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NEWSLETTER

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Working fluids for a sustainable future

Heat Pumps - The Solution for a Low-Carbon World

F-gas refrigerants: status and trends

Low-GWPs: HCs, HFOs

Market report from China

IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 29 - No. 4/2011

In this issue

Heat Pump Centre Newsletter, 4/2011
The always interesting subject of working fluids for heat pumps is the topic of this issue. Low-GWP natural and synthetic refrigerants are discussed, and some views on F gases, especially regarding the F gas regulation within the EU, are expressed.

Further in this issue, we get an account on the recent developments of sorption cooling.
Also, the heat pump market of China is presented.

Enjoy your reading!

Johan Berg
Editor

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Working fluids for a sustainable future : A comprehensive approach is needed.

Hilde Dhont,
Environment Research Center
Daikin Europe N.V.

Several climate change models[1] predict a substantial increase in fluorinated greenhouse gas emissions, mainly from HFC refrigerants (R410A, R404A, R134a,..). The primary cause is a growing demand for air conditioners and refrigeration products in developing countries, where HFCs are the candidate replacements for ozone-depleting HCFCs - R22 is still used in many parts of the world today.

Consequently, research into working fluids with a lower impact on global warming is gaining increasing attention. Natural refrigerants and HFCs with a lower GWP (such as HFC-R32, HFOs and their blends) are being evaluated by product and component manufacturers, by the chemical industry and by universities and research centers around the world.

When assessing working fluids, a comprehensive approach is needed: not only the GWP value of the chemical needs to be considered, but also the required quantity for a given application, the impact on energy efficiency in different climates, safety aspects such as flammability and toxicity, efficient use of natural resources, end of life treatment, affordability and possibility of early adoption in developing countries. Unfortunately, many studies focus on only one or a few of these aspects. This creates uncertainty for readers on what the best solution for a specific application would be. What is becoming clear, however, is that there will be no "one-size-fits-all" refrigerant: product manufacturers will need the freedom of choice to select the best balanced solution for their application, and in some cases there will be no better alternative than the HFCs used today.

Politically, the issue is debated at United Nations level, where some countries call for an international HFC production and consumption phase-down under the Montreal Protocol. In the EU, the European Commission intends to propose new legislative measures on F-gases next year. As is the case for manufacturers and researchers, it will be important for legislators not to focus on GWP values only, but to take a holistic view when addressing HFC emissions.

What does this mean for the heat pump sector? As IEA studies indicate, heat pumps have a unique potential to reduce global greenhouse gas emissions (from an estimated 6 % up to 16 %). Greater use of heat pumps is beneficial for the climate, even when it entails a growing consumption of HFC working fluids. This apparent paradox will need to be taken into account in the negotiations for an HFC phase-down scenario. However, the heat pump sector is also looking into more sustainable solutions. Whether these solutions are based on today's HFCs, on HFCs with a lower GWP or on natural refrigerants, is for each manufacturer to evaluate on a case-by-case basis and with a comprehensive view.

[1] *Sources: Guus Velders et al.: "The large contribution of projected HFC emissions to future climate forcing", PNAS study, May 2009. See also B. Gschrey, W. Schwarz : "Projections of global emissions of fluorinated gases". Study for the German Federal Environmental Agency, November 2009*

Column

Refrigerants and the need for developments for the low-CO_2 future society

Dr. Monica Axell, General Manager, HPC

Dr. Roger Nordman, Technical Editor, HPC Newsletter

Heat pumps are a key technology for saving CO_2 emissions in society, and can considerably reduce energy costs for home owners. Most residential heat pumps presently use HFC's or HCFC's, which both have various degrees of GWP impact, from low to very high.

Present challenges to combat climate change calls for heat pumps with low CO_2-eq. emissions, both regarding direct and indirect emissions. TEWI/LCCP analysis consider both direct emissions, which refers to leakage of refrigerant during operation and scrapping, and indirect emissions, which refers to emissions from producing the electricity that the heat pump uses.

In a recent UNEP synthesis report[1] it is stated that "without intervention, the increase in HFC emissions is projected to offset much of the climate benefit achieved by the earlier reduction in ODS emissions". Many political goals have therefore been, and will continue to be, set to reduce the use of high-GWP refrigerants as one of the means of tackling CO_2-eq. emissions. For example, the F-gas directive in Europe sets requirements for equipment using certain amounts of refrigerants, and requirements on certification of the personnel allowed to work with certain systems, with the purpose to minimize leaks. Likewise, the MAC directive sets requirements that new cars' AC's in Europe should not contain refrigerants with GWP values larger than 150, by 2017.

