominate the market; the share of DX heat pumps is in the range of 5 %. The problem of polluting the groundwater in the case of a leakage has been solved and the required space for ground collectors reduced while compressors with continuous capacity control have been improved significantly. In terms of efficiency, DX heat pumps are still the most efficient solution for heating homes.

Introduction

After the second oil price shock in 1979 heat pumps installed in Austria were, like in other countries in Northern and Central Europe, heating-only systems. They were either ground water heat pumps for monovalent operation for new buildings equipped with floor heating systems or outside air heat pumps for bivalent systems combined with existing boilers for retrofitting existing buildings with high-temperature radiators; bivalent systems dominated the market. The rapid drop in oil price in 1985 combined with the reduction of governmental subsidies eliminated the retrofit market. Although heat pump installations in new buildings were not so sensitive to the oil price, a new heat source had to be found, since air source bivalent systems were no longer competitive and groundwater was limited. This new heat source was the ground itself.

Initial thoughts to use the ground as a heat source were made in 1912 by Heinrich Zoelly from Switzerland. In the forties, investigations on ground-source heat pumps, partly direct expansion systems, started again in the US and in Germany [1]. However, the commercial utilisation of the ground as a heat source for heat pumps began in the seventies. The systems installed at this time were mainly secondary loop systems. Later on, direct expansion systems, now called direct exchange – DX - ground source heat pumps, mainly with horizontally installed ground coils, have been introduced [2]. In Austria in the mid nineties DX heat pumps covered 65 % of the heating only heat pump market. They were the most efficient heat pump type achieving SPFs higher than 4, if building standards were kept and the design of the overall system had been made carefully. The main concern was pollution of the groundwater in the case of leakage; this problem has now been solved. A tube-in-tube system is used, with an inner tube of copper for the refrigerant, and an outer tube of plastic; and where both can withstand the maximum operating pressure. Additionally, in off-operation and in the case of a leakage, a pump down takes place, evacuating the in-ground evaporator.

Nowadays the situation has changed significantly: the market is dominated by air source heat pumps followed by secondary loop ground coupled heat pumps; the share of DX heat pumps is in the range of 5 %. The reasons for this development are limited space for horizontally installed ground collectors and the aim of manufacturers to sell units and not highly efficient systems. A brine/water heat pump can be tested easily in a lab, but for a DX unit a special test rig is necessary and there are only a few DX test rigs available. The space problem is reduced by improved buildings with reduced heat load. In terms of efficiency, DX heat pumps are still the ground-coupled heating solution with the highest efficiency [3].

Ground-Source Heat Pumps

Ground-source heat pumps use media – water, earth, rock etc. - below the surface as the heat source/heat sink [4]. The following nomenclature has been adopted by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to distinguish among the various types of earth connection systems:

- Ground-Coupled Heat Pumps (GCHPs) - use the ground as a heat source and sink, either with vertical or horizontal Ground Heat eXchangers (GHXs);
- Groundwater Heat Pumps (GWHPs) - use underground (aquifer) water as a heat source and sink;
- Surface Water Heat Pumps (SWHPs) - use surface water bodies (the sea, lakes, ponds, etc.) as a heat source and sink.

Ground Frost Heat Pumps (GFHPs) is another specialized type to maintain sound structural fill in natural permafrost around foundations by extracting heat from the fill.

A ground-coupled heat pump uses the shallow ground as a source of heat, thus taking advantage of its seasonally moderate temperatures. In the summer, the process can be reversed so the heat pump extracts heat from the building and transfers it to the ground (Fig. 1). Transferring heat to a cooler space takes less energy, so the cooling efficiency of the heat pump gain benefits from the

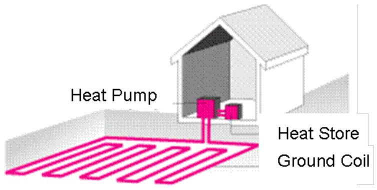

Figure 1. Ground-Coupled Heat Pump

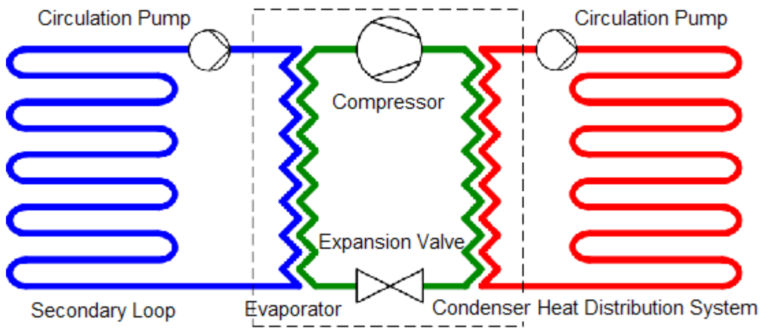

Figure 2. Secondary Loop Ground-Coupled System

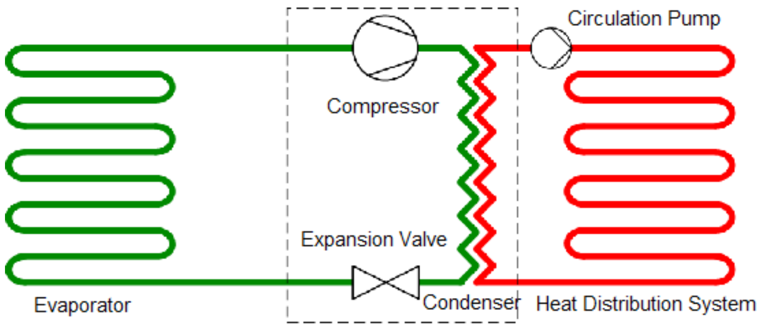

Figure 3. Direct Exchange Ground Coupled System

lower ground temperatures. Shallow horizontal heat exchangers experience seasonal temperature cycles due to solar gains and transmission losses to ambient air at ground level. These temperature cycles lag behind the seasons because of thermal inertia, so the heat exchanger can harvest heat deposited by the sun several months earlier. Deep vertical systems rely heavily on migration of heat from surrounding geology. In the case of heating-only operation, recharging of the ground has to happen by natural effects, in the case of heating and cooling operation recharging can happen by the excess heat from cooling operation.

Ground-coupled heat pumps must have a heat exchanger in contact with the ground to extract or dissipate heat. Several major design options are available for these, which are classified by fluid and layout, Secondary loop systems and Direct exchange systems.

