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IEA HEAT PUMP CENTRE

NEWSLETTER
VOL. 29
NO. 1/2011

Thermally driven heat pumps

A key technology for the future

Gas-driven sorption heat pumps

Solar thermal cooling

Testing and performance evaluation methods

IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 29 - No. 1/2011

In this issue

Heat Pump Centre Newsletter, 1/2011

While vapour-compression heat pumps dominate the heat pump market, thermally driven heat pumps are experiencing rising interest. According to their advocates, this is due to a number of factors, such as cost of electricity and environmental concerns. The topical articles of this issue discuss these heat pumps from various views – an overview of gas-heated heat pumps, a discussion of standards in the area, the seemingly unlikely application of solar cooling, and experiences from large-scale thermally-driven district cooling.

Enjoy your reading!

Johan Berg
Editor

Heat pump news

Regulars

Topical articles

Non-Topical articles

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Foreword

Thermally driven heat pumps

Peter Schossig, Fraunhofer Institute for Solar Energy Systems (ISE), Germany

Mention heat pumping processes nowadays, and thoughts usually turn to electrically driven vapour-compression machines, providing either heating or cooling for the desired purpose. Effectively, vapour-compression machines have become a synonym for heat pumps and for chillers. However, this was not always the case in history. In the beginning of refrigeration and heat pumping in the early 1800s, sorption processes were paid the same attention as vapour compression for heat transformation. Some even consider absorption technology as the oldest applied heat transformation process. Nevertheless, novel refrigerants and widely available electricity led to a de-facto success for vapour-compression heat pumps and chillers in the 20th century, and thermally driven heat pumps became more or less a niche market.

Nowadays, rising electricity prices in combination with environmental considerations may bring about a revival of thermally driven heat pumps. Using solar or waste heat as a driving force for chilling processes, or gas-fired heat pumps instead of condensing gas boilers, might lead to significant primary energy savings for the heating and cooling of buildings. Another interesting aspect of thermally driven heat pumps is the use of refrigerants with no or very low Global Warming Potential (GWP). Consequently, more and more thermally driven heat pump products could be seen on the market, and particularly in the low power range (< 50 kW), e.g. applications such as gas-driven heat pumps for single-family houses as well as many applications focusing on solar-assisted cooling.

This growing market generates a need for performance evaluation procedures of these technologies, since existing heat pump and chiller standards are not applicable to thermally driven heat pumps, failing to take their specific features into account as is needed in order to make a useful comparison of different heating or cooling devices.

This newsletter tries to give an overview of the state of the art of these technologies, and makes first proposals for performance evaluation procedures for thermally driven heat pumps.

I am pleased that after five years a HPC newsletter issue covers the topic of thermally driven heat pumps again, describing the progress of these technologies, and particularly the advances of the last few years. In addition, I hope that thermally driven heat pumps will help to enrich the family of heat pumps in order to achieve the goal of environmentally friendly heating and cooling in buildings for the future.

A brief introduction to the Chinese "Key Technology Research and Demonstration of Ground Source Heat Pump Systems" programme

Xu Wei, Director of the Institute of Building Environment and Energy Efficiency, China Academy of Building Research.

China's largest R&D programme for ground-source heat pumps has been running since the end of November 2006. The lead organisation is the China Academy of Building Research, supported by the Chinese Academy of Geological Sciences, Chongqing University, Harbin Institute of Technology and Shandong Fuerda Air-conditioner Equipment Co. Ltd. The programme leader is Professor Xu Wei.

R&D of GSHPs in China started in the 1980s, and GSHPs now provide heating, cooling and hot water to a total floor area of about 140 million m^2. However, there are still various problems, such as a lack of systematic basic regional geological research, inadequate regional environmental systems analysis, and regional planning for the use of underground water source heat pump systems. In some areas, there are problems with groundwater recharging systems. GSHP systems using surface layers as their heat sources are unable to handle the load difference between summer and winter. Use of water heat sources in rivers, lakes and sewage effluent is not properly developed or utilised. Unit COPs and quality need to be improved, and products need to be developed to suit different types of water heat sources as well as different end use temperatures.

The programme has utilised the findings of regional hydrogeological surveys and investigations of shallow geothermal energy sources over the last 60 years, as well as experience from such systems in developed countries. It has developed planning of shallow geothermal energy sources and the use of heat from rivers, lakes and sewage effluents to construct a data base of typical design conditions for different regions. Work also included development of environmental impact assessment methods under varying geological conditions and development of associated software.

The programme has already received 13 patent grants. 44 scientific papers have been published, and parts of the results are summarised in "Development Report of Ground Source Heat Pumps in China (2008)", "Technical Guide to Renewable Energy Building Utilization" and "Ground Source Heat Pump Technical Manual". Results are being used to support revision of the national regulations for GSHPs. The programme is running 18 demonstration projects, of which ten are surface earth type, four use aquifers, two use surface water, one uses sewage effluent and one uses sea water. On-site measurements of performance of the demonstration systems have also been made.

For the realization of China's energy saving goal, the promotion and dissemination of the ground source heat pump systems will play a significant role in the future.

Continuation work includes:
1. Nationwide dissemination of the results via seminars, workshops and conferences;
2. On-site testing for basic data for programme analysis and improvement;
3. R&D to link heat pumps and solar energy, in addition to other building energy efficiency improvement measures, with the aim of designing a net zero energy building.

The 10th IEA Heat Pump Conference 2011

Heat pumps-The Solution for a Low-Carbon World

Date: 16 May 2011 ~ 19 May 2011
Venue: Chinzan-so Tokyo, Japan

1. Registration:
Online registration has started since Oct 1, 2010. We have 3 kinds of fee categories, general participants, students and accompanying persons. Technical and non-technical tours information, accommodation booking have also been available.

2. Conference Program

- Monday 16 May 2011
  AM/PM Workshops

- Tuesday 17 May 2011
  AM: Opening plenary session
  PM: Two parallel Sessions including poster presentation
  EV: Welcome Reception

- Wednesday 18 May 2011
  AM: Two parallel Sessions including poster presentation
  PM: 8 Technical and 2 Non technical tours
  EV: Banquet

- Thursday 19 May 2011
  AM: Two parallel Sessions including poster presentation
  PM: Two parallel Sessions including poster presentation
  EV: Closing plenary session
  *Exhibition: from May 16 through 19.

Web: For more information, please log on to the Conference website at: http://www.hpc2011.org

Regional Coordinators

For information on papers and workshops, conference program, etc., please contact the Regional Coordinator for your area:

- Asia and Oceania: Mr. Makoto Tono, tono.makoto@hptcj.or.jp
- North and South America: Mr. Gerald Groff, ggroff2@twcny.rr.com
- Europe and Africa: Mrs. Monica Axell, monica.axell@sp.se

General

Heat pumps as energy storage in smart grids

The increasing proportion of solar and wind power in energy grids is creating peaks and valleys of power production that need to be balanced out. In order better to integrate renewable energies into a smart energy grid, researchers and industry developers are looking for efficient energy storage systems. A new position paper released by the Bundesverband Wärmepumpe (BWP), the HEA Fachgemeinschaft für effiziente Energieanwendung, the Zentralverband der Deutschen Elektro- und Informations- technischen Handwerke (ZVEH) and the ZVEI – the German Electrical and Electronic Manufacturers Association, examines the potential of heat pumps as energy storage devices in smart grids.

At times of peak production, electricity from renewable sources can be transformed into heat energy and then stored. Systems that transform electrical energy into heat or cold, such as heat pumps, can offer a storage potential of up to 4 400 MW for smart grids by the year 2020.
http://www.energie-server.de/energie-server/newsletter_engl/NL126hp_engl.htm

Final energy savings figures announced for 2010 energy standard

Energy savings of more than 30 % can be achieved by using the recently published 2010 version of Standard 90.1 as against the 2004 standard, according to an announcement made by ASHRAE at its 2011 Winter Conference, taking place this week.

ANSI/ASHRAE/IES Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings, which specifies minimum requirements for energy-efficient design of buildings other than low-rise residential buildings, was published in November 2010. ASHRAE was awaiting the final results of analysis work from Pacific Northwest National Laboratories in support of the U.S. Department of Energy (DOE) Building Energy Codes Program on addenda included in the standard.
http://www.ashrae.org/pressroom/detail/2011-01-31

Global map of surface permeability

University of British Columbia researchers have produced the first map of the world that outlines the ease of fluid flow through the planet's porous surface rocks and sediments.

The maps and data, recently published in Geophysical Research Letters, could help improve water resource management and climate modelling, and eventually lead to new insights into a range of geological processes.
http://www.nationaldriller.com/Articles/Industry_News/BNP_GUID_9-5-2006_A_10000000000000981589

ASHRAE's 2012 Winter Conference seeks papers

Papers addressing advances in high-performance buildings, integrated design and numerous high-intensity HVAC applications are being sought for ASHRAE's 2012 Winter Conference in Chicago, IL, January 21-25. The deadline for paper submissions is April 18, 2011.
http://ashraem.confex.com/ashraem/w12/cfp.cgi

EHPA award "Heat pump city of the year"

Europe's climate protection and energy savings targets are demanding, requiring immediate action on all political levels if meaningful results are to be achieved by 2020. Heat pumps are an available, reliable, efficient and cost-effective solution to this quest. Unfortunately, the technology is often very well hidden in basements or plant rooms of buildings.

The European Heat Pump Association has taken this as a challenge, and decided to establish a new award: "The heat pump city of the year". The trophy will be given to the city that has shown the biggest effort in integrating heat pumps into its energy infrastructure (measured as additional heat pump installations per 10 000 inhabitants).
http://www.ehpa.org/news/article/ehpa-award-heat-pump-city-of-the-year/

Trio face jail for refrigerant release

In what is thought to be one of the first such cases of its kind, three thieves in Georgia, USA, convicted of stealing copper coils for scrap from air conditioning units, have pleaded guilty to additional charges of conspiring to release ozone-depleting substances.

The three men were indicted in June last year on one conspiracy count and twelve counts of releasing R22 into the environment. As reported in ACR News (August 2010), this involved the dismantling of approximately 35 air conditioning units from 14 locations, including a church.
http://www.acr-news.com/news/news.asp?id=2362&title=Trio+face+jail+for+refrigerant+release

Policy

MEPs seal deal on crisis funds for clean energy

The European Parliament has approved a deal between the EU institutions to free up €146 million of unspent EU recovery funds to finance energy efficiency and renewable energy projects.

MEPs voted overwhelmingly in favour of an agreement struck last month to create a fund to finance projects, including renovating Europe's buildings to improve their energy efficiency, grid-connected renewable energy generation, electric vehicles and energy-saving local infrastructure such as smart grids and electricity storage.

http://www.euractiv.com/en/energy-efficiency/meps-seal-deal-crisis-funds-clean-energy-news-499688?utm_source=EurActiv+Newsletter&utm_campaign=f1c3037af2-my_google_analytics_key&utm_medium=email

Home refrigeration heads to new standards

Refrigeration contractors and technicians who work in the domestic refrigeration sector should be aware of increased efficiency standards that are also affecting ice-making equipment and room air conditioners. All those in refrigeration should look at such efficiency upgrades as a growing trend across the board.

http://www.achrnews.com/Articles/Feature_Article/BNP_GUID_9-5-2006_A_10000000000000975949

EU's energy summit, February 2011

EU leaders agreed to merge and strengthen energy networks at their first ever energy summit on 4th February, giving a boost to the renewable energy industry and helping to curb Europe's growing reliance on fossil fuels.

European Commission President José Manuel Barroso told EU leaders that Europe should rein in its annual €310 billion spending – equivalent to 2.5 % of GDP - on oil and gas imports. "Major efforts are needed to modernise and expand Europe's energy infrastructure," a summit accord said.

At the heart of the summit declaration was a realisation that industry is not delivering some critical energy infrastructure and that taxpayers will soon have to step in. The summit accord acknowledged that further green growth would require a high-tech "smart" power grid - estimated to cost about €200 billion - to carry wind power from the north and solar power from the Mediterranean to central cities such as Paris and Prague.

http://www.euractiv.com/en/energy/energy-summit-grapples-fossil-fuel-habit-news-501989

AREA call for waste and energy reduction

AREA, the European refrigeration and air-conditioning contractors' association, has produced an advisory document for European decision-makers outlining the contribution that the industry can make to reducing energy use and wastage.

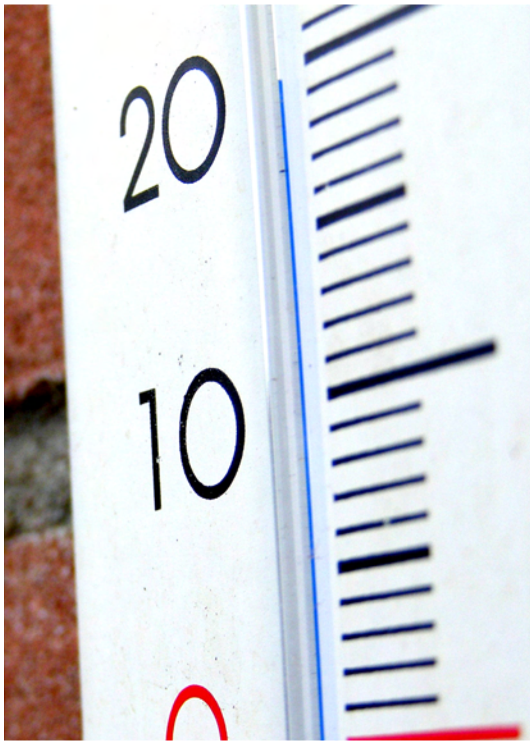
http://www.acr-news.com/news/news.asp?id=2382

Heat pumps: a largely overlooked potential

In early October 2010, ENDS Europe (Europe's environmental news and information service) issued a special report on the National Renewable Energy Action Plans. Renewable Energy Europe outlines goals and measures to boost renewable energy use.

Unfortunately, the heating sector, which uses approx. 40 % of Europe's energy, does not receive a similar focus in the current versions of the Renewable Energy Action Plans. In particular, the potential of heat pumps is still largely overlooked. This is also reflected in a recent EREC (European Renewable Energy Council) press release that comes to the conclusion that "the EU Member States collectively forecast to exceed the binding 20 % RES target."

http://www.ehpa.org/news/article/heat-pumps-a-largely-overlooked-potential/



Spain mandates building temperatures

The Spanish Cabinet recently passed a law to establish minimum and maximum temperatures for public buildings. Buildings such as shops, bars, airports, cinemas, railway stations and airports cannot be cooled below 26 °C (79 °F) in summer. During winter, thermostats cannot be set higher than 21 °C (70 °F). The Economic Sustainability Law is designed to reduce Spain's reliance on imported energy and to save money.

http://business.timesonline.co.uk/tol/business/markets/europe/article6936931.ece

Working Fluids

New process reclaims refrigerants to their original components

A US company has devised a process to break down refrigerants to their original chemical constituents. The system, if successful, would enable hydrogen fluoride (HF), an increasingly scarce key chemical component of fluorocarbon refrigerants, to be reused.

The only method currently available to deal with the millions of tonnes of ozone-depleting substances in use worldwide is incineration – a hugely energy-intensive and costly process. HFCs will also need to be dealt with in the future if, as expected, they also become subject to a phase-down.
Midwest Refrigerants' CTC Refri-Green process converts or transforms fluorocarbon refrigerants into their original component chemicals for re-use.
http://www.acr-news.com/news/news.asp?id=2332&title=New+process+reclaims+refrigerants+to+their+original+components

EPA issues final approval for HFO refrigerant

The US Environmental Protection Agency (EPA) has issued final approval for HFO-1234yf refrigerant in motor vehicle air conditioning systems. The chemical, which does not deplete the ozone layer, may now be used in air-conditioning systems in new cars and light trucks. When used appropriately, EPA says, this chemical can reduce the environmental impact of motor vehicle air conditioners, and has a global warming potential that is 99.7 % less than the current chemical (HFC-134a) used in most car air conditioners. *http://www.greencarcongress.com/2011/02/hfo-20110228.html*

Turbomiser chiller is the first with HFO refrigerants

The ground-breaking Turbomiser chiller, which uses the oil-less Turbocor compressor, is to be made available using the latest "fourth generation" HFO refrigerants.

British companies Klima-Therm and Cool-Therm, who first developed the chiller with Italian manufacturer Geoclima, have now announced the immediate availability of models to run on 1234ze, with 1234yf versions to follow when that refrigerant becomes available in commercial quantities.

The low-GWP HFOs are being developed by a number of refrigerant manufacturers for stationary equipment, with Honeywell, DuPont and Mexichem all recently announcing imminent availability of blends based on these gases.

HFO-1234ze has been available since 2008 and is currently mainly used as a blowing agent in the foam industry. Previous tests with HFO1234yz and HFO1234ze on a beverage cooler are said to have shown similar performances to R134a, but with a 300 times better GWP (GWPs of 4 and 6, respectively). The new refrigerants also have lower discharge temperatures than R134a.
http://www.acr-news.com/news/news.asp?id=2348&title=Turbomiser+chiller+is+the+first+with+HFO+refrigerants

Developers withdraw HFO chiller

A week after announcing the introduction of a chiller to run on the new HFO refrigerants, the developers have withdrawn the product pending "further development work".
Klima-Therm and Cool-Therm, the developers of the Turbomiser chiller, came in for criticism from Danfoss Turbocor who maintained that their compressor, which is used in the Turbomiser product, had not been verified for use with HFO refrigerants.
A spokesman for the chiller developers last night said: "We believe that HFO refrigerants show great promise for the future and could meet the pressing need for an in-kind, low GWP alternative to HFC refrigerants. However, following discussions with Geoclima Srl and Danfoss Turbocor, we accept that further development work and testing are required before these products can be introduced to the market."

"We will continue our research and development activities with these new refrigerants, and plan to offer an HFO-based Turbomiser chiller to the market when it is fully qualified through our supply chain."
http://www.acr-news.com/news/news.asp?id=2365&title=Now+developers+withdraw+HFO+chiller

British companies stand by HFO chiller development

The British companies behind the development of the first chillers to run on the new "fourth generation" HFO refrigerants are forging ahead with their plans despite claims from Danfoss Turbocor that its compressor has not been validated to use with these new gases.

Doug Bishop, vice-president of sales at Danfoss Turbocor, manufacturers of the oil-less compressor used in the new Turbomiser chiller, told ACR News that his company did not offer an HFO1234ze or 1234yf compressor. But Klima-Therm and Cool-Therm, the British companies who developed the chiller in association with Italian manufacturer Geoclima, stood by the story.
http://www.acr-news.com/news/news.asp?id=2360&title=British+companies+stand+by+HFO++chiller+development

Europe bans HFC23 credits

The European Commission has finally voted to ban emission offset credits for the destruction of HFC23, produced as a by-product of R22 production, but it will not come into force until May 2013. The ban, which also includes nitrous oxide from adipic acid production, was originally proposed to come into force from January 1, 2013, but was delayed after resistance from a small number of countries.

Just 23 such industrial gas projects are said to account for roughly two-thirds of all the credits generated through the Kyoto Protocol's Clean Development Mechanism (CDM), with most of the projects carried out in China and other advanced developing countries.

The EC proposed the ban last November after it was widely recognised that the EU's cap-and-trade system perversely encouraged developing countries to over-produce R22 in order to cash in on credits available for destroying the high-GWP by-product HFC23.
http://www.acr-news.com/news/news.asp?id=2342&title=Europe+bans+HFC23+credits+but+thieves+steal+%8028%2E7m

Consumer Goods Forum pledges to phase out HFCs

The Consumer Goods Forum (CGF), a body comprising over 650 retailers, manufacturers, service providers and other stakeholders from 70 countries, has pledged to phase out HFCs from 2015. CGF members boast a combined turnover of $2.8 trillion and include, in the UK, retailers Alliance Boots, Booker, M&S, Tesco and Waitrose, together with manufacturers GlaxoSmithKline, British American Tobacco, Innocent Drinks, Kraft Foods and Kimberley Clark.

