IEA Heat Pump CENTRE
Volume 27
No. 4/2009

The role of heat pumps in future energy systems

IEA
OECD
heat pump centre

IEA **Heat Pump** CENTRE
NEWSLETTER
Volume 27 - No. 4/2009

In this issue

In this issue

The market for heat pumps is steadily increasing throughout the world. At the same time, large efforts are made to decrease the energy use in buildings through numerous regulations and directives. Passive house concepts and zero emissions buildings are also becoming increasingly popular. This could change the market conditions for heat pumps in the future. This issue presents some technologies and views on the role heat pumps could have in the future.
Enjoy your reading!

Roger Nordman
Editor, HPC Newsletter

COLOPHON

Published by IEA Heat Pump Centre
Box 857, SE-501 15 Borås,Sweden
Phone: +46 10 516 55 12
Fax: +46 33 13 19 79

Publisher:
IEA Heat Pump Centre
PO Box 857, S-501 15 BORAS
SWEDEN
Tel: +46-10-516 50 00, Fax: +46-33-13 19 79
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org

Editor in chief: Monica Axell
Technical editing: Roger Nordman,
Ulf Mårtensson - IEA Heat Pump Centre
Language editing: Neil Muir, Angloscan Ltd

IEA
OECD
heat pump
centre

Heat pumps in 2050 – a saga of success

Roger Nordman
Editor of the HPC newsletter

What will heat pumps look like in 2050? Where will they be used? What is their market potential? Questions like these are very important in the current era of energy efficiency and climate change. Some issues that will affect heat pump developments up until 2050 are discussed below.

Utilising renewable energy that other technologies cannot.
Heat pumps have the ability to utilise heat sources that no other heating technologies can, namely low temperature ambient heat and ground heat that is upgraded in the heat pump unit. The proportion of this heat that can be used in the total heat generation depends on heat pump efficiency, which is likely to improve by year 2050.

Electricity production and distribution
Electricity production is currently dominated by fossil fuels, especially coal. Global average CO2 emissions per kWh electricity are 505 gCO2/kWh in 2006 (source: CO2 Emission from fuel combustion 2008 edition, IEA). With increasing electricity production from green technologies such as solar PV, wind and biomass-fuelled CHP plants, CO2 emissions will probably decrease. With accumulators, heat pumps could take an increasing role in energy storage in distribution systems to level out peak production.

Changing operating conditions in buildings
Buildings account for 30–40% of global energy use and 20% of GHG emissions. Building codes are aimed increasingly at reducing energy use, and reductions of 50–75% could be achieved by low-energy or passive houses. These savings mainly apply to new buildings, but the retrofit market is progressively adopting stricter energy use codes. Heat pumps will therefore face new operating conditions, with a much larger share of DHW production, and a total lower heat supply. Product development and new innovations that will meet these new demands are already in the pipeline.

Product development
Product innovations and ongoing development could lead to large heat pump efficiency gains. For example, Japan has launched a program to double the efficiency and halve the cost of heat pumps by 2050. Such bold programs are expected to take place in other parts of the world as well.

New markets
Since heat pumps are a mature technology, their market is expected to continue to grow steadily. Few other technologies have the same CO2 saving potential.
But this is no reason to think of heat pumps as being for space heating and DHW production only. There are already tumble dryers and washing machines using integrated heat pumps. In principle, only the imagination is the limit when conceiving new applications where heat pumps could supply heating, cooling or both simultaneously.

In conclusion, heat pumps represent a mature, reliable technology that is already cost efficient, and with future improvements on the way, their use will become even more widespread.

The 10th IEA Heat Pump Conference

HP 2011 TOKYO
10th IEA
Heat Pump Conference

Early Notice – Call for Papers
May 16 – 19, 2011, Tokyo, Japan

The Conference program will cover the following topics:

- **Environment-friendly Technology**
  Advances in equipment design and development
- **Systems and Components**
  Advanced electrically and thermally operated systems, and ground source systems
- **Applications**
  Demonstrated energy efficiency and environmental advantages
- **Research and Development**
  New developments and new refrigerants in heat pumping technologies
- **Policy, Standards, and Market Strategies**
  Government, utility and professional society activities related on heat pumps
- **Markets**
  Market status, trends and future opportunities
- **International Activities**
  Discussion of actions in response to climate change initiatives

Papers: Papers will be presented both orally and as posters. Abstracts (200 - 300 words)
should be submitted through our website, www.hpc2011.org by 30 June 2010.

The abstracts will be screened by an appropriate Regional Coordinator then authors will be advised of acceptance by 31 August 2010. Full papers will be required by 31 January 2011.

Workshops: There will be opportunities for organization of workshops during the Conference. Interested organizations should contact one of the Regional Coordinators.

Exhibition: There will be an exhibition in connection with the Conference. For those interested in exhibiting, please contact your Regional Coordinators.

Web: For more information, please log on to the Conference website at: 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

IEA welcomes Copenhagen Accord but calls for more efforts

(Published 22 December 2009)
The International Energy Agency welcomes the Copenhagen Accord, which provides guidance on the next steps towards a legally-binding agreement on climate change. The Accord provides a clear environmental goal of limiting the increase in global temperature to 2 degrees Celsius. It calls for emissions to peak as early as possible as well as for a collective commitment by developed countries to financially support developing country actions in AGW mitigation and adaptation. It also lays out the foundation for supporting developing country actions, over and above their unilateral actions. The IEA estimates that developing countries will need to invest around USD 200 billion annually by 2020 to move to less carbon-intensive energy systems. The USD 100 billion pledged by developed countries is a significant contribution towards that goal.

However, IEA calculations show that emission reduction pledges to date fall short of what is needed to limit the long-term concentration of greenhouse gases in the atmosphere to 450 parts per million (ppm) of CO2-equivalent, in line with a 2 degrees C increase. The IEA has produced a blueprint for achieving the 450 ppm goal in the energy sector (see World Energy Outlook 2009), and in the first half of 2010 it will assess the possible gap between countries' commitments and actions under the Copenhagen Accord and this goal. The Agency will work with all countries to ensure that best energy and climate policy practice is widely shared and can be put to work to reach a higher level of ambition at the lowest cost for society.

Climate policy is an integral part of the energy policy portfolio. The IEA intends to ensure coherence between environmental, economic and security goals, which is crucial to an effective climate policy response.
Source: http://www.iea.org/journalists/index.asp

EGEC presents national geothermal targets

EGEC (European Geothermal Energy Council) has presented national targets for geothermal heating & cooling and geothermal electricity in 2020. Recommendations on how to reach these targets will be presented in the beginning of 2010 in order to help EU Member States write their Renewable Action Plans (NREAPs).
Source: http://www.egec.org/index.html (click on "News", then see 4.12.09)

AHRI publishes standard for walk-in coolers and freezers

The Commercial Refrigerator Manufacturers Section of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) has approved the publication of AHRI Standard 1250-2009, Performance Rating of Walk-In Coolers and Freezers. The standard, which is available for free download at www.ahrinet.org, establishes definitions, test requirements, rating requirements, minimum data requirements for published ratings, operating requirements, marking and nameplate data, and conformance conditions for walk-in coolers and freezers.
Source: http://www.ahrinet.org/Pages/ShowMeMore.aspx?src=single&lpk=1160

From frankincense to fridges – camels bear cool answer

Forget the three wise men and their 'precious' gifts of gold, frankincense and myrrh, camels are now transporting medicine to remote African communities by bearing solar-powered refrigeration units on their backs. Convoys of camels have been kitted up with lightweight saddles each carrying a solar-powered generator and a refrigeration unit full of medicine. Medicines requiring refrigeration can be transported through rough terrain to the desired destination where the solar power generators are used to power clinics. The project is currently being tested in isolated areas of Ethiopia, and the Laikipia and Samburu areas of Kenya.
Source: http://www.acr-news.com/news/news.asp?id=1844&title=From+frankincense+to+fridges+%2D+camels+bear+cool+answer

Working Fluids

EPA issues R-22 rules

The EPA has 'pre-released' two long-awaited final rules on the R-22 phase-out. This phase-out impacts contractors and the entire HVACR supply chain. The rules took effect on January 1, and can be found at EPA's website (see below). ACCA (Air Conditioning Contractors of America) will release a 'plain English' analysis for its members as soon as possible.

One rule covers the production and consumption of HCFCs, including R-22, for 2010-2014; the other relates to the sale, installation and distribution of appliances pre-charged with R-22 on or after January 1, 2010.
See http://www.epa.gov/Ozone/title6/phaseout/22phaseout.html
Source: http://www.acca.org/press/news.php?id=260

AREA calling for prevention of illegal import of HCFCs into the EU

AREA (the European association representing refrigeration, air conditioning and heat pump contractors) calls on European Union Member States to take the necessary steps to prevent illegal imports of HCFCs into the EU. Indeed, in line with EU Regulation (EC) 1005/2009, as of January 1, 2010, the use of HCFCs will be banned in the European Union, with the exception of HCFCs reclaimed and recovered when servicing equipment.

However, HCFCs are still used in a wide variety of applications, including process chilling, food storage and air conditioning, and the amount of recovered HCFCs is only a small fraction of the amount of HCFCs currently used for service and maintenance of air conditioning and refrigeration equipment. This may lead to the creation of an illegal market for the importation of HCFCs from outside the EU, as previously happened with the phase-out of CFCs.
Source: http://www.fluorocarbons.org/templates/_NewsDetail/index.php?page=65f4c7c703c51d71d1a31d4d0f87d921&detail=e3b11ac572cf7033552901d13de56e2b&lang=en&category=
Original source: http://www.area-eur.be/_Rainbow/Documents/AREA%20letter%20HCFCs.pdf

Technology

Heat pump technology gains momentum in household applications

Since heat pumps are at the core of several household appliances, CECED, the European household appliance manufacturers' association, has created a new issue group to support further technological development for the use of renewable resources in the household.
Heat pumps are one of the fastest growing domestic technologies. They are part of heating, ventilation and air conditioners; recently their use was also extended to water heaters and dryers. This relevant technical development for sustainability needs to be better promoted towards policy makers in Europe and each member state.

Domestic heat pumps fall under the scope of the Renewable Energy Sources (RES) Directive which places declaration requirements on manufacturers as a way of promoting renewable energies.

The new issue group will focus on strengthening the representation of the technology used in domestic heat pumps at European level. The group will coordinate their activities with existing organisations to identify common heat pumps issues covering the renewable energy field in order to ensure full coherence of proposed policies.
Source: http://www.ceced.eu/ICECED/easnet.dll/GetDoc?APPL=1&DAT_IM=20E302

AREA publishes recommendations to national authorities for setting up national certification schemes for heat pumps installers

AREA has published its recommendations to national authorities for setting up national certification schemes for heat pumps installers, with the aim of assisting the EC and member states in ensuring the successful transition of those aspects of the Renewable Energy Sources (RES) Directive 2009/28/EC, relating to heat pumps, into national schemes by 2012.
Please refer to the AREA Position Paper, at http://www.area-eur.be/_Rainbow/Documents/AREA%20PP%20ImplRESDir.pdf

Markets

Pilot building energy labelling program launched by ASHRAE with leading owners and designers

A new program to inform building owners and operators, tenants and prospective buyers on the energy use of buildings, similar to nutrition labels on food or miles per gallon ratings on cars, was launched today to encourage the building industry to find ways to cut energy use and costs.

The Building Energy Quotient program, which will be known as Building EQ, will include both As Designed (asset) and In Operation (as

operated) ratings for all building types, except residential. It also will provide a detailed certificate with data on actual energy use, energy demand profiles, indoor air quality and other information that will enable building owners to evaluate and reduce a building's energy consumption. The program is administered by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).
Source: http://www.ashrae.org/pressroom/detail/17380

Heat pump boost from Darling's pre-budget report

Heat pump manufacturers got a welcome boost from the British government's decision to offer £400 to householders to help finance the upgrade of their G-rated boilers with 'a new boiler or renewable heat unit'.

Chancellor Alistair Darling's 2009 pre-budget report stated the Greener Boiler Incentive scheme will benefit 125,000 UK households. The Department of Energy and Climate Change said it will work with industry to launch the scheme at the earliest opportunity in 2010.

"We were initially concerned that the scheme would only look at replacing old gas boilers for new gas boilers, which would have penalized green technologies such as air source heat pumps, so we are delighted that they have been included in the scheme," said John Kellett, General Manager of Mitsubishi Electric's heating systems division.
Source: http://www.acr-news.com/news/news.asp?id=1833&title=Heat+pump+boost+from+Darling%27s+PBR+

Sainsbury's starts selling heat pumps in stores

Sainsbury's has become the first supermarket to sell heat pumps in its stores, its Home Energy Centres opened at three stores in the UK during December 2009. Customers will have a range of energy saving and renewable energy products to choose from, including air source heat pumps. The products will be delivered to customers' homes and installed by EDF Energy fitters. The initiative has the backing of the Energy Savings Trust (EST).
Source: http://www.acr-news.com/news/news.asp?id=1814&title=Sainsbury%27s+starts+selling+heat+pumps+in+stores+++

Ongoing Annexes

Bold text indicates Operating Agent.