Secondary Loop Systems

Secondary loop systems have two loops on the ground side: the primary refrigerant loop is contained in the appliance cabinet where it exchanges heat with a secondary loop that is buried underground (Fig. 2). The secondary loop is typically made of high-density polyethylene pipe and contains a brine, a mixture of water and anti-freeze (propylene glycol, denatured alcohol or methanol). After leaving the internal heat exchanger, the brine is pumped through the secondary loop outside the building to exchange heat with the ground before returning. The secondary loop is placed below the frost line where the temperature is more stable, it can be installed horizontally as a loop field in trenches or vertically as a series of long U-shapes in wells. The size of the loop field depends on the soil type and moisture content, the average ground temperature and the heat loss and or gain characteristics of the building being conditioned.

Vertically Installed Systems
A vertical secondary loop field is composed of pipes that run vertically in the ground. A hole is drilled into the ground, typically 20–120 (240) m deep. Pipe pairs in the hole are joined with a U-shaped cross connector at the bottom of the hole. The borehole is commonly filled with a bentonite grout surrounding the pipe to provide a thermal connection to the surrounding soil or rock to improve the heat transfer. Thermally enhanced grouts are available to improve this heat transfer. Vertical loop fields are typically used when there is a limited area of land available.

Horizontally Installed Systems
A horizontal secondary loop field is composed of pipes that run horizontally in the ground. A horizontal trench, deeper than the frost line, is excavated and U-shaped or slinky coils are placed horizontally inside the same trench. Excavation costs for horizontal loop fields are about half of those for vertical drilling, so this is the most common layout used wherever there is adequate land available.

DX - Direct Exchange Systems

The direct exchange ground-coupled heat pump (also called direct expansion, direct evaporation ground coupled heat pump) is the oldest type of ground-coupled heat pump technology (Fig. 3). It is also the simplest and easiest to understand. The ground-coupling is achieved through a loop circulating refrigerant in direct thermal contact with the ground. The refrigerant leaves the heat pump appliance cabinet, circulates through a loop of copper tubes protected with a plastic coating against corrosion buried underground, and exchanges heat with the ground before returning to the heat pump. The name "direct exchange" refers to heat transfer between the refrigerant and the ground without the use of an intermediate fluid. There is no direct interaction between the fluid and the earth; only heat transfer through the pipe wall.

Direct exchange systems are more efficient and have potentially lower installation costs than secondary loop borehole systems. Copper's high thermal conductivity contributes to the higher efficiency of the system, but heat flow is predominantly limited by the thermal conductivity of the ground, not the pipe. The main reasons for the higher efficiency are the elimination of the secondary fluid circulation pump (which uses energy), and avoiding the heat transfer between brine and refrigerant (which is a source of energy losses).

Ongoing Developments

Future development will be characterised by the improvement of components, probably other refrigerants, and advanced systems [5].

In the small to medium size capacity range the reciprocating compressor has been practically replaced by the rotary compressor and the scroll compressor. These two compressors have some advantages, a minimum of moving parts, they are highly suitable for variable speed operation or variable capacity operation, respectively. Variable capacity operation means no mixing losses – heat pump outlet temperatures higher than the supply temperature needed – and in part load operation especially in the case of ground-coupled systems an increased evaporation temperature due to a smaller heat flux and therefore a lower temperature drop between ground and refrigerant. To achieve high SPFs, 4 up to 6 in some applications, the design of the heat pump unit as well as the whole system have to be carried out very carefully.

The refrigerant velocity in the evaporator has to be kept as low as possible to minimize the pressure drop, which means also a drop in the evaporation temperature, but it has to be high enough to ensure oil return. In horizontally installed collectors the required velocity at the evaporator outlet has to be about 5 m/s.

In the case of variable capacity operation this speed has to be achieved at full-load operation. To guarantee oil return, depending on the compressor used, after a defined number of hours in part-load operation the compressor has to be switched for 10 minutes to full-load operation to bring the oil back.

Soldering on site is limited to the connection heat pump cabinet and ground coil; the coil is made of endless double wall tubes. In order to avoid soldering completely on site one heat pump manufacturer in Austria has developed a packaged direct-expansion heat pump using propane as the refrigerant. The heat pump unit – designed for outdoor installation due to Austrian regulations – connected with the ground evaporator is prefabricated, filled with the refrigerant charge required, and tested at the factory. The complete unit is transported to the site on a pallet, the heat pump part is mounted on a small foundation. The evaporator coil, folded on the pallet, is laid out in the excavated ground, covered with sand and then with the excavated ground material. The connection to the heating system in the building consists of the supply and the return pipe and cables for the power supply and control. The control itself and the heating water circulation pump are mounted in the building.

Conclusion

Currently, these highly efficient systems play a minor role, however, a lot of developments have been made in recent years. Improved buildings can be heated with a supply temperature below 30 °C, the reduced heat load reduces the space requirement of the ground coil. Variable speed compressors reduce the temperature drop ground/refrigerant significantly, which increases the evaporation temperature and efficiency. Coils are made from endless double-wall tubes, copper on the refrigerant side and plastic on the ground side, where both can withstand the maximum operating pressure independently. Taking these developments into consideration, DX heat pumps with horizontally installed coils are reliable and, when considering efficiency, reduced CO_2 emissions and the utilisation of renewable energy, an excellent heating system.

Author contact information
Hermann Halozan, Univ-Prof,
Graz University of Technology, Austria,
halozan@tugraz.at

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Case studies for GSHP demonstration projects in the US

Xiaobing Liu, Mini Malhotra, Piljae Im, Bahman Habibzadeh, USA

Under the American Recovery and Reinvestment Act , twenty-six ground source heat pump (GSHP) projects were competitively selected and carried out to demonstrate the benefits of GSHP systems and innovative technologies for cost reduction and/or performance improvement. This article gives an overview of the case studies for six of the systems. These case studies evaluated efficiencies, energy savings, and costs of the demonstrated systems. In addition, it was found that more energy savings could be achieved if controls of GSHP system are improved.

Introduction

High initial cost and lack of public awareness of ground source heat pump (GSHP) technology are the two major barriers preventing rapid deployment of this energy saving technology in the United States [1]. To tackle these barriers, 26 GSHP projects were competitively selected by the US Department of Energy (DOE) in 2009 and awarded with grants under the American Recovery and Reinvestment Act (ARRA) to demonstrate the benefits of GSHP systems and innovative technologies for cost reduction and/or performance improvement. Six of these demonstration projects were selected for case studies, which cover a range of building types and system configurations.