The statement made on the opening day of the sixth United Nations Climate Change Conference in Paris said that the CGF board recognised the increasing contribution that HFCs make to total greenhouse gas emissions.

"We are therefore taking action to mobilise resources within our respective businesses to begin phasing-out HFC refrigerants as of 2015 and replace them with non-HFC refrigerants (natural refrigerant alternatives) where these are legally allowed and available, for new purchases of point-of-sale units and large refrigeration installations."
http://www.acr-news.com/news/news.asp?id=2297&title=Consumer+Goods+Forum+pledges+to+phase+out+HFCs

Support grows for HFC curbs

Support for curbs on the production and consumption of HFCs gained momentum at the recent Montreal Protocol meeting in Bangkok. While, as expected, no decision was taken on the future of these refrigerants, 91 countries signed a declaration of support for what has popularly been dubbed a phase-down. This was a significant increase on last year's meeting when only 41 countries showed support for the idea. However, three of the most influential developing countries - China, India and Brazil - argued for further discussions of the amendments proposed by the USA, Mexico, Canada and the Federated States of Micronesia.
http://www.acr-news.com/news/news.asp?id=2285&title=Support+grows+for+HFC+curbs

Customs seize over 108 tonnes of refrigerant

Over 108 tonnes of illegal refrigerant have been seized by customs officers around the world in a special operation code-named Sky-hole Patching II.

The joint operation by the World Customs Organization and the United Nations Environment Programme (UNEP) over a six-month period ending in November led to the confiscation of more than 7 500 cylinders of CFCs, HCFCs and other ozone-depleting substances. Also included in the seizures were 668 pieces of equipment containing ODS.
http://www.acr-news.com/news/news.asp?id=2301&title=Customs+seize+over+108+tonnes+of+refrigerant

Carrier has CO_2 refrigeration contained

CARRIER'S Transicold transport refrigeration business has come up with a system to use CO2 in container refrigeration systems.
The NaturaLine system is said to have already been tested around the world this year by Hamburg-based Hapag-Lloyd. Carrier will conduct full field trials in 2011.

Carrier's technology is said to incorporate numerous innovations, some of which are new to container refrigeration applications. These include a new gas cooler/condenser coil that wraps around the fan and has enhanced surfaces to maximise heat transfer. It also takes advantage of a new marine-duty multi-stage compressor. New power electronics and an advanced software control system are said to be combined to optimise fan speeds and compressor capacity to match cooling loads and temperature control.
http://www.acr-news.com/news/news.asp?id=2299&title=Carrier+has+CO2+refrigeration+contained

Technology

Canadian inventor wins Manning Innovation Award for sonic drill

Ray Roussy, a mechanical engineer from Surrey, British Columbia, took home a coveted $10 000 Innovation Award from the Ernest C. Manning Awards Foundation for developing one of the fastest drilling systems in the world.

Roussy's sonic drilling technology, which he began developing in his own backyard nearly three decades ago, is in use on six continents and gaining worldwide recognition, especially as an environmentally-friendly alternative.
Today, Roussy's sonic drill is commonly used quickly to install geothermal energy loops, provide continuous core samples for environmental investigations, and explore possible mineral deposits.
http://www.nationaldriller.com/Articles/Industry_News/BNP_GUID_9-5-2006_A_10000000000000948245

Energy-saving air conditioner

The National Renewable Energy Laboratory has invented a new air conditioning process with the potential to use 50 to 90 percent less energy than today's units. The Desiccant-Enhanced eVaporative air conditioner

(DEVap) uses membranes, evaporative cooling, and liquid desiccants, resulting in an air conditioning system that provides better humidity control with hydrophobic membranes.
http://www.nrel.gov/features/20100611_ac.html

Markets

GEA to buy German compressor manufacturer Bock

GEA Refrigeration Technologies is to buy German refrigeration compressor manufacturer Bock for an undisclosed sum. A family-owned business headquartered in Frickenhausen, Bock has more than 300 staff, and additional manufacturing sites in the Czech Republic, India and China.

This strategic acquisition extends GEA's compressor offering in the lower and medium performance ranges (from 5 to almost 300 m3/h refrigerant flow) and complements the company's GEA Grasso industrial compressor ranges.
http://www.acr-news.com/news/news.asp?id=2316

AHRI applauds president's call for more efficient buildings

AHRI, the US trade association for manufacturers of heating, cooling, water heating, and commercial refrigeration equipment manufacturers, applauds President Obama's "Better Buildings Initiative" as a sign that government will take a more aggressive partnership role with industry in promoting energy efficiency. Obama's initiative aims to bring about a 20 % improvement in building efficiency by 2020 by reforming the tax code, promoting more creative financing, and providing targeted government grants for efficiency improvements.
http://www.ahrinet.org/ahri+applauds+president_s+call+for+more+efficient+buildings+equipment+certification_+tax+incentives+should+be+part+of+mix.aspx

CGC testifies before Energy & Environment Committee

The Canadian GeoExchange Coalition has testified before the Standing Senate Committee on Energy, the Environment and Natural Resources. In their testimony, CGC staff explained the role of ground source heat pump technology for a Canadian sustainable energy strategy. The Canadian GeoExchange Coalition estimates that there are more than 80 000 ground source heat pump systems installed throughout Canada. Ontario and Québec account for more than 80 % of ground source heat pumps installed in Canada in the past four years. With such numbers, lack of knowledge and awareness of the technology is certainly no longer the issue. CGC made a very strong statement to the effect that the industry is well developed and organised, and has the capacity to respond quickly to growth challenges.
http://www.geo-exchange.ca/en/cgc_testifies_before_the_standing_senate_committee_nw198.php

DOE facilitates market-driven solutions for air conditioners

US Energy Secretary Steven Chu has announced that the Department of Energy is joining with the private sector to support market-based efforts to develop and deploy next-generation high-efficiency air conditioners for commercial buildings. As part of a voluntary program, the Department worked with members of the DOE Commercial Building Energy Alliances, including Target and Walmart, to develop new performance criteria for 10-tonne capacity commercial air conditioners, also known as rooftop units (RTUs). When built according to the requirements of the new specifications, these high-efficiency rooftop units are expected to reduce energy use by as much as 50-60 % in comparison with current equipment. Commercial buildings account for 18 % of U.S. energy use, and include significant opportunities for energy and financial savings that can help American companies be more competitive on a global scale.
http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=473

Positive future likely? New study on the German heat pump market says so.

A study recently presented by the International Geothermal Center, Bochum, Germany finds that by 2017 the number of ground-source heat pumps (GSHP) using geothermal and hydrothermal energy, sold annually in Germany, will reach approx. 65 000. This number is a projection of the guidance given by the ministry for the environment in its own study ("Leitscenario").
By 2020, the stock would have reached approx. 800 000 ground-source units. On top of this, about the same amount of air-source heat pumps are expected to be sold. Mainly installed as air-water units, this variant of the technology will mainly be used for renovation.
http://www.ehpa.org/news/article/positive-future-likely-new-study-on-the-german-heat-pump-market-says-so/

Daikin, Mitsubishi and TEV share £3.75m heat pump deal

DAIKIN, TEV (Heat King), and Mitsubishi have secured contracts to provide some 2 500 air-to-water heat pumps over the next two years to UK homes that are off the gas network.

Non-profit organisations Community Energy Solutions (CES) and Renewables East tendered for heat pump suppliers to heat 2 500 off-gas homes. The contracts, for the supply and distribution of the heat pumps, are worth an estimated £3.75 million.
http://www.acr-news.com/news/news.asp?id=1884

The market for heat pumps in Norway

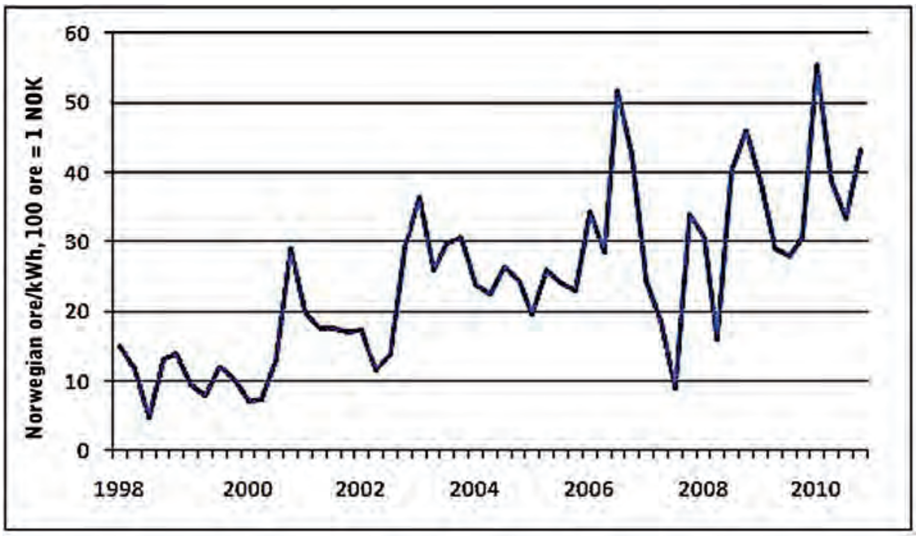
Bård Baardsen, NOVAP, Norway

This article describes the present situation, together with future perspectives and potential for the heat pump market in Norway. Although Norway is not a member of the European Union, it implements most of the EU directives as part of European Economic Area.

Introduction

Over the past 30 years, Norway has installed many large heat pumps for industrial applications, district heating and large commercial buildings having a heating and cooling demand. During the past ten years heat pumps have also established themselves in the domestic sector, with over half a million installations in total. Future years are expected to see growth in the commercial sector in parallel with a strong domestic market.

Facts about Norway	
Country:	Population 4.9 million
Area	385 000 km^2
Capital	Oslo
Number of single/two family houses	1,6 million
Average heat demand for single family house	15 - 20 MWh/year
Share of energy from renewables	58,5 percent
Binding targets 2020	n/a
Rate of new construction per year	10 000

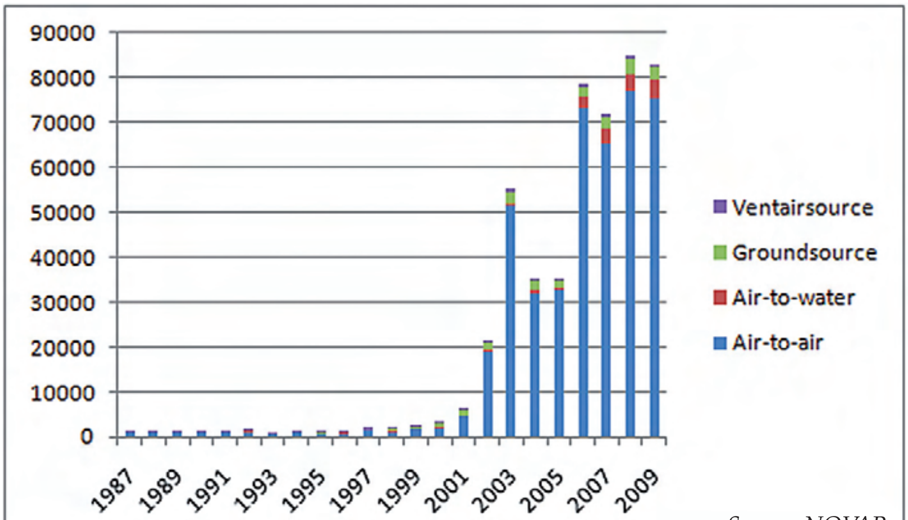


Market for heat pumps in the domestic sector

Norway has traditionally had very low prices of electricity, due to strong regulation and production based almost entirely on hydro power. The electricity market was deregulated in 1991, with supply shifting gradually from abundance to constraint due to higher demand without new production capacity. The production of hydro power in Norway varies from 90 to 150 TWh per year, depending on weather conditions. Consumption in 2010 was 130 TWh. In years with low production there is a sharp rise in prices, especially if there is a cold winter with a high demand for heating. The most common type of heating in single-family houses in Norway is direct electric heating in combination with a wood stove. Because most houses do not have a hydronic distribution system for heating, air-to-air heat pumps are the dominant type of heat pump installed in the domestic sector. Over the last couple of years. between 70 000 and 80 000 air-to-air heat pumps have been installed each year. Air-to-water heat pumps are popular in new houses. Today, 34 % of single-family houses have a heat pump installed, with almost all of them having been installed in the last ten years.

Market for heat pumps in the commercial sector

There has been steady growth in the numbers of heat pumps in the commercial sector in Norway over the last couple of years, which will continue as a result of new building regulations since July 2010. The regulations require all buildings over 500 m^2 to meet at least 60 % of their annual heating demand from renewable sources. As only a few large towns or cities have district heating, buildings outside these areas have the choice of heat pumps or bio-energy. Higher levels of insulation in buildings mean that more buildings need air conditioning systems, and so heat pumps than can deliver both heating and cooling are a very competitive solution. Heat pumps also have an advantage over bio-energy and district heating because the energy labelling system for buildings



Source: NOVAP

rewards efficient systems. Buildings with a heat pump in combination with a free cooling system, either from water or from boreholes, have the lowest energy consumption and best energy classification.

Heat pumps in district heating

Heat pumps have gained increased popularity in district heating over the last couple of years. One of the plants supplying heat to the Oslo district heating system includes a 27 MW heat pump recovering heat from sewage effluent. Refrigerant is R134a, and output temperature is 90 °C. A heat pump in Drammen, south of Oslo, delivering 14,3 MW from sea water, is the first heat pump using ammonia as its refrigerant and is capable of delivering heat at over 90 °C. A large district heating and cooling system, abstracting heat from sea water, is being built at Fornebu Airport to supply over ten thousand houses and many commercial buildings. A new market for district heating companies in Norway is that of independent energy plants selling heating and cooling to one large building. A new hospital is being supplied with packaged heating and cooling by Fortum Energi, using one of the largest ground-source heat pumps in the world, with more than 300 boreholes. Fortum is also supplying a new mail distribution centre with heating and cooling from a ground-source heat pump.

Industrial heat pumps

A large number of heat pumps are used in fishing, food and processing industries, many with very high COPs. The company, 'Hybrid Energy', has developed a specialised heat pump for the food industry which uses both the compression and the absorption cycle and delivers high-temperature water by using ammonia/water as a working fluid. Another Norwegian company, 'Single Phase Power', has specialised in high-temperature heat pumps for industrial applications, and will be supplying its first commercial installation this year after many prototype installations.

Subsidies for heat pumps and renewable energy

Grants are available for most types of heat pumps for various applications, except for air-to-air heat pumps. Grants for commercial applications are subject to some limitations if the heat pump would be profitable without a subsidy. Private households can receive grants of up to EUR 1200 for air-to-water heat pumps and for ground-source heat pumps. Each year, the government provides about EUR 200 – 300 million in the form of grants for renewable energy and improving the efficiency of energy use. From 2012, there will be a certificate market for green electricity.

The Renewables Directive

Although not a member of the EU, Norway will implement the Renewables Directive. In 2005, renewable energy sources accounted for 58.2 % of total energy supply, which is higher than any EU country. Norway and the EU are at present negotiating the required renewables share for 2020, but it is expected to be 70 – 75 %. Heat pumps can contribute a lot to a higher share of renewable energy use in Norway, especially in the 300 000 thousand houses which still use fossil heating.

The Heat Pump Association: NOVAP

The Norwegian Heat Pump Association was established in 1991 by distributors and installers. Today, the association has two employees and is working with training and education, public information, and creation of a political framework for the heat pump industry.

Conclusion

The future for the heat pump industry looks bright in Norway. Awareness of heat pump technology is increasing, and heat pumps are recognised as a good solution both for the environment and for the user. The industry has to adapt to the fact that new houses has lower heating demand and need more cost-effective heating solutions. It also needs to address the need for more education and training at all levels to support the growth of the heat pump market.

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Annexes, ongoing

IEA Annex 34: Thermally Driven Heat Pumps for Heating and Cooling

Most heat pumps and chillers, providing the building sector with heat or cold, are electrically driven. However, substitution of the electrically driven compressor by a thermally driven one could lead to significant primary energy savings, especially if the thermal energy is provided from solar or waste heat.
The objective of this Annex is therefore to reduce the environmental impact of heating and cooling by the use of thermally driven heat pumps (e.g. absorption and adsorption machines). It is based on the results of Annex 24, "Absorption Machines for Heating and Cooling in Future Energy Systems", and cooperates with Task 38, "Solar Air-Conditioning and Refrigeration" of the IEA "Solar Heating and Cooling" (SHC) Implementing Agreement. Annex 34 is concerned with the development of performance evaluation standards and with further development of thermally driven heat pumps with higher efficiencies.

While an experimental setup to demonstrate sorptive heat pumping in general has been discussed in Newsletter no. 4/2010 (Volume 28) the evolution of highly efficient adsorbers as a heat pumping force, or visualised as a vacuum pump, is presented here. Remember, the adsorber withdraws water molecules from the evaporator and thus reduces the pressure and temperature there (cold production). In turn, it must dispose of the heat released when water vapour is adsorbed on its surface, e.g. heat rejection to cooling tower (in cooling case only) or floor heating (in heat pump operation mode).

Figure 1 illustrates the performance enhancement of the adsorber heat exchanger in several development steps. The left-hand photo shows an automotive cooling unit used to create a packed bed adsorber where the sorbent is prevented from falling out at the bottom by a wire mesh, and a brush helps to fill in the sorbent very closely. Although the volume specific density (sorbent per volume) is very high in this case, the thermal connection between the sorbent and the heat exchanger fin is fairly poor, hindering the released heat (arising by adsorption of the water molecules on the adsorber) to flow from the granules to the heat transfer fluid. The reason is that there exists 'at most' two point contacts per sphere only between the sorbent (sphere) and the heat exchanger fin (the fin gap is greater than the sphere's diameter) and the re-maining surface area of the sphere has to face a higher thermal resistance (air gap) while transporting the released heat to the fins. To overcome this, for example a binder based dip coating of the lamella heat exchanger can be applied as next step (middle). Here, a uniform connection is realised all over the heat exchanger and only small air gaps (if any) exist between sorbent and fin. Finally, a direct crystallisation connection, as can be seen in the right hand photograph (150 times enlarged), can be done on top of a metallic short fibre structure (sinter-fused structure), giving an enormous increase of surface area (3-D). This combination provides both good thermal conductivity in the metal and an excellent sorption-material-to-metal-mass ratio.

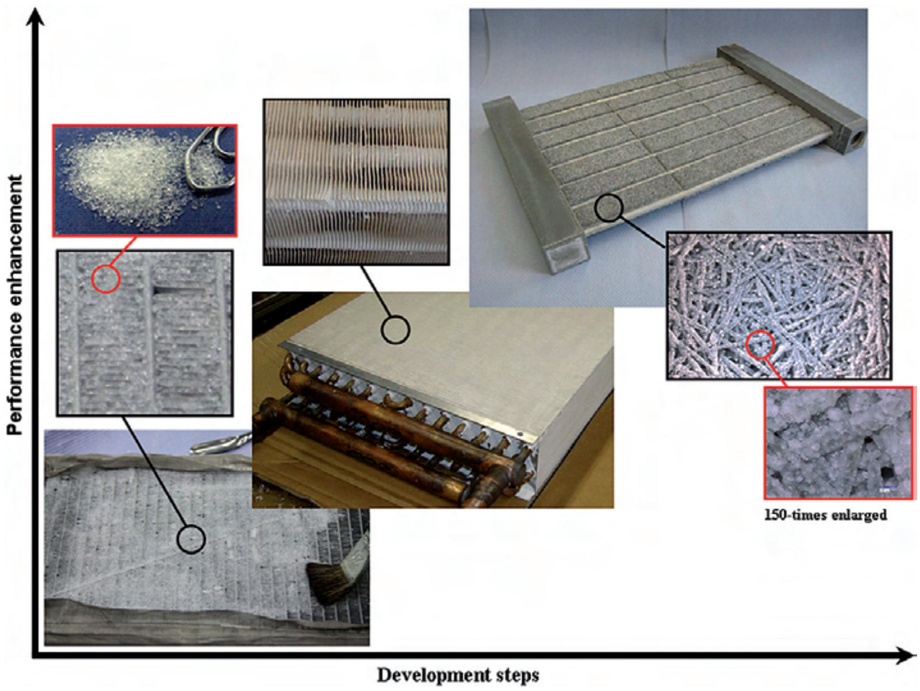


Figure 1: Different evolution steps of the performance enhancement in adsorber development: Packed-bed heat exchanger (left), binder based dip-coated lamella heat exchanger (middle) and direct crystallisation connection of the sorbent (right) on 3D-metal structure heat exchanger.