Annex 29 Ground-Source Heat Pumps - Overcoming Market and Technical Barriers	29	AT, CA, JP, NO, SE, US
Annex 30 Retrofit heat pumps for buildings	30	DE, FR, NL
Annex 31 Advanced modelling and tools for analysis of energy use in supermarkets.	31	CA, DE, SE, UK, US
Annex 32 Economical heating and cooling systems for low-energy houses.	32	CA, CH, DE, NL, SE, US, JP, AT, NO
Annex 33 Compact Heat Exchangers In Heat Pumping Equipment	33	UK, SE, US, JP
Annex 34 Thermally Driven Heat Pumps for Heating and Cooling	34	AT, **DE**, NL, 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 States (US). All countries are members of the IEA Heat Pump Centre (HPC). Sweden is Operating Agent of the HPC.

Challenging future of heat pumps

Vasile Minea, Canada

Introduction

Historically, world primary energy consumption has been based chiefly on oil (35%), coal (25%) and natural gas (21%) at relatively cheap costs (Figure 1). Today, the price of natural gas is rising and is putting up the cost of 20% of world electricity, while the cost of coal remains relatively low and is the favoured fuel for 40% of the world's power plants. However, coal causes pollution and power companies will have to pay for carbon dioxide as pollutant. At the same time, the supply of petroleum will peak as consumption continues to grow and new reserves become harder to find. The global rate of fossil fuel usage will inevitably lead to an energy crisis during the 21st century. Global CO2 emissions (23,579 million tonnes/year) come from power generation (40%), industry (17%), buildings (14%) and transport (21%). According to the Kyoto Protocol, the industrialized nations are required to reduce greenhouse gas emissions to below 1990 levels. In spite of this, our reliance on fossil fuels is not expected to change significantly between now and 2050.

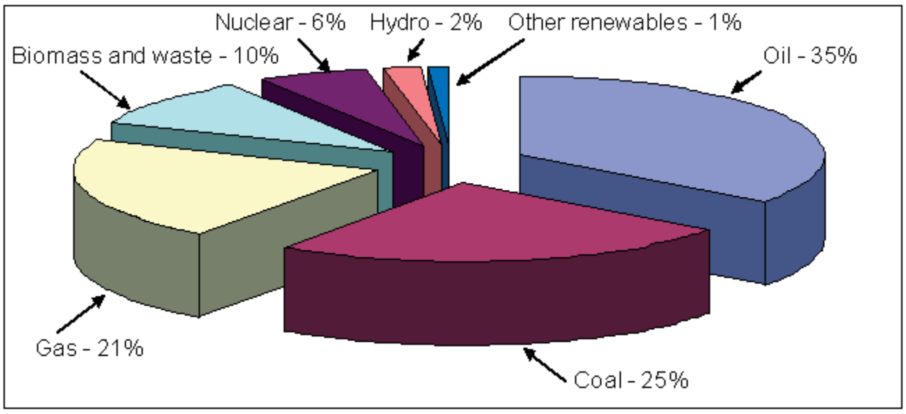


Figure 1 - Word primary energy consumption by fuel (2004) (source: IEA)

World energy demand could effectively grow by as much as 55% by 2030 and potentially double by 2050 [1]. This context opens up opportunities for developing alternative renewable and clean energy sources, such as solar, wind, hydrogen, water hydrokinetic, nuclear, ambient air and geothermal. The key strategic policy will concern energy efficiency and security, and the reduction of related greenhouse gas emissions by investments in technology development, manufacturing and commercialization of emerging clean technologies.

Canadian energy context

Canadian energy production in 2007 is shown in Figure 2a [2]. Of the country's total annual energy production (18,028 PJ), industry consumes 48% and residential and commercial buildings 28%, of which 70% is for space and domestic hot water heating (Figure 2b).

Global issues such as commodity prices and economic growth will continue to be the dominant drivers for changes in energy demand

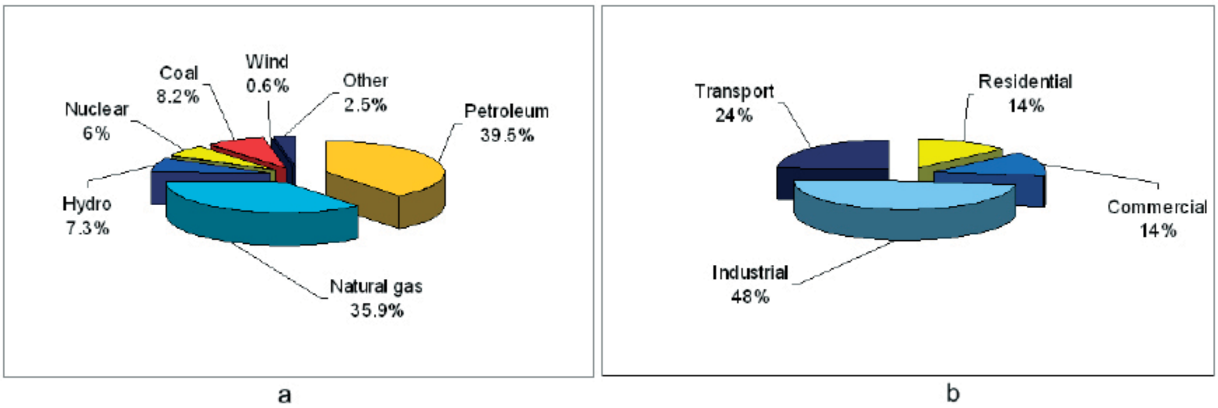


Figure 2 – Canada's domestic energy production by energy source (a) and end user demand by sector (b)

in Canada. New technologies, policies, regulations, and even changes in consumer energy use behaviour will influence future energy demand. This is projected to grow at a rate of between 0.3% and 1.4% per year, or by up to 35% by 2030, and energy intensity is expected to improve. Emerging technologies and alternative energy resources will also grow, but they will not play a large role in meeting Canadian demand.

Conventional energy sources, such as fossil fuels, will continue to be predominant. Significant changes are expected in the Canadian electricity supply sector, owing to the resurgence of nuclear energy in Ontario and the development of wind technology in Quebec. New interprovincial transmission projects and international connections will increase electricity exchanges and exports.
At the same time, overall Canadian greenhouse gas emission intensity will decline modestly as a result of energy demand management programmes. This will mean fewer greenhouse gas emissions to produce the same amount of goods and services. In order to achieve the Canadian government's target of a 20% reduction in greenhouse gas emissions by 2020, reduction strategies will be found in agriculture and forestry carbon sinks, as well as in international emissions trading.

Major investments are also needed to develop new sources of energy and materials with little or no influence on the global environment.

Heat pumping context

The peak electric demand of Canadian cold climate HVAC systems is increasing in both heating and cooling modes. Heat pumps are used for upgrading low-temperature free heat from renewable sources such as air, water, ground and waste heat, to useful temperatures. As components of air-conditioning systems, heat pump compressors and evaporator fans absorb most of the electrical power (up to 75% and 10%, respectively) while neglected maintenance accounts for about 10% of energy use. A lot of resources are also spent troubleshooting problems and implementing remedies, and refrigerant leakage remains high today. At lower ambient temperatures heating capacity decreases, while in cooling mode at higher ambient temperatures, compressor power input increases and cooling capacity decreases. At the same time, dirty evaporators and condensers reduce heating and/or cooling capacities by up to 40% while increasing the total power input by, for example, up to 60% in cooling mode.

Past R&D activities in Canada have targeted design and control improvements in low, medium and high-temperature heat pumps used for industrial drying, especially for hardwoods, softwoods and food products, in order to provide safe and efficient operations and to accelerate industrial implementation. Heat pumps have been successfully implemented as heat recovery devices in advanced supermarkets [3], as well as in combined space and domestic hot water heating systems [4]. Studies aimed at overcoming market and technical barriers to ground-source heat pumps [5] and providing economical heating and cooling systems integrated into low and net zero energy houses [6] have contributed to the development and promotion of heat pumping technologies in cold climates. Several works on integration of heat pumps with commercial building HVAC systems, such as ice rinks and retail stores, industrial processes and cogeneration units for residential applications, have been successfully performed in the recent past.

Current R&D projects in Canada aim at improving the efficiency of residential, commercial and industrial heating and cooling/air-conditioning processes reduce the total costs of ground-source heat pump systems, efficiently using the heat pumps in future low/net-zero energy houses, and the further use of natural refrigerants (ammonia, CO2) and hydrocarbons. Projects aim at developing industrial heat pumps for agricultural industries and the efficient integration of ground-source and exhaust air heat recovery heat pumps into commercial/institutional, multi-apartment community buildings and cold storage plants.

Financial incentives

The biggest drawback for geothermal heat pumps is that their initial cost is higher than that of traditional heating and cooling systems. A Canadian geothermal heat pump system costs roughly US$2,500 per ton (3.5 kW) of nominal cooling capacity, so an average-size home using a 3-ton unit would end up paying US$7,500. To that we must add the cost of up to US$7,600 per home for drilling, generally vertically deep underground. However, while geothermal systems cost more than conventional oil- or natural-gas-dependent systems, the cost of running heat pumps is actually less than for a conventional system using fossil fuel. Geothermal heat pumps can thus pay for themselves over time with reduced energy bills. A homeowner can save 30 to 70% on heating and 20 to 50% on cooling costs over conventional systems. These savings allow simple payback periods of 10 to 12 years. Durable and almost maintenance-free because their components are sheltered underground, geothermal heat pumps are guaranteed to last 25 to 50 years.

Canadian financial incentives, as described below in this section, will be needed in the next few decades to stimulate the implementation of heat pumps in residential and institutional buildings and industrial processes.

Natural Resources Canada [7] currently provides financial support to homeowners, small and medium-sized businesses, public institutions and industrial facilities for the installation of earth-energy systems with ground or groundwater energy sources compliant with Canadian standard CAN/CSA-C448.

The ecoENERGY programme helps with the implementation of energy saving projects that reduce energy-related greenhouse gases and air pollution. Single-family homes, including detached, semi-detached and low-rise multi-unit residential buildings are eligible. The maximum grant for a single home is US$4,500. For the replacement of a heat pump unit in an existing earth-energy system, the grant is US$1,600 per unit replaced. For the installation of an ENERGY STAR qualified air-source heat pump for both heating and cooling, the grant is US$450 per unit installed.

The New Brunswick efficiency programme offers owners of detached, semi-detached or row houses either a grant (maximum US$1800), or an interest-free loan of up to US$9,000, repayable over a maximum 6-year term.

In Ontario, three electrical utilities offer financing for amounts from US$1,800 up to US$45,000 with amortization periods of up to 120 months through the *PowerHouse* programme.

The power utility SaskEnergy offers rebates of US$3,150 per installation of CAN/CSA-C448 compliant geothermal systems.

The Hydro-Québec electricity utility offers grants when work is carried out by contractors accredited by the *Canadian GeoExchange Coalition.* The grant is US$2,520 for new homes, while for existing houses 100% heated by electricity before retrofitting, the grant for a new geothermal system is US$1,800. Additional grants for existing detached houses are available through the *Rénoclimat* programme offered by Québec's *Agence de l'efficacité énergétique*, as well as through the *ecoENERGY Retrofit* programme. The total grant for an existing house may amount to US$7,000 [8].

Finally, Manitoba's *Residential Earth Power Loans* assist homeowners with the costs of new installations and retrofits of geothermal heat pumps. The financing is up to US$18000 for a maximum term of 15 years at an interest rate of 4.9% over the initial 5-year term.

The future of heat pumps

In the future, most countries will continue to be net energy importers exposed to supply security risks.
In this context, heat pumps could contribute to reducing these risks through the use of electricity as a multi-fuel based energy carrier. Thus, end-users will be less dependent on one particular fuel source, since electricity can be generated from a wide range of fossil and renewable sources. This will put heat pumps in a good position compared to wind, biomass and solar energy installations. In a context where most developed countries recognize aerothermal, hydrothermal and geothermal energy as renewable sources, next generation heat pumps will have to use electrical energy efficiently in order to reduce the demand for fossil energy for heating and decrease greenhouse gas emissions.

Future factors influencing the use of heat pumps will be higher demand for air cooling and dehumidification as a consequence of climate changes, and changes in building and living standards (e. g. a lower specific energy requirement for heating, a higher demand for domestic hot water, and a growing demand for a more comfortable indoor climate in both summer and winter). Other global energy issues such as higher prices for primary energy sources and higher production costs will also motivate investments in heat pump technologies to make them more competitive with, for example, wind, hydro, solar and nuclear energy.

Global targets

By 2030, institutional and commercial buildings will have to use 25% less energy. Almost all new buildings and 75% of retrofit buildings will be equipped with heat pump technologies, and 25% of industrial waste heat will be recovered. The heat pumps' annual performance factors, in contrast to present levels, including heat pump water heaters, will increase by 25% by 2020, 50% by 2030 (Europe), and 200% by 2050 (Japan). About 20% of overall energy consumption will be renewable.

The initial cost of heat pumps will be reduced by 15% by 2020 and 25% by 2030 compared to 2000. The total cost of heat pump systems compared to current levels would be reduced by 50% by 2050. Finally, global greenhouse gas emissions will be reduced by 20% by 2020, while future building regulations and subsidy schemes will be provided.