Figure 1. Location of ARRA-funded GSHP demonstration projects (red star with red circle indicates the six projects that have completed case studies)

This paper presents the characteristics of the six GSHP systems, the analysis methodology, evaluations of key performance metrics, and identified common issues. Figure 1 shows the location of the 26 ARRA-funded GSHP demonstration projects and indicates the location of the six case studies.

Overview

A brief overview of the six selected GSHP systems and the buildings they serve are provided below.

Case #1

This project is located at Kalispell, Montana. The GSHP system uses groundwater extracted from a 11 m (35 ft) deep well as the heat source for a central modular 280 kW (80 ton) water-to-water heat pump (WWHP), which provides only space heating to an existing 2 044 m² (22,000 ft²) warehouse and truck bay, and a newly added 864 m² (9,300 ft²) truck bay. The hot water supply temperature is reset based on the outdoor air (OA) temperature.

Case #2

This project is located at Cedarville, Arkansas. A new distributed GSHP system was implemented to replace aged existing HVAC systems in a 6 000 m² (65,000 ft²) high school building, and provide space conditioning to a newly added 511 m² (5,500 ft²) cafeteria and laboratories. The GSHP system uses vertical bore closed-loop ground heat exchangers (GHXs) and 45 packaged water-to-air heat pump (WAHP) units with a combined cooling capacity of 812 kW (232 tons). Most of the WAHP units provide dedicated humidity control to the conditioned space. Unconditioned outdoor air is ducted to each WAHP unit and modulated based on the indoor CO_2 level.

Case #3

This project is located at Raleigh, North Carolina. It is a distributed GSHP system that serves a 2 230 m² (24,000 ft²) new office building. This system uses closed loop vertical bore GHXs, 27 WAHP units (with a total 300 kW or 84.5 ton combined capacity) for space heating and cooling, a 175 kW (50 ton) WAHP unit to condition outdoor air in a dedicated outdoor air system (DOAS), and a 87.5 kW (25 ton) WWHP dedicated for domestic water heating.

Case #4

This project is located at Albany, New York. It is a distributed GSHP system that provides space conditioning and outdoor air ventilation in a new 17 187 m^2 (185,000 ft^2) university student housing building. This system consists of vertical bore closed loop GHXs, 188 WAHP units with a combined capacity of approximately 1,253 kW (358 tons), four rooftop units to provide conditioned OA to common areas, and 27 energy recovery ventilator (ERV) units, each delivering partially conditioned outdoor air to the WAHP units in the suites.

Case #5

This project is located at Rochester, Michigan. It uses a water source variable refrigerant flow (WS-VRF) system and a DOAS system to condition a 15 979 m^2 (172,000 ft^2) new institutional building. The GSHP system consists of vertical bore closed loop GHXs, 50 WS-VRF heat pumps with a combined capacity of 1120 kW (320 ton) to provide space conditioning, and 3 WWHP units, each with 140 kW (40 ton) capacity to provide chilled and hot water to the DOAS for OA ventilation.

Case #6

This project is located at Butte, Montana. It consists of a 175 kW (50 ton) WWHP and closed-loop GHXs immersed in a nearby flooded mine as the heat source and heat sink. The GSHP system works in conjunction with the originally installed central steam heating and chilled water system to condition a 5 200 m^2 (56,000 ft^2) newly constructed research facility.

Analysis

Performance data of the demonstrated GSHP systems were collected from the award recipients. Typical data points included temperature and flow rate in the ground loop (and the load-side water loop for central systems using WWHPs) and power draw (or pump speed) of circulation pump(s). For one central GSHP system (case #1), power draw of the WWHP was also measured, but for most distributed GSHP systems (except for case #3), the power draw of each heat pump and its heating/cooling output were not measured due to additional cost for the sensors to measure power draw, air/water flow rate and temperature (and humidity) at each heat pump. In most cases, only heat pump runtime data was recorded.

Performance evaluation for distributed GSHP systems is more challenging than for centralized systems due to the multiple heat pump units that can provide space heating and space cooling simultaneously in different zones at any given time, especially during shoulder seasons. Thus it is necessary to determine the heating and cooling outputs and the associated power consumptions for each individual heat pump.

The heating/cooling outputs and the associated power consumptions for each individual heat pump unit are calculated based on the measured run time data, the measured coincident heat pump entering fluid temperature, and the performance data presented in the heat pump manufacturer's catalog. This calculation procedure is discussed in more detail in a technical report [2] and has been validated against measured data. The validation was conducted by comparing the daily sum of the calculated heat rejection and/or heat extraction of each heat pump against the measured daily heat transfer load imposed on the ground loop. The comparison indicated that the two sets of data match well with less than a 20 % discrepancy for most weekdays. The low resolution of the daily run time data (i.e., hours per day) is thought to be a reason for the discrepancy.

Performance analysis was conducted in two steps:

1. measured data analysis
2. annual energy analysis

The measured data were analyzed to:

a. assess the operating efficiency of the heat pump and the overall GSHP system
b. assess the operation of the pump(s)
c. identify faults/abnormalities in GSHP system operation and determine potential improvements to the GSHP system.

Annual energy analysis was performed with computer models of the host buildings, which were calibrated against available data of the building heating and cooling loads to:

a. predict full-year performance of a baseline system
b. estimate the energy savings, operating cost savings, and emissions reduction benefits compared to the baseline system.

The baseline HVAC system for each case study was selected based on building use and availability of natural gas to the building.

Results

Table 1 summarizes the key design parameters, performance data, and costs of the demonstrated GSHP systems. Detailed information for the case studies are presented in technical reports and papers [3 through 10].

Performance of the GSHP systems were evaluated with a system coefficient of performance (SCOP) metric. SCOP is the ratio of the aggregated heating/cooling output of each heat pump (excluding backup heater if there is any) to all the power consumed to provide such output, including the power consumed by the heat pumps and the circulation pumps. Case study results indicated that SCOP varied from 2.2