Preliminary results of Annex 34 will be presented at a workshop at the HPC Conference 2011 in Tokyo. The following Task description summarises the current work in 2010 and gives a foretaste of what will be discussed at the workshop:

Task A Market overview and state-of-the-art – More Country Reports were collected and a first summary will be presented at the 10th IEA Heat Pump Conference 2011. Much work has been carried out to rebuild the web page fundamentally (www.annex34.org) in order to simplify the teamwork of the contributing participants. Unfortunately, an application for EU funding, aiming to ensure the co-operation of the participants beyond the project duration failed, but will be re-submitted.

Task B Performance evaluation – The database of existing standards was updated with new and revised documents currently under revision or development (e.g. EN14825, EN12309) and is accessible on the internal webpages. The German directive (VDI-Richtlinie) has already been published. A final proposal for the definition of performance figures was presented and agreed upon. The outcome - i.e. a proposal for a description of a standard to determine COP values and other energy performance figures of TDHPs and of systems using TDHPs - has been divided into four technical reports.

Task C Apparatus technology – The sorption material database has been expanded on the internal web pages with further material data according to the proposed measurement procedures. This includes mainly new promising commercially available silica gels and zeolites.

A technical report on the different technologies, their potentials and limits and a description of standards to determine sorption material properties will be provided soon. Work on continuous extension of the database, material sources and experimental expertise is also being carried out.

Task D System technology – A template to summarise data from existing plants has been developed. First results were already gained, providing information on system understanding, i.e. how does the TDHP work (proper functioning), how it is integrated (system components) and how does it operate within the whole system (control strategies). This included calculation of the system performance by analysing the monitoring data. In addition, available tools for the design of TDHP systems and for calculating their energy and economic performances were summarised.

Task E Implementation – A number of useful demonstration projects have been collected. Authors as well as responsible authors for most chapters of the planned handbook have already been decided upon. It is planned to finish the first chapters, i.e. an overview of standards as the outcome of Task B, at the beginning of 2011.

IEA HPP /IETS Annex 35 / 13 Application of Industrial Heat Pumps

While the residential heat pump market has already been satisfied with standardised products and installations, most industrial heat pump applications need to be adapted to unique conditions. In addition a high level of expertise is crucial.

Industrial heat pumps are here defined as heat pumps in the medium and high power ranges which can be used for heat recovery and heat upgrading in industrial processes, but also for heating, cooling and air-conditioning in industrial, commercial and multi-family residential buildings as well as district heating.

The main market barriers for the introduction of industrial heat pumps are expected to be lack of experience and thus lack of acceptance in the market with operators, industrial partners and its supply and consulting chains.

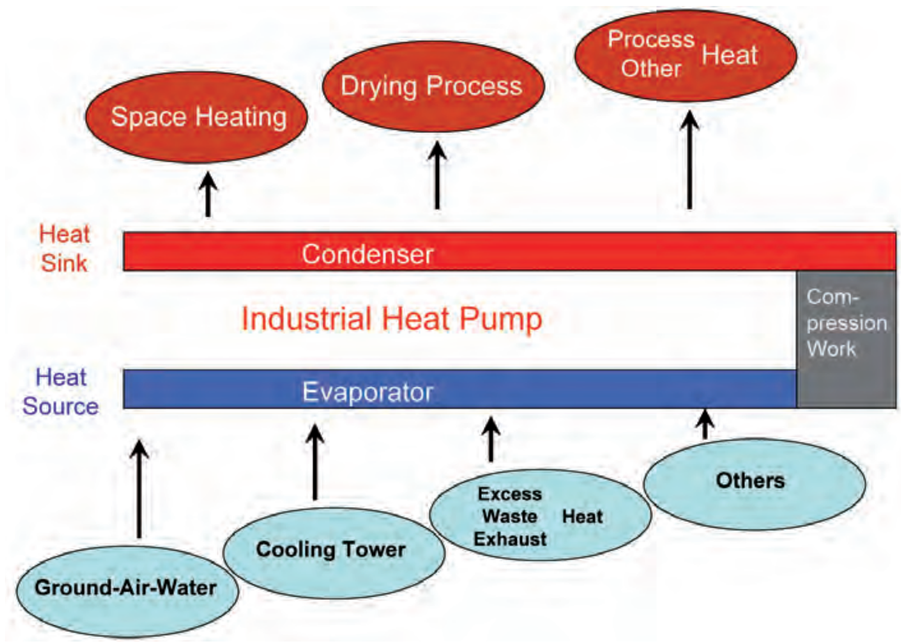
It was therefore agreed to start an new Annex entitled "Application of industrial Heat Pumps" as a joint venture of the IEA Implementing Agreements "Industrial Energy Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP).
The Annex 35/13 officially started on the April 1, 2010 with 16 participating organisations from 10 member countries of IETS and HPP.

The annex will focus on the
- reduction of energy costs, fossil energy consumption and CO_2-emissions in industrial and commercial heat generation
- constraints related to medium and high temperature refrigerants with low GWP
- adapted compressors for high temperature
- Process methodology for integration of HPs

A first kick-off meeting took place on April 26, 2010 at the European Academy of Refrigeration and AC in Maintal/Germany with 14 participants from 8 countries. The meeting discussed and decided on the following topics:
- Role and objectives of the Annex
- Expected contribution of the participants
- Detailed work plan
- Main tasks and time schedule
- Number of meetings

It was agreed that the following tasks
1. Market overview, barriers for application
2. Modeling calculation and economic models
3. Technology
4. Application and monitoring
5. Communication

should form the frame of the work



programme and each task should have a task leader with specific competence for the individual task.

The first annex meeting took place on the October 11, 2010 in connection with Chillventa 2010, Nürnberg/Germany with 19 participants from 10 countries.
The Annex Coordinator IZW e.V. presented the present status of contracting parties / participants, specific obligations and responsibilities of the participants and the status of work.
The main topic of the meeting was the presentation related to Task 1 with an overview of the energy situation and the overview of energy use in segments of industries of the participating countries and a detailed discussion on the work programme.

The next meeting and workshop will take place in connection with the 10th IEA Heat Pump Conference in May 2011 in Tokyo/Japan.

Further information is available from the Operating Agent:

The Information Centre on Heat Pumps and Refrigeration - IZW e.V., Germany (Informationszentrum Wärmepumpen und Kältetechnik - IZW e.V.), in collaboration with Laurent Levacher, EDF-R&D-ECLEER (European Centre & Laboratories of Energy Efficiency Research), France.

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IEA HPP Annex 37: Demonstration of field measurements on heat pump systems in buildings - Good examples with modern technology

Annex 37 aims to expand acceptance of heat pumping technology and to increase take-up in new markets. The intention is to demonstrate energy and environmental potentials of heat pumping technology, using existing field performance measurements, and with the emphasis on best available technology. It should be possible to predict the most suitable heat source and heat pump system for particular applications.

In order to ensure reliable results, it is most important that the quality of the measurements should be assured, and so the criteria for good and assured quality will be defined in the Annex. As the results will also be used to compare given heat pump systems with alternative heating systems, it is therefore important to define measuring conditions such as measuring points and system boundaries that influence energy savings and CO_2 reduction.

An important outcome of Annex 37 will be a data base of existing field measurements, using a common method to express performance values such as seasonal efficiency and energy savings. The data base will be linked to the IEA Heat Pump Centre's website.

The work of Annex 37 started with an initial meeting on February 24th 2011 in Sweden. Annex 37 is an "Annex lite", which implies limitations in time and meetings. Confirmed participants of the Annex are Austria, Switzerland, the United Kingdom and Sweden (Operating Agent). Other countries are invited to join the Annex.

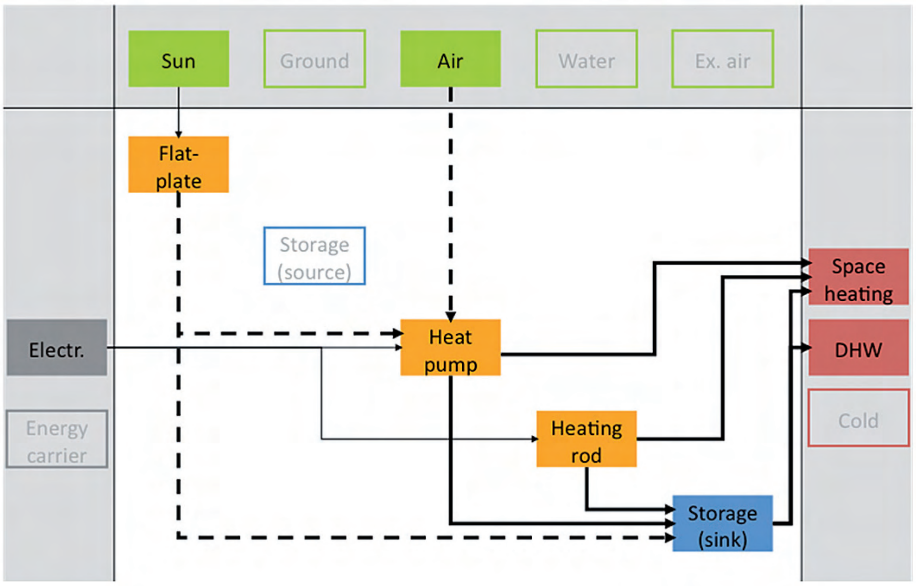
IEA HPP Annex 38: Solar and Heat Pump Systems

Some news from Annex 38

January 2011
The combined SHC Task 44 and HPP Annex 38, under the name of "Solar and Heat Pump Systems", is a joint effort of the SHC and the HPP bodies, and will be led by a single operating agent (JC Hadorn of Switzerland) from 2010 to 2013.
The objective of the work is to analyse and compare the most common combinations of solar heating and heat pumps for a single-family house.
The Task is organised into four subtasks:

- Sub-task A: Solutions and generic systems, led by Germany (Fraunhofer ISE, Sebastian Herkel)
- Sub-task B: Performance assessment, led by Austria (AIT, Ivan Malenkovic)
- Sub-task C: Modelling and simulation led by Switzerland (SPF, Michel Haller)
- Sub-task D: Dissemination and market support, led by Italy (EURAC, Wolfram Sparber).

From the Solar Heating and Cooling Programme, participating countries are Austria, Belgium, Canada, Denmark, France, Germany, Italy, Spain and Switzerland. From the Heat Pump Programme, they are Finland, Germany, the UK and Switzerland.
One achievement of 2010 was in Sub-task A, to develop a new way of describing a system combining solar heating and a heat pump. Such a combination can be complex, and it is not always easy quickly to grasp the features and functions of the system from a system diagram. It was therefore decided in Annex 38 that a new way to represent a system should be set up. This new way should provide a rapid understanding of the global system in order to ease comparisons. After some



The square layout: a new Task 44 / Annex 38 way of describing the sources, the sinks, the inputs and outputs, and the links in a solar and heat pump system.

discussions and many alternatives, the group ended up with what has been given the name of the "square layout" of a system, which makes it possible to see all the functional connections in a solar and heat pump system at once. (In fact, this presentation format is not restricted to this particular combination, but can be applied to any heating system).

More on the Annex will be presented at the HPP Tokyo conference in May 2011.

Link to Task 44/Annex 38 technical website
http://www.iea-shc.org/task44
For more information on this work contact the Operating Agent, Jean-Christophe Hadorn, jchadorn@baseconsultants.com from Switzerland

IEA Annex 39: A common method for testing and rating of residential HP and AC annual/seasonal performance

Participating countries: Austria, Finland, France, Germany, Japan, The Netherlands, South Korea, Sweden (Operating Agent), Switzerland and the United States

To achieve a properly working heat pump system, the right type of heat pump must be chosen and installed with a matching heat distribution system. For this reason, it is important to have reliable information on both the heat pump itself and on how it is influenced by the surrounding system.

A common SPF method would be important for fair comparison between different types of heat pump systems as well as fair comparison with other competing technologies using fossil fuels. A common SPF method can later be incorporated in different labelling, rating and certification schemes.

There is therefore a need for an improved transparent and harmonised method for calculation of heat pump system SPF, **based on repeatability and reliable test data from laboratory measurements.**

There are many national standards for both testing and calculation of SPF. Manufacturers have made it clear that they would like to see common testing methods and common SPF calculation methods, since this would make it simpler for them to export heat pumps to different countries. The question has been highlighted in the European countries after the RES Directive was approved. In Japan, too, existing standards need to be updated, and a common methodology is desired.
The outcome from the project will be a proposal for a common transparent SPF calculation method for domestic heat pumps, including heating, cooling and domestic hot water production.

The idea is to conduct prenormative research, which later can be incorporated in standardisation (ISO and CEN) in the same way as Annex 28.
The Annex builds on such material as experience and findings from Annex 28, "Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating".

In order to achieve the objectives of the Annex, the following task-sharing activities have been planned:

Task 1 Review and evaluation of existing test methods and calculation methods for SPF

Task 2 Matrix definition of needs for testing and calculation methods

Task 3 New calculation method for SPF/ Commonly accepted definitions on how SPF is calculated

Task 4 Identify improvements to existing test procedures

Task 5 Validation of SPF method
Task 6 Development of an alternative method to evaluate heat pump performance
Task 7 Communication to stakeholders

A project kick-off meeting was held at the ASHRAE Annual Meeting in Albuquerque in June 2010. At this meeting, participants from six countries contributed to the development of the final draft of the legal text. However, the start of the Annex has been delayed, due to the fact that some countries did not have the financial contribution settled. The Annex legal text was finally approved at the ExCo meeting in Vienna, Austria in November 2010, and in December 2010, most countries have established supporting national projects for input to the Annex. Because of this, the launch of the Annex work has been postponed until the beginning of February 2011.

A workshop is planned for the HPP triennial heat pump conference, to be held in Tokyo, May 16, 2011.

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Attend Annex Workshops at the Heat Pump Conference in Tokyo, May 16-19!

Each of the Annexes 32, 34-39 will host a Workshop on May 16, in connection with the Conference. Also, the IEA Implementing Agreement ECES (Energy Conservation through Energy Storage) will host a Workshop. These workshops are free to attend, for all registered Conference Participants. See http://www.hpc2011.org/ , click on "Workshop".

Ongoing Annexes

Bold text indicates Operating Agent. * Participation not finally confirmed, ** Participant of IEA IETS or IEA SHC

Annex 34 Thermally Driven Heat Pumps for Heating and Cooling	34	AT, CA, CH, DE, FR, IT, NL, NO, US
Annex 35 Application of Industrial Heat Pumps (together with Task XIII of "Industrial Energy-Related Technologies and Systems" (IEA IETS))	35	AT, CA, DK**, FR, DE, JP, NL, KR, SE, CH*
Annex 36 Quality installation and maintenance	36	CA*, CH*, DE*, FR, JP*, KR*, SE, UK, US
Annex 37 Demonstration of field measurements of heat pump systems in buildings – Good examples with modern technology	37	AT, CH, SE, UK
Annex 38 Systems using solar thermal energy in combination with heat pumps	38	AT**, BE**, CA**, CH, DE, DK**, ES**, FI, FR**, IT**, 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, NL, KR, SE, US

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

Gas-driven sorption heat pumps; a potential trend-setting heating technology

Belal Dawoud, Viessmann Werke Allendorf GmbH, Germany

Increased efforts to reduce CO_2 emissions and continuous increases in fossil energy prices have led to stronger legislation concerning energy utilisation efficiency in the domestic heating sector. Accordingly, German gas utilities and the key European manufacturers of gas heating appliances have teamed up to form what is known as the "Gas Heat Pump Initiative" to introduce new heating technologies, which are capable of achieving an incremental improvement of gas utilisation efficiency compared to that delivered by gas condensing technology. This article provides a brief introduction to these innovative heating appliances and a presentation of the gas heat pump initiative.

Introduction

According to the "EE-Wärmegesetz, 2008" (the Renewable Energy Heating Law) for increasing the share of renewable energy in household heating applications in Germany, all heating appliances to be installed in new buildings must have a minimum primary energy efficiency of 120 %. This means that more efficient and environmentally friendly gas heating appliances will have a significant market share compared with conventional technologies.

The spread of natural gas on the market was based, among other factors, on developments of low-pollution burners and later energy-efficient low-temperature boilers. The role of natural gas as a modern and ecologically compatible energy source was substantially extended by the introduction of gas condensing boiler technology in the 1990s. The heating market has subsequently become the largest consumption sector for natural gas. Since 2005, and particularly in the new buildings sector, the growth of the gas heating market has been clearly reduced, with a decline in service connection density from 80 % to now less than 60 %. In addition, expansion of the gas supply networks has reached the limits of economic feasibility.

The gas industry therefore needs to respond to customers' increased environmental awareness and demands for autonomous solutions with innovative and modern heating technologies utilising renewable energy. Along with the established condensing boilers plus solar energy solutions, gas heat pumps, in particular, enable end users to meet the market's political demands for high-efficiency heating systems in conjunction with renewable energy utilisation.

In addition, sorption heat pumps have attracted considerable attention due to their lower environmental impact than that of conventional vapour compression heat pumps using HCFCs and HFCs, since sorption systems make use of natural refrigerants (ammonia and water), which have zero global warming potential. For these reasons, German gas utilities and the key European manufacturers of gas heating appliances established the Gas Heat Pump Initiative (www.igwp.de) in 2008 as a concerted action to carry out laboratory and field tests, prepare the market and work out the required standards framework for the introduction of gas heat pump-based heating appliances. This article presents a brief introduction to the sorption heat pump technologies involved, as well as to the Gas Heat Pump Initiative (IGWP) and its activities.

Working principles of the gas-driven sorption heat pump heating processes

Heat pumps can in general be classified by the following technical principles:

- Vapour compression heat pumps (electrically-driven or gas-motor-driven heat pumps). In this type, the heat pump process is delivered solely by mechanical energy.
- Sorption heat pumps (absorption or adsorption heat pumps), in which heat is the main driving energy.

Common to both heat pump processes is that the liquid refrigerant leaving the condenser after transferring its heat of condensation to the heating system passes through an expansion valve in order to reduce its pressure, and therefore its temperature, below the temperature of the ambient heat source before entering the evaporator. In the evaporator, the expanded refrigerant vaporises as it picks up its heat of evaporation from the ambient heat source (air, ground, groundwater or solar collectors).

In a vapour compression heat pump, the gaseous refrigerant leaving the evaporator is compressed by a mechanical compressor, where its pressure, and therefore temperature, is increased before entering the condenser to be liquefied again.

The duty of the mechanical compressor is tackled differently in a sorption heat pump, where heat becomes the main driving energy (thermal compression). There are several ways of realising what is known as the "thermal compressor" in a sorption heat pump. The main idea remains, however, to apply a sorbent for the refrigerant in the thermal compression process. If the sorbent remains in the solid state (silica gel, zeolite or active carbon are typical adsorbents for water, methanol or ammonia as refrigerants), we talk about an adsorption heat pump. Absorption heat pumps utilise liquid sorbents (LiBr-H_2O solution or diluted NH_3-H_2O solutions for water or ammonia as refrigerants).