Decreasing the direct emissions from refrigerants can be made in many parallel ways, including decreasing refrigerant charge, applying leak-tight components, applying equipment for no-leakage scrapping, applying secondary loop systems, conducting periodical leak searches, applying requirements regarding automatic gas detectors and shifting refrigerants from high-GWP to low-GWP. All of these strategies are applied in varying extents in different parts of the world.

We now see a lot of activities in developing new low-GWP refrigerants, and equipment development to utilize these new refrigerants, as well as already available "natural" refrigerants. This is a development very important for future generations of heat pumping technologies. *However, it must never be forgotten that the main emissions are currently from indirect sources during the operation; therefore heat pump efficiency must not be decreased by the introduction of new refrigerants.* For the refrigerants manufacturers, the challenge is therefore to develop refrigerants which have low GWP values and at the same time maintain or even improve thermophysical properties.

For the heat pump industry, the recent developments in low-GWP refrigerants is therefore utterly important, as sharpened and new regulations, restricting the use of the currently used HFC's, could result in a situation where the heat pump market lack high efficiency products using low-GWP refrigerants. It is therefore urgent to speed up research and development in both refrigerants and products to meet such future regulations.

The present refrigerants developments, that can be read about in this issue, together with products adapted for these refrigerants and increasing renewable electricity generation help improve heat pumps' leading position as a key technology in combating climate change!

[1] *HFCs: A Critical Link in Protecting Climate and the Ozone Layer, A UNEP Synthesis Report November 2011*

General

HPTCJ establishes multinational network in Asia

The Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ) has established the Asian Heat Pump and Thermal Storage Technology Network, Asia's first network dedicated to heat pump and thermal storage technologies, with the aim of facilitating peak electric power reductions and energy savings as well as lower CO_2 emissions. A signing ceremony was held in Tokyo on October 4.
http://www.ejarn.com/news.asp?id=17421&classid=10

USA and Canada agree to share building energy performance tool

The U.S. Environmental Protection Agency (EPA) and Natural Resources Canada (NRCan) have signed an agreement that will create a common platform for measuring and assessing the energy performance of commercial buildings in both countries. The agreement calls on EPA to enhance its ENERGY STAR Portfolio Manager software tool to track and rate the energy performance of Canadian commercial buildings, including the development of a Canadian-based energy performance scale and the addition of Canadian reference data. The agreement will remain in effect until March 30, 2016.
http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/2d85476b30cc156785257943005aafea!OpenDocument
http://listman.ashrae.org/t/5623093/18967439/3319/34

Two new studies focusing on European building regulation

The Buildings Performance Institute Europe (BPIE) has presented two new studies focusing on European building regulation:
http://www.bpie.eu/eu_buildings_under_microscope.html
http://www.bpie.eu/nearly_zero.html

A thermostat that's clever, not clunky

Steve Jobs may have transformed a bunch of industries, but his great skill wasn't really inventing. Instead, he was the world's greatest makeover wizard. He'd look at some industry, identify what had been wrong with it for years, and then figure out how to make it beautiful and simple and joyous. Now that Steve's gone, who will look around for worlds that need changing? Well, how about Tony Fadell? He seems to have the pedigree. He helped design the iPod. He ran the iPod and iPhone divisions of Apple for years.

He's got that spot-what's-wrong-with-it gene. With his new company, Nest, he has decided to reinvent a tech item that hasn't seen much innovation in decades: the thermostat.

Don't snicker. This isn't trivial. According to Nest, there are a quarter of a billion thermostats in this country alone; 10 million more are bought each year.
Half of your home's energy is controlled by this ugly, beige tool. Most people never even bother to program their programmable thermostats. As a result, their houses actually use more energy than homes without them. Two years ago, the federal government eliminated the entire programmable thermostat category from its Energy Star program.