Table 1. Summary of case studies

	#1	#2	#3	#4	#5	#6
System configuration	Central (space heating only)	Distributed	Distributed	Distributed	Distributed	Central
Heat pump	280 kW WWHP unit	45 WAHPs with 812 kW total capacity	28 WAHPs with 475 kW total capacity (27 for heating and cooling, and one for DOAS), one 87.5 kW WWHP for DHW	188 WAHPs and 4 ground source RTUs (1253 kW total capacity)	50 HR/HP type WS-VRF systems with 1120 kW total capacity and 3 140 kW WWHPs to supply hot/chilled water to DOAS	175 kW WWHP unit
Ground source	Open loop with 2 shallow ground water wells (11 m deep)	Closed loop vertical GHXs, 98 bores (11948 m total bore length)	Closed loop vertical GHXs, 60 bores (6126 m total bore length)	Closed loop vertical GHXs, 150 bores (20,574 m total bore length)	Closed loop vertical GHXs, 256 bores (24,969 total bore length)	3657 m 19 mm HDPE pipe immersed in mine water
OA ventilation	Heated with GSHP and HRV/ERV	Unconditioned and modulated with CO_2 level	Ground source DOAS with ERV	Ground source DOAS and ERV	Ground source DOAS with ERV	NA
Pump and control	A 5.6 kW VS pump with fixed DP control	Two 18.65 kW VS pumps with fixed DP control	Two 14.9 kW VS pumps with fixed DP control	Three 14.9 kW VS pumps (primary) with fixed temperature control and two 29.8 kW VS pumps (secondary) with fixed DP control	Two 44.8 kW VS pumps to circulate constant flow rate in WS-VRF units	Two 5.6 kW constant speed pumps
Annual system performance						
SCOP (Cooling)	-	3.1	4.2	3.0	2.3	3.6*
SCOP (Heating)	2.7	3.3	4	2.5	2.2	3.7*
Pumping energy fraction	17 %	21 %	18 %	45 %	16 %	19 %*
Installed cost	$1,182 per kW	$2,060 per kW	$2,684 per kW	$3,958 per kW	$4,896 per kW	Unavailable
Energy savings and emission reduction benefits						
Baseline	Electric boiler	Variable air volume (VAV) with hot water (HW) reheat	VAV with HW reheat	ASHP with electric heater	VAV with HW reheat	Central steam heating and air-cooled chiller
Source energy savings	66 %	53 %	37 %	49 %	33 %	38 %
CO_2 emissions reductions	66 %	52 %	36 %	49 %	25 %	39 %
Energy cost savings	65 %	53 %	39 %	49 %	23 %	43 %

* *Does not include load-side pump, which is from the existing system*

to 4 for heating, and from 2.3 to 4.2 for cooling. Due to the inclusion of pumping energy use, SCOP is lower than the efficiency of the heat pump units, especially during part-load conditions (Fig. 2).

The percentage of total GSHP system energy use due to pumping varied from 16 to 45 %. It was found in case #4 that an improper control strategy had made variable speed pumps run at high speed almost year round, which consumed nearly the same amount of energy as all the heat pumps combined!

As shown in Table 1, the GSHP systems saved 33-65 % source energy compared with the baseline HVAC systems. Correspondingly, they reduced CO_2 emission in the range from 25 to 65 %. The operating cost was reduced by 23 to 63 %.

The installed costs of the six GSHP systems varied from $1 182 per kW to $4 896 per kW ($4 140 per ton to $17 136 per ton), with the lowest cost at case #1, which uses a shallow aquifer as the heat source, and the highest cost at case #5, which uses a sophisticated ground coupled WS-VRF system. It was found that GHXs were oversized in a few projects for future extension. In addition, extra engineering work was performed for implementing the relatively new GSHP technologies (e.g., the WS-VRF in case #5). These factors may have resulted in higher installed cost than it would be when the application of the new technologies becomes more common.

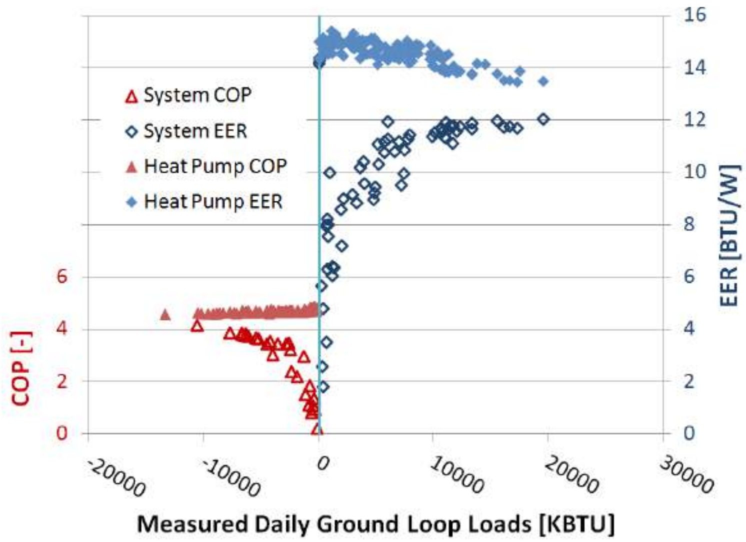

Figure 2. GSHP system efficiency vs. heat pump efficiency at various loading conditions (example results of case # 2)

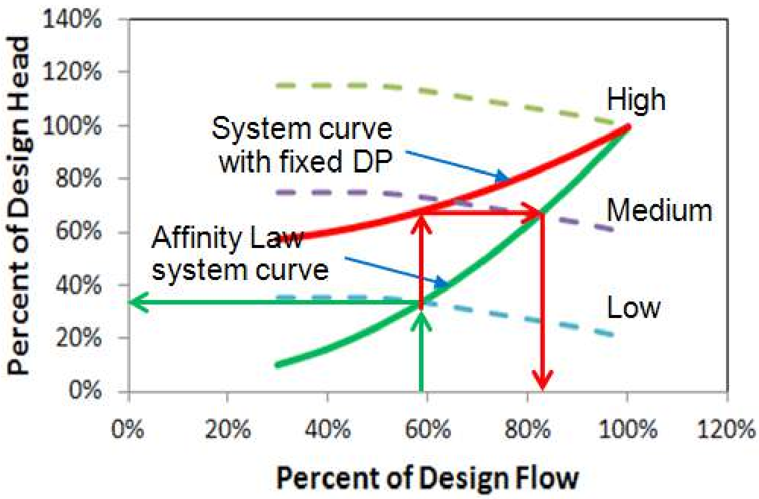

Figure 3. Conventional pumping control with fixed differential pressure set point results in overflow at part load conditions

Lessons Learned

More energy savings would have been achieved if controls for the GSHP systems were improved.

Pumping control

Excessive pumping, which is indicated by a small temperature differential across water loop, is a common issue. It is due to oversized pumps and, more often, non-optimal controls:

- Fixed differential pressure (DP) set point for variable speed (VS) pumping control, which resulted in overflow at part load conditions (Fig. 3)
- Continuous pumping all year long even when no heat pump was running
- Pumping control for chilled water system was used for ground loop.