Figure 1 shows a simplified schematic of the gas-driven absorption heat pump process. The right-hand side of the diagram shows the components of the thermal compressor. Refrigerant vapour is first absorbed into the liquid sorbent after being expanded in the solution expansion valve, to form a refrigerant-rich solution. Both the heat of condensation of the refrigerant vapour and the binding energy of the refrigerant into the absorbent (the latent heat of absorption) are then transferred to the heating water in the form of useful heat. The pressure of the enriched solution is then raised to the condenser pressure by a solution pump, which requires only about 1 % of the mechanical energy required to raise the pressure of the refrigerant vapour in a mechanical compressor (mechanical work required for compression is proportional to the specific volume of the medium). The high-pressure enriched solution enters the generator, which is directly fired by natural gas. From here, refrigerant vapour at high pressure and temperature flow into the condenser, while the weakened refrigerant solution flows back to the absorber after being expanded to the absorber or evaporator pressure to absorb more refrigerant coming out of the evaporator. This is a simplified explanation: in fact, the real absorption heat pump process employs more units for internal heat recovery and therefore for further improvement of gas utilisation efficiency. The first gas-driven heat pump technology in the IGWP framework utilises ammonia-water as a working pair and is available in a heating power range of 40 kW [1]. This type of heat pump technology can be used to cover the nominal heating demand or to cover the base load if integrated with a condensing boiler for peak loads.

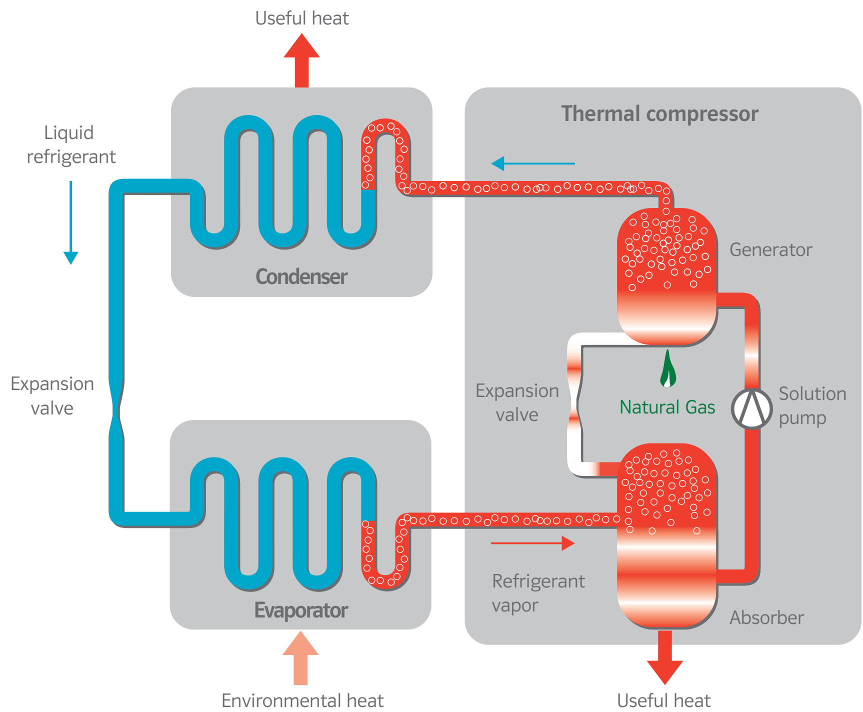

Figure 1: Schematic of the single-stage absorption heat pump process

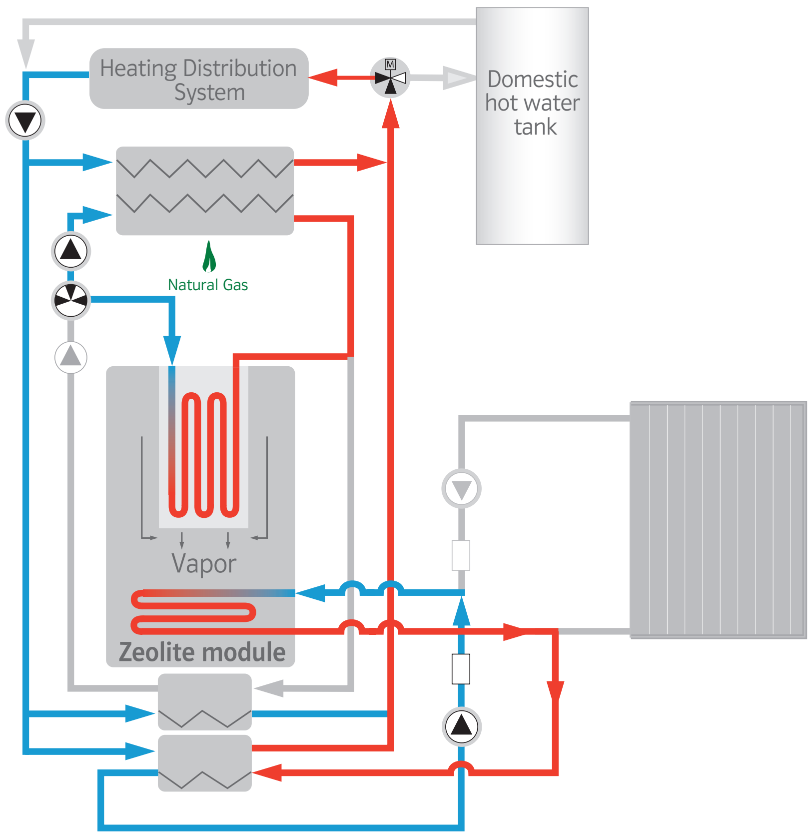

Figure 2.a: Vaillant gas-driven heat pump during the desorption phase

The second type of gas-driven heat pump technology in the IGWP framework is shown in Figure 2. It is a hybrid heating appliance, comprising a gas condensing boiler to drive an intermittent adsorption heat pump module and to meet the peak load if the required heat demand exceeds the rated heat pump heating capacity [2]. This Vaillant zeolite heat pump module is referred to as a two-heat exchanger module, as it incorporates two heat exchangers. The top heat exchanger functions either as a desorber or an adsorber, while the lower heat exchanger works respectively as a condenser or evaporator. This technology utilises zeolite (as an adsorbent) in the form of loose pellets between the fins of a finned-tube adsorber heat exchanger, with water as a refrigerant. One important feature of this technology is the utilisation of solar collectors as an ambient heat source. Figure 2a depicts the heating appliance in the desorption phase, during which zeolite is heated up by a hot water loop connecting the adsorber heat exchanger with the gas burner heat exchanger. The water vapour from the zeolite pellets condenses on the lower heat exchanger (working as a condenser), delivering useful heat to the heating water through the lower plate heat exchanger. After reaching a certain desorption end temperature, the burner is switched off and the adsorber heat is transferred to the house heating system through the plate heat exchanger just below the zeolite module, resulting in reducing the temperature of the zeolite. The cold and dried zeolite then adsorbs water vapour from the condenser, progressively reducing its temperature until it is lower than the temperature of the brine flowing out of the solar collector panel. From then on, the lower heat exchanger works as an evaporator, feeding ambient heat into the process (Figure 2b).

The third heating appliance based on a gas-driven heat pump process is from Viessmann and is shown in Figure 3. This is again a hybrid system comprising an intermittent heat pump module with a condensing boiler driving the heat pump process, assisting the heat pump in the mixed-operation mode, and working alone as a peak boiler in the direct heating mode [3]. The main differences between Viessmann and Vaillant technologies can be summa-

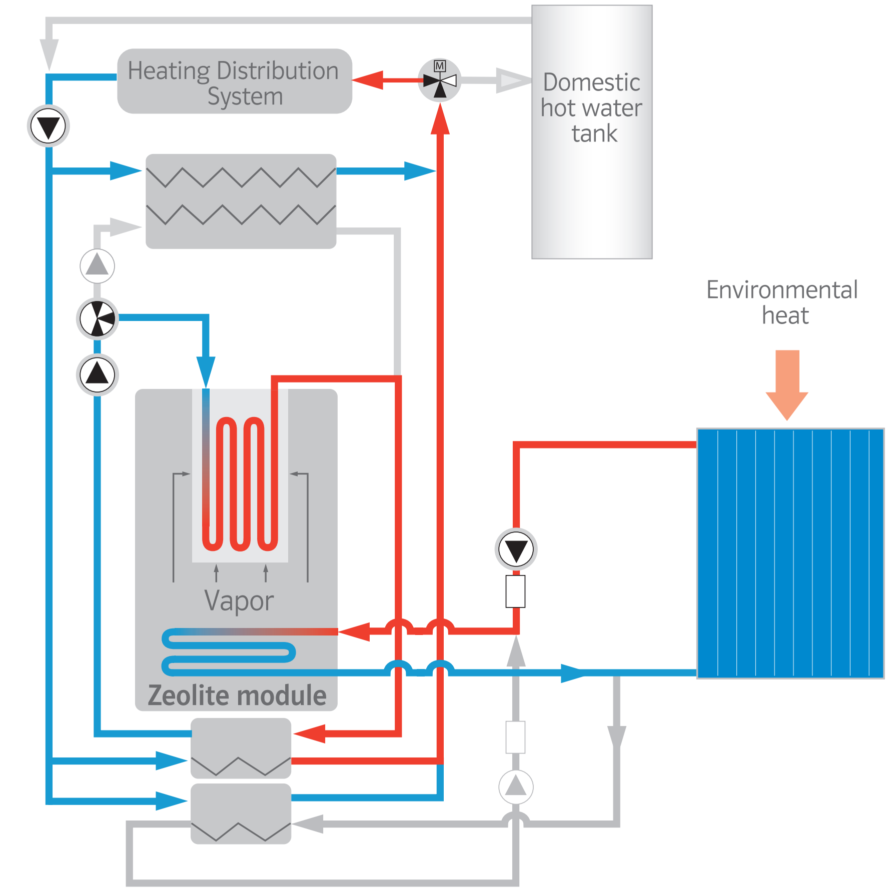

Figure 2.b: Vaillant gas-driven heat pump during the adsorption phase

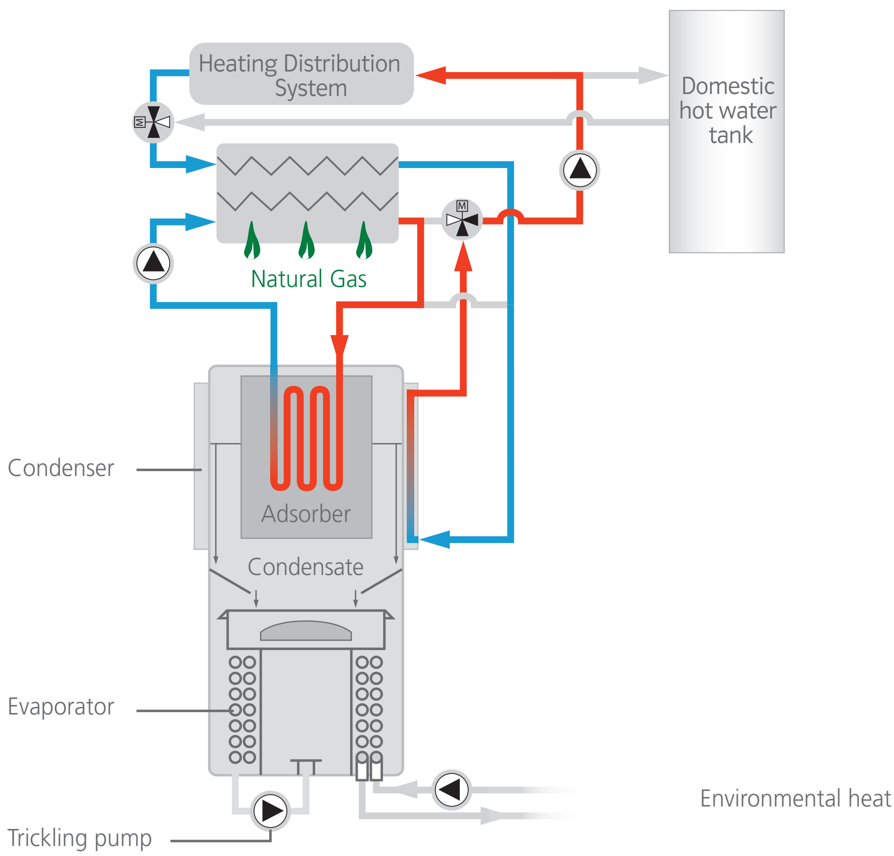

Figure 3.a: Viessmann compact heating appliance based on a gas-driven intermittent heat pump during the desorption phase

rized as follows:

1) The Viessmann heat pump module comprises three heat exchangers; namely, adsorber-desorber, condenser, and evaporator, thus eliminating the internal heat losses from heating up and cooling down the same heat exchanger working periodically as an evaporator or condenser [4].
2) There is always a direct heat transfer between the heating water and either condenser or adsorber [4].
3) Zeolite is utilised in form of consolidated layers over the fins of the adsorber heat exchanger [5].
4) The evaporator is constructed as a falling film evaporator [6].

For a vapour compression heat pump with a rated heating capacity of 8 kW, 2 kW of electrical energy and 6 kW of ambient energy are required to deliver a seasonal performance factor (SPF) of 4. With an assumed average power station efficiency of 38.5 %, this SPF equals 1.54 based on primary energy consumption. With a gas-driven heat pump, the 8 kW are delivered from 5.2 kW of gas and 2.8 kW of ambient heat, to give a primary energy SPF of 1.54. This means that the ambient heat utilised by a gas-driven heat pump is less than 50 % of that utilised by a vapour compression heat pump of the same heating capacity and same primary energy SPF. This gives a cost benefit concerning the ambient heat source in favour of gas-driven sorption heat pumps.

The Gas Heat Pumps Initiative (IGWP)

The IGWP was founded in February 2008 by the German gas utility companies EnBW, E.ON Ruhrgas, ESB, EWE, GASAG, MVV, RWE and VNG, together with key European appliance manufacturers Bosch Thermotechnik, Robur, Vaillant and Viessmann. The know-how of all these member companies is brought together to promote the market maturity of the previously described heating appliances. Appliance development remains with each manufacturer, but marketing and lobbying work is done cooperatively. So far, twelve gas heat pump heating appliances have been successfully tested in the E.ON Ruhrgas laboratory, and three more units are planned for tests this year. These units have been subjected to a comprehensive test program to ensure their durability and to evaluate their gas utilisation efficiencies under laboratory and real conditions. In addition, 39 units from the different manufacturers have been installed and are being field-tested by the gas utility customers, distributed over the entire country. A further 27 units are planned for installation before the beginning of the 2011-2012 winter season. The laboratory and field test results obtained so far confirm the high efficiency and durabil-

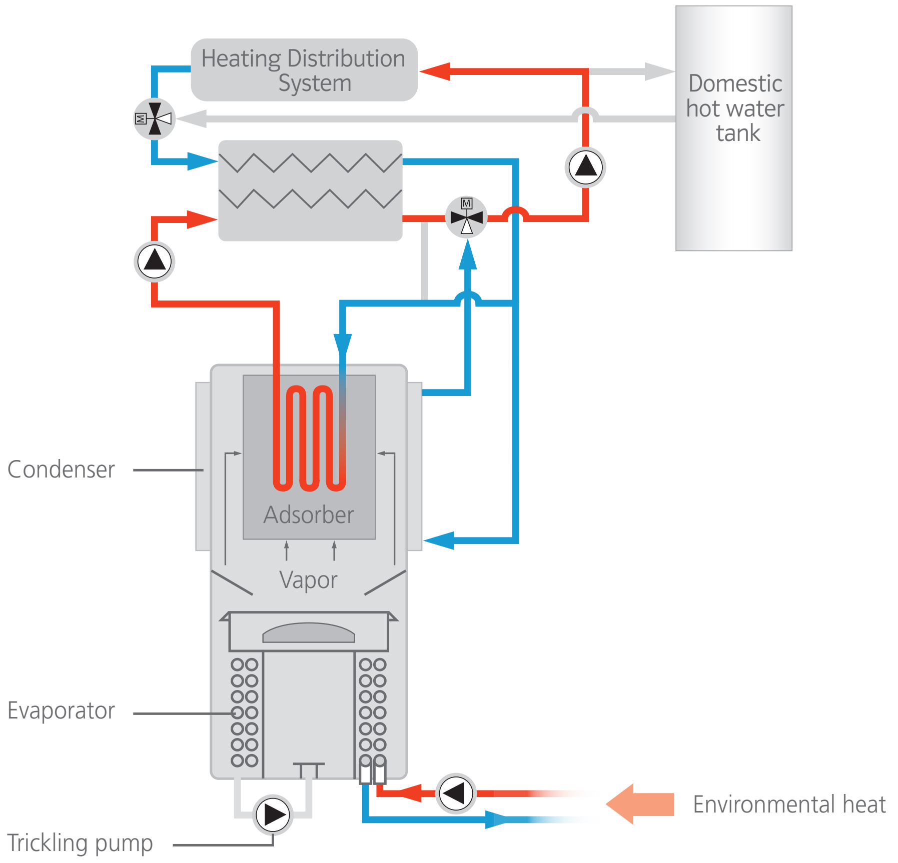

Figure 3.b: Viessmann compact heating appliance based on a gas-driven intermittent heat pump during the adsorption phase

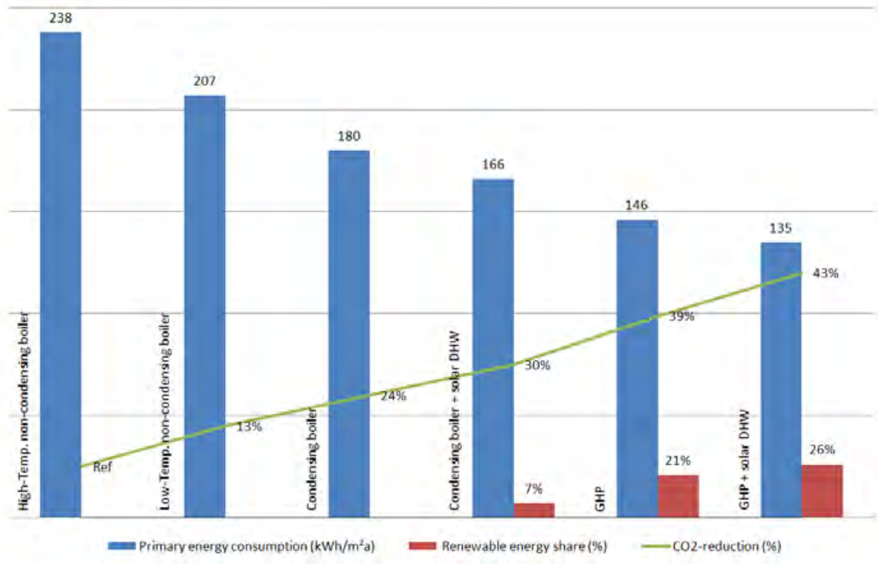

Figure 4: Potential of gas-driven sorption heat pumps for a typical 150 m^2 existing house in Germany [7]

ity of all the tested appliances. However, a good deal of development and optimisation work is still needed in connection with thorough investigation of the field test results, leading to more efficient control and hydraulics and better gas utilisation efficiencies in the field.

In parallel with this work, market analyses and an IGWP-sponsored marketing campaign have been started. Technical seminars and training programs for the installation sector have also been started. A guideline for evaluating the seasonal performance factor of gas-driven sorption heat pumps has also been worked out (VDI-4650-2), and is now being considered as a basis for the corresponding DIN and EN standards.

A study has been carried out to estimate the potential of gas-driven sorption heat pumps compared with different heating technologies [7]. Figure 4 illustrates the differences in primary energy consumption, CO_2 reduction, and the share of renewable energy for an existing German house having 150 m^2 floor area as delivered by seven different heating methods. Compared with high-temperature non-condensing technology, which is the main heating technology in existing houses in Germany, the GHP technology offers 39 % reduction in primary energy consumption, and therefore also in CO_2 emissions, and, at the same time, delivering 21 % of the heating from renewable energy. Coupling solar energy for domestic hot water with a GHP results in 19 % less primary energy consumption and CO_2 emissions, and utilises 26 % renewable energy share compared with state-of-the-art gas-condensing boilers. This emphasises the need to promote GHPs as a possible trend-setting heating technology in the household sector.