Low GWP refrigerants

Refrigerants currently in use still affect global warming. Future efficient heat pumps using low GWP working fluids will help to reduce the environmental impact from refrigerants. The focus will gradually turn toward natural refrigerants regarding global environmental preservation. Ammonia, and CO_2, as well as hydrocarbons (propane, etc.), are considered to be future low GWP refrigerants. Although these refrigerants are excellent in terms of global environmental preservation, they possess shortcomings in chemical characteristics and/or thermo-physical properties. However, the toxicity of ammonia does not weaken its excellent thermo-physical properties, and zero ozone depletion and warming potentials. Safer installation and operation measures along with new national standards will have to be implemented for the large-scale use of ammonia.

Because CO_2 has a low boiling point, systems are designed to run at high service pressures, as the refrigerant exceeds the critical point. Components that use CO_2 are already on the market. The target of R&D activities is to improve the performance of existing components and to expand the application field by developing new types of compressors, heat exchangers and controls.

Because hydrocarbons are flammable, it will be necessary to take measures to reduce the amount of refrigerant charges and to prevent leakage and/or accidents.

Advanced components and controls

Particularly in cold climates, the compression ratios of air source heat pumps are large and subject to harsh operating conditions at very low ambient temperatures. They lower both heating capacity and performance. To improve overall heating performance, heat pumps have to be equipped with inverter-controlled or double-stage compressors (scroll, rotary) with or without refrigerant injection at intermediate pressure. Capacity modulation allows better matching of capacity and load.

Recovering expansion work and using it for compression in the case of high-pressure refrigerants as CO_2 is another challenge. The most difficult things to control are expander and compressor rotating speeds for maximum power recovery, and to reduce the internal friction losses and leakage.

The development and integration of simple or cascade ejectors in mechanical vapour compression and absorption heat pump cycles will improve the thermodynamic cycle and the coefficients of performance. Future systems with distributed liquid refrigerant and charge control will deliver refrigerant where it is necessary for best performance and improvement of system efficiency and reliability.
The development of cost-effective and efficient micro-channel gas-to-water and gas-to-air coolers for CO_2 heat pumps with small temperature approaches and improved joint and insulation technologies is another R&D objective. Efficiency improvements in heat pump evaporator heat transfer by means of nanofluids and advanced defrosting strategies will also be necessary.

Cost-effective ground heat exchangers, including direct expansion coils with CO_2 as secondary fluid for new and retrofit low-energy houses and buildings, will need to be developed.

Compact micro-fin absorbers will reduce the size of absorption heat pumps and optimize overall heat transfer coefficients.
Improvements in control strategies will involve forecast technologies, intelligent on-board fault detection and diagnostics, smart user interfaces, bi-directional connectivity and demand response readiness.
In cold climates, double-source (bivalent, hybrid) (e. g. coupled with gas boilers) and multi-function heat pumps (e. g. simultaneous or alternate space and domestic hot water heating, radiant floor and air heating and cooling) will be developed. For industrial applications, both electrically and thermally driven high-temperature heat pumps will capture the market.

Other projects will target such emerging technologies as chemical, desiccant, secondary coolant fluids (CO_2, brines), magnetic and thermoelectric systems.

Building and process integration

Future low energy buildings will be provided with tighter insulation and lower infiltration losses and will probably have higher cooling demands.

Most of the buildings of 2050 are already built and consequently it will be a retrofit market. In this future market context, heat pumps will have to be designed around prevailing climatic conditions and integrated further with energy, automation and smart metering systems in buildings.

Future targets concern advanced design methods and efficient integration in low/net-zero energy houses (with photovoltaic and solar thermal heat recovery devices, passive thermal storage and cogeneration units) and in industrial processes (e. g. food, pulp and paper drying), as well as in district heating and cooling systems.

Pinch analysis of industrial processes will provide a powerful tool for the efficient integration of heat pumps.
Combined systems using air-to-air, water-to-air and water-to-water heat pumps with solar thermal energy as the main or secondary (back-up) heating system will be further developed.

Heat pumps will be integrated in future cold climate district heating systems to recover heat, for example from disused mines, city sewers, rivers, lakes and the sea.

Advanced heating and cooling systems will have to include low temperature distribution systems (e. g. radiant heating floors and cooling ceilings) with little or no fan energy consumption, multi-zones with heat recovery and variable refrigerant flow, and ductless indoor distribution systems.

Being efficient at exhaust air heat recovery, heat pump applications will be extended in cold climates to supermarkets, ice rinks and cold storage plants and to residential heating at very low ambient temperatures, as well as for snow melting.

In some applications, such as ground-source heat pumps in community and large-scale building applications, seasonal underground heat storage will improve the annual performance factors of HVAC systems.
Heat pump installation costs will be reduced by optimizing the design and developing new concepts, cost-effective packaged units, materials and thermal fluids.

A major issue is cost reduction, especially of ground-source heat pumps, by designing efficient and more compact ground heat exchangers.

It will be important to harmonize, regionally and/or globally, calculation methods of Seasonal Performance

Factors for combined heat pump systems.
Periodical analysis of market potential and economic issues, the development of new standards, simulations, laboratory tests and field demonstrations of various prototypes will all help heat pumps achieve future technical, economical and environmental targets.

Finally, utilities, manufacturers and governments need to work in closer cooperation to improve the energy efficiency and market penetration of future electric and gas-fired heat pumps.

Environmental impact

Because of the synergy between heat pumping and lower-carbon electricity supply, heat pumps can efficiently help to reduce not only energy demand and consumption, but also the carbon footprint of buildings. They could effectively save 50% of building sector and 5% of industrial sector CO_2 emissions. This means that 1.8 billion tonnes of CO_2 per year could be saved by heat pumps, corresponding to nearly 8% of total global CO_2 emissions [9].

Conclusions

Finding new ways to produce and use energy to minimize environmental impact is one of the key challenges the world faces in the 21st century.
In this context, industrial processes and higher market penetration of heat pumps in new low energy buildings will increase energy savings, lower power demand and reduce exposure to supply risks in many countries.
Wider use will also reduce carbon dioxide emissions because heat pumps are often more carbon efficient than the direct use of fossil fuel for the same purposes. A 30% market penetration of heat pumps in retrofit heating markets would reduce total global emissions by up to 8% because heating energy efficiency will be improved and electricity generation can become less-carbon-intensive. Finally, global warming issues will drive new regulation, force new government subsidies and influence consumer behaviour.

As a direct result of this it is expected that new technology-related business opportunities over the next 30 years will represent several tens of trillions of dollars.

Heat pumping technologies certainly have a promising, brilliant future in the context of the world's declared energy crisis.

References

[1]http://www.worldenergyoutlook.org/
[2] http://www.statcan.gc.ca/
[3] Minea, V., 2003 - Advanced Supermarket Refrigeration/ Heat Recovery Systems, CEA Technologies, CEATI Report No. T011700-7005, August
[4] Minea, V., 2007 – Simultaneous performance factors for combined multifunctional ground-source heat pumps, IEA Heat Pump Centre Newsletter, Volume 25, No. 4/2007, pages 16-22. www.heatpumpcentre.org
[5] Minea, V. 2007 – Design Improvements of large ground-source heat pump systems in Canada, IEA HPP Annex 29, 3rd International Workshop, January 15, 2007, Sapporo Japan. http://www.annex29.net
[6] Candanedo, J.; Minea, V., Athienitis, A., 2008 – Low-energy houses in Canada - national initiatives and achievements, IEA HPP Annex 32 International Workshop, May, Zürich, Switzerland
[7] http://www.nrcan-rncan.gc.ca
[8] http://www.hydro.qc.ca
[9] http://www.heat pumpcentre.com

Author contact information
Vasile Minea, Ph.D.
Hydro-Québec Research Institute
Laboratoire des technologies de l'énergie (LTE)
600, avenue de la Montagne, G9N 7N5
Shawinigan, Canada
E-mail: minea.vasile@lte.ireq.ca
Phone: 1-819-539-1400
Fax: 1-819-539-1409

Thermally driven heat pumps in future energy systems

Giovanni Restuccia, CNR-ITAE, Italy

This paper presents a short survey of closed-cycle, thermally driven heat pumps. Following a concise description of operating principles and of the main components of liquid absorption and solid adsorption technologies, a comparison of their main properties and performance is presented. Subsequently, different products commercially available are mentioned together with the main producers. Finally, a technology perspective is provided.

Background

Thermally driven heat pumps/air conditioners, using environmental friendly refrigerants, represent an energy efficient technology [1]. Their use, in comparison with traditional vapour compression systems, can create benefits in terms of reduction of electricity peak load, mitigation of global warming potential and primary energy saving, especially where waste heat or solar energy are used as primary energy sources [2].

Basically, heat-driven heat pump/chillers work at three levels of temperature: the machine is driven by a heat source at high temperature; heat is rejected at medium temperature and collected at low temperature. The heat rejected at medium temperature is the useful effect provided in a heat pumping operation. The cold produced at low temperature is the useful effect provided in chilling mode. The most important examples of heat-driven cooling systems are closed absorption and adsorption cycles. Other options adopting an open cycle are available such as the desiccant cooling systems for direct cooling and drying of air. Only closed-cycle cases are discussed here. Sorption technologies range from small units of 10 kW (or even less) to huge units of a few MW, and may be driven by a large variety of heat sources, including waste or solar heat and the direct combustion of fuel. Another advantage is the utilization of a "thermal compressor" instead of a mechanical compressor, ensuring silent operation, which is particularly attractive for applications in buildings such as residential houses, museums, theatres, etc.

Liquid absorption and solid adsorption closed-cycles

Both technologies are based on a working pair of a refrigerant and a sorption medium. In absorption devices the refrigerant is absorbed, i.e. dissolved, in the liquid sorption medium changing the former's concentration. Most common working pairs are Lithium Bromide/Water and Ammonia/Water. In the case of adsorption chillers, the refrigerant is adsorbed in the pores of the solid adsorption medium. Most common working pairs are Zeolite/Water, Silica Gel/Water, Activated carbon/ammonia, and Activated carbon/methanol [3]. Both technologies are thermodynamically similar and have analogous basic configurations, which consist of four main components: a reactor called a generator, where the sorbent (liquid or solid) is heated at high temperature; the condenser, where the desorbed refrigerant vapour is condensed into liquid; the evaporator, where the cooling effect is produced, and a reactor called an ab/adsorber that receives refrigerant vapour from the evaporator. In the case of liquid absorption machines, a pump is used to continuously circulate the rich solution from the absorber to the generator and the weak solution back to the absorber. The two reactors in a solid adsorption machine operate in counter-phase to ensure continuous useful cooling effect and are alternately heated for desorption and cooled for adsorption. In contrast to absorption machines, a circulation pump is not required. For further details about basic operating principles of absorption and adsorption systems, please see [4] [5].

In order to increase the performance of the machines, more sophisticated configurations have been developed, such as double and triple-effect liquid absorption machines and multi-bed or thermal wave solid adsorption machines [6]. Such advanced configurations are thermodynamically more efficient but may be driven by a heat source at higher temperature and usually require complex hydraulic arrangements and elaborate control criteria.

Table 1 summarises the technologies, the pairs used and compares the main properties and performance of the most-used thermally driven products.

In general, liquid absorption machines can guarantee high COP in both cooling and heat-pumping modes. Some practical hazards still exist such as crystallization and cor-

Table 1 – Available thermally driven heat pumps

Process	Adsorption		Absorption		
Refrigerant/sorbent	water silica gel	water zeolite	water/LiBr Single-effect	water/LiBr double-effect	ammonia water
Temperature Heat source [°C]	60–90	75–150	75–110	135–200	100–180
Capacity [kW]	7.5–500	7–15	15–12000	200–6000	18–700
COP heat pumping	1.4–1.6	1.3–1.5	1.4–1.6	1.8–2.2	1.4–1.6
COP cooling	0.5–0.7	0.4–0.6	0.6–0.7	0.9–1.3	0.5–0.7

rosion problems and high circulation pump energy consumption. Ammonia/water machines require specially designed solution pumps. Solid adsorption machines have lower thermodynamic efficiency but can be driven by lower driving temperatures, which makes this technology particularly interesting for the exploitation of low grade waste heat or solar energy. Moreover, operation of solid sorption machines is not affected by motion, so that another attractive application is the cooling/air conditioning of automobiles or boats.

The diffusion of thermally driven heat pumps

Absorption chillers/heat pumps have been extensively studied and developed and are now considered a mature technology; high quality products are sold by several manufacturers. Absorption heat pumps for space heating and cooling are often gas-fired, i.e. are integrated with a gas boiler that produces the driving thermal energy of the sorption heat pumps; in this case good integration of the condensing boiler with the sorption device is needed in order to obtain an efficient overall system.

On the market here are several gas fired absorption heat pump products available that are generally ready for small-to-medium capacity sorption devices. Of these products, one of the most interesting is based on the ammonia/water pair and is produced by Robur (Italy). It is integrated with the boiler and is able to supply heat for ambient heating and cooling with a seasonal global performance factor as high as 1.4.

Different lithium bromide/water absorption machines have been available on the market for many years, in single or double-effect configurations and driven by various heat sources (direct fired, hot water, district heat and steam). Triple-effect machines have been developed only as pre-commercial prototypes that require very high driving temperatures (>200°C). Many manufacturers of LiBr/water machines are located in Asia (Sanyo, Yazaki, Broad, LG, Hitachi, etc.) and the USA (Carrier, York, TRANE, etc.). Frequently, LiBr-water absorption chillers are integrated with cogeneration plants or solar-assisted systems. However, a single-effect machine might require a heat source of about 88°C or higher, so that expensive evacuated tube collectors must be employed instead of cheaper, flat-type collectors.