Poor pumping design and control could result in low system efficiency and reduce energy savings of GSHP systems. In some cases, pumping energy use can be reduced by more than 50 % with improved pumping control.

DOAS control

OA ventilation system configuration, operation schedule, and supply OA temperature can significantly impact the indoor thermal comfort and energy consumption. It is desirable to have a guideline of best OA ventilation practices for various building types at different climates.

Heat pump control

The operating efficiency of central GSHP systems using WWHPs could be improved by applying OA reset control to allow lowering the hot water supply temperature at part-load conditions. Case study shows that the operating COP of the WWHP can be increased by 28.6 % if the OA reset schedule is shifted down by 10 °F (about 5.5 °C). However, since the hot water supply temperature affects the heat transfer performance of the terminal units, a holistic design approach is needed to optimize the OA reset schedule to ensure that sufficient heat is delivered to the building.

Conclusions

Results of six case studies indicate that significant energy savings and CO_2 reductions have been achieved by the demonstrated GSHP systems, but the installed cost is high, in part due to oversized GHXs and over-complicated system designs.

The operating efficiency of GSHP systems can be further improved with better controls for circulation pumps, OA ventilation systems, and heat pump supply water temperatures. In addition, performance monitoring and continuous commissioning are very helpful to identify design/control/operation issues.

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Author contact information
Xiaobing Liu
R&D Staff, Oak Ridge National Lab
USA
Liux2@ornl.gov

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Integration between a geothermal heat pump and thermo-photovoltaic solar panels

Francesca Bazzocchi, Lorenzo Croci, Italy

The article describes an experimental facility consisting of a geothermal heat pump coupled with thermo-photovoltaic solar collectors. The thermal energy produced is used for heating both domestic hot water and, at lower temperature, the water circulating in the geothermal circuit. The results of the monitoring campaigns, shown in this article, allow us to assess the actual performances of the geothermal heat pump and of the thermo-photovoltaic solar collectors and the best logic for using the two sources.

Introduction

The results of the monitoring campaign performed at an experimental facility consisting of a geothermal heat pump coupled with thermo-photovoltaic solar panels are presented in this article. The heat pump can represent a valid way to improve the energy performance of both new and existing buildings [1]. Hybrid solar panels consist of a photovoltaic panel behind which an absorber plate is placed. Different hybrid panel typologies are on the market; the principles are sheet and tube models, and roll bond models (see Figure 1). The absorber plate captures the thermal energy produced, which would otherwise be lost in the environment. In fact, only a small proportion of solar radiation (normally 12–20 %) is converted into electrical energy in standard photovoltaic modules, with the rest wasted as heat [2].

The coupling of these two devices is particularly interesting because hybrid solar panels can generate the electricity used by the heat pump and, at the same time, can support it in domestic hot water (DHW) production. Moreover, in this specific case, the low temperature heat produced by hybrid panels during winter is used to heat the water in the geothermal circuit. This system can help to avoid the gradual cooling of the ground, called thermal drift, that can take place in a geothermal plant, with consequences for heat pump performance [3].

Figure 1. Typologies of hybrid solar panels. Sheet and tube on the left and roll bond on the right.

This article is focused on showing the efficiency achievable by using these two technologies, and highlighting the influence of the management system on plant performance, regardless of the cost effectiveness of this type of plant.

Experimental facility

The plant under study consists of a geothermal heat pump coupled with thermo-photovoltaic solar panels, see Figure 2.

This system is installed in a prefabricated house with a heated floor area of 60 m^2 divided into four rooms simulating a living room, a kitchen, a bedroom and a bathroom. The house is located in Milan and is equipped with five fan coils used both for space heating and cooling. The DHW drawings, in order to simulate the use by a typical family, are performed daily according to a household profile: a total of 150 litres is drawn per day at a temperature of 40 °C.

The machine is a geothermal heat pump with a rated capacity of 7.8 kW, the compressor is a variable speed rotary which allows for modulation of the capacity supplied, and the refrigerant is R410A. The heat pump is equipped with a 186 litre DHW tank. The geothermal field comprises a single-U and a double-U borehole heat exchanger, both 100 metres deep and 10 metres from each other. The manifolds are arranged in order to facilitate the use of one or both heat exchangers, but only the single U borehole heat exchanger was used during this specific monitoring campaign.

Hybrid PVT modules were also installed, with a covered area of 6.4 m^2 and a typical electric power of 1 kWp. These panels are able to generate, at the same time, thermal and electric energies, thanks to the heat exchanger placed in the rear of the photovoltaic module.