As a result of the previous concerted actions within the framework of the IGWP, Robur could launch its E3 gas absorption heat pump model [1] at the ISH Fair 2009 in Frankfurt. In addition, Vaillant launched its zeolite heating appliance [2] in April 2010. In addition, Viessmann is planning to launch its zeolite compact heating appliance in 2012.

Conclusions

The German gas utilities and the key European manufacturers of gas heating appliances have established an outstanding platform to support and stimulate the market introduction of a new heating technology based on small-scale gas-driven sorption heat pumps. The "Initiative Gas Heat Pump" was established in February 2008 and has since then comprehensively tested twelve heating appliances of this type in the E.ON Ruhrgas laboratory for durability and gas utilisation efficiency. In addition, 39 heating appliances have been installed in the field at customers of the German gas utilities. A further 27 units are planned for installation this year. Both laboratory and field test results have proved the durability of the new heating appliances and their clear efficiency enhancement over condensing boiler technology allowing at least compliance with the German Renewable Energy Act, 2008. An independent study of the potential of the new heating appliances in existing houses in Germany found that around 39 % primary energy savings could be achieved compared with high-temperature non-condensing heating systems, which represent the state of the art of heating in existing houses, together with utilising a renewable energy share of 21 %. Compared with condensing boilers, the GHP with solar collectors for domestic hot water production has the potential to save 19 % of primary energy and deliver 26 % from renewable energy. This indicates the need to promote the GHP as a possible trend-setting heating technology in the household sector.

References

[1] Harald Dummer, Innovation – Gas-Absorptionswärmepumpe, Die VDI-Fachkonferenz „Wärmepumpen; Umweltwärme effizient nutzen", 08. Und 09. Juni 2010, Stuttgart, pp. 119-127.

[2] Rainer Lang and Uwe Marx, Zeolith-Gas-Wärmepumpe mit Einbindung von Solarwärme, Die VDI-Fachkonferenz „Wärmepumpen; Umweltwärme effizient nutzen", 08. Und 09. Juni 2010, Stuttgart, pp. 129-136.

[3] Belal Dawoud, Stefanie Chmielewski, Peter Höfle and Andreas Bornmann, Das Viessmann Zeolith-Kompaktgerät – Eine gasbetriebene Wärmepumpe, Die VDI-Fachkonferenz „Wärmepumpen; Umweltwärme effizient nutzen", 08. Und 09. Juni 2010, Stuttgart, pp. 111-117.

[4] Dawoud B. and Stricker M., A hydraulic concept of an intermittent adsorption heat pump; EP 1 985 948 A1, 2008.

[5] Dawoud, Belal; Sauer, Jürgen; Chmielewsli, Steffanie, Van Heyden, Hendrik and Klaschinsky, Heike, Adsorber Element and Method for Producing an Adsorber Element, WO 2010/040355 A2, 2010.

[6] Dawoud, Belal; Bornmann, Andreas and Lohmöller, Steffanie, A construction and working process of an intermittent sorption heat pump with a falling film / spray evaporator; DE 10 2008 006 420 B3, 2009.

[7] Bert Oschatz and Manfred Kleemann, Potenzial der Gaswärmepumpentechnologie - Abschlussbericht, http://www.igwp.de

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Testing and performance evaluation methods for thermally driven heat pumps

Current work in IEA HPP Annex 34

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Thermally driven heat pumps and chillers have experienced a revival in recent years, with substantial market growth being observed in many areas such as solar cooling or domestic gas heat pumps. Both the market and policies are now calling for testing and performance evaluation standards to ensure a sustainable market growth and competitiveness of the technology. A proposal for a uniform and transparent evaluation procedures is currently being developed within IEA HPP Annex 34.

Introduction

With globally rising awareness of the need for efficient and sustainable energy use, the market for thermally driven heat pumps (TDHP) – as one of the technologies offering a way of reducing primary energy consumption – has been constantly growing in recent years. Both the market and policy need standardised procedures for uniform and transparent performance evaluation of different products (e.g. for labelling) and their comparison with other technologies. Currently, only a relatively small number of standards for TDHP is available and in practical use.

On the other hand, standards for electrically driven heat pumps are quite well developed on national and international levels, and widely used and accepted among all stakeholders. This experience can be used as a starting point for systematic development of standardised testing and performance evaluation procedures for TDHP. However, due to differences in technology, the approach used for electrically driven heat pumps needs to be comprehensively reviewed and modified. This has been set as one of the goals of IEA HPP Annex 34.

TDHP technologies

With a growing market, a fair number of new products have reached the market lately, see Table 1. Most are in the low to mid capacity range (5-50 kW), as for many years only a few (or no) products of that size could be found.

Currently available products cover both absorption and adsorption technologies. Although these are closely related regarding the basic processes, they differ when it comes to operational characteristics. While absorption machines mostly operate continuously, adsorption units tend to be designed for dis-continuous operation. This has a considerable impact on definition of the test procedures. Therefore, classification of TDHP units based on the differences in their time-related useful energy output curves is important when defining performance test methods. In Annex 34, the machines were divided into three groups [1]:

Continuous – all four basic processes of sorption refrigeration are performed continuously in dedicated components of the machine. There are no, or only very small fluctuations in energy output;

Semi-continuous – the overall process is divided into phases, generally a "desorption-condensation" phase and a "sorption-evaporation" phase. The processes are performed by the same components alternately - the machine changes between two phases, which leads to dis-continuous operation for a short period of time during the changeover;

Batch-mode – discontinuous operation, mostly due to the unit design (e.g. one sorption bed) or process control (e.g. more beds with the possibility of simultaneous charging/discharging processes - phases). This process is highly discontinuous, with clear interruption in the useful energy supply by the refrigeration circuit.

Although in most cases these operation modes are of little or no significance for the user, they are important when it comes to performance evaluation of the machines and, therefore, for their marketability. To offer a fair chance to all machine types, their specific behaviour must be taken into account. First ideas have already been presented (see [1]), with discussion among Annex 34 experts still ongoing. Final results are expected by the end of 2011.

The current standardisation situation

Over the last decade or so, the heat pump (including air-conditioning) market has experienced rapid growth in many countries. This development has been accompanied by increased activity in the area of standardisation. At both national and international levels, new standards have been developed and many standards have been revised or are under revision. However, this trend in standardisation applies mostly for electri-

Manufacturer	Type(s)	Technology	Nominal capacity	Operation mode
ECOPLUS Energy Systems	Helioplus	gas fired, absorption, water-NH_3	~40 kW heating ~18 kW cooling	continuous
Robur	GAHP line	gas fired, absorption, water-NH_3	~40 kW heating ~18 kW cooling	continuous
Vaillant	zeoTHERM	gas fired, adsorption, zeolite-water	10 kW heating	discontinuous
AbKM Klimatechnik	Suninverse	indirect fired, LiBr-water	~10 kW cooling	continuous
Broad	BCT23	indirect fired, LiBr-water	23 kW cooling	continuous
Climatewell	SolarChiller	indirect fired, absorption, LiCl-water	~10 kW cooling	semi-continuous, discontinuous
EAW	WEGRACAL 15, 30, 50	indirect fired, absorption, LiBr-water	15, 30, 50 kW cooling	continuous
Invensor	LTC 09, HTC 11	indirect fired, adsorption, zeolite-water	9 and 11 kW cooling	semi-continuous
Jiangsu Huineng	RXZ 11, 23, 35 XRZ 11, 23, 35	direct or indirect fired, absorption, LiBr-water	11, 23, 35 kW cooling	continuous
Pink	PC14, PC19	indirect fired, absorption, water-NH_3	14 and 19 kW cooling	continuous
Robur	GA ACF series	gas fired, absorption, water-NH_3	~18 kW cooling (~21 kW heating)	continuous
SorTech	ACS 8, ACS 15	indirect fired, adsorption, silica gel-water	8 and 15 kW cooling	discontinuous
Thermax	Cogenie	indirect fired, absorption, LiBr-water	35 kW cooling	continuous
Tranter Solarice	XS 30	indirect fired, absorption, water-NH_3	40 kW cooling	continuous
Yazaki	WFC-SC 5 WFC-SC 10	indirect fired, absorption, LiBr-water	17.5, 35 kW cooling 25, 50 kW heating	continuous

Table 1: Overview of recent thermally driven heat pump products of less than 50 kW power output (not exhaustive)

cally driven machines. The situation is somewhat different for thermally driven units,.

Although there are several standards for testing and performance evaluation methods, a closer look reveals substantial shortcomings. For example, although nominally applicable to all gas direct-fired sorption heat pumps, European standard EN 12309-2 cannot be applied for most of the adsorption machines due to its definition of the steady-state condition. This standard is currently under revision, and some changes in this respect are expected. Although TDHP are explicitly mentioned in the Scope section of EN 15316-4-2, the given equations do not always take into account some features of the thermally driven technologies, making proper calculation of the performance quite difficult or even impossible. JIS B 8622, a Japanese standard revised in 2009, applies only to absorption LiBr-water machines. ARI Standard 560 applies only to LiBr-water machines, indirect single and double-effect, water-cooled and direct-fired double effect units, and so on.

In addition, the standards applicable in different countries or regions are rarely compatible among each other: system boundaries differ, test conditions are not the same and so on. Currently, no ISO standard is available for TDHP.

Nevertheless, a number of initiatives have been started recently which might get things moving. One of these is Annex 34, which aims, among other goals, at the development of a basis for a systematic approach towards the creation of testing and performance evaluation procedures for TDHP. VDI (The Association of German Engineers) is about to finalise a guideline for estimation of the seasonal performance factors of directly fired heat pumps. Although not having the status of a standard, VDI guidelines are widely accepted as standardised and reliable methods both by industry and policy-makers in many countries. Finally, EN 12309 is currently undergoing a thorough revision, and will probably be expanded.

Another European initiative in the area of solar cooling - one of the applications of TDHP which has been pretty much in the focus of interest in the recent years – is assessment of the possibility of including solar cooling systems in the solar standard EN12977.

One of the objectives of Annex 34 is to provide a unified basis for the development and/or revision of an (at present missing) standardisation framework to help thermally driven technologies to consolidate and further develop their market position.

TDHP system classification

Development of test standards requires a thorough analysis of the technology's state of the art, as well as a precise definition of the technologies and applications within the scope of the test standard.

A classification proposal for the units themselves has been given above. At the system level, a reference TDHP system for small to medium domestic and commercial use has been developed by Annex 34, Figure 1. It is based on an analysis of the most common system configurations. The nomenclature and graphical representation follow those proposed in SHC Task 38 for solar cooling systems.

Based on the reference system, different basic configurations for various applications can be arrived at by deleting the system parts not needed. These systems define the minimum mass, energy and enthalpy flows which have to be considered for the performance evaluation of a system.

Basically, TDHP systems can be classified by the type of driving energy (directly or indirectly fired) and the useful energy output (heating incl. DHW and cooling). This classification yields six applications which are also significant for definition of the operating conditions for unit testing: see Figure 2.

Performance evaluation

In times of rising energy prices, growing awareness of climate-related issues and greater commitment of the international community towards sustainable development, performance evaluation of energy-using products is becoming more important.

It is therefore crucial to identify a common basis for transparent assessment of the energy efficiency of different products of the same technology, but also comparison of products using different technologies for the same purpose.

The concept proposal presented in Annex 34 is primarily based on current definitions in EN heat pump standards. It aims at standardising the nomenclature of different performance figures with allowance for system boundaries and the types of input values, as shown in Figure 3.

The COP and EER describe the performance of the TDHP unit under carefully defined, steady-state operating conditions in the laboratory. As in EN 14511, the energy input and output are corrected for the energy input and loss of the liquid pump needed to overcome internal pressure losses.

The SCOP and the SEER give the calculated performance of the TDHP unit for defined loads and climate conditions. Measurements under laboratory conditions are to be used for input data. The method proposed is the temperature bin method used (for example) in prEN 14825 and EN 15316-4-2.

SPF and PER are both calculated from field measurements at system level. Basically, the SPF is the ratio of the overall useful energy output to the overall energy input. However, definitions of different levels based on different system boundaries can be defined in order to be able better to analyse and optimise the system. This approach has been also used for electrically driven heat pumps, and was described in the IEE SEPEMO-BUILD project [2].

One missing performance figure is the calculated SPF (CSPF), which is not covered in Annex 34. Unlike the SPF obtained from field measurements of all relevant parameters, the CSPF is obtained by laboratory measurements of one or more system components. The performance of the whole system is then obtained using a calculation method that assumes certain boundary conditions and characteristics of components not measured (e.g. EN 15316-4-2).

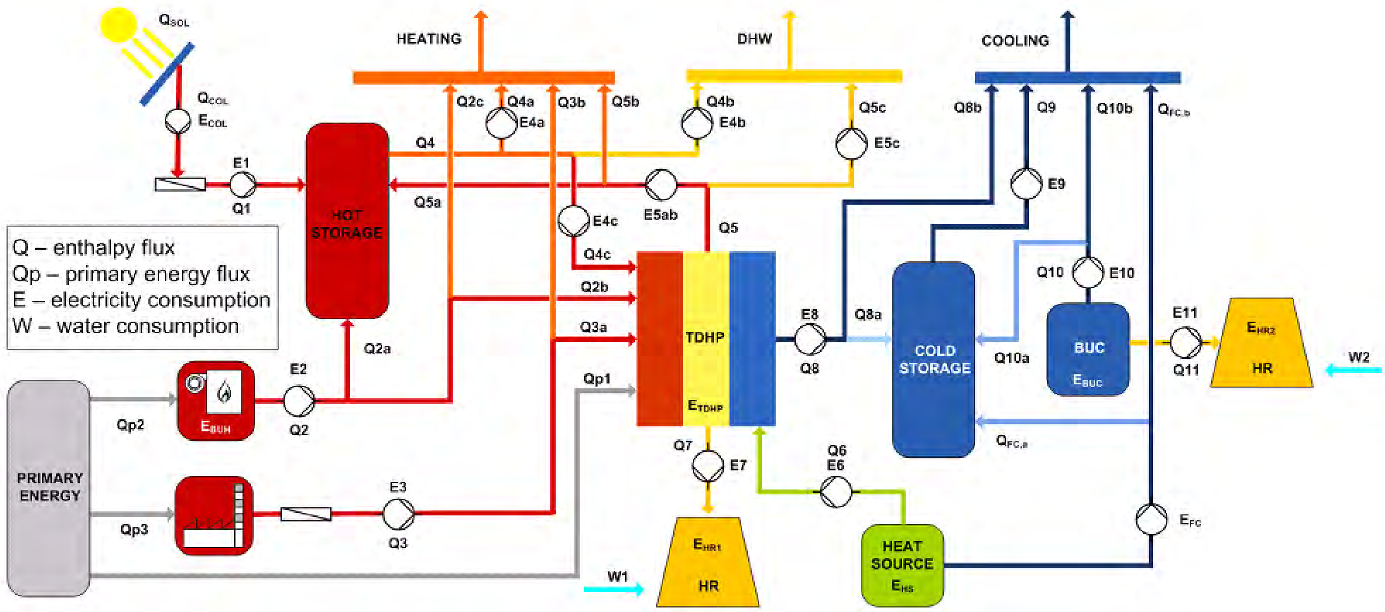

Figure 1: Reference TDHP system

Conclusions

A harmonised normative framework is needed for retention and further growth of the current positive market trend for thermally driven heat pumps. Currently available standards do not cover all applications and/or technologies. In addition, there is no common approach in the test requirements or definition of performance figures in the present standards.

Annex 34 will present a basis for further development of standards and possible harmonisation of different approaches and definitions. The proposal will be presented at the Heat Pump Conference in Tokyo in May 2011, and will be open for further discussion.

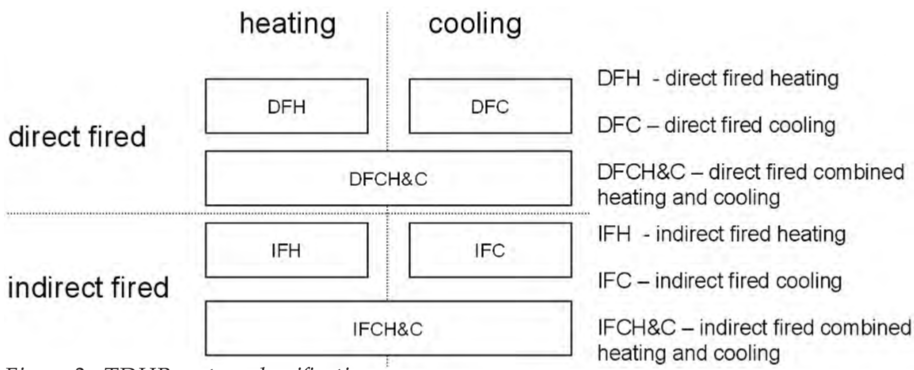

Figure 2: TDHP system classification

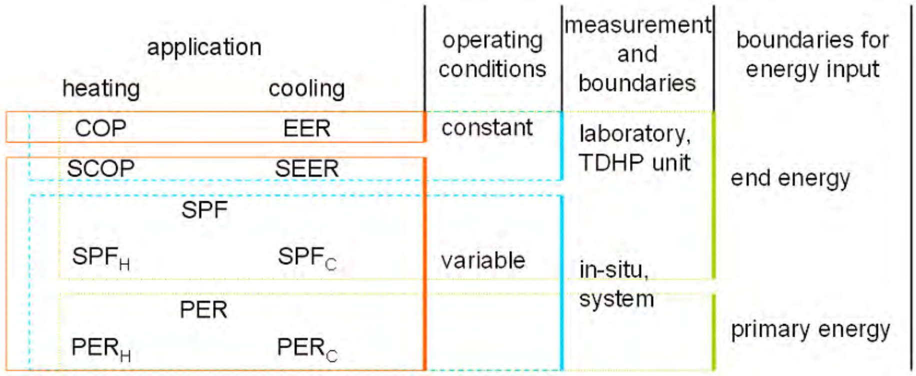

Figure 3: Classification of performance figures

References

[1] Melograno, P. N., Fedrizzi, R., Sparber, W., Franchini, G., 2010. "Test Procedures for Sorption Chillers Based on the Working Mode". Proc. of the 2nd Int. Conference on Solar Heating, Cooling and Buildings, Graz.

[2] SEPEMO 2010. A defined methodology for calculation of the seasonal performance factor and a definition which devices of the system have to be included in this calculation. Deliverable D4.2 of the IEE SEPEMO-BUILD project, contract Nr. IEE/08/776/SI2.529222

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Solar thermal cooling – technologies and market situation

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Solar thermal cooling technologies are based on the smart idea of using solar energy – which is what produces the very need for cooling in buildings - to create 'cold'. Present-day designs use refrigerants which are environmentally friendly. Using energy from the sun - which also has the benefit of being free of charge – helps to save primary energy and therefore also helps to 'keep the globe cold'. This article points out the growing need for cooling in general, describes opportunities to convert solar irradiation into cooling, describes the most common thermal technologies in more detail, together with their current market situation, and presents worldwide installation statistics. The article concludes with a discussion of the current market situation and obstacles to widespread market penetration, followed by an outlook for the coming years.