Solid adsorption systems have been studied and developed to lesser degrees than liquid absorption systems, so there is still a wide margin for development in process optimisation, performance improvement and reductions in manufacturing costs [7]. Historically, the first silica gel/water adsorption chillers produced by Nishiyodo and Mycom (Japan), appeared in the market in the late 80s. Such chillers, still available on the market, have different cooling capacities (30–470 kW) and can be efficiently driven by hot water at 60–90°C, ensuring a COP of up to 0.6. Germany is the country most recently active in the development and construction of solid sorption heat pumps/chillers, especially for small-capacity systems, thus exploiting one of the most interesting properties of solid sorption devices, i.e. a non-reduction of performance for small-capacity systems. Nowadays there are a couple of small German companies (SorTech, Invensor) producing chillers based on silica gel–water and zeolite–water with cooling capacities starting from 7 and 5 kW respectively.

Furthermore, Viessmann and Vaillant are ready to launch a product consisting of a boiler integrated with a solid adsorption heat pump for single-apartment heating that would have a field seasonal heating performance factor higher than 1.2. Viessmann and Vaillant (solid sorption), Bosch Thermotechnik and Robur (liquid sorption), in collaboration with Ruhrgas and other gas utilities, are participating in a very interesting joint project 'Gas Heat Pump Initiative (www.IGWP.de)', whose main aim is to continue to develop absorption and adsorption heat pump technology to market maturity, through practical laboratory tests and field trials [8]. Other significant contributions in the development of this technology are provided by a couple of companies located in China (DY Refrigeration and Jiangsu Shuangliang).

A special contribution, at material level, is provided by Mitsubishi Chemical (Japan), which has developed a new class of adsorbent materials (AQSOA-FAM), specifically designed to be used in adsorption chillers. These new adsorbents, having a crystalline structure, are preferable to amorphous silica gel and can be regenerated with a thermal source in the range 60–90°C. Nowadays, activity on solid adsorption machines is almost absent in USA.

Technology perspective

Until now, most of the installed systems are large units for buildings and also in district heating and cooling networks. However, as the small units have the potential to form the larger proportion of the market, deeper market penetration by thermally driven heat pumps/chillers can be achieved when small (5–20 kW), compact, efficient and cost-effective machines become available. Accordingly, there are several aspects still under investigation to improve machine design and overall performance. Concerning liquid absorption systems, the most important directions in today's R&D are the reduction of driving temperatures, mitigation of corrosion problems, and investigation of novel working pairs such as ionic fluids. Concerning solid adsorption systems, results presented in the recent state of the art are encouraging, but a lot of advancements are still expected, especially with reference to heat transfer intensification, improved cycles, development of novel adsorbent materials with advanced sorption properties, reduction of size and techno-economic optimization.

References

[1] Ziegler F.; 2006; Heat-pumping heat exchangers: thermally-activated heat pump systems transfer heat upstream with negligible need for electricity; IEA Heat Pump Centre Newsletter Volume 24, N. 1

[2] Meunier F.; 2001; Adsorptive cooling: a clean technology; Clean Products and Processes Vol.3 n. 1, pp. 8–20

[3] Wang, L.W., Wang, R.Z., Oliveira, R.G.; 2009; A review on adsorption working pairs for refrigeration; Renewable and Sustainable Energy Reviews Vol. 13, n. 3, pp. 518–534.

[4] Alefeld G., Radermacher R.; 1994; Heat conversion systems; CRC Press

[5] Cacciola G., Restuccia G.; 1999; Adsorption heat pumps: a new way for energy saving and CFCs replacement; in Adsorption and its Application in Industry and Environmental Protection, Studies in Surface Science and Catalysis, vol. 120B, A. Dabrowski editor, Elsevier Science, pp. 949–978

[6] Ziegler F.; 2002; State of the art in sorption heat pumping and cooling technologies; International Journal of Refrigeration; vol. 25; pp.450–459

[7] Critoph R.E., Zhong Y.; (2005) Review of trends in solid sorption refrigeration and heat pumping technology, Proceedings Of The Institution Of Mechanical Engineers Part E 219 Part E 285 - –300

[8] Albus R., Weßing W., Ramesohl S.; 2009; Gas heat pumps the renewable heating system for the future?; http://www.igu.org/html/wgc2009/papers/docs/wgcFinal00323.pdf

Author contact information:
Giovanni Restuccia
Consiglio Nazionale delle Ricerche
Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano"
Santa Lucia sopra Contesse, 98126 Messina – Italy
Phone: +39 090624229
Fax: +39 090624247
giovanni.restuccia@itae.cnr.it

The role of heat pumps in future energy systems

Takashi Yatabe, Japan

Introduction

The 2009 United Nations Climate Change Conference, commonly known as the Copenhagen Summit, was held at the Bella Center in Copenhagen, Denmark, between 7 December and 18 December, 2009. It included the 15th Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change and the 5th Meeting of the Parties (COP/MOP 5) to the Kyoto Protocol. COP15 initially aimed at determining the new greenhouse gas emission reduction target and adopting a new legally binding protocol. However, the greenhouse gas emission reduction target remained stalled over disputes between the developed and developing worlds, which resulted in a document called “the Copenhagen Accord” instead of the new legally binding protocol, which has instead been carried over to the following year.

After the so- called “the Lehman Shock”, discussions over the global economic crisis and measures to deal with the crisis, and to prevent similar crises in the future, took on a higher priority than environmental problems. However, environmental problems are regaining world attention.
In Japan, for instance, as soon as the government changed in the summer of 2008, the Hatoyama administration made a policy pledge to reduce CO_2 emissions by 25% by 2025. And Brazil, as the first among emerging countries , has set a voluntary target to reduce CO_2 emissions by a maximum of 39% by 2020.

Global environmental problems have broadened our view from domestic issues to encompass international trends. In the past, there were many issues that could have been dealt with globally in theory, but in reality, these issues were not handled globally because ultimately the countries involved were limited or had limited objectives. But now that all of us -- nations, corporations and each and every individual in the world -- are both perpetrators and victims at the same time, can we not agree that climate change is a truly global, mutual issue?

As is well known now, global warming is mainly caused by an increase of CO_2 emissions resulting from fossil fuel combustion. We have enjoyed comfortable lives by exploiting energy obtained from the combustion of fossil fuels since the Industrial Revolution. Modern life cannot go on without fossil fuels.
Until now it was mainly developed countries that benefited from fossil fuels, but the emerging BRIC economies are increasing their consumption of fossil fuels significantly these days in line with their socioeconomic development.

An increase in consumption (demand) is said to be responsible for pushing up the price of fossil fuels and other natural resources. In the late 90s the price of crude oil was stable around at around USD 10 per barrel, but it exceeded USD 100 per barrel in 2008; in other words, the price surged by more than 10 times over the last 10 years. After 2008, the price dropped in line with a downturn in demand due to the economic crisis. After another price rise at the end of 2009, prices are currently around USD 80.

On top of the environmental problems, economic issues have complicated things further. Because fossil fuels are vital for our modern way of life, price has enormous impact on household finances and business activity. A quick way to solve the difficult problems of CO_2 emissions and fossil fuel prices would be to reduce the consumption of fossil fuels to become more independent of them. For instance, in our everyday lives the challenge could be met and overcome by taking measures against heating water and rooms by fossil fuel. Under these circumstances, heat pump technology attracts attention as an efficient, eco-friendly measure that can be taken without changing present-day household comforts and business advantages.

Figure 1 CO2 refrigerant heat pump water heater (EcoCute)

In Japan, in particular, electrical heat pump appliances in the household and buildings sectors, such as the heat pump washer-dryers, have increased sales volumes considerably since their launch in2005. The Eco-Cute heat pump water heater has also shown a remarkable increase. (Figure 1)

Global Warming Countermeasures and Energy Security

Apart from the environmental problems arising from the fossil fuels which have brought us such comfortable lives, we also face serious issues over energy security. The 1973 Arab-Israeli War was one that caused an entire world to understand that crude oil was no longer an inexpensive energy option. And it taught countries like Japan that depended heavily upon imports for resources to realize that their energy supply and demand structures were very vulnerable. This was the turning point where energy conservation technology innovation accelerated the development of energy sources other than oil. Energy suppliers have devoted ceaseless efforts to the development of alternatives such as wind, hydroelectric, solar, nuclear and biomass power generation, in addition to existing fuels including natural gas. It is important to establish an energy supply structure that is independent of oil by creating a best mix of the advantages of the above alternatives. In other words, it is critical for suppliers to prepare for a variety of options and alternatives.

Consumers are also required to try to overcome the problems. In order to reduce energy consumption, it will be important to establish energy-saving standards for factories, offices and stores, and to make efforts to live up to such standards. Would not countries with more energy conservation measures and a greater choice of energy source options be less affected by wild fluctuations in oil prices? Efforts by suppliers and consumers on their respective sides of the equation will result in highly effective countermeasures.

Ref. Panasonic catalogue
Figure 2 Heat pump washer-dryer

Applications of Aerothermal, Geothermal and Hydrothermal Energy

The promotion of energy conservation is inseparable from global warming countermeasures. Decreasing the consumption of fuels by applying energy conservation measures means a reduction in CO_2 emissions caused by combustion, which will lead to measures against global warming. It was believed energy conservation was associated with tolerance. However, the tolerant image has changed a little. Take automobiles as an example. Hybrid vehicles and diesel-powered vehicles which get 30 km or more per litre have been launched on the market. Fuel efficiency improved without a reduction in performance. Some of them not only show performance as good as ordinary gasoline-powered vehicles, but also boast better acceleration. With an ecologically aware approach, you can save energy driving these eco-friendly cars without undue mental effort.

In Japan one hears advertising slogans such as “Dry laundry by dry air” or “Boil water by heat from the air” in commercials from power companies and electrical appliance manufacturers. Through such commercials the public has begun to recognize that “heat from the air” could be the key to future energy conservation. The key phrase is “heat pump”. Panasonic and Toshiba put “heat pump” in their washer-dryer brand names, which promotes heat pumps in general. (Figure 2)

Heat pumps have been predominant in refrigerators, freezers and cooling appliances in buildings for a long time due to a lack of cooling and refrigeration alternatives. Neither were they popular in water heaters, heating appliances and washer-driers. Because heat pumps were expensive and complicated and because other inexpensive options were available such as fossil fuel boilers and water heaters, heating appliances and inexpensive gas combustion systems for washer-driers. However, technological developments over the last few years have brought acceptable prices and higher performance heat pump equipment to market, which makes it possible to increase their market share.

A heat pump has two major features. Needless to say, one is the technology to pump up heat (heat transport), while the other is energy-saving technology. When speaking of new technologies, fuel cells often spring to mind. While it is important to research and develop new technologies, we must take immediate action against global warming and we do not have time to sit and wait for new technologies to mature. Heat pumps are very effective at reducing CO_2 emissions, and are also already commercially available, which is one of their great advantages. The majority of technological developments have resulted from a steady stream of improvements being applied time after time. The heat pump is one of the leading, highly efficient eco-technologies. But we must continue with research and development in the search for greater efficiency, because actual COP is only 1/4 to 1/5 of theoretical COP.

Heat Pumps Highly Anticipated in Households and Buildings Sector

Housing is one of life's necessities. In the modern age, comfort is a housing requirement over and above such basics as protection from wind, rain and the elements. While the economic efficiency of household appliances is regarded as important, new functions have been added in respect of information, crime prevention, nursing and so forth. As a result, energy consumption is steadily increasing.

In the average Japanese household, about 40% of all energy is consumed by electrical appliances (excluding air conditioners), about 30% by heating and cooling appliances (mostly heating) and the remaining 30% for water heating. In Europe and North America on the other hand, heating accounts for about 50% as they have longer cold periods. The closer to the equator a region is, the higher the proportion of cooling. Although heating in cold districts was essential to prevent people from freezing to death, cooling was generally considered a luxury since being hot is not generally fatal. But cooling appliances are now considered one of the necessities of life now that we are getting wealthier and experiencing more extremely hot days.

Energy-saving measures for electrical appliances and lighting include frequent switching off and the control of stand-by power. On the other hand, measures for cooling, heating and water heating whose energy sources are heat, include appropriate temperature settings, more insulation in homes and the introduction of solar water heaters, these are miniscule and remain plenty of room for further measures remains. The Japanese government gives particularly high priority to water heaters among global warming countermeasures, given the fact that soaking in the bath is a part of Japanese culture.

A water heater equipped with heat pump systems and nicknamed EcoCute was launched under the policy in 2001. Its formal name is "CO_2 refrigerant heat pump water heater" and it is the first domestic water heater in the world to use CO_2 as a refrigerant. At the meeting of the energy conservation task force under the Agency for Natural Resources and Energy in 2002, the prototype 2001 model was reported as being able to save more than 30% energy compared to conventional combustion-type water heaters. EcoCute alludes to two ECOs; one is "Ecology" which reflects the facts that it is equipped with a highly efficient energy conserving heat pump system and that its refrigerant is CO_2 from Mother Nature. The other is "Economy" which reflects the fact that its running cost is one-fifth or less than that of conventional units through its taking advantage of the economical option for night time power use provided by power companies to practice electricity supply load levelling.