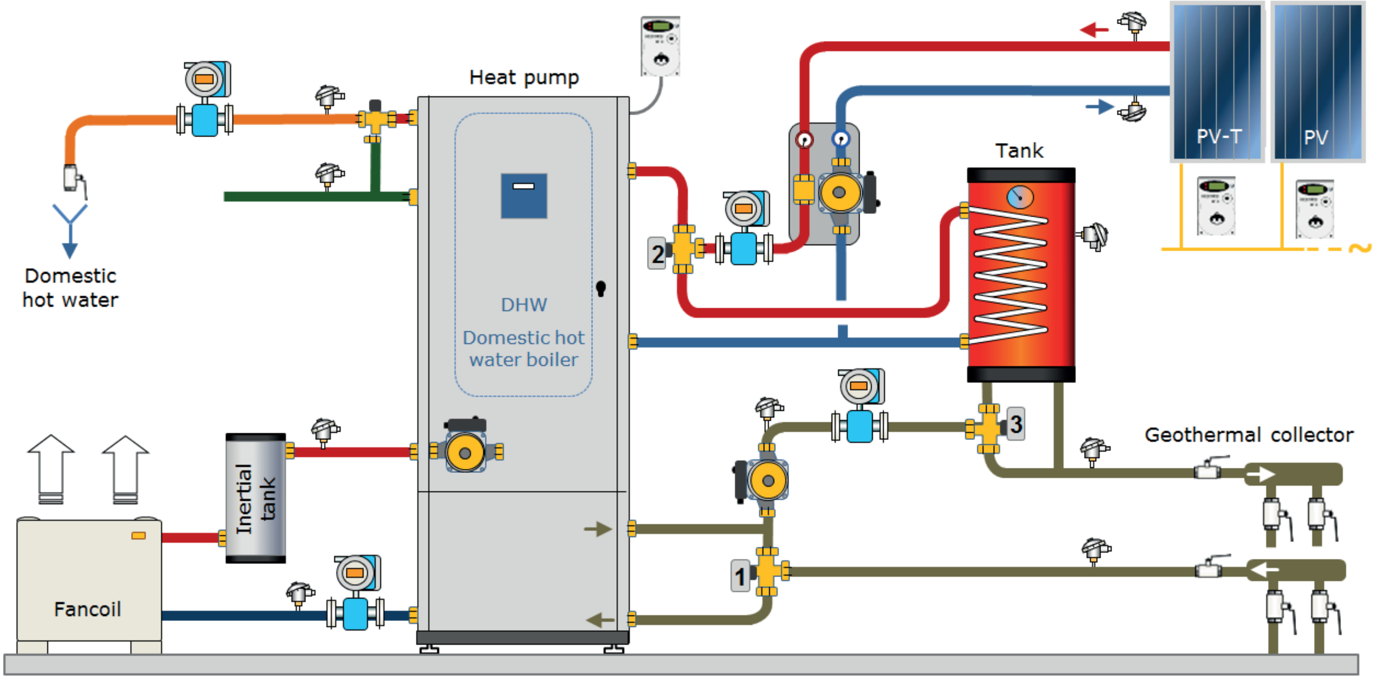

Figure 2. Plant scheme and monitoring system

The thermo-photovoltaic modules can supply heat both to the DHW tank, integrated into the heat pump, and to the water leaving the heat pump evaporator, before reaching the geothermal boreholes. This configuration was adopted to avoid the possibility of high temperature water coming from the solar panels entering the evaporator, causing damage to the heat pump. An 80 litre tank is used for the heat exchange between geothermal and solar circuits, with a pipe coil through which water from the solar panels flows, while the geothermal fluid circulates outside. A similar type of plant configuration was also used in [5].

When the solar panels have reduced performance due to lower insolation and outdoor air temperatures during the winter, it is possible to exploit the low-temperature heat supplied by the solar collectors as an auxiliary source for the heat pump. The heat produced by solar panels during the summer is instead used exclusively for the production of DHW. The heat pump is used mainly for cooling and, in case of insufficient solar radiation, for charging the DHW boiler.

Table 1. The results of a monitoring campaign divided into the heating and cooling seasons.

	Heating season 2014	Cooling season 2014
Average external air temperature [°C]	7.8	22.4
Average water supply temperature, leaving the heat pump and entering the fan coils [°C]	36.6	10.0
Average water temperature from boreholes [°C]	11.3	18.8
Seasonal thermal energy delivered/ absorbed by the heat pump [kWh]	8177.4	2239.5
Seasonal COP/EER for the heat pump	4.0	5.2
Seasonal COP/EER	A 5.6 kW VS pump with fixed DP control	Two 18.65 kW VS pumps with fixed DP control
heat pumps + geothermal pumps	3.8	5.1
PER (Primary Energy Ratio)	1.8	2.4

The main quantities analysed are the thermal energy delivered or absorbed by the heat pump, the thermal energy delivered or absorbed by the ground, and the energy – both thermal and electric – delivered by the solar panels.

The results of a one year monitoring campaign are shown in Table 1. It can be seen that the seasonal performances of the heat pump, both in heating and in cooling, are 3.8 in heating mode and 5.1 in cooling mode. The average water temperature from the boreholes is always at favourable levels for the heat pump, especially during the winter.

The daily average water temperature from and to the boreholes is shown in Figure 3, compared to the daily average air temperature across the entire year monitored. It can be observed that the average water temperature from the boreholes are always higher than the external air temperature during the heating period, and lower during the cooling period. It can also be observed that there is a difference of 4 °C between the temperature of the water from the boreholes at the beginning and at the end of the winter season. The ground source tends to cool gradually in the colder months and return to the initial temperature when the outside temperature rises. On the other hand, there are only daily fluctuations during the summer, due to the low thermal need of the building during summer.

In Figure 4 the hourly average COP is related to the hourly average water temperature from the boreholes. The linear relation is due to the influence of the source temperature on the heat pump performance and to the weather compensation strategy.

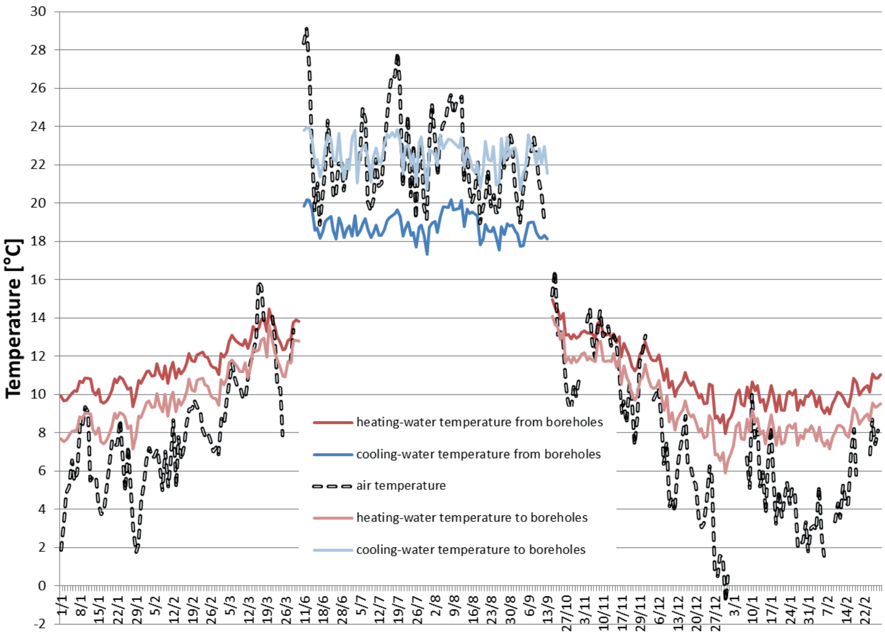

Figure 3. Daily average temperature of external air and of water from boreholes

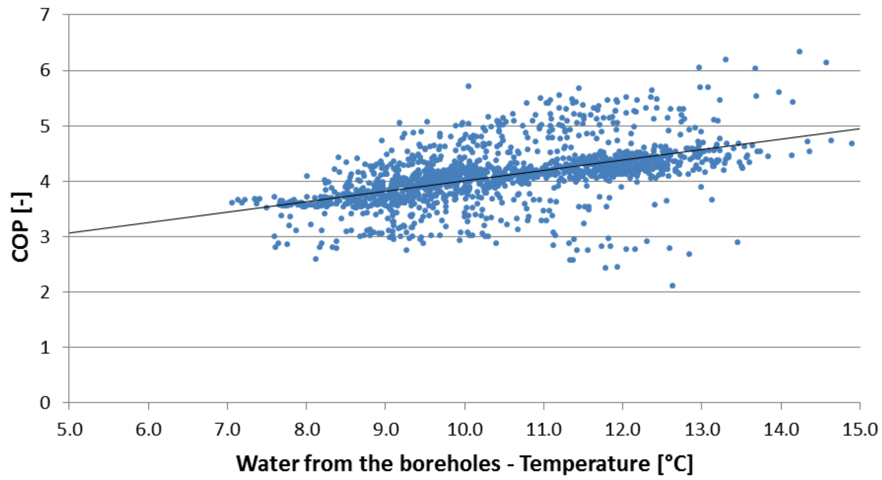

Figure 4. Hourly average COP related to hourly average water temperature from boreholes