The Nest Learning Thermostat ($250) doesn't introduce just one radical rethinking of the thermostat; it introduces four of them.
Read more at
http://www.nytimes.com/2011/12/01/technology/personaltech/nest-learning-thermostat-sets-a-standard-david-pogue.html?_r=2

Policy

China releases national energy-saving standard for central ACs

According to China's National Standardization Committee, the country's national energy-saving standard for central air conditioners has been approved and became effective on November 1, 2011.
'The Technical Specification for Energy-saving Control Device for Central Air-conditioning Chiller System,' with standard code GB/T 26759 – 2011, was drawn up by an expert committee led by China's leading central air conditioning company, Guizhou Huitong Huacheng Building Technologies. The standard is China's first technical standard in the field of central air conditioning control system. The use of the standard will greatly reduce central air conditioning system energy consumption
http://www.ejarn.com/news.asp?id=17052&classid=20

Backstage battle over EU energy efficiency directive

Targets proposed in the EU's draft energy efficiency directive are being contested by member states, with Britain and the Netherlands pushing for some provisions to be deleted entirely.
One headline figure in the original directive – a mandatory 3% annual public buildings renovation rate – has been slated for deletion in the latest EU draft, seen by EurActiv.
One EU diplomat involved in the discussions told EurActiv that the amendment had been made because of "the current budgetary restraints of member states."
"Because of these, there are many questions by member states about what the implication of this specific provision would be," the diplomat said. "There are many different views in play on how this could be changed."
http://www.euractiv.com/energy-efficiency/backstage-battle-energy-efficiency-directive-news-508705

Beijing requiring solar energy household heaters from 2012

Beijing is taking the lead in China by applying a 75 % energy saving standard for residential buildings next year. As a result, newly-built urban buildings and qualified public buildings will be required to install solar energy heaters. The Beijing Municipal Commission of Housing and Urban- Rural Development and the Beijing Municipal Commission of Development and Reform have jointly released the energy saving plan for residential buildings during the 12th Five-year Plan on September 1.
http://www.ejarn.com/news.asp?ID=17059

Comment by CECED on the WEEE Directive: Let's iron out the inconsistencies

As a comment to the Waste Electrical and Electronic Equipment (WEEE) Directive, CECED points out that two-thirds of WEEE never finds its way into producer recycling schemes. This WEEE falls outside the WEEE Directive's recycling target. The Directive's revision must address this issue.
According to the WEEE revision (article 11.1), only producers, and recyclers contracted on behalf of producers, are obliged to meet the recycling target. The article does not cover other players who want to arrange WEEE treatment. This leads to unsatisfactory recycling results.
According to CECD, Article 11.1 needs to be corrected: all players must meet the recycling target.
http://www.ceced.org/

Canadian GeoExchange Coalition Vice President Ted Kantrowitz to Chair National Renewable Energy Initiative

Canada's Electricity Sector Council today confirmed that CGC Vice President Ted Kantrowitz will chair the Steering Committee for its new Building Bright Green Futures (BBGF) initiative. The steering committee, made up of representatives from key Canadian industry stakeholders including associations, employers, unions, utilities and educational institutions, will oversee a comprehensive human resources study of the renewable energy industry.
http://www.geo-exchange.ca/en/vice_president_ted_kantrowitz_to_chair_national_re_nw210.php

DOE Updates National Reference Standard for Commercial Buildings to ASHRAE 90.1-2010

Following its analysis that ASHRAE's 2010 energy efficiency standard contains significant energy savings over the 2007 standard, the U.S. Department of Energy (DOE) has issued a ruling that establishes the 2010 standard as the commercial building reference standard for state building energy codes.
DOE attributes the greater energy savings to improvements in ANSI/ASHRAE/IESNA Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings, related to better lighting, daylighting, controls and building envelope and better mechanical systems and application to more systems.
http://www.achrnews.com/articles/118360-nov-29-2011-doe-updates-national-reference-standard-for-commercial-buildings-to-ashrae-9012010

Report highlights benefits of hybrid ground-source heat pump technology

The U.S. DOE has announced the availability of a report — Hybrid Ground-Source Heat Pump Installations: Experiences, Improvements and Tools — that DOE says demonstrates hybrid ground-source heat pumps (GSHP) as a viable solution to reduce energy use in commercial buildings. The report states that new hybrid systems significantly decrease upfront costs while delivering financial and environmental benefits nearly equivalent to standard ground-source heat pumps. With its lower price, hybrid GSHP technology could be deployed widely, saving energy and money in new and existing commercial, industrial, and institutional buildings, according to the report.
http://www.achrnews.com/articles/118264-nov-16-2011-report-highlights-benefits-of-hybrid-groundsource-heat-pump-technology