In Japan there is a widespread, entrenched perception that water is heated by fire. Conventional combustion-type water heaters dominate domestic markets with a share of more than 90% of water heater units. The latest latent heat recovery-type water heaters have reached 95% (higher heating value standard) thermal efficiency; this is very close to the theoretical 100% upper limit as a result of intensive research and development in combustion type water heaters. It can be said that there is no more room for further development. In other words, it's high time we came up with a practical answer to the widespread "myth" that water is heated by fire, so that we may achieve further efficiencies.

Heat pump water heaters show a thermal efficiency of 148% (= 4 (COP) x 36.9% (Japanese generating efficiency)) even when generating efficiency is considered. That is to say, one practical solution is the use of atmospheric energy instead of electricity or fuels. Solar water heaters and heat pump water heaters are the same in this regard. However, there is a big difference between them; solar water heaters are very much dependent on weather conditions that result in an unstable energy supply, while heat pump systems allow us to use stable atmospheric heat, although there are seasonal differences.

We have achieved over 50% improvements in efficiency and have had seen pump water heater COP reach 4.9 (when heating water to 60ºC at an outside temperature of 7ºC) since 2001 when EcoCute first came to market. Although COP changes in keeping with outside temperatures and the temperature we wish to achieve, we would be able to decrease CO_2 emissions by approximately 65% if we could maintain COP 4 throughout the year.

Below are examples of conceivable measures for EcoCute improvements.

(1) **Improved efficiency in components**
As EcoCute uses supercritical CO_2 as a refrigerant; it requires more durable design elements. EcoCute has a short history and still has plenty of room for development. Continued research and development on e.g. pressure recovery in the compressor or fan is called for. One of the biggest efficiency improvements ex-

pected in the future is in heat exchangers. The air heat exchanger has been developed to a certain level technologically because its structure is basically the same as that of an outdoor unit of an air conditioner. The water heat exchanger, on the other hand, was developed exclusively for EcoCute, and seems to have plenty room for improvement. At present, scale prevention is a bottleneck regarding pipe shape design, and a solution is sought.

(2) **The recovery of energy lost during the Expansion Process**
In EcoCute units, the recovery of energy lost during the expansion process is quite large because in current systems, the compression ratio in refrigerant circulation is high and there is an expansion valve that twists flow to generate resistance so that we can adjust the quantity of refrigerant flow from high to low pressure. We have found that the introduction of an ejector in the circulation is highly beneficial for the recovery of energy lost during the expansion process and the technology is being improved by further developments. For EcoCute units equipped with rotary compressors, the solution could be the installation of double rotary compressors or the application of a gas injection cycle as in an air conditioning unit. Moreover, it should be possible in the future to develop an expansion machine that recovers energy lost during the expansion process and use it for a compressor engine.

(3) **Downsizing**
The mainstream size of current domestic EcoCute units is 4.5 kW for heat pump units and 300 to 460 litres for hot water tank units. EcoCute units have these two devices. At times, the large hot water tank has presented difficulty for some people in big cities in finding an installation location. Downsizing is required to solve these problems and thus increase market share. Specific requirements are: new developments for a high-output, high-efficiency compressor; further developments in heat exchanger efficiency and downsizing to achieve water tank downsizing, and a more powerful heat pump with greater output. The following are also thought to be necessary; the matching of water tank unit capacity to heat pump output and the associated system control technology.

(4) **Cold Climate measures**
EcoCute market share remains at a low level in colder regions as it is unable to realize its full performance due to low outdoor temperatures. Operations under low outdoor temperatures cause frost to form, which degrades heat exchanger performance. And the facts that defrost operations require extra energy is another major problem. We need research and development to overcome these problems.

As a result of the continuous research and development mentioned above, we are able to forecast efficiency improvements of up to 50 % by 2050 by having innovative technologies developed and installed on each component. (Figure 3)

We have used EcoCute in the examples above to illustrate the direction of developments, but these could also apply to hot water circulating heaters used mainly in Europe and North America, not only in households but also in offices and shops. When it comes to heat sources, aerothermal heat is used in Japan mainly because of the mild climate; however, we have other options such as geothermal, hydrothermal, waste or ventilation exhaust heat. Exploiting exhaust or waste heat is to recycle the actual energy within a house. This enables us to realize household energy recycling systems which do not release energy inside a house when recycling it. Research and development by power suppliers regarding the reduction of CO_2 emissions per unit are necessary and would bring synergy effects.

Heat Pump Innovations in the Industrial Sector

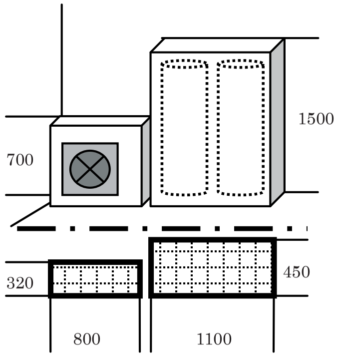
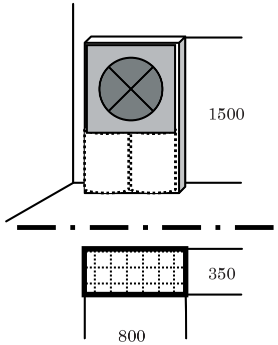
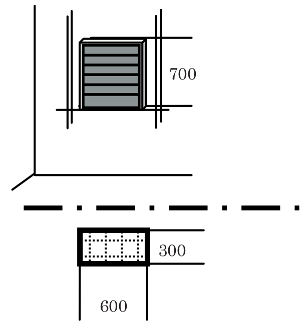
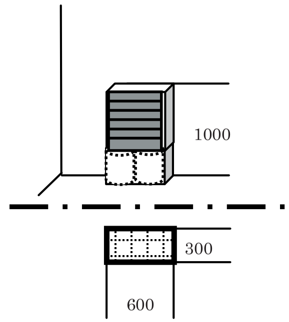
Quite large amounts of heat are generally consumed in factories, especially in clean rooms with air-conditioning units or production operations using drying, washing and sterilization processes. Research and development in steam infrastructures has been carried out as one of the measures for heat energy conservation and it is very important that such efforts continue. It's high time to take other innovative steps, and the heat pump springs to mind. In particular it should be possible to raise temperatures to levels suitable for air conditioning, water heating and drying by adding a small amount of high exergy power to aerothermal, geothermal or hydrothermal heat. In other words, we could replace energy generated from burning fossil fuels or electric heating with a heat cycle.

Heat pumps such as EcoCute have been developed mainly for heating households and buildings, but they could also be applied to drying or heating (below 100 ºC) processes and this paves the way for introduction into production processes. If we reconsider the common premise that heating and drying are exclusively steam processes, could we not postulate that steam is not the only option? (Figure 4)

A number of larger heat pump water heaters for the industrial sector have appeared on the market since 2006.

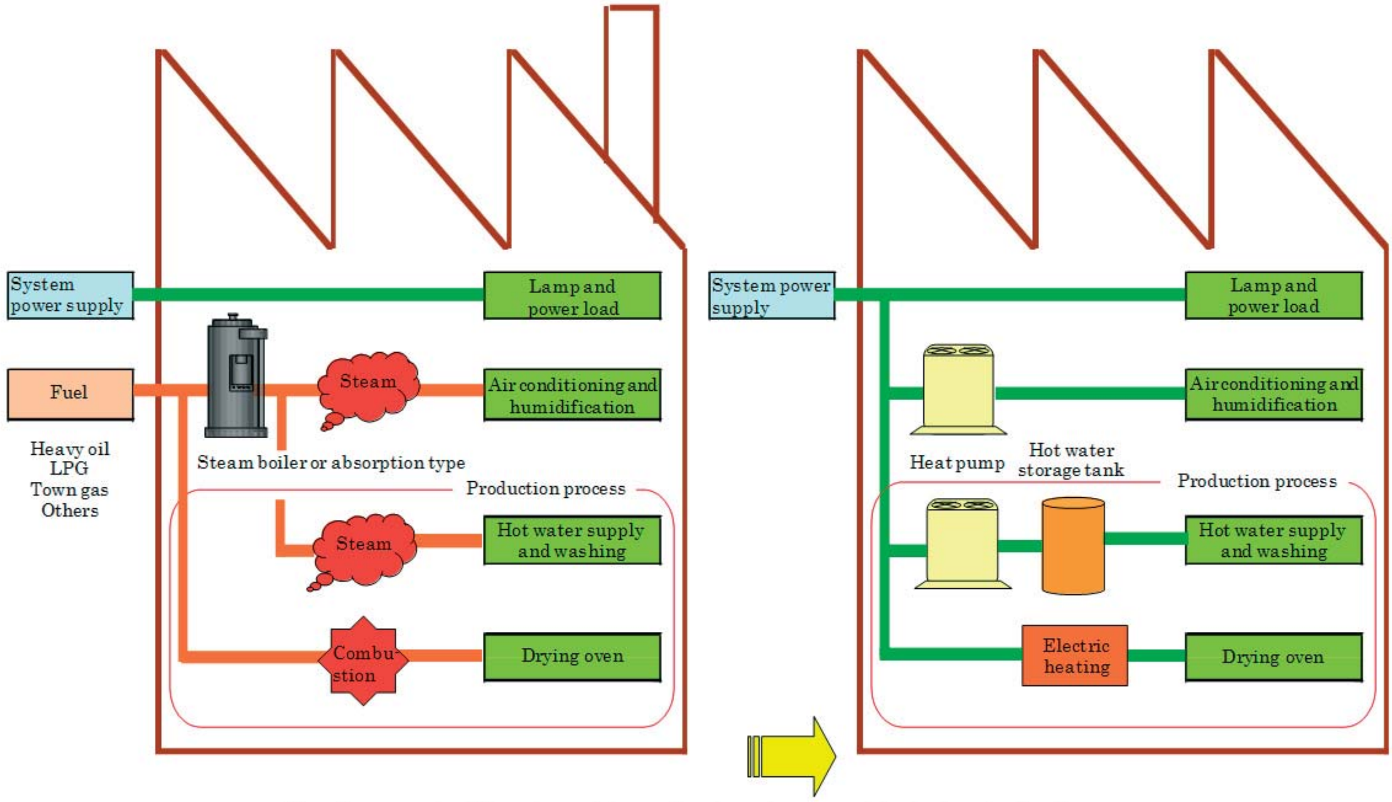
Examples of the potential demand for hot-water supply in production processes are as follows:
- Hot water at 60 to 80 ºC is used in a shower in the washing process before vehicle body painting.
- Hot water at 80 to 90 ºC is used in a pipe washing process at night after daytime production in a food processing plant.

Figure 3 Outlook for Eco Cute technology development

Type	Hot water storage type (combination of HP unit and hot water storage tank)	Semi-instantaneous type (integration of HP unit and hot water storage tank)	Small HP unit adapted to instantaneous water heater	
Period of sale	2001 (as of development)	2010 (now)	Around 2040 thru 2050	
			Use method as instantaneous type For apartment buildings	Use method in combination with hot water storage unit For detached houses
Image of size and installation				
Footprint	0.735 m² (100)	0.28 m² (38)	0.18 m² (24) Ceiling suspended type	0.18 m² (24)
Annual COP	3.0	3.5	6.0 or more	6.0 or more (8.0 or more when waste heat is recovered)
Hot-water supply capacity	42 kW	42 kW	18 kW	28 kW (maximum of 42 kW)
HP heating capacity	4.5 kW (90°C)	10 kW (90°C)	20 kW (65°C)	20 kW (65°C)
Hot-water storage tank	300 litters	50 to 100 liter	None or very small	50 liter or less

Development issues instantaneous water heaters

		Technical issues	Conceivable measures	Target
Technology concerning improvement of hot-water supply capacity	Enlargement of heat exchange area	- The heat exchanger area needs to be enlarged by more than 1.4 times.	- Substantial increase in heat transfer area by minutely processing a heat exchanger such as an increase in fin surface area - Development of a three-dimensional heat exchanger	Improvement in heat exchange area More than 1.4 times
	Improvement of heat exchanger heat transfer rate	- The heat exchanger heat transfer rate needs to be improved by 1.4 times as high as now for air to refrigerant and refrigerant to water.	- Improvement in heat transfer rate by thinning a temperature boundary layer of fluid with parallel arrangement of thin tubes and uneven surface treatment - Adoption of functional material which substantially improves heat transfer rate in one direction	Improvement in heat transfer rate More than 140%
Technology concerning instantaneous type	Reduction in area heat capacity	- Heat radiation loss to the area of compressed and high temperature refrigerant must be reduced. - Material with small specific heat needs to be developed.	- Reduction in amount of sealed refrigerant and improvement of insulation, development of heat radiation reduction technology during warming-up by developing and adopting material with small specific heat and heat transfer - Development of technology which shortens distance between compressor and heat exchanger and integrates these two components	Reduction of warming-up time to approx. 10 seconds
Technology concerning efficiency improvement	Control of tapping temperature	- Temperature (compression ratio) when refrigerant is compressed needs to be changed. - Systematization using waste water and ventilation as heat source	- Control technology which allows temperature to rise only up to required hot-water supply temperature - Waste heat recovery technology and circulation heating technology	Variable heating capacity mechanism and heat recovery technology
	Improvement of refrigerant cycle and compressor	- Improvement of output and durability required when improving efficiency (COP).	- Development of refrigeration cycle technology such as power recovery technology and multi-stage compression and a compressor which operates efficiently even with small amount of refrigerant	COP equal to or better than hot-water storage type even if actuation and stop is repeated