Solar Panels

The surface area of the solar hybrid panels is 6.4 m^2 and the total electrical power is 1 kWp. The panels are arranged both for DHW and low temperature hot water production, and are used for regenerating the ground. An equivalent area of 6.4 m^2 was covered by photovoltaic panels of the same quality and electrical power of 1 kWp in order to compare hybrid panels performances with standard ones.

Hybrid solar panels are dedicated to DHW production during the summer and they covered 85 % of the total thermal DHW needs. The thermal efficiency of the hybrid solar panels is calculated as:

$$\eta = \frac{Enth_{panels}}{Rad} \qquad Eq.\ (1)$$

where $Enth_{panels}$ is the thermal energy produced in the analysed period, Rad is the total solar radiation incident on a 45° plane, during the same period, calculated only when there is thermal production. The thermal efficiency for the summer period is 16.1 %. Electric efficiency is calculated in the same way and is equal to 13.2 %. These are typical values for hybrid panels that have lower thermal efficiency than standard thermal collectors, due to the coupling with photovoltaic panels.

Two different logics are used during the winter period. In the first part of the year two thermal levels are set: high temperature (minimum 42 °C) for DHW production and low temperature (22 °C on average) for borehole regeneration. In the last part of the year the hybrid panels are dedicated only to regeneration of the boreholes. This method eliminates the possibility of producing DHW but increases thermal efficiency. Thermal efficiency for the winter period is 18.3 %, corresponding to

15.4 % for the first period (DHW and borehole regeneration) and 22.1 % for the second (only boreholes regeneration). This difference allows us to evaluate the influence of the temperature on the thermal efficiency. Electric efficiency in the winter season is 13.8 %.

Both hybrid and photovoltaic panels, for a total covered surface of 12.8 m^2, covered 73 % of the electricity consumption of the heat pump (both for air conditioning and DHW production): 34 % during heating mode (from January to March and from October to January), whereas during cooling mode (from June to September) the electricity generation exceeded the consumption. This is due to the lower building cooling need, compared to heating one (see Table I), and due to the higher electricity generation during the summer (because of higher solar radiation than in winter).

Conclusions

The results of the monitoring campaign performed at an experimental facility consisting of a geothermal heat pump coupled with thermo-photovoltaic solar panels, are presented in this article.
The data collected are focused on the efficiency of heat pumps and solar hybrid panels, and on interaction between the two devices. The results of this coupling are very interesting: the results show that the heat pump has high efficiency both in heating and in cooling, and that hybrid panels facilitate the generation of both electric and thermal energy without having a negative impact on photovoltaic efficiency. In addition to this, hybrid solar panels can support the heat pump in generating a fraction of both the electric energy consumed and the DHW requested.

Author contact information
Francesca Bazzocchi, Ing.
RSE s.p.a. (Ricerca sul Sistema Energetico)
Italy
francesca.bazzocchi@rse-web.it

Lorenzo Croci, Ing.
RSE s.p.a.
Italy
lorenzo.croci@rse-web.it

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Renewables 2015 Global Status

First released in 2005, REN21's Renewables Global Status Report (GSR) provides a comprehensive and timely overview of renewable energy market, industry, investment and policy developments worldwide. It enables policymakers, industry, investors and civil society to make informed decisions. The Renewables Global Status Report relies on up-to-date renewable energy data, provided by an international network of more than 500 contributors, researchers, and authors.
http://www.ren21.net/status-of-renewables/global-status-report/

Source: www.ehpa.org

Building Efficiency software for automated audits

A set of automated calibration techniques for tuning residential and commercial building energy-efficiency software models to match measured data is now available as an open source code. The Autotune code, developed at the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL), is available on software source code repository GitHub. By cheaply producing calibrated building energy models, Autotune enables users to perform "no-touch" audits, optimal retrofits and other simulation-informed applications to be cost-effectively realized for buildings too small (less than 50,000 ft^2 [4 645 m^2]) to warrant a traditional building audit.

Autotune is available via GitHub, *github.com/ORNL-BTRIC/Autotune*.

Source: www.phys.org

Events

2015

30 September – 2 October
ASHRAE Energy Modeling Conference
Atlanta, USA
https://www.ashrae.org/membership--conferences/conferences/ashrae-conferences/2015-ashrae-energy-modeling-conference

19 October
HPT Annex meetings and Kick off Annex meetings
Nuremberg, Germany

20 – 21 October
Heat Pump Summit
Nuremberg, Germany
http://www.hp-summit.de/en/

22 October
HPT National Teams' meeting
Nuremberg, Germany

20 – 23 October
8th International Conference on Cold Climate-Heating, Ventilation and Air-Conditioning (Cold Climate HVAC 2015)
Dalian, China
http://www.coldclimate2015.org/

9 November
National workshop
Basel, Switzerland

10 November
HPT ExCo meeting (open meeting)
Basel, Switzerland

11 November
HPT ExCo meeting (closed meeting for designated ExCo members)
Basel, Switzerland

2 – 4 December
46th International HVAC&R Congress and Exhibition
Belgrade, Serbia
http://kongres.kgh-kongres.rs/index.php?lang=en

2016

23 – 27 January
ASHRAE Winter Conference
Orlando, USA
https://www.ashrae.org/membership--conferences/conferences/2016-ashrae-winter-conference

23 – 26 February
HVAC&R JAPAN 2016
Tokyo, Japan
http://www.hvacr.jp/en/index.html

31 March– 2 April
12th International HVAC+R & Sanitary Technology Symposium
Istanbul, Turkey
http://www.ttmd.org.tr/sempozyum2016/eng/

7 – 9 April
4th IIR Conference on Sustainability and the Cold Chain
Auckland, New Zealand
http://www.iifiir.org/medias/medias.aspx?INSTANCE=exploitation&PORTAL_ID=general_portal.xml&SETLANGUAGE=EN