Working Fluids

Waitrose trials world-first HFO chiller

The first chillers using the new HFO refrigerants are being trialled by Waitrose at its supermarket in Bromley, Kent, UK.
Believed to be the world's first such installation, the Italian-made Geoclima chillers are based on Frascold reciprocating compressors and operate on Honeywell's HFO R1234ze.
The supermarket chain which announced two years ago that it was to switch to using hydrocarbons for all future new stores and refurbs has opted to trial one of the new so-called fourth generation low GWP HFOs.
http://www.acr-news.com/news/news.asp?id=2657&title=Waitrose+trials+world%2Dfirst+HFO+chiller

Germans inflame debate over 1234yf

The introduction of HFO-1234yf as the replacement for R134a in car air conditioning systems continues to cause controversy and deep divisions of opinion in Germany.
While car manufacturers around the world appear to have accepted 1234yf as the new refrigerant, its flammability is still a cause for concern in Germany where CO_2 had originally been championed to replace 134a.
http://www.acr-news.com/news/news.asp?id=2618&title=Germans+inflame+debate+over+1234yf

F-Gas company certification numbers grow

No more than 15% of companies are still to achieve full company certification under the F-gas regulations, according to latest figures from F-Gas Support. This marks a huge improvement on the situation on the July 4 deadline day when only around 50% of companies had upgraded to the mandatory full certification, leaving around 2,500 companies trading illegally.
Since the deadline it has been an offence to undertake installation, servicing and/or maintenance on stationary refrigeration, air-conditioning and heat pump equipment that contains or is designed to contain F gas refrigerants without valid certification.
http://www.acr-news.com/news/news.asp?id=2600&title=F%2DGas+Company+Certification+numbers+grow+

HFCs represent 0.6% of greenhouse gas emissions

THE 2010 AGGI (Annual Greenhouse Gas Index) reveals that in 2010, despite a continuous growth, HFCs represented only 0.605% of the atmospheric level of greenhouse gases, as communicated by the US NOAA global observing networks. In 2009, their share was 0.58%, and in 2008, 0.55%.
The EFCTC has reported that the figure reveals the high share of radiative forcing results for the "major gases", accounting for about 96% of the total, while the 15 "minor" halogenated gases contribute the remaining 4%. Major gases include CFC-11 and CFC-12 but exclude all other ODS.
Within the 4% "minor" gases contribution, HFCs (including HFC-134a, HFC-152a, HFC-125, HFC-143a, and HFC-23) represented 0.605 per cent of all GHG emissions.
http://www.acr-news.com/news/news.asp?id=2642&title=HFCs+represent+0%2E6%25+of+greenhouse+gas+emissions

The EIA urges EU to phase out F-gases by 2020

The Environmental Investigation Agency (EIA) is calling on the European Union to phase out HFC refrigerants by 2020.
EIA's new position paper End in Sight: Phasing Out Fluorinated Greenhouse Gases in Europe claims that with simple revisions to the F-Gas Regulation, currently under review, Europe could eliminate the use of HFCs. A phase-out of F-gases in the EU, based on prohibitions on use and placement in products, would save at least 60 million tonnes of CO_2 equivalent per year by 2030, says the EIA.
http://www.acr-news.com/news/news.asp?id=2653&title=The+EIA+urges+EU+to+phase+out+f%2Dgases+by+2020

HFCs must be curbed to protect climate, urges the UN

The United Nations has urged that HFCs, which are increasing in the atmosphere at a rate of 8% per year, could cancel the climate benefits won by the phase-out of CFCs and other ozone-depleting substances.
HFCs which have been widely used to replace CFCs and HCFCs are assessed by the UN's recent report HFCs: A Critical Link in Protecting Climate and the Ozone Layer, produced by the UN Environment Programme (UNEP). The report suggests that the global warming potential of HFCs in 2050 could be comparable with current emissions from the global transport sector.
http://www.acr-news.com/news/news.asp?id=2660&title=HFCs+must+be+curbed+to+protect+climate+urges+the+UN

No agreement on HFC "phase-down"

While support for the initiative grows, plans to curb the use of HFC refrigerants were again baulked at the latest Montreal Protocol meeting in Bali in November.
The number of countries backing a "phase-down" in the use of high-GWP HFCs has grown to 108 countries (up from 91 last year) out of the 197 signatories, but the initiative failed to be passed because China and India objected. Meanwhile, reports suggest that Canada, one of the first to sign up to the Kyoto Protocol in 1998, may be about to pull out.
http://www.acr-news.com/news/news.asp?id=2670&title=No+agreement+on+HFC+%22phase%2Ddown%22