Fixed concept of "heat used in a plant = steam and hot air = boiler"
→ Image of heat pump introduction in the production process which utilizes the latest heat pump technology and IH technology for the production process

Figure 4 Diagram showing the introduction of heat pumps in production processes

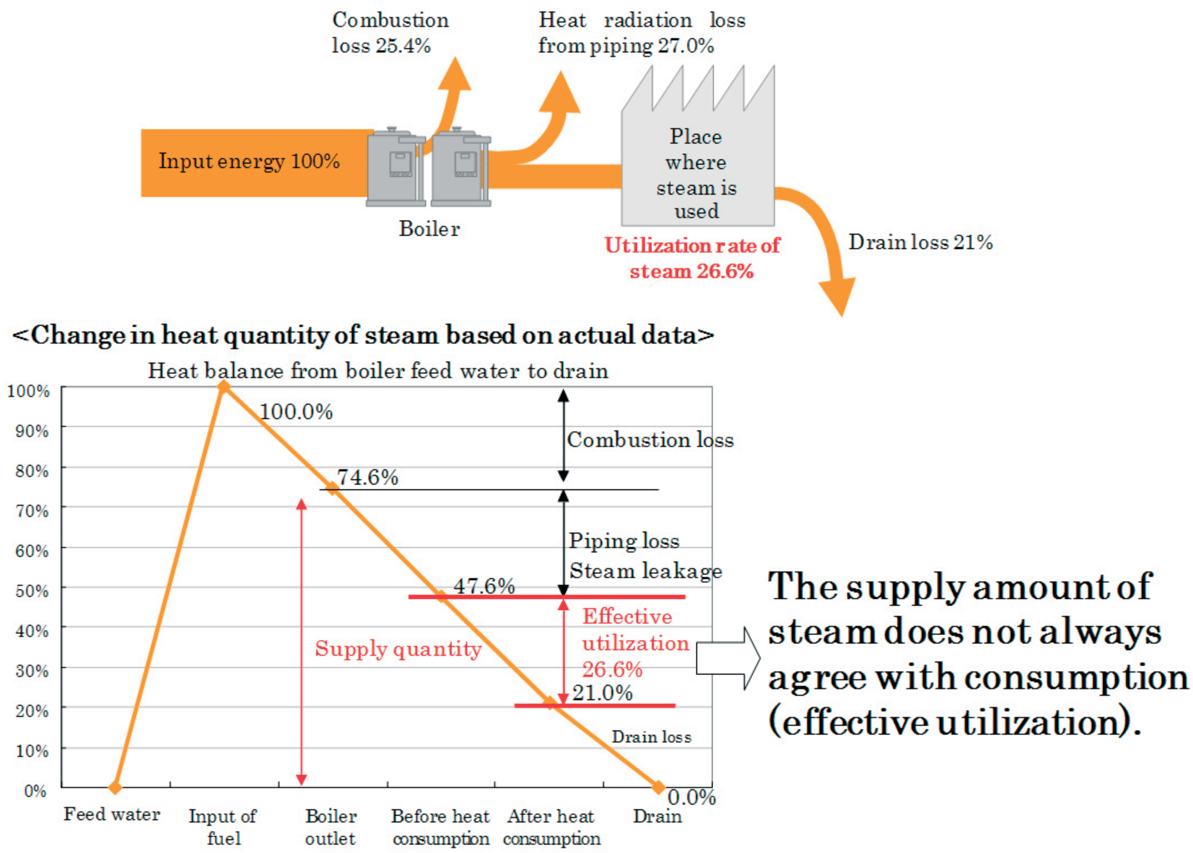


Figure 5 Example of boiler heat balance

- Hot water at 40 to 50 ºC is used in the washing of electrical parts.
- Hot distilled water at 80 ºC is used in the manufacturing process in a pharmaceutical industry.

In each of the above cases, steam is generated in a boiler, and heat is transported by steam to heat water. Steam is very convenient when it comes to energy transportation in factories. Unlike electricity, however, there is a lot of energy loss during intermediate stages; one case is reported where steam losses accounted for as much as 30% of the entire boiler output. (Figure 5)

Heat pump water heaters should be considered for energy saving measures wherever there is demand for hot water that is applicable to a factory heat pump system (e.g. production processes, kitchens, washing and bathing, etc.) and where they can be applied in systems to rationalize the utility of entire plants without the need to continue with a central steam supply system infrastructure.

In addition, it would be important to request research and development by manufacturers and general contractors for sufficiently high quality to supply heat in production process. We already have components with highly developed technology and we might say we are within reach of commercialization by combining such components.

Heat pump technology could theoretically be applied to steaming and reheating. In steaming, VRC (Vapour Recompression) is a heat pump in a broad sense. It is possible to produce steam by compression under high temperature and high pressure conditions instead of reheating in a boiler, and this can be applied not only to steaming but also to distillation processes in petrochemical plants. Besides, vaporization at low temperatures becomes possible by utilizing a vapour compression heat pump under decompression rather than compression. This means vapour compression heat pumps, by being utilized as vacuum technology, enable steaming at low temperatures, which could be applied to drying processes where paper is made from pulp. The first step we should take is to study how to apply these innovative technologies to production lines and air conditioning equipment.

There are measures available other than the introduction of equipment and systems. All equipment expels heat and waste energy; maybe there are ways to re-use this energy or recover thermal energy from hot waste water tanks. Industrial sector technology advances could be achieved by tackling the issues mentioned above.

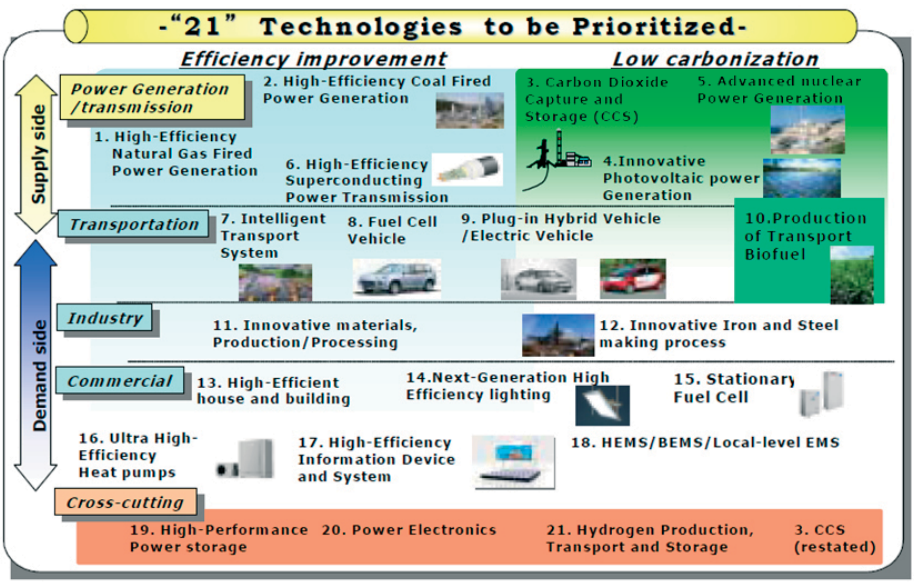
Future Trends in Heat Pump Technology Developments

As often mentioned in IEA HPP newsletter articles, the Ministry of Economy, Trade and Industry of Japan or METI studied innovative technological developments which should be focused in our country with an eye to 2050, summarizing them in their report titled; "Cool Earth – Innovative Energy Technology Program" (March 2008). (Figure 6)

In this program, the so-called "a Super-Highly Efficient Heat Pump" is listed as one of the innovative energy technologies to be focused on by energy consumers, especially in the household and buildings sectors.

In the "innovative energy technology development roadmap through 2050" program, efficiency (SPF) is targeted at 1.5 times greater by year 2030 and 2 times greater by year 2050 compared to current figures, while initial costs are set to be reduced by 3/4 by year 2030 and by 1/2 by year 2050 in comparison to current levels, through developments in components such as refrigerants and heat exchangers. This is based on high expectations for the super-high efficient heat pumps that are applicable not only to air-conditioning and water heating -- these account for approx. 50 % of all CO_2 emissions in household and buildings -- but also to air-conditioning, process cooling and heating in the industrial sector. In other words they are credible technologies that will contribute to further reductions in CO_2 emissions.

Although the program was set up from a backcasting point of view regarding current technology status, it should not be technologically impossible. Targets set by government are milestones for engineers. METI began its own R & D projects last summer in order to achieve its targets. A heat pump roadmap is also mentioned in the New National Energy Strategy from ME.



Ref: Cool Earth-Innovative Energy Technology Program (March 2008) by Ministry of Economy, Trade and Industry

Figure 6 Innovative energy technologies for prioritization

Technology targets

HPT: Heat Pump Technologies	ACT: Emissions Stabilisation	BLUE: 50% Emissions Reduction
RD&D		
More efficient components and systems for heating and cooling applications, using environmentally neutral working fluids. More efficient integrated HPT systems for net zero energy buildings. High-efficiency, high-temperature HPT.	Increased penetration of HPT in retrofit markets. 15% of industrial waste heat upgraded by HPTs. 15% less energy used in commercial buildings by use of HPT.	Energy-efficient systems using environmental benign working fluids available by 2020. 25 % industrial waste heat upgraded by 2030. 25% less energy used in commercial buildings.
Deployment		
HPT included as an option in building codes to reduce GHG emission. Financing schemes in place to stimulate HPT diffusion	Policies to support wide adoption of HPT for heating and cooling by 2020. Majority of new buildings equipped with HPT systems, 25% retrofits by 2030	Majority of new buildings equipped with HPT, 75% retrofits by 2030.
Increased awareness of annual performance and benefits of HPT systems	75% of installers certified in 2015	100% of installers and equipment certified in 2020

Figure 7-1 Heat Pump Technology Development Scenario Vol.1 (energy technology perspective 2008, International energy agency)

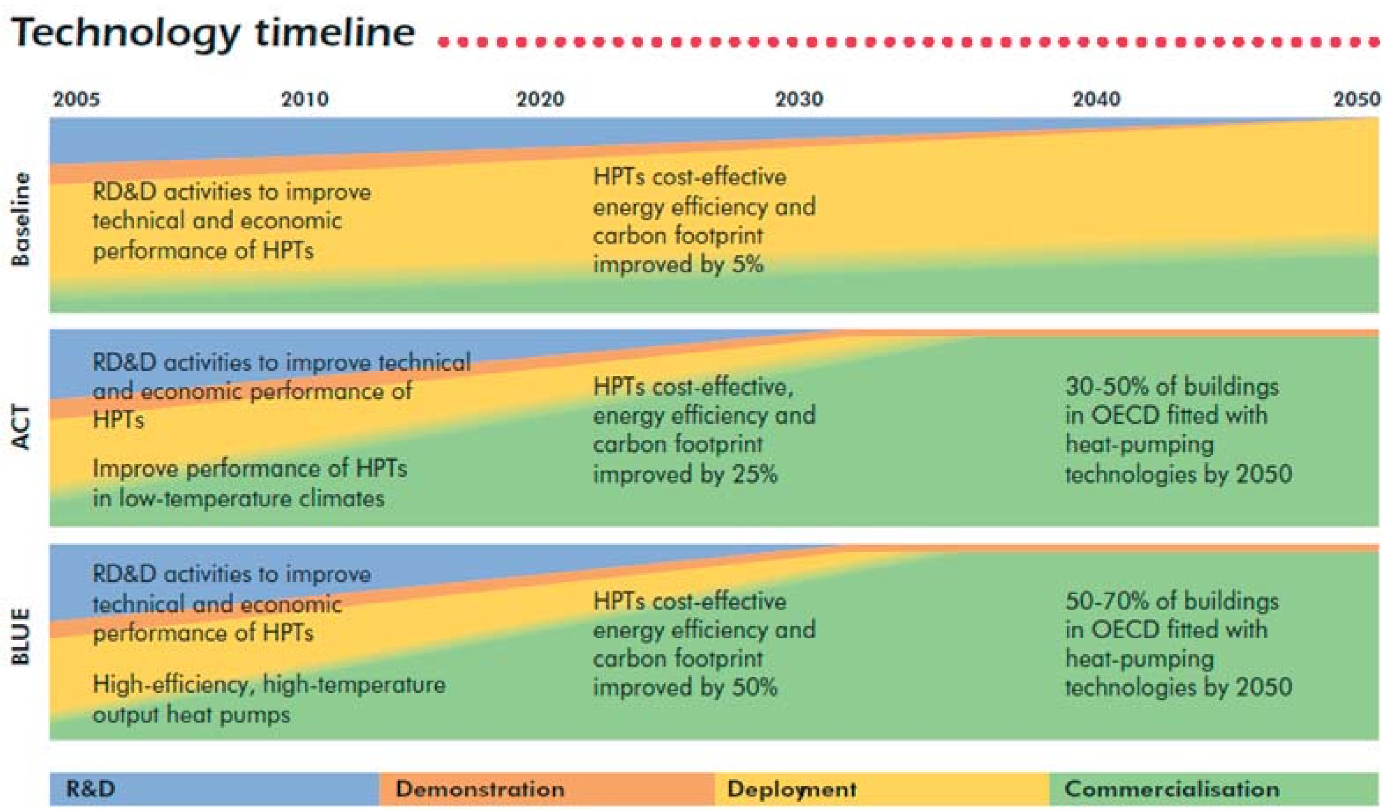


Figure 7-2 Heat Pump Technology Development Scenario Vol.2 (energy technology perspective 2008, International energy agency)

Heat Pumps are regarded as being one of 17 important technologies to combat global warming in the 2008 IEA energy technology perspective. Its blue scenario states that heat pumps will be fitted in 50 to 70 % of buildings in OECD countries by 2050. (Figure 7-1, 7-2)

IEA HPP stated that the proliferation of heat pumps has the potential for reducing CO_2 emissions by approximately 1.2 billion tons in the entire world and we can add that this figure is backed by the "Cool Earth Plan". Substantial heat pump efficiency improvements that utilize unused energy sources such as atmospheric heat and the full range of usable heat sources are highly likely to bring about changes to the conventional energy supply and demand structure.