18 – 20 May
11th IIR Conference on Phase Change Materials and Slurries for Refrigeration and Air Conditioning
Karlsruhe, Germany
http://www.hs-karlsruhe.de/pcm2016.html

22 – 25 May
12th REHVA World Congress - CLIMA2016
Aalborg, Denmark
http://www.clima2016.org

25 – 29 June
ASHRAE Annual Conference
St. Louis, USA
http://ashraem.confex.com/ashraem/s16/cfp.cgi

3 – 8 July
The 14th international conference of Indoor Air Quality and Climate
Ghent, Belgium
http://www.indoorair2016.org/

11 – 14 July
Purdue Compressor, Refrigeration and High Performance buildings Conferences
West Lafayette, USA
https://engineering.purdue.edu/Herrick/HomepageFeatures/2016-purdue-conferences-july-1114

10 – 12 August
ASHRAE and IBPSA-USA SimBuild 2016: Building Performance Modeling Conference
Salt Lake City, USA
http://ashraem.confex.com/ashraem/ibpsa16/cfp.cgi

21 – 24 August
Gustav Lorentzen Natural Working Fluids Conference
Edinburgh, Scotland
http://www.ior.org.uk/GL2016

In the next Issue

Innovative/alternative/non-conventional HP technologies

Volume 33 - No. 4/2015

International Energy Agency

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

IEA Heat Pumping Technologies (HPT)

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

Vision

The IEA HPT is the foremost worldwide source of independent information and expertise on environmental and energy conservation benefits of heat pumping technologies (including refrigeration and air conditioning).

The IEA HPT conducts high value international collaborative activities to improve energy efficiency and minimise adverse environmental impact.

Mission

The IEA HPT strives to achieve widespread deployment of appropriate high quality heat pumping technologies to obtain energy conservation and environmental benefits from these technologies. It serves policy makers, national and international energy and environmental agencies, utilities, manufacturers, designers and researchers.

IEA Heat Pump Centre

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

The IEA Heat Pump Centre is operated by

SP Technical Research Institute of Sweden

IEA Heat Pump Centre
c/o SP Technical Research Institute of Sweden
P.O. Box 857
SE-501 15 Borås
Sweden
Tel: +46 10 516 55 12
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org

IEA OECD heat pump centre

National team contacts

AUSTRIA
Prof. Hermann Halozan
Consultant
Waltendorfer Höhe 20
A-8010 Graz
Tel: +43 316 422 242
hermann.halozan@chello.at

CANADA
Dr. Sophie Hosatte
CanmetENERGY
Natural Resources Canada
1615 Bd Lionel Boulet
P.O. Box 4800
Varennes
J3X 1S6 Québec
Tel: +1 450 652 5331
sophie.hosatte@nrcan.gc.ca

DENMARK
Mr. Svend Pedersen
Danish Technological Institute
Refrigeration and Heat Pump Technology
Kongsvang Alle 29
DK-800 AArhus C
Tel: +45 72 20 12 71
svp@teknologisk.dk

FINLAND
Mr. Jussi Hirvonen
Finnish Heat Pump Association
SULPU ry
Lustetie 9
FI-01300 Vantaa
Tel: +35 8 50 500 2751
jussi.hirvonen@sulpu.fi

FRANCE
Mr. David Canal
ADEME
Service des Réseaux et des Energies Renouvelables
500 route des Lucioles
FR-06560 Valbonne
Tel: +33 4 93 95 79 19
david.canal@ademe.fr

GERMANY
Prof. Dr.-Ing. Dr. h.c. Horst Kruse
Informationszentrum Wärmepumpen und Kältetechnik - IZW e.V
c/o FKW GmbH
DE-30167 Hannover
Tel. +49 511 167 47 50
email@izw-online.de

ITALY
Dr. Giovanni Restuccia
Italian National Research Council
Institute for Advanced Energy Technologies (CNR – ITAE)
Via Salita S. Lucia sopra Contesse 5
98126 Messina
Tel: +39 90 624 229
giovanni.restuccia@itae.cnr.it

JAPAN
Mr. Takeshi Hikawa
Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ)
1-28-5 Nihonbashi Kakigaracho
Chuo-ku, Tokyo 103-0014
Tel +81 3 5643 2404
hikawa.takeshi@hptcj.or.jp

NETHERLANDS
Mr. Raymond Beuken
Netherlands Enterprise Agency (RVO)
Team Renewable Energy
P.O. Box 965
6040 AZ Roermond
Tel: +31 88 620 22 26
E-mail: raymond.beuken@rvo.nl

NORWAY
Mr. Rolf Iver Mytting Hagemoen
NOVAP
P.O. Box 5377 Majorstua
N-0304 Oslo
Tel. +47 22 80 50 30
river@novap.no

SOUTH KOREA
Mr. Hyun-choon Cho
KETEP
Union Building, Tehyeranro 114-11
Department of Renewable Energy
Gangnam-gu, Seoul
Republic of Korea 135-280
Tel: +82 2 3469 8302
energy@ketep.re.kr

SWEDEN
Ms. Emina Pasic (Team leader)
Swedish Energy Agency
Energy Technology Department
Bioenergy and Energy Efficiency Unit
Kungsgatan 43
P.O. Box 310
SE-631 04 Eskilstuna
Tel: +46 16 544 2189
emina.pasic@energimyndigheten.se

SWITZERLAND
Mr. Stephan Renz
Beratung Renz Consulting
Elisabethenstrasse 44
CH-4010 Basel
Tel: +41 61 271 76 36
E-mail: renz.btr@swissonline.ch

UNITED KINGDOM
Ms. Penny Dunbabin
Department of Energy & Climate Change (DECC)
Area 6D, 3-8 Whitehall Place
London SW1A 2HH
Tel: +44 300 068 5575
penny.dunbabin@decc.gsi.gov.uk

THE UNITED STATES
Mr. Van Baxter - Team Leader
Building Equipment Research
Building Technologies Research & Integration Center
Oak Ridge National Laboratory
P.O. Box 2008, Building 3147
Oak Ridge, TN 37831-6070
Tel: +1 865 574 2104
baxtervd@ornl.gov

Ms. Melissa Voss Lapsa - Team Coordinator
Whole-Building and Community Integration
Building Technologies Research & Integration Center
Oak Ridge National Laboratory
P.O. Box 2008, Building 4020
Oak Ridge, TN 37831-6324
Tel: +1 865 576 8620
lapsamv@ornl.gov