China threatens climate ransom over HFC-23

China has responded to efforts to ban the trading of HFC-23 offsets by threatening to release huge amounts of the chemical into the atmosphere unless other nations pay what amounts to a climate ransom.
China has made the threat in the run-up to the international climate negotiations in Durban later this month and comes after the European Union and other nations moved to ban HFC-23 credits from internal carbon trading mechanisms which recognises perverse incentives that are created by these credits in the Clean Development Mechanism (CDM).
The vast amounts paid for HFC-23 offsets have led to factories in China and elsewhere manufacturing more HCFC-22 and its HFC-23 by-product than necessary, just to maximise the amounts paid to destroy HFC-23 through the UN-backed carbon trading scheme.
In a shocking attempt to blackmail the international community, Xie Fei, revenue management director at the China Clean Development Mechanism Fund, threatened: "If there's no trading of [HFC-23] credits, they'll stop incinerating the gases" and vent them directly into the atmosphere. Speaking at the Carbon Forum Asia in Singapore last week, Xie Fei claimed he spoke for "almost all the big Chinese producers of HFCs" who "can't bear the cost" and maintain that "they'll lose competitiveness."
http://www.acr-news.com/news/news.asp?id=2650&title=China+threatens+climate+ransom+over+HFC%2D23

California rolls out new refrigeration regulations

In an effort to reduce leaks of refrigerant gases that contribute significantly to global warming, the California Air Resources Board is rolling out unprecedented state regulations on supermarkets and other facilities that use commercial refrigeration systems.

The regulations, launched in January 2011 but scheduled to ramp up on Jan. 1, 2012, apply to any business using more than 50 pounds of refrigerants with high global warming potential (GWP); these refrigerants include the HCFCs and HFCs commonly used by food retailers.

The initial regulations include periodic leak inspection (annually, quarterly or monthly, depending on size), repairs, retrofit or retirement plans, required service practices and recordkeeping; any detected leaks must be repaired within 14 days of discovery. Adding 5 pounds or more of refrigerant, or 1% or more, would trigger a leak inspection under the rules.
http://supermarketnews.com/technology/california_refrigeration_1115/

Fake refrigerants becoming a 'serious problem'

Companies have been warned to only purchase refrigerants from authorised and reputable suppliers as evidence mounts that highly dangerous fake refrigerants are a far greater problem and more widespread than many realise.

The recent fatal incidents involving refrigerated cargo containers are far from unique and similar incidents have already hit Europe. There have been previous deaths and the problems aren't restricted to R134a systems or to mobile applications.
Leading German independent research company ILK Dresden has been researching incidents with methyl chloride, or R40, since 2009 when it was called in to investigate a case involving mobile air conditioning systems in Greece. Since then the company has been involved in a number of investigations involving R22/R40 cocktails turning up in both stationary and mobile systems.

Ulrich Grimm, head of group new technologies/materials at ILK Dresden, declined to be drawn into specific details for reasons of client confidentiality, but warned: "This is a serious problem". Although not involved in the current reefer explosion investigations, Ulrich Grimm revealed that his company had been called in to look at four other new cases recently, one particularly serious and on-going. "I am expecting to see an increasing situation over the next month," he said.
http://www.acr-news.com/news/news.asp?id=2654&title=Fake+refrigerants+becoming+a+%27serious+problem%27

Honeywell extends fight against fake refrigerants

Honeywell today announced today that it has expanded its ongoing campaign against counterfeit refrigerants being fraudulently sold under the Honeywell Genetron brand name in the Middle East.

Approximately 6,000 cylinders of fake refrigerant branded as Honeywell Genetron 134a were seized in August in the UAE. They were found to contain "dangerous toxic and flammable substances" says the press statement.

This recent seizure is part of the refrigerant manufacturer's 10-year campaign against counterfeiters with successful seizures in more than 20 countries over six continents. During the last two years alone, Honeywell, working with local governments, have seized more than 200,000 counterfeit products.
http://www.acr-news.com/news/news.asp?id=2666&title=Honeywel+extends+fight+against+fake+refigerants

ACR industry will exceed emission reduction targets, says EPEE

A new study by EPEE suggests that the European refrigeration and air conditioning industry will exceed the emission reductions targets set by the EC.