Conclusion - Heat Pump is Renewable Energy

Violent fluctuations in crude oil prices, reviews of nuclear electric power generation in Europe and North America and controversial energy nationalism in resource-rich nations demonstrate the enormous changes in the energy situation. Regarding related issues, heat pumps are described as renewable energy in an EU Directive that came into force in June 2009, and which EU member countries must enact into law. In Japan, "renewable energy source" is defined in the "Enforcement Order of the Act on the Promotion of the Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Source Material by Energy Suppliers", and aerothermal energy is listed among them. The use of aerothermal, geothermal and hydrothermal energy in energy-poor European countries and Japan is equivalent to finding inexhaustible clean oil fields in the atmosphere or underground.

It is however impossible to replace all combustion systems with heat pumps at the same time, and timing is absolutely essential in equipment introduction. It is also important to promote technological developments that synchronize timing. For example, if equipment lifetime is estimated to be 10 years, all equipment must be replaced within 10 years. Building a society in which consumers are independent of fossil fuel is not just a fantasy, and isn't it about time the world set its sights on the introduction of appliances that consume no fossil fuel? Adding action upon action will lead to global warming countermeasures across the entire world.

REFERENCES

Yatabe.T. 2008. "The Effect and Potential of Heat Pump Technology," 9th IEA Heat Pump Conference

Heat Pump & Thermal Storage Technology Center of Japan 2007. "Heat pump and Thermal Storage White Paper"

Heat Pump & Thermal Storage Technology Center of Japan 2009. "Heat pump and Thermal Storage White Paper 2"

Heat Pump & Thermal Storage Technology Center of Japan 2007. "Heat pumps: Long Awaited Way out of the Global Warming"

Intergovernmental Panel on Climate Change 2007. "IPCC Fourth Assessment Report: Climate Change 2007,"

Yatabe, T. 2006. "Heat pumps the trump card in fight against global warming" The Japan Journal (October 2006), pp. 22-24

Ministry of Economy, Trade and Industry of Japan 2008. "Cool Earth-Innovative Energy Technology Program,"

International Energy Agency 2008. "Energy Technology Perspectives 2008"

Author contact information:
Takashi Yatabe
Manager
Urban Energy Solution Group
Kanagawa Branch
The Tokyo Electric Power Company
1-1 bentendori nakaku
yokohama, kanagawa, Japan
E-mail : yatabe.takashi@tepco.co.jp

Heat pumps in future industrial processes

A.K. Wemmers, The Netherlands

Heat pumps are primarily associated with space heating. Given the future scarcity and environmental impact of fossil fuels, energy efficient technologies such as heat pumps have a bright future in industrial processes. This article describes the opportunities for industrial heat pumps and takes a look behind the scenes at new developments.

Do heat pumps have a future in industrial processes?

Heat pumps are nowadays primarily associated with space heating in dwellings and offices. Heat pumps are occasionally found in industrial processes, mostly hidden away as mechanical vapour recompression in evaporators or distillation columns. However, heat pump technology is widespread in industry as refrigerators in food processing and the production of oxygen and nitrogen.

Will heat pumps continue to lead a marginal existence in industrial processes or does the future hold a more prominent role for them? To answer this question we first take a look at energy use in industrialized societies and how this is likely to evolve. Will boundary conditions for energy-efficient technologies such as heat pumps improve or deteriorate over time? Secondly we take a look at industrial processes. If heat pumps are to play a bigger role, where will they be applied and which heat pump technologies are likely to make an appearance.

Future energy use

According to the IEA, global primary energy demand under current policies is projected to increase by 1.5% per year between 2007 and 2030. Fossil fuels will remain the predominant sources of primary energy worldwide.

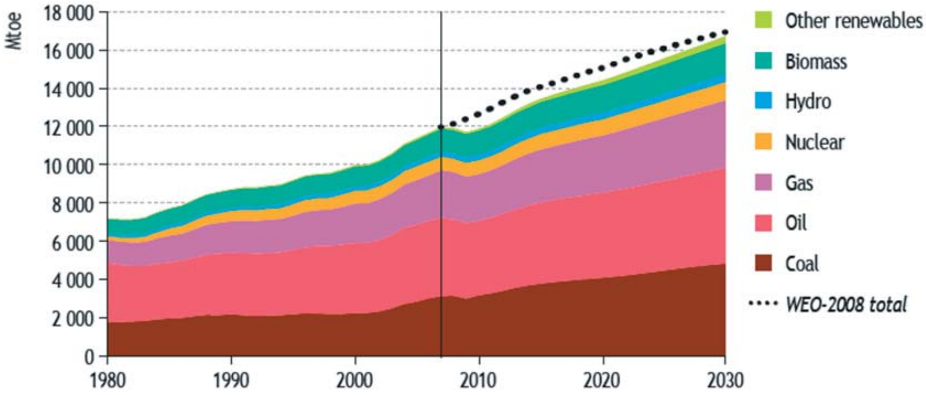


Figure 1: World primary energy demand by fuel (Source World Energy Outlook 2009 © OECD/IEA, 2009, page 75, Figure 1.1: "World Primary Energy Demand by Fuel in the Reference Scenario")

The combination of steadily growing demand and increasingly difficult oil and gas field exploration justifies the expectation of scarcity and high prices for fossil energy carriers in the future. In combination with the environmental impact of the use of fossil energy this will lead to significant incentives to improve energy savings and increase the share of renewable energy. A large energy savings contribution is expected from industry.

Industrial Energy use

In industrialized societies energy is used in three sectors: build environment, transport and industrial processes. Here we focus on industrial energy use. Data from an analysis of Dutch industrial energy consumption is used for the sake of convenience.

About 40% of industrial energy input is used as feedstock. Heat is the predominant final energy carrier, representing more than 80% of final energy use. Most heat at temperatures below 100°C is used for space heating, while heat at temperatures above 100°C is used to drive industrial processes. In addition, useful heat 105 PJ is lost as waste heat in conversion processes like Combined Heat and Power stations.

Heat pumps in industry

Rising energy prices will improve conditions for energy-efficient technologies such as heat pumps. Given that heat is the chief final energy carrier, both at present and in the future, conditions for heat pumps in particular will improve over time. This section describes the conditions under which industrial heat pumps should operate.

Pinch temperature

One of the tools used to analyze energy use in industrial processes is the Pinch analysis, in which all the heat flows of a process are mapped and all the thermodynamic opportunities for heat exchanges between process flows are identified through systematic analysis. One crucial parameter in a Pinch analysis is the Pinch temperature, or the Pinch for short. Above the Pinch there is a net shortage of heat, below the Pinch a net surplus. For a heat pump to contribute to the energy efficiency of a process it must transfer heat from temperatures below the Pinch to temperatures above the Pinch.

Heat demand above Pinch

In industrial processes heat is used for heating raw materials, and for reaction and separation processes. Conversion processes such as the production of steel, glass, ceramics, concrete, the cracking of hydrocarbons, etcetera need temperatures above 600°C. The temperature of heat used for heating raw materials and driving separation processes is generally between 100°C and 250°C. Examples of heating and separation processes are typically found in the chemical, food processing and pulp and paper industries. Based on information from the IEA Data services (World Energy Balances 2007) raw materials heating and separation processes make up about 50% of the world's industrial energy use.

Heat source below Pinch

Every heat pump needs a source of heat that can be upgraded. Within industry, industrial waste heat can be used as such a source. An inventory of waste heat in processes, products and waste flows was made regarding the Dutch chemical and refinery industries. The result is shown in figure 3. High temperature waste heat (above 200°C) in flue gasses is not included in the inventory. It is clear from figure 3 that the temperature of industrial waste heat is typically between 50°C and 150°C.

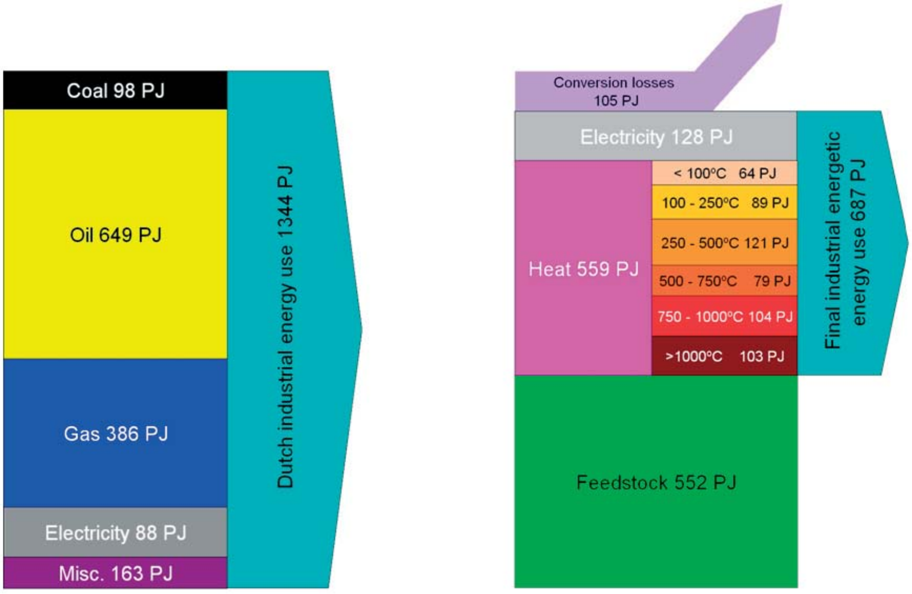


Figure 2 The Dutch industrial energy use in 2006 in PetaJoules (10^{15}J)

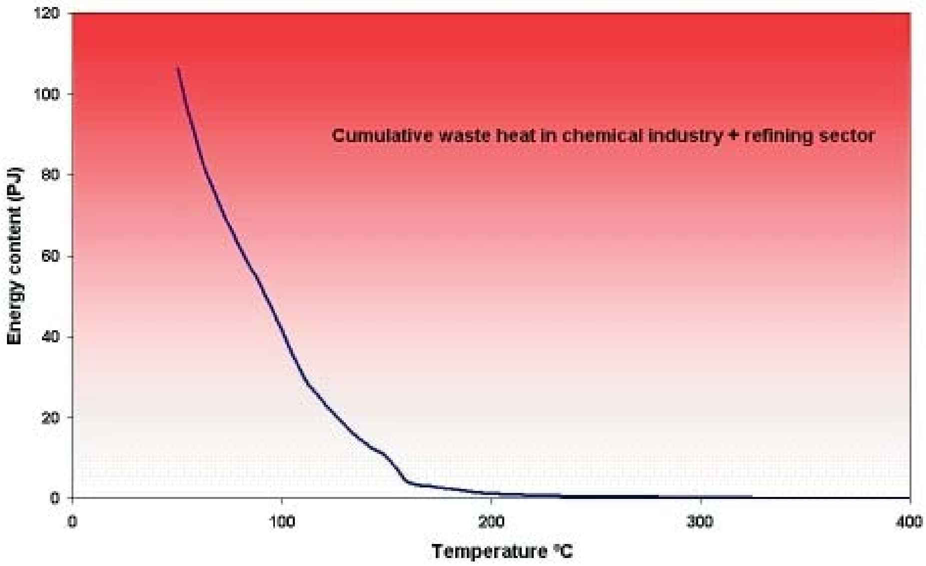


Figure 3 Waste heat in process, product or waste flows in the Dutch chemical and refinery industries.

Given the temperature dependence of heat demand in industry, waste heat temperatures, and the Pinch temperature, some general guidelines for the application of industrial heat pumps can be derived.

- It is unlikely that heat pumps will be applied for high temperature (> 250°C) processes.
- Industrial heat pumps should be able to produce heat in the temperature interval between 100°C and 250°C).
- The temperature difference between heat source and heat demand is quite high. An industrial heat pump should preferably generate temperature lifts up to 100°C.

Example of industrial heat pump

In a distillation column, heat is supplied at a high temperature in the reboiler at the bottom of the column. About the same amount of heat is removed from the condenser at the top of the column. The temperature differences between reboilers and condensors can range from a few Kelvin up to a few hundred Kelvin. Mechanical vapor (re)compression heat pumps are sometimes applied to upgrade the temperature of condenser heat to be used in the reboiler. This is only feasible at low temperature lifts (< 30 K) thus seriously limiting the applicability of heat pumps in distillation processes.