Introduction

About 40 % of the primary energy consumption in Europe is used for services in buildings (private and commercial), for such purposes as heating, hot water, air conditioning, lighting and other mainly electrical equipment.
Although building design concepts aiming at a reduction of the energy demand are well established and supported by building regulations, the demand for small capacity air-conditioning appliances is still increasing in Europe. While the primary energy consumption of air-conditioning systems in Europe was about 11 TWh in 1996, this value is expected to increase to about 44 TWh by 2020. This figure refers only to small systems up to 12 kW of cooling capacity, and does not include the systems generally installed in large commercial buildings [1]. The main reasons for this growth are rising living standards, architectural characteristics and trends, as well as an increased demand for food refrigeration. Attempting to meet this demand with conventional air-conditioning technology, i.e. electrically driven compression chillers, results in high electricity peak loads during summer months, with the danger of grid blackouts. In addition, some of the common refrigerants that are used in electrically driven chillers have a significant greenhouse impact.
To overcome this, the use of solar thermal energy in combination with thermally driven cooling systems is a promising alternative. Figure 1 shows the coincidence between seasonal cooling loads and the available solar radiation as the main advantage of solar driven cooling. Using solar energy for space heating in winter and domestic hot water production, in addition to providing cooling in summer, reduces seasonal solar energy gains and building load mismatching if used for heat applications only. Thus, high solar energy utilization and, in turn, primary energy savings are possible by increasing the overall usefulness of solar thermal energy.

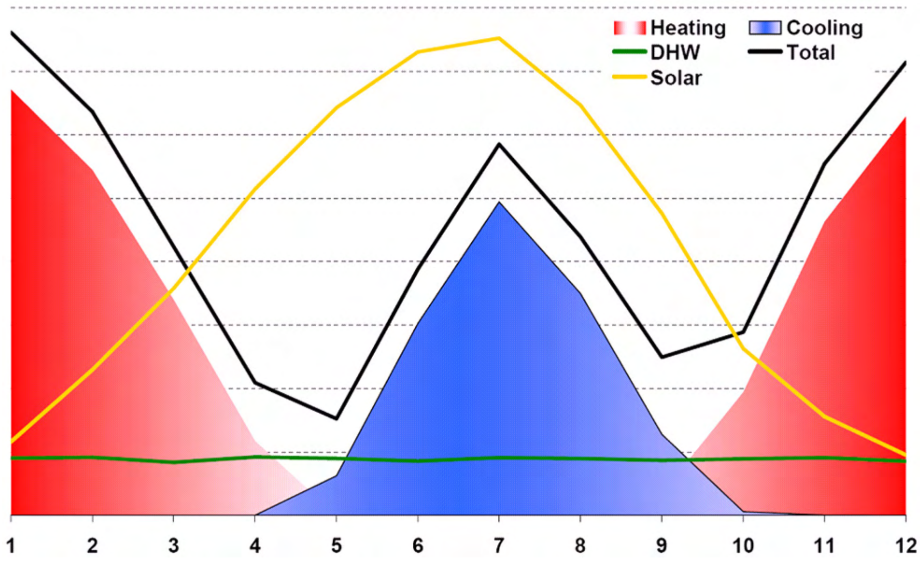

Figure 1: Qualitative example of cooling, heating, domestic hot water (DHW) and total loads, in relation to available solar radiation over the year.

Technologies

Solar irradiation must first be converted into secondary energy in order to be useful for cooling purposes: either to electricity by photovoltaic modules or to heat by solar thermal collectors. Depending on this, different technologies are relevant to create 'cold'. Figure 2 provides a general overview of physical methods to use solar energy for cooling or air conditioning. Commercially available technologies are listed in black, technologies currently under development in blue, and those still far away from practical application are listed in red. Most applied technologies are based on the use of the physical phenomena of sorption, while both liquid and solid sorbents are available (cf. heat transformation sub-division). These systems are further classified into open and closed cycle systems, respectively providing conditioned air or cold water to the building. Both are briefly described as follows.

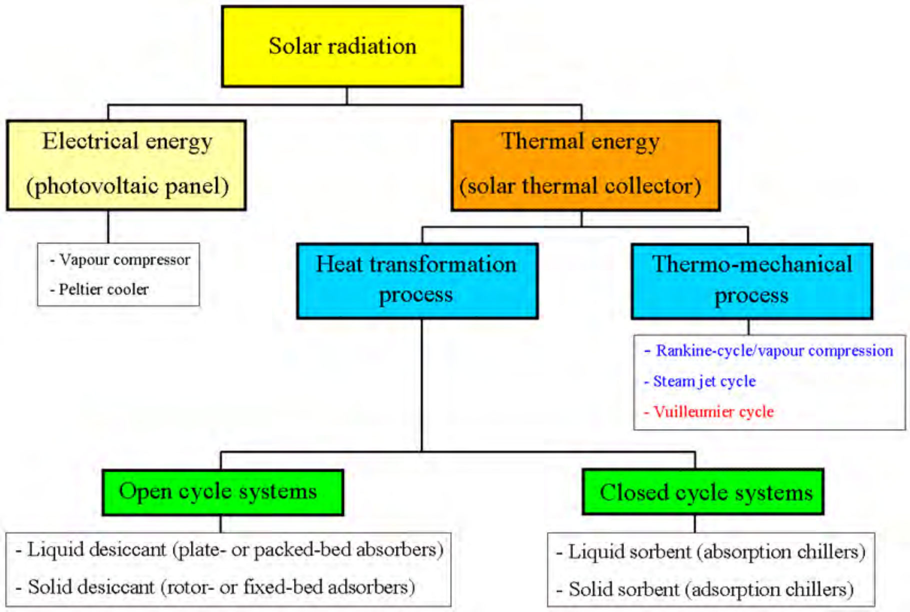

Figure 2: Physical methods of using solar radiation for cooling or air conditioning.

1) Open-cycle systems

Figure 3 illustrates an example of an open-cycle system based on a rotating desiccant sorption wheel which provides cooled and dehumidified air for room air conditioning. Here, water is used to cool the air stream by evaporative cooling, in direct contact with the ventilation air. Systems of this type are called 'open' as water vapour, providing the cooling effect, is expelled to the ambient with the exhaust air. They can be used in buildings in which the cooling loads can be totally or in part met by controlled ventilation. As already mentioned, solid and liquid sorbent systems exist. In both cases the processes of dehumidification and evaporative cooling are separated in different system components. Coupling these processes leads to the name Desiccant Evaporative Cooling (DEC). In typical configurations for moderate climates, ambient air is dehumidified in a first step (cf. dehumidifier wheel). It is then pre-cooled by heat transfer to the exhaust air stream ('cold' recovery) before it is finally further cooled by controlled direct evaporative cooling. The 'heating' heat exchanger in this arrangement is not active in the air cooling case, but is used only in winter mode to provide the required heat to the building. Solar thermal heat is used as the driving energy to dehumidify the sorbent in the wheel, and is introduced directly in front of it via a second heat exchanger (cf. regeneration heat). The basic system concept is similar in liquid systems using salt solutions for dehumidification.

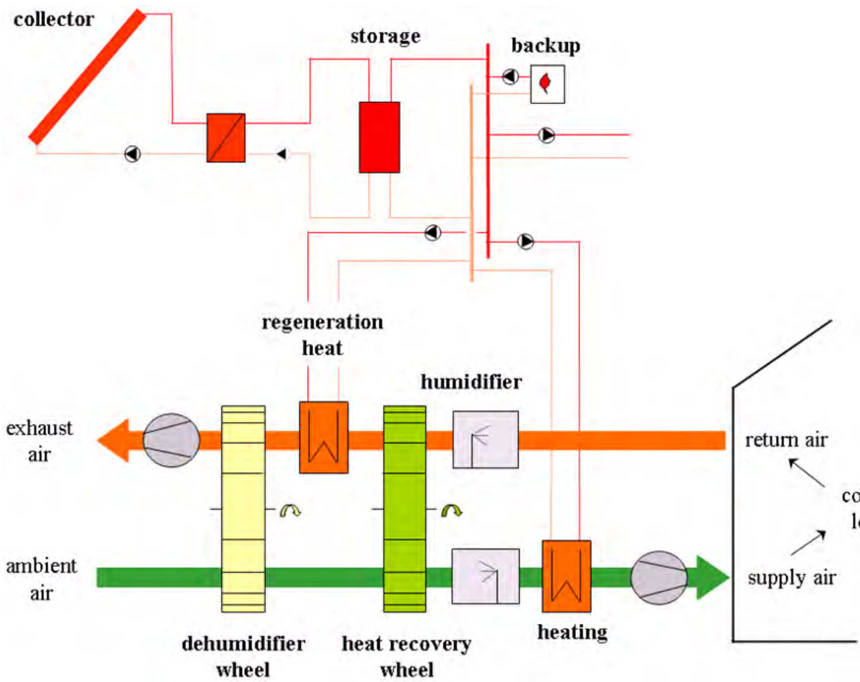

Figure 3: Example scheme of an open cycle system based on rotor technology.

2) Closed-cycle systems

Closed-cycle systems used for comfort cooling produce chilled water (cf. Figure 4), which can then be used either in air handling units for cooling and dehumidification of ventilation air, or can be distributed by a chilled water network within the building, removing heat through fan coils, chilled ceilings or other means. The main component of these systems is the thermally driven chiller, which again can either contain liquid or solid sorbents. The term 'closed' refers to the fact that the refrigerant (e.g. water) undergoes a cycling process of evaporation, ab- or adsorption respectively and condensation in a closed thermodynamic cycle. For cold production below the freezing point typically ammonia is used as the refrigerant and water is used as liquid sorbent. In chillers using water as refrigerant, mainly lithium bromide is used as the liquid sorbent. One market available system uses lithium-chloride; in this system the salt is completely dried to the solid phase and used as thermochemical storage. For solid sorbents zeolite and silica gel are used, while new zeolite-like sorbents are currently under development with very promising results. A good overview of small-scale and market-available thermally driven sorption chillers up to 35 kW has been published by Jakob [2].

Regardless of the type of refrigerant, and of whether the chiller uses liquid or solid sorbents (ab- or adsorption), these machines have a so called 'thermal compressor', rather than an electrically driven compressor, as in conventional mechanical chillers. For cold production the sorbent withdraws the refrigerant molecules from the evaporator. A more detailed explanation of the cooling process is available at www.annex34.org ('The magic of thermal cooling').

While absorption machines require an additional circulation pump (solution pump), adsorption systems do not need internal pumps at all unless a pump for the refrigerator is employed. Figure 4 shows a typical example for the liquid circuit of a closed solar cooling system. In the same way as for DEC systems, solar energy is applied to regenerate the sorbent inside the generator (adsorber). Figure 5 presents an overview of the currently applied technologies in solar assisted cooling and differs between small and large scale systems.

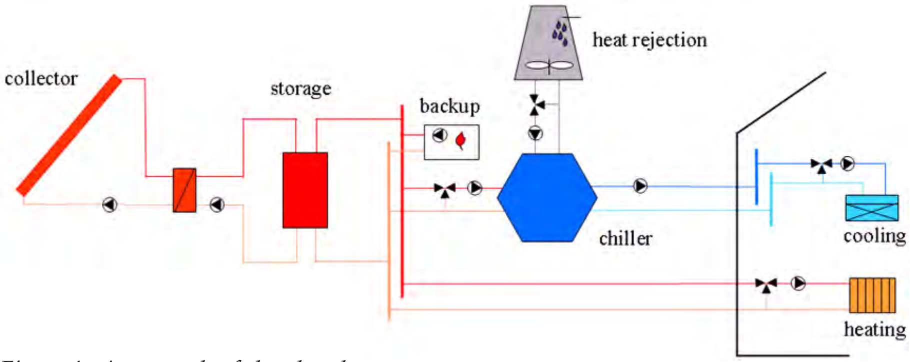

Figure 4: An example of closed cycle systems.

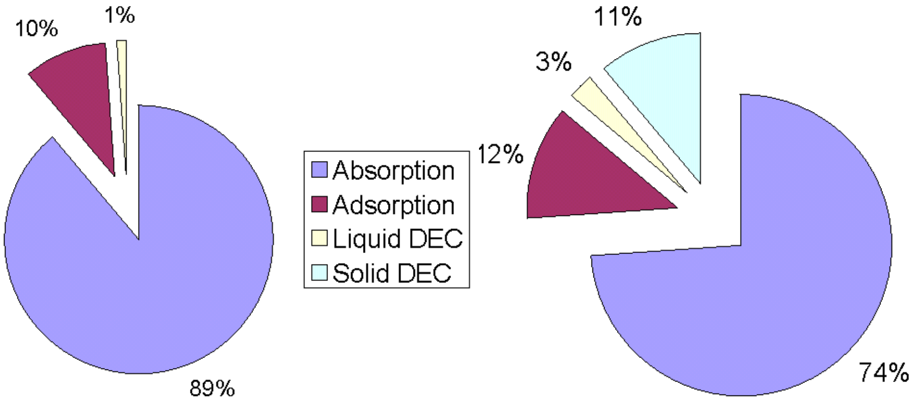

Figure 5: Proportions of technologies by application size (small scale – left hand, large scale – right hand) [3].

Primary energy consideration

To give an idea of possible energy savings, and of the effect of various influencing factors, Figure 6 shows the relationship between specific primary energy demand of solar thermally driven closed cycle cooling systems and conventional systems. The system boundary for the solar system includes a solar collector as the heat source (separated through a heat exchanger), a fossil-fuelled gas boiler as back-up, the thermally driven chiller, a cooling tower and four hydraulic pumps, while the (conventional) reference system includes only the compression chiller (cf. the insert in Figure 6). The primary energy demand for the reference system is shown as constant value (horizontal field) in Figure 6; its value depends only on the conventional COP_{co} of machines of this type. In contrast, the primary energy demand for the solar-assisted system decreases with increasing solar fraction and depends on the thermal

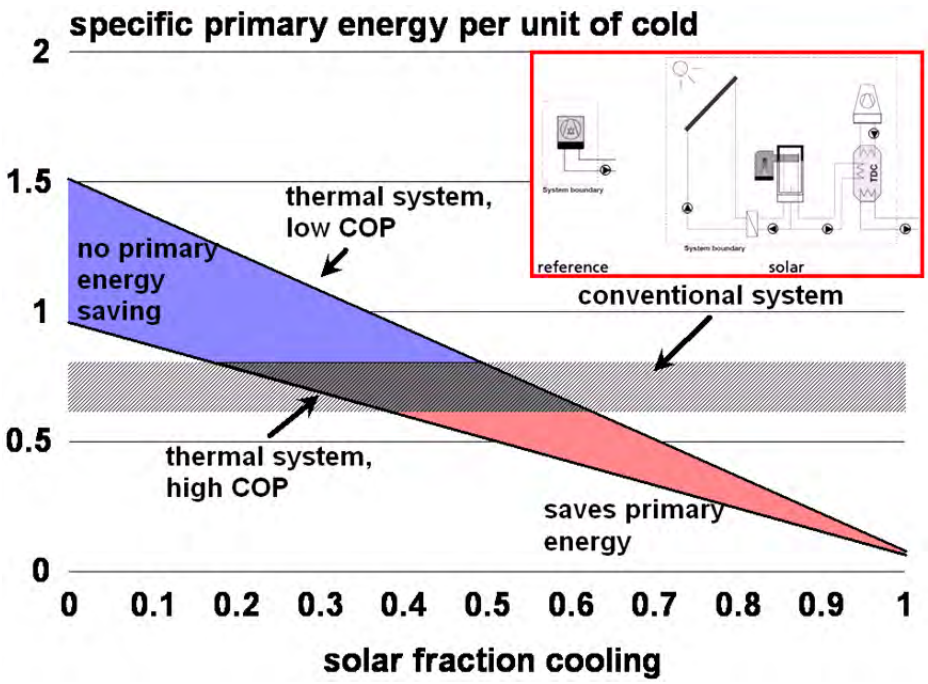

Figure 6: General dependency of specific primary energy demand of solar thermally driven cooling systems in comparison with a conventional reference system [3]. (Source: Aiguasol).

COP_{th} of the thermal cooling machine. Above a certain value of the solar fraction the primary energy demand of the solar assisted cooling system falls below that of the reference system and hence saves primary energy.

To ensure that the solar-assisted air conditioning system saves primary energy, system design has to be carried out carefully. For detailed information on design and configuration, the website of the EU-funded project SOLAIR [4] is suggested.

Statistics of installed systems

A survey of worldwide installed solar cooling plants, carried out as part of the work of IEA-SHC Task 38 'Solar Air-Conditioning and Refrigeration', reported nearly 280 documented installations in Europe as of September 2010. A further 32 installations are documented on other continents. Worldwide, there are probably about 1000 systems installed. Among the documented systems, there are 168 prefabricated small-scale systems and 135 custom-made large scale installations. 23% of the small systems are installed in residential applications, while 38% are installed for air-conditioning in offices. Of the large-scale systems, 54% are installed in office applications. By far the majority of the installations are used for air conditioning applications, while only a few of them provide industrial refrigeration [3].

Situation of solar thermal cooling

Looking back at the last five years, a remarkable progress has been made in the development of the technologies. New systems have been installed successfully and much data and experience has been collected by system monitoring – much of this as a result of the work of IEA-SHC Task 38. New manufacturers of solar thermally driven chillers have entered the market, as have companies offering complete systems for solar thermal cooling. However, it must be realised that solar thermal cooling is still a niche technology. Despite the success and increasing reliability (of most) of the installed systems, and customer satisfaction, it is not yet possible to forecast a date for widespread application and use of the technology. One of the main obstacles for market penetration so far, especially concerning small and medium size systems, is the high initial cost of solar thermally driven cooling systems compared to conventional electrically driven cooling systems.

As far as technical aspects are concerned, the main components of solar thermal cooling systems are already well engineered, both for solar heating and for cooling and air conditioning. The main technical weaknesses are still at the system level, particularly in connection with energy management of systems as a whole, and including the efficiency of the heat rejection unit. In addition, installation, commissioning and operation require well trained technical competence and understanding of the technology.

Conclusions and outlook

Over the last few years, much work has been carried out within the framework of IEA-SHC Task 38 (hand-in-hand with industry) to investigate solar thermal cooling. As a result the technology has reached the stage of early market deployment, and can be an economically feasible solution under particular boundary conditions. What is now required are appropriate incentives and/or support schemes, training and education programmes for installers, companies and planners as well as demonstration programmes with accompanying monitoring activities. Currently, a new Task in the IEA Solar Heating and Cooling Programme, entitled 'Quality assurance measures for solar thermally driven heating and cooling systems', is under preparation.

References

[1] Henning, H.-M., 2007. "Solar-Assisted Air-Conditioning in Buildings - A Handbook for Planners". Second Revised Edition. Springer-Verlag/Wien.

[2] Jakob, U., 2010. "Performance Analysis of Small-Scale Sorption Chillers". Proceedings of the Conference on Innovative Materials for Processes in Energy Systems IMPRES (Singapore).

[3] Sparber, W., Napolitano, A., 2010. "Survey on existing SHC-plants - updated ppt-slide on Solar Cooling Installations". Work within IEA-SHC Task 38 'Solar Air-Conditioning and Refrigeration'. Source available at http://iea-shc-task38.org/documents/monitoring2.

[4] SOLAIR, 2009. "Requirements on the design and configuration of small and medium sized solar air-conditioning applications – Guidelines". Source available at http://www.solair-project.eu/122.0.html (cf. SOLAIR_Guidelines_EN.pdf).

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Operational experience from, and arguments for investment in, absorption heat pumps for district cooling production in Sweden

Åsa Jardeby, SP Technical Research Institute of Sweden

Absorption heat pumps can generate cooling water from heat and are therefore an interesting alternative for district heating companies who have access to waste heat, especially during the summer. However, the technology has not had any major breakthrough on the Swedish market yet despite the possible potentials. This article summarises some of the findings from a study made by SP Technical Research Institute of Sweden [1], which investigated experience from operation and important investment factors among district heating companies in Sweden. The study included companies both with and without absorption heat pumps.

Introduction

A questionnaire survey was carried out in 2008/2009 by SP Technical Research Institute of Sweden in order to give a picture of operational experience of absorption heat pumps in district heating systems in respect of operation and maintenance. Factors important for investment decisions were also investigated. A key reason for the survey was that interest in district cooling systems is steadily increasing in Sweden, while rising electricity prices have made regular chillers more expensive to run.