Classification of industrial heat pumps

Industrial heat pumps that can be applied in the conditions specified above can be classified according to the following categories:

1. Work driven:
Work driven heat pumps use mechanical work, usually from electric motors, to generate temperature lift. The most common are heat pumps based on the reverse Rankine cycle. This type of heat pump is commercially available and can deliver heat at a maximum temperature of approximately 130°C. With alternative refrigerants, e.g. pentane, higher temperatures up to 180°C are possible. It is technically possible to generate high temperature lifts. However, because of the relatively high price of electricity compared to the price of heat, economic temperature lifts are generally below 50K.

2. Thermally driven:
Thermally driven heat pumps use waste heat to generate temperature lift. This waste heat should have a minimum temperature level (> 100°C) to generate sufficient driving force. Heat transformers allow waste heat to be upgraded, almost without the use of external drive energy. Medium temperature waste heat at e.g. 100°C is supplied to the system, and useful heat at a higher temperature e.g. 150°C, is given off by the system. Current systems use water and a lithium bromide solution as the working pair. These heat transformers can achieve delivery temperatures of up to 150ºC, with a maximum lift of 50ºC.

3. Hybrids:
Hybrids use two sources of power to generate temperature lift: work and work potential from waste heat.

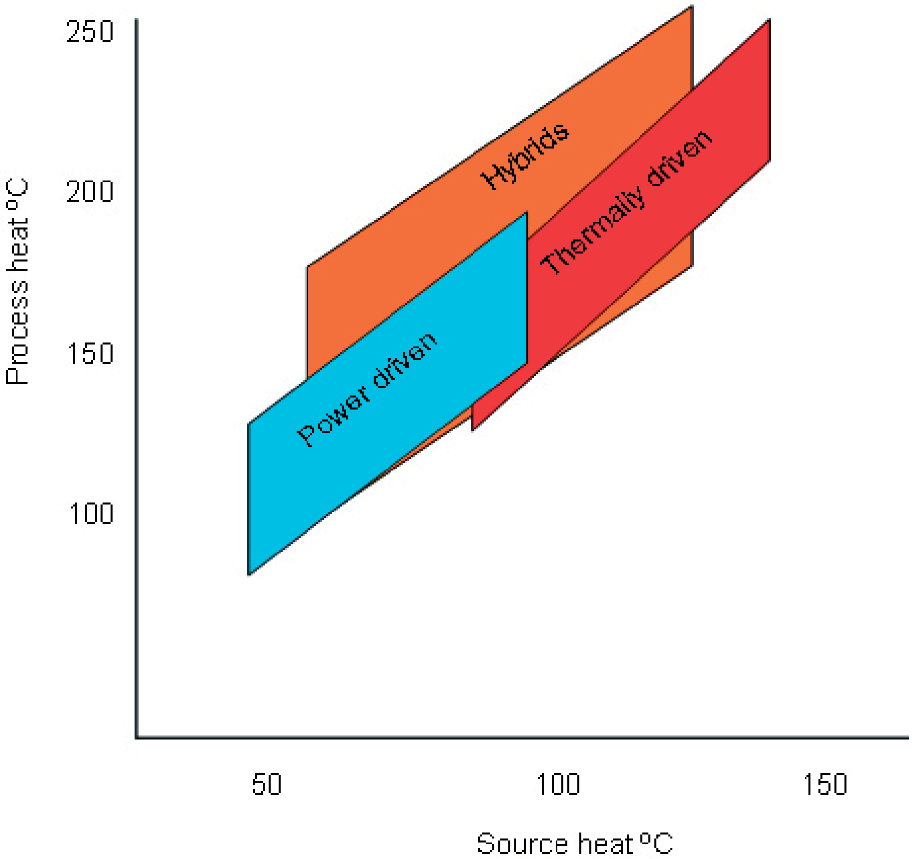


Figure 4 Temperature ranges of different types of industrial heat

Figure 5 Linear motor driven thermo acoustic heat pump at the ECN laboratory

This kind of system is useful when waste heat temperatures are too low to generate the required lift. This extends the operating range compared to work or thermally driven systems. An ammonia/water hybrid heat pump was recently developed by IFE in Norway.

Each type of heat pump covers a range of combinations of source heat and process heat as shown in figure 4.

Industrial heat pump developments

An example is given of a new development in each of the three categories.

Work driven

Thermoacoustic heat pumps and engines are under development at ECN. Thermoacoustic technology can accommodate work and thermally driven heat pumps over a broad range of temperatures (–100°C to 600°C) and high temperature lifts (up to 100 K). The underlying thermodynamic cycle is the Stirling cycle, in which gas is compressed, heated and cooled using a moving piston and displacer. In a thermoacoustic heat pump the piston and displacer are replaced by a sound wave. Figure 5 shows an experimental acoustic heat pump driven by a linear motor. A linear motor converts electrical power into acoustic power, which in turn drives the heat pump.

Thermally driven

Higher operating temperatures and larger temperature lifts compared to conventional sorption heat pumps can be achieved by using other working pairs as is done with solid sorption. Systems using the reversible absorption of ammonia in salts or hydrogen in metalhydrides are capable of delivering temperatures above 200°C. A prototype high-temperature heat transformer system, shown in figure 6, is under development at ECN. It uses a combination of LiCl and MgCl2 with ammonia and produces heat at 200°C from a heat source at 130°C.

Figure 6 Thermochemical heat transformer.

Figure 7 Silicagel water sorption heat pump which will be converted into a hybrid system.

Hybrids

A project investigating the possibilities for hybrid heat pumps based on thermo-chemical heat pump technology began recently at ECN. In this project compressors will be built into existing sorption test rigs to investigate the performance of hybrid solid sorption heat pumps. Figure 7 shows an experimental silicagel water sorption heat pump which will be used in the project.

The future of heat pumps in industrial processes

An increasing demand for energy to drive industrial processes combined with scarcer and thus more expensive fossil energy carriers will increase opportunities for energy-efficient technologies such as heat pumps in industrial processes. Given the technical constraints, heat pumps are likely to emerge in the chemical, food processing, paper and pulp industries where they will be used to heat raw materials and drive separation processes. Industrial processes demand high temperatures and high temperature lifts. To upgrade waste heat to process heat three types of heat pumps are likely to appear: power driven, thermally driven and hybrids.

The IEA recognizes the growing importance of industrial heat pumps and is currently in the process of establishing an annex dedicated to industrial heat pumps.

Author contact information
Anton K. Wemmers
Energy Research Centre of the Netherlands
P.O. Box 1, 1755 ZG Petten, The Netherlands
E-mail wemmers@ecn.nl
Phone +31 (0) 224 - 564376
Fax +31 (0) 224 - 568615

Events

2009

14 - 16 November AHRI Annual Meeting
Scottsdale, AZ, USA
E-mail: ahri @ ahrinet.org
www.ahrinet.org

26 - 28 November RENEXPO® Austria
Messezentrum Salzburg, Austria
www.renexpo-austria.com

2 - 4 December 40th International Conference on Heating, Air Conditioning and Refrigeration
IIR-co-sponsored, Commissions B1, B2, D1, E1, E2
Belgrade, Serbia
E-mail: office @ kgh-kongres.org
http://www.kgh-kongres.org/content/view/108/105/lang,english

2010

23 - 27 January ASHRAE Winter Meeting
Orlando, USA
www.ashrae.org/events/page/562

25 - 27 January International Air-Conditioning, Heating, Refrigerating Exposition (AHR Expo)
Orlando, USA
Co-sponsored by ASHRAE and ARI
www.ahrexpo.com

1 February Interclima+ Elec Home & Building
Paris, France
www.interclimaelec.com

17 - 19 February 2010 International Symposium on Next-generation Air Conditioning and Refrigeration Technology
Tokyo, Japan
http://2010nextacr.com

14 - 17 March IIAR 2010 Industrial Refrigeration Conference & Exhibition
San Diego, CA, USA
https://www.iiar.org/conferences/exhibitinfo.cfm

22 - 26 March EU Sustainable Energy Week
http://www.sustenergy.org/tpl/page.cfm?pageName=home

23 - 27 March Mostra Convegno Expocomfort
Milan, Italy
www.mcexpocomfort.it/en/aspx/ShowFolder.aspx?idFolder=156

In the next Issue

ATES/BTES systems for commercial buildings

Volume 28 - No. 1/2010

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 effi ciency 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 benefi ts 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.

The IEA Heat Pump Centre is operated by

SP Technical Research Institute of Sweden

IEA Heat Pump Centre
SP Technical Research
Institute of Sweden
P.O. Box 857
SE-501 15 Borås
Sweden
Tel: +46 10 516 50 00
Fax: +46 33 13 19 79
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org

IEA OECD heat pump centre

National team contacts

AUSTRIA
Prof. Hermann Halozan
Technical University of Graz
Innfeldgasse 25
A-8010 Graz
Tel.: +43-316-8737303
Fax: +43-316-8737305
Email: halozan@tugraz.at

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

FINLAND
Mr Jussi Hirvonen
Chair of the Board
Finnish Heat Pump Association SULPU ry,
Tel: +358 50 500 2751
Email: jussi.hirvonen @ ivt.fi
Internet: www.sulpu.fi

Dr Arto Kotipelto - Alternate
Senior Technology Advisor
TEKES (Finnish Funding Agency for Technology and Innovation)
PO Box 266
Yrjönkatu 20
FI-28101 Pori, Finland
Tel: +358 44 712 4138
E-mail: arto.kotipelto@tekes.fi

FRANCE
Jean-Michel Parrouffe
ADEME
Service des Réseaux et des Energies Renouvelables
500 route des Lucioles
FR-06560 Sophia Antipolis

GERMANY
Prof. Dr.-Ing. Dr. h.c. Horst Kruse
Informationszentrum Wärmepumpen und Kältetechnik - IZW e.V
c/o FKW GmbH
D-30167 Hannover
Tel. +49-(0)511-16 74 75-0
Fax +49-(0)511-16 74 75-25
E-mail: email@izw-online.de

Prof. Dr.-Ing. H.J. Laue - Alternate
Informationszentrum Wärmepumpen und Kältetechnik - IZW e.V.
Unterreut 6
D-76 135 Karlsruhe
Tel.: +49 721 9862 856
Fax: +49 721 9862 857
E-mail: laue.izw@t-online.de

ITALY
Dr Giovanni Restuccia
Italian National Research Council
Institute for Advanced Energy Technologies (CNR – ITAE)
Via Salita S. Lucia sopra Contesse
5 - 98126 Messina
Tel.: +39 (0)90 624 229
Fax: +39 (0)90 624 247
E-mail: giovanni.restuccia@itae.cnr.it

Dr Angelo Freni - Alternate
Italian National Research Council
Institute for Advanced Energy Technologies (CNR – ITAE)
Via Salita S. Lucia sopra Contesse
5 - 98126 Messina
Tel.: +39 (0)90 624 229
Fax: +39 (0)90 624 247
E-mail: angelo.freni @ itae.cnr.it

JAPAN
Mr Makoto Tono
Heat Pump & Thermal Storage Technology Center of Japan
1-28-5 Nihonbashi Kakigara-Cho Chuo-Ku,
TOKYO 103-0014
Tel: +81-3-5643-2404
Fax: +81-3-5641-4501
E-mail: tono.makoto@hptcj.or.jp

NETHERLANDS
Onno Kleefkens
Agentschap NL
Divisie NL Energie en Klimaat
P.O. Box 8242
Croeselaan 15
3521 BJ Utrecht
Tel: +31 30 2393 449
Fax: +31 30 2316 491
E-mail: onno.kleefkens@agentschapnl.nl

NORWAY
Mr Bård Baardsen
NOVAP
P.O. Box 6734, Rodeløkka
N-0503 Oslo
Tel. +47 22 80 5006
Fax: +47 22 80 5050
E-mail: baard.baardsen@rembra.no

SOUTH KOREA
Mr Seong-Ryong Park
Korea Institute of Energy Research
Department of Renewable Energy
71-2, Jang-dong, Yuseong-gu, Daejeon
Republic of Korea 305-343
Tel.: +82 42 860 3224
Fax: +82 42 860 3133
E-mail: srpark@kier.re.kr
http://www.kier.re.kr/eng/index.jsp

SWEDEN
Mr Mattias Törnell (Team leader)
Swedish Energy Agency
Energy Technology Department
Electricity production and Energy Use Unit
Kungsgatan 43
PO Box 310
SE-631 04 Eskilstuna
Tel.: +46 16 544 2169
Fax: +46 16 544 2099
mattias.tornell@energimyndigheten.se

SWITZERLAND
Dr Thomas Kopp
Hochschule Rapperswil
On behalf of the
Swiss Federal Office of Energy
Energy Renewable Division
Oberseestrasse 10
8640 Rapperswil
Tel.: +41 55 222 4923
E-mail: tkopp@hsr.ch

USA
Ms Melissa Voss Lapsa
Oak Ridge National Laboratory
Engineering Science and Technology Division
Bethel Valley Road
PO Box 2008
Oak Ridge, TN 37831-6054
Tel.: +1-865-576-8620
Fax: +1-865-576-0279
E-mail: lapsamv@ornl.gov