Common arguments for not using absorption heat pumps are that these machines are expensive, have operational problems and/or poor efficiency. For the survey, questionnaires where sent out to all district heating companies in Sweden (134 companies), followed by questionnaires with targeted questions based on the answers to the first questionnaires. The project included a reference group with substantial experience of absorption chillers, and which provided valuable input in design and analysis of the questionnaires.

High electricity prices assist absorption heat pumps

Sweden's first district cooling plant was commissioned in 1992. Today, some 30 companies in Sweden provide district cooling, corresponding to just over 700 GWh/year: see Figure 1. The potential for district cooling is estimated to be considerably greater. According to the Swedish District Heating Association, studies show that the total annual demand for district cooling is equivalent to 2000-5000 GWh [2].

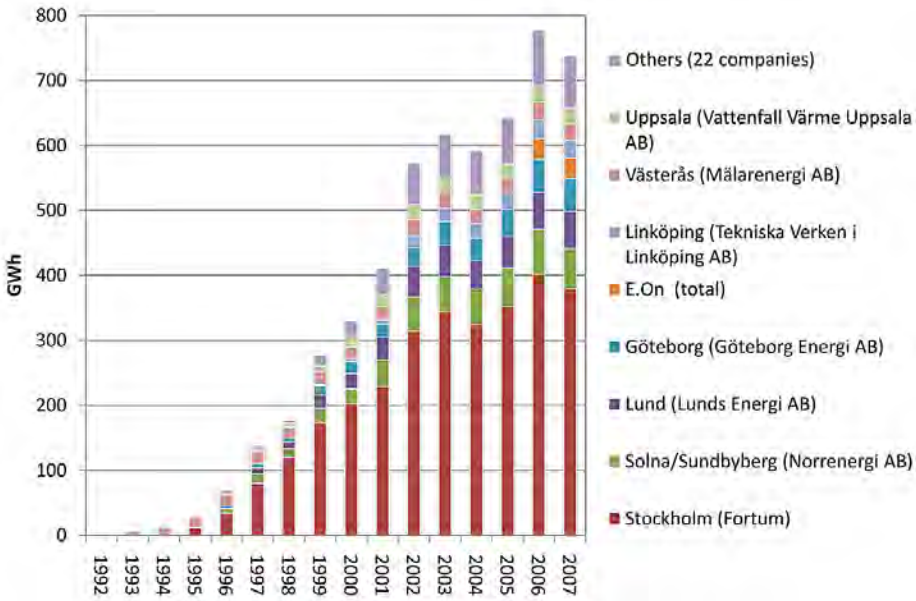


Figure 1 Development of district cooling in Sweden 1992-2007, by supplying companies [7].

Since absorption heat pumps are not primarily powered by electricity, they have been most successful where electricity prices are high, as in Japan, China and Korea [3]. The potential in Europe is increasing as electricity prices rise, but it is important that the relationship between electricity and heat prices are favourable. If heat prices increase (e.g. as could be caused by a shortage of combustible waste for use as fuel), they would probably affect profitability. There are several reasons why the demand for absorption heat pumps is increasing in Sweden. Rising electricity prices and increased demand for district cooling contribute, but the 2002 ban on landfill disposal of combustible waste, followed in 2005 by an extension of the ban to include organic waste [4], [5] has played a major part. Landfill bans result in a need for waste incineration even in the summer period. This means that excess heat is available when the heat from incineration of the waste exceeds that needed for district heating. In addition, if CHP plants have insufficient heat demand, they cannot generate full electricity output. For this reason, many district heating companies are investigating the possibility of using absorption heat pumps to increase the heat demand, so that they can maintain or increase electricity production.

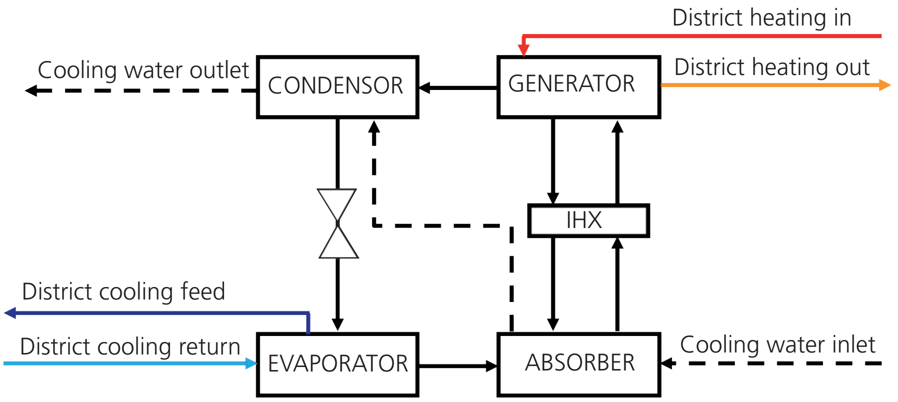
Two-stage questionnaires

The purpose of the survey was to investigate operational experience and to collect the companies' views on purchase of absorption heat pumps. A first-stage questionnaire was therefore designed. It was sent to all member companies of the Swedish District Heating Association and only regarded if the companies offered district cooling and, if so, what technologies they used, or if they planned to do so in the future. Depending on the answer to the first questionnaire, respondents were divided into four groups, as shown in Table 1. Group 0 was not followed up, but the other three groups all received a second questionnaire that was tailored depending on to which group each company belonged. The questionnaire to Group 3 was divided into operational and marketing issues. The answering frequency to all questionnaires can be seen in Table 2.

Arguments for investing (or not investing) in absorption machines

Out of the 87 responding district heating companies, 19 (22 %) offered district cooling, using different combinations of absorption heat pumps (AHP), free cooling (FC), heat pumps (HP) and vapour-compression chillers (VCC) to produce district cooling. According to the survey, nearly 40 % of the responding companies that deliver district cooling use absorption heat pumps. Information on the absorption heat pumps installed by the companies is summarised in Table 3.

Among the companies that are planning to deliver district cooling in the future (Group 1) 56 % stated that absorption heat pumps are included in their plans, while the remainder



Schematic diagram of an absorption heat pump for district cooling, driven by district heating. The principle of the machine is the same as a conventional chiller except that the drive energy is heat. For detailed information about the function of absorption heat pumps, see the final report of IEA HPP Annex 24 [6] .

Table 1 Grouping of the district heating companies after the first questionnaire

Name	Description
Group 0	Does not supply district cooling, and has no plans to do so.
Group 1	Does not supply district cooling today, but plans to do so in the future
Group 2	Supplies district cooling, but does not use absorption heat pumps
Group 3	Supplies district cooling, and uses absorption heat pumps

Table 2 Number of replies to the different questionnaires

	Number of recipients	Number of responders	Per cent
Questionnaire 1	134	87	65 %
Questionnaire 2, Group 1	21	9	43 %
Questionnaire 2, Group 2	10	6	60 %
Questionnaire 2, operational, Group 3	5	5	100 %
Questionnaire 2, market, Group 3	7	4	57 %

Table 3 Installed absorption heat pumps

Manufacturer	Year of manufacture	Total installed power [MW]	Number of years in service	Drive energy	Feed/ return temp [°C]
Wier Entropi	2002	7	6	Feed/**supply** coupling (d.h.)	91/-
York	2000	4.87	8	Feed/**supply** coupling (d.h.)	95/83
Carrier	2004	1.3	3	Feed/**supply** coupling (d.h.)	85/75
Carrier	1998	1.2	10	Feed/**return** coupling (d.h.)	90/80
Thermax	2005	11 (5.5*2)	3	Steam	-/-

answered "Don't know". The condition that all respondents identified as a positive factor is the availability of excess heat, and half of respondents mentioned environmental arguments. Although absorption heat pumps typically have low operational costs, especially with rising electricity prices, only one company in this group gave operational cost as an argument.

In the group having absorption heat pumps installed (Group 3), half of the respondents used external consultants for procurement, while the other half managed procurement in-house. Among the companies with absorption heat pumps, three out of four stated operational cost and availability of waste heat as arguments for investment. One company indicated investment cost as a positive argument, and another one stated environmental arguments. One company stated that absorption heat pumps provided a useful addition to the heat sink, thus enabling more electricity to be produced.

Among the companies that use other equipment for producing district cooling, investment costs are mentioned as a reason for not choosing absorption heat pumps. If excess heat is available, such as from waste incineration, absorption heat pumps tend to be a profitable way to produce district cooling, despite the higher investment costs, especially if their use allows higher electricity generation, which also generates an income. The investment arguments are summarised in the box.

Three out of four companies with absorption heat pumps stated that the procurement process was difficult. Comments included: "The hard part is evaluating the various machines fairly in an objective, pre-determined manner", "Our purchasing staff are not familiar with the necessary competence areas" and "Some problems with responsibilities for the machinery and for the control system, as the machine would be installed in a plant with another manufacturer's existing control system ". In addition, the absorption heat pump supplier in the reference group felt that there were major shortcomings in the procurements. These deficiencies arose from poor specifications of the required performance of the absorption heat pump which, according to the survey, may be because the costumer does not have the detailed knowledge required. Although the client specified various operating points at part load, these operating points were not tested during commissioning, according to the reference group. The survey also showed that half of the companies felt that the machines did not meet the conditions that were specified.

Overall satisfaction with operational experience

The companies participating in the survey were asked to indicate what they believe has been the major operational problem with their absorption heat pumps. Here are quotes from four of the companies:

- "The minimum capacity is too low."
- "Control system and control parameters"
- "Fouling of the tubes on the cooling water side"
- "The control system, since the supplier could offer no system suited to our specific operating conditions. Training of staff that had to been done in-house "

On a scale of 1-5, where 5 is very satisfied and 1 is very dissatisfied, with the general operation, 60 % responded with a 4 and 40 % with a 3.

Some district heating companies have absorption heat pumps located at the customer's facilities, and use the district heat delivered to the facility as the drive energy. The heat pump is owned and often also maintained by the district heating company. This can be an alternative when a customer is located outside the district cooling network, and is referred to as distributed cooling production. Of the total ten district cooling providers who responded to the second questionnaire, only one company operated predominantly distributed cooling production. However, half of the companies have one or more distributed absorption heat pumps, although central production dominates. The choice of centrally or distributed located equipment often depends on the presence of existing installed heat pumps and access to the district cooling network, although there were also comments that it is difficult to be profitable in small distributed systems, and that it is harder to optimise their operation. According to the survey, several of the companies who have only centrally located absorption heat pumps are in favour of distributed systems in the future, often depending on where potential customers are located and the size of their cooling demand.

The responsibility for maintenance and service of the machines varies between companies. Two companies use their own technicians; one uses the supplier's technicians, and the remaining two use a combination of both.

Two of the five companies do not think that they have received sufficient information from the supplier on service and maintenance of the machine. Two out of five do not feel that they have received adequate information on service and maintenance requirements either for the machines or for ancillary equipment

Investment arguments (from the survey)

Pros:
1. Availability of excess heat
2. Operational costs
3. Environmental arguments
4. Increased heating demand which allows greater electricity production

Cons:
1. Investment costs
2. Availability of other resources (e.g. free cooling from lakes)
3. No availability of excess heat
4. Poor information available

such as cooling towers, etc., whether from the supplier of the heat pump or from the supplier of the cooling towers. One of the companies reported that it had received information on the latter, while the two remaining companies stated that the knowledge already existed within the company. When asked about the biggest operating problem of absorption heat pumps, one company also answered "training of personnel, which had to be done in-house".

Table 4 shows some of the known operational problems that the companies have experienced. All companies use some form of corrosion inhibitor. As can be seen from the table, two of the five companies have not experienced any of the known operational problems that can generally be found in absorption heat pumps.

The survey indicates that control issues are a problem for a number of district cooling providers. The problems arise from the connection to the district heating system network (feed/feed or feed/return coupling in the DH network) (see Figure 2), and the need for a greater temperature difference across the absorption heat pumps. Some companies optimise operation manually.

A study conducted in 2000 [6] showed that lack of knowledge and maintenance was the major cause of damage to the machines, and that there was a lack of educational and maintenance companies in the industry. We can see from this survey that these problems still exist, almost ten years later. Several of the companies feel that they have received insufficient information about service and maintenance, which can, if addressed properly, prevent the development of operational problems. One can conclude that not much has happened in this area. With, as the survey demonstrates, the increasing demand for absorption heat pumps, the need for service personnel also increases. The problems known to occur in absorption heat pumps appear to be manageable today, and with the right knowledge can safely be kept under control in future operation.

Table 4 Operational problems

	Corrosion in the water circuit	Corrosion in the LiBr circuit	Crystallisation	Leakage
Company A	X	X		
Company B			X	X
Company C				X
Company D				
Company E				

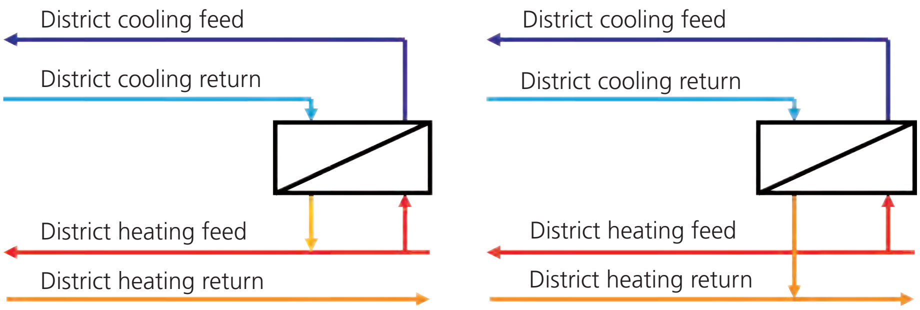


Figure 2 Schematic diagram of the absorption heat pump connected to the district heating network, feed/supply and feed/return respectively.

Expansion plans for district cooling in Sweden

Over 31 % of the district heating companies that currently do not supply district cooling are planning to do so in the future. According to the survey, the main reason for doing so is to be able to offer customers an environmentally friendly alternative to their own vapour-compression chillers (78 % gave this option). Other reasons included availability of resources and keeping abreast of market developments, both of which were stated by 56 % of respondents. 44 % quoted customer demand. Among the companies currently supplying district cooling produced by equipment other than absorption heat pumps (Group 2), five of the six companies plan to invest in new equipment in order to expand their district cooling production. This means that district cooling is expected to grow, with correspondingly increased demand for information and expertise in various equipment conditions.

References

[1] Jardeby, Å. and R. Nordman, (2009). "Inventering av installerade absorptionskylmaskiner - drifterfarenheter och argument för inköp", Svensk Fjärrvärme Rapport 2009:49. [In Swedish]

[2] Swedish District Heating Association (2009). Information retrieved 23 January, 2009, from www.svenskfjarrvarme.se.

[3] Zinko, H., S.-O. Söderberg, et al. (2004). Integration av absorptionskylmaskiner
i fjärrvärmesystem. FoU-rapport. Svensk Fjärrvärme. [In Swedish]

[4] Naturvårdsverket (2001). Förordning om deponering av avfall NFS 2001:512. [In Swedish]

[5] Naturvårdsverket (2004). Naturvårdsverkets föreskrifter och allmänna råd om hantering av brännbart avfall och organiskt avfall. NFS 2004:4. [In Swedish]

[6] Tozer, R., M. Gustafsson, et al. (2000). Absorption machines for heating and cooling in future energy systems - Final report Annex 24, IEA Heat Pump Centre. HPP-AN24-4

[7] Swedish District Heating Association (2008) E-mail from Anna Land, Swedish District Heating Association.

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Chillventa Congressing 2010: Industrial Heat pumps

Rainer Jakobs, Germany

Chillventa 2010 was a complete success. 29,312 trade visitors from all over the world met at the exhibition highlight from 13–15 October 2010, when the Nürnberg exhibition centre was the hub of the international refrigeration, air conditioning, ventilation and heat pump community. The top-calibre Chillventa Congressing programme, with a good 400 international participants, started the day before the exhibition. The Chillventa forums, parallel to the exhibition, provided extensive and expert information covering all segments of refrigeration, air conditioning, ventilation and heat pumps. This report gives an overview of selected heat pump presentations during Chillventa 2010.

Introduction

Chillventa 2010 was a great success for exhibitors from all over the world. This is definitely shown by the number of exhibitors: Chillventa set a new record with a 10 % increase, to 881 companies. The internationality of 63 % is also excellent. Companies from 42 countries exhibited at the event.

Chillventa Congressing started on the day before the exhibition with the Industrial Heat Pump (IHP) workshop, with ten presentations. This was a joint activity of the "Supporting Programme Chillventa Congressing" in cooperation with the Heat Pump Programme of the International Energy Agency and the Information Centre on Heat Pumps and Refrigeration – IZW e.V., chaired by Prof. Dr.-Ing. Hans-Jürgen Laue. Annex 35, "Application of Industrial Heat Pumps", of the International Energy Agency's "Heat Pump programme" and "Industrial Energy Systems and Technologies" Implementing Agreements, is a cooperation of at present twelve participating organisations from eight countries. "Industrial Heat Pumps" are defined as being heat pumps in the medium and high power ranges, which can be used not only for heat recovery in industrial processes but also for heating, cooling and air-conditioning in commercial and industrial buildings, as well as for district heating.

In the first presentation, Dr. Roger Nordman from SP & HPP, Sweden, gave an **introduction to the IEA Heat Pumping Programme**, describing HPP as an international framework of cooperation/networking for different HP actors (industry, governments, research representatives etc). HPP is a forum for the exchange of knowledge and experience between countries. HPP contributes to technology improvements by RD&D.

Current energy use and application of heat pumps in Swedish industry was a paper from Dr. Roger Nordman, SP Technical Research Institute of Sweden, and Dr. Per-Åke Franck, CIT Industrial Energy Analysis, Sweden, which gives an update on the number of installed heat pumps in industry today. The paper also gives an overview about the current state of energy use in the Swedish industry. Sectors of particular interest are identified by their share of the energy consumption, and also by the temperature levels at which the majority of the energy is used. This mapping contributes to identifying the potential for heat pumps in industry. Pulp & paper mills are major energy users in Sweden.

Industrial heat pump applications in the Canadian energetic context was presented by Dr. Vasile Minea, Hydro-Québec Research Institute, Laboratoire des technologies de l'énergie (LTE), Canada. Waste heat recovery heat pumps provide industry with benefits such as process heating and cooling energy savings and improved environmental performance. Despite such benefits, the number of industrial heat pumps in use is still low compared to the enormous technical and economical potentials. This paper presented an overview of Canadian energy production and demand trends, as well as national environmental initiatives and greenhouse gas reduction targets. Estimates of global energy requirements and losses by industrial sectors and processes were given. In this context, technical, economical and legal barriers to wide application of heat recovery industrial heat pumps in Canada were identified. A number of successful applications and future developments of industrial heat pumps were also briefly discussed. The paper illustrates current Canadian experience, supported by technical information and lessons learned.

Maximizing Capacity at Minimum Cost for Plate Heat Exchangers in Industrial or Commercial Applications was a paper from Prof. Dr.

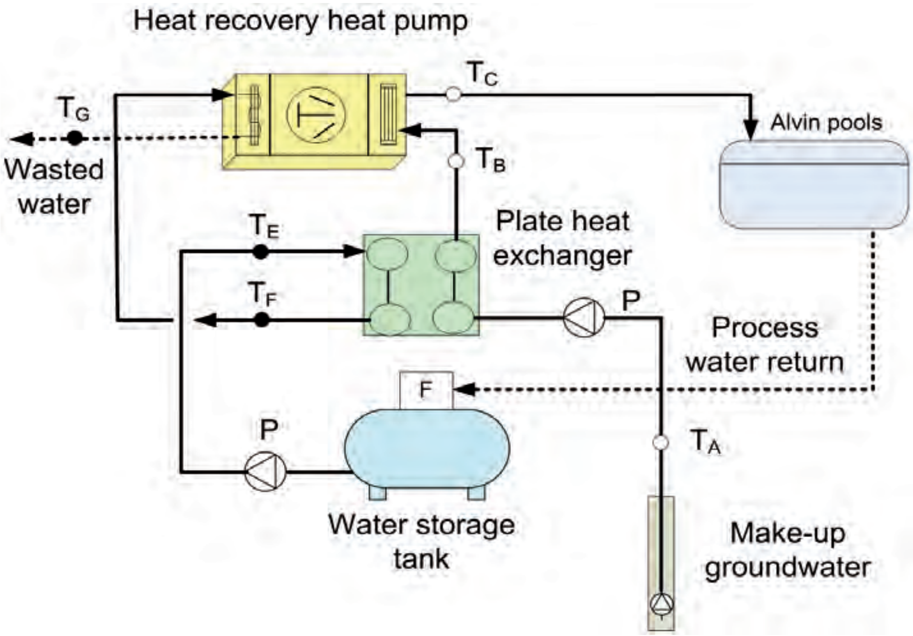


Figure 1 Heat recovery in fish farming, Source: Minea, V., IERE Conference, Canada, 1999

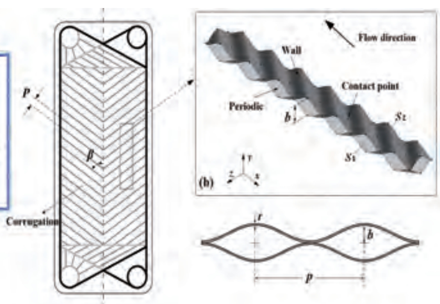
Problem Definition

maximize $f_1(x) = HTC$

minimize $f_2(x) = DP/L$

Subject to $1\,kPa/m < DP/L < 100\,kPa/m$

$HTC > 5000\,W/m^2K$



Design Variables

Design Variable	Lower Limit	Upper Limit
Corrugation depth, b [mm]	3.18 mm	6.35 mm
Corrugation angle, β [degree]	22°	68°
Corrugation pitch , p [mm]	9.5 mm	38 mm
Velocity, u [m/s]	0.1 m/s	1.2 m/s

Figure 2 Plate HX optimisation

Reinhard Radermacher and Khaled Saleh, Center for Environmental Energy Engineering, University of Maryland.

Plate heat exchangers are used in many different industrial and commercial applications, such as air conditioning, refrigeration, heat pumping, heat recovery, transportation, and manufacturing industries. Finding an optimum and cost-effective design of plate heat exchanger for a particular application can be a challenge. This is especially the case when a considerable number of design variables are considered, and when several design objectives are to be met.

This presentation gave an overview of using approximation-assisted optimisation techniques in finding optimum plate heat exchanger designs, while reducing computational time by over 95 %. The results are validated using CFD simulations.

System build-up and selection of the two-stage Air-to-Water heat pump for multi-family houses was presented by François Bruggemans, DAIKIN Europe Brussels Office.

The sales of air-to-water heat pumps for heating single-family houses have shown an upward trend over the last few years, and these units are gaining acceptance as an ecological and economical alternative to traditional combustion-based heating. For multi-family houses, the use of individual small capacity air-to-water heat pumps often fails to be considered due to practical limitations on the installation of the required outdoor parts, whereas collective high-capacity heat pumps require a complex hydraulic distribution system in order to be able to offer each apartment sufficient flexibility for controlling the heat supply. In addition, traditional single-cycle heat pumps are limited in their operational temperature range for efficient operation. Although this may not necessarily limit heating comfort, it often leads to reverting to electric immersion heaters to supply domestic hot water.

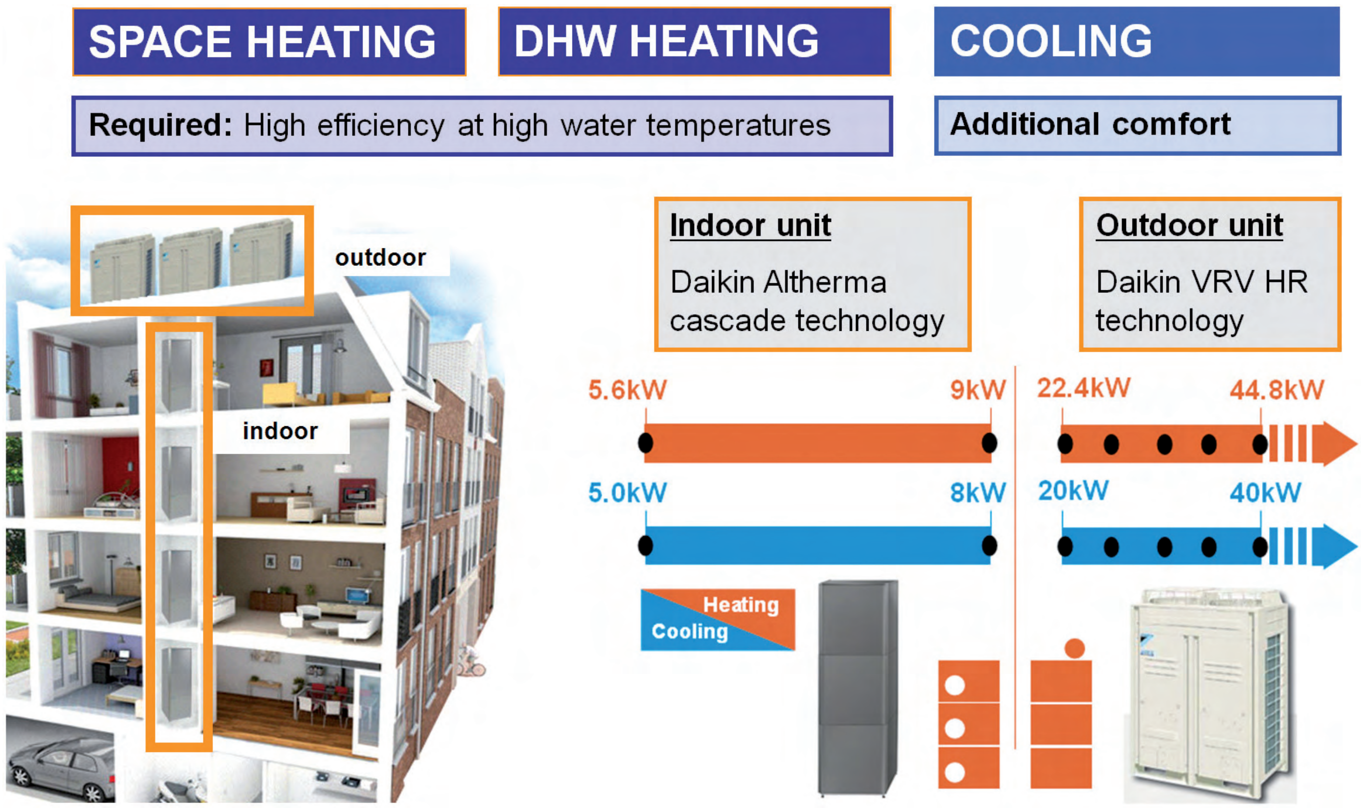


Figure 3 Modular 3-in-1 heat pump system

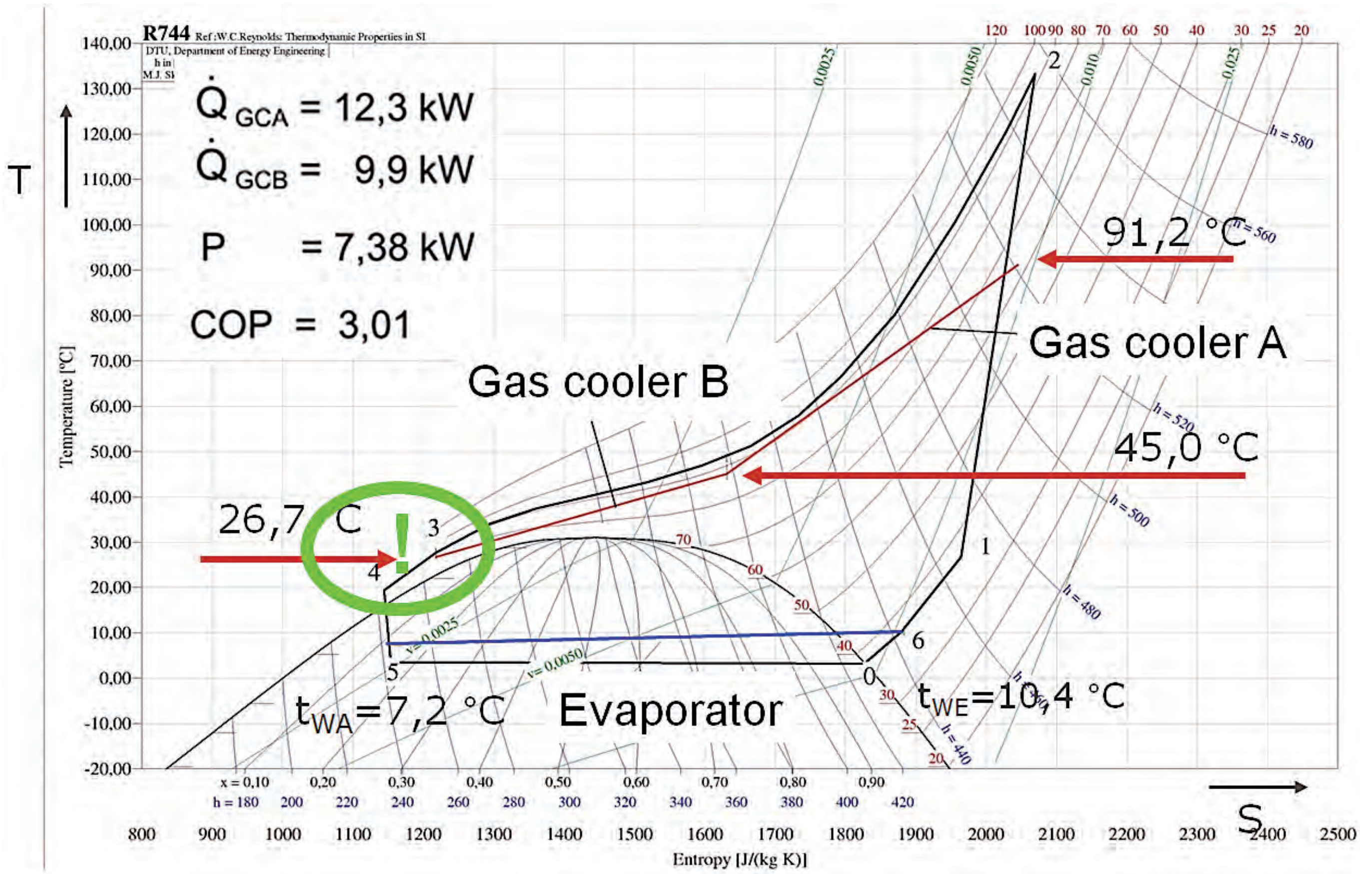


Figure 4 Transcritical heat pump cycle

Figure 5 Self-contained ammonia heat pump for food processing

By combining a collective R410A VRF-based high-capacity outdoor unit with individual R134a cascaded indoor units, DAIKIN has developed an air-to-water heat pump system suitable for multi-family houses.

The proposed system has several benefits: low installation footprint of both outdoor and indoor parts; each individual indoor unit can operate independently from the other indoor units; high temperature range allows wide selection of heat delivery systems and avoids the need for immersion heaters for DHW preparation; possibility of cooling, with the benefit of heat recovery for DHW preparation and inverter control of both indoor and outdoor units. The paper described the commercial range and system build-up of the two-stage R410A / R134a air-to-water heat pump system for multi family houses and an application example for a typical multi-family building.

Transcritical Heat Pumps for Raising Low Temperature Heat to High Temperature Levels was presented by Prof. Eberhard Wobst, thermea. Energiesysteme GmbH, Germany.

Performance requirements of heat pumps for industrial applications clearly differ from those for heating systems in flats or single-family dwellings. Higher capacities, higher temperature levels, longer operating times and different energy prices are examples of the differences. Using transcritical heat pumps it is possible to achieve higher supply temperatures with the same COP as that of conventional heat pumps. Low return temperatures are a prerequisite for the good COP values, as the heat transfer takes place at a gliding refrigerant temperature in the supercritical area without condensation.

A suitable refrigerant for such processes is CO_2, with its critical point at 31.1 °C and 73.9 bar. It is ecologically friendly, non-toxic, non-flammable and has high volumetric efficiency. The paper explained the specific features of the process. thermea has developed a portfolio of heat pumps with CO_2 as the refrigerant, using reciprocating compressors, in the capacity range of 45 kW to 360 kW. A heat pump with a nominal capacity of 1000 kW has the world's first CO_2 screw compressor.

The heat pumps are designed for recovery of industrial waste heat at cooling tower temperature level, and can reach up to 90 °C supply temperature. The screw compressor uses a high-viscosity lubricant, with the heat from the oil cooler making a contribution to the total heat output.

A test rig for experimental investigation has been assembled, and the first test results of the screw compressor heat pump were presented. In parallel with the development, thermea started analysing first applications, with an example of hot water production in a slaughterhouse with a heating demand of 800 kW.

Heat pump integration in a dairy: how to recover waste heat to provide process heating was presented by Ing. Eugenio Sapora, EDF R&D, Eco-efficiency & Industrial Process Department, France.

Increasing concerns about greenhouse gases and fossil fuel prices increase lead to consideration of waste heat recovery in industry. Thus, in recent years, EDF has been assisting the development of efficient heat recovery systems, which include industrial-scale heat pumps.

When energy streams in an industrial process are steady, the pinch method provides correct integration of heat pumps in the process. Oil refineries and chemical plants often meet this condition. However, in the agro-food industry, most energy streams are discontinuous, and so a new method of integration which takes into account the dynamic behaviour of the process must be defined.
This paper presented a case study of heat pump integration in a dairy. Energy, environmental and economic analyses have been carried out. The importance of heat storage in simplifying the design, reducing investment costs and improving the energy efficiency, was evaluated.

Breakthroughs in Industrial Ammonia Heat Pumps presented by Sam Gladis, Emerson Climate Technologies, UK.

Advances in screw compressor technology have contributed to the development of heat pumps for industrial applications. These advances have provided higher capacities and a greater range of temperatures than prior generations of heat pump compressors. The paper presented a series of case studies on actual applications utilizing this advanced screw compressor technology. A stand-alone type ammonia heat pump system extracts heat from water in a district heating application; a self-contained ammonia heat pump system provides beneficial cooling and heating in a food processing application; and a scavenging ammonia heat pump system extracts heat from the discharge side of an existing ammonia refrigeration system and delivers high-temperature potable water for sanitary use in a food processing plant.

In each of these cases, the attractive thermal properties of ammonia result in substantially enhanced COPs (3 to 7), while delivering the ideal environmental properties of zero Global Warming Potential (GWP).

Dipl.-Ing. Anatolii Mikhailov, Danfoss A/S, Denmark, gave an **Overview of the components for industrial heat pumps**

Industrial refrigeration heat pumps cover a wide range of capacities from several hundred kW to several MW. The number of industrial refrigeration heat pumps is increasing with the increased demand for energy-efficient solutions, as well as the pressure on reduced carbon footprint from energy-producing systems.

The presentation highlighted the points where special attention should be paid to industrial refrigeration heat pumps in comparison with typical refrigeration systems. The main layouts of the heat pumps cover stand-alone heat pumps as well as heat pumps integrated with industrial refrigeration systems. Discussion of refrigerants covered ammonia and CO_2, in terms of their application ranges, advantages and disadvantages and energy efficiency. Some specifics of the control systems include primarily the high-temperature control, as well as high-pressure control for transcritical CO_2 heat pumps.

The paper gave an overview of the state of the art of Danfoss components (valves and controls) that are used in industrial refrigeration heat pumps today. They cover a wide range of pressures, as well as the high temperatures required in the heat pump applications. Danfoss can supply unique products, even for the pressure levels of 65 bar and 140 bar as required by high-temperature ammonia and transcritical CO_2 heat pumps. The above-mentioned concepts were illustrated by several case studies.

The workshop was closed with a forward look to the

10th IEA Heat Pump Conference 2011 - Heat Pumps – The Solution for a Low-Carbon World, May 16-19, 2011, Tokyo, Japan
and the
Heat pump mission is low or no emission.

Source: Chillventa Congressing 2010
http://www.chillventa.de/congressing

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ASHRAE GreenGuide: The Design, Construction and Operation of Sustainable Buildings, third edition.
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User's Manual Key to Meeting Requirements of the Green Standard
Knowing what to do is not the same as knowing how to do it. A new User's Manual educates industry professionals on how to meet the requirements of a green building standard published by three leading industry organizations.

Standard 189.1-2009, Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings, was published earlier this year by ASHRAE in conjunction with the Illuminating Engineering Society of North America (IES) and the U.S. Green Building Council (USGBC). The standard provides a long-needed green building foundation for those who strive to design, build and operate green buildings.
A newly published User's Manual is now available.
http://www.ashrae.org/pressroom/detail/17671

2011

16-19 March
11th Heating, Air-Conditioning, Refrigeration & Fluid Exhibition
Koyong-city, South Korea
http://www.harfko.com/

4-6 April
ASHRAE Energy Modeling: Tools for Designing High Performance Buildings Conference
Atlanta, Georgia, USA
http://www.ashrae.org/events/page/2749

5-7 April
Sources/Sinks alternative to the outside Air for Heat Pump and Air-Conditioning Techniques (Alternative Sources - AS)
Padua, Italy
http://www.aicarr.org/Pages/PadovaIIR2011/home.aspx

6-8 April
International Sorption Heat Pump Conference (ISHPC11)
Padua, Italy
http://www.aicarr.org/Pages/PadovaIIR2011/home.aspx

7-9 April
China Refrigeration 2011
Shanghai, China
http://www.cr-expo.com/en2009/Default.asp

13-15 April
Conference V.E.R.T.E '11 On Energy Valorization of Thermal Effluents and Environment
Paris, France
http://sites.google.com/site/verte2011

14 April
High efficiency heat pump systems - from best practise to mainstream
Organized by SEPEMO-build
http://www.sepemo.eu and
http://www.eusew.eu

14-16 April
IIR Ammonia Refrigeration Conference
Ohrid, R. Macedonia
http://www.mf.ukim.edu.mk/web_ohrid2011/ohrid-2011.html

5-6 May
Second Annual Conference of the European Technology Platform on Renewable Heating and Cooling
Budapest, Hungary
http://www.rhc-platform.org/cms/index.php?id=84

8-13 May
World Renewable Energy Congress (WREC) 2011
Linköping, Sweden
http://www.wrec2011.com/

16-19 May
10th International IEA Heat Pump Conference 2011
Tokyo, Japan
http://www.hpc2011.org
or read more here on this website >>>
http://www.heatpumpcentre.org/en/hppactivities/ieaheatpumpconference/Sidor/default.aspx

21 May
International Conference, The Heat Pump in Europe and the Czech Republic
Prague, Czech Republic
http://www.avtc.cz/?page=82.the-heat-pump-in-europe-and-the-czech-republic

1 June
4th European Heat Pump Forum
London, United Kingdom
http://www.ehpa.org/calendar/list-view/?tx_cal_controller%5Bgetdate%5D=20110309&tx_cal_controller%5Bcategory%5D=2&cHash=0f90784b5b

24-26 May
3rd International Concerence on Heating, Ventilating and Air Conditioning
Tehran, Iran
http://www.hvac-conference.ir/

10-11 June
The latest technologies in air-conditioning and refrigeration, 14th European Conference
Milano, Italy
http://www.centrogalileo.it/milano/

In the next Issue

IEA Heat Pump Roadmap

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International Energy Agency

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

IEA Heat Pump Programme

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

Vision

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

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

Mission

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

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heat pump centre

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