A report carried out on behalf of EPEE by the French research bodies ARMINES / ERIE reveals that CO_2 eq emissions from refrigeration, air-conditioning and heat pump equipment have decreased by over 13% since 1990 and are set to decrease even further in the coming 20 years. The evidence suggests that regulations on ozone depleting substances and fluorinated gases (F-gases) have made an impact on the figures even though the refrigerant bank doubled over the past 10 years. CO_2 eq emissions have already decreased substantially by more than 13%, for the coming 20 years, the study predicts a further emissions reduction between 15% and 60% whilst assuming continuous market growth.
http://www.acr-news.com/news/news.asp?id=2624&title=Acr+industry+will+exceed+emission+reduction+targets%2C+says+EPEE

Technology

Will air-conditioned clothing soon be a reality?

A micro-compressor the size of a pen could soon enable personal air conditioning. The 10-cm long and 5-cm wide unit weighing 100 g was developed by Embraco. It can be sewn into the fabric of clothing such as fire-fighters' or Formula-1 drivers' clothing. When temperatures rise, hot air is sucked into the unit, cooled by the micro-compressor, then propelled through a network of thin tubes in the clothing.
Discussions with Formula-1 teams, armies and fire-fighting services are underway and the developers also hope the product will be used in paramedics' blankets to help reduce bleeding, to refrigerate organs being transplanted and against overheating of LCD screens. A pilot-line of the micro-compressor is scheduled for the second half of 2011.
http://www.embraco.com/default.aspx?idNoticia=109&tabid=207

Markets

MHI in AC joint venture with Chinese retailer

Mitsubishi Heavy Industries has established a residential air conditioning sales joint venture with China's largest home appliance retail chain Suning Appliance.

The new company, MHI Residential Air-Conditioners (Shanghai), is to begin operation on 1 January 2012 with a view to developing the growing residential-use air-conditioning market in China. MHIRS is capitalised at around £3.1m, with MHI holding 85 per cent and Suning Appliance 15 per cent.
In China, annual demands for residential-use air-conditioners are more than 30 million units per year; however, with large shares of the market taken by Chinese manufacturers, Japanese manufacturers are facing tough times. The demand for AC units with inverter functions has been increasing rapidly due to enhanced energy-saving regulations which has resulted in Japanese manufacturers aiming to gain ground through product technology established in the Japanese market.
http://www.acr-news.com/news/news.asp?id=2623&title=MHI+in+ac+joint+venture+with+Chinese+retailer

Daikin to build its largest ever factory in China

DAIKIN is to build an air conditioning factory capable of producing 1.5 million units per year in China's Jiangsu Province, according to unconfirmed reports in the Chinese media.

The factory will cost Daikin will invest about 18 billion yen (£150m) in the new plant and employ around 4,000. The new plant is scheduled to start operations in April 2012, they said.
http://www.acr-news.com/news/news.asp?id=2591&title=Daikin+to+build+its+largest+ever+factory+in+China

Refrigerated display cabinet market to hit $5.34bn by 2017

A new report from Global Industry Analysts, Inc. suggests that the world market for refrigerated display cabinets (RDC) will boom in the coming years.
The report proposes that a change in lifestyles and expendable income that will result from an increase in urbanisation, and greater demand for refrigerated products will specifically increase the demand for RDCs in supermarkets, hypermarkets and grocery shops to preserve, store and transport temperature-sensitive products.
http://www.acr-news.com/news/news.asp?id=2612&title=Refrigerated+display+cabinet+market+to+hit+%245%2E34bn+by+2017

Increasing HFC production in China

With demand for HFCs still rising around the world, a number of top producers have acted to increase supplies into the Far East.

The Arkema Daikin Advanced Fluorochemicals joint venture formed last year has announced a 30% increase in the production of HFC125 and the construction of a refrigerant blend unit at its Changshu site in China. The additional HFC125, a key component of R410A, will merely meet increasing demand from air conditioning manufacturing customers in China and South East Asia. The joint venture has also announced the construction of a new production plant for R410A on the same site.
http://www.acr-news.com/news/news.asp?id=2606&title=Increasing+HFC+production+in+China

Energy-saving buildings boom in China

China is promoting energy-saving and low-carbon building renovation in the construction industry. Many local governments have also implemented policies to realize energy-saving goals during the 12th 'Five-year Plan.' According to statistics from the China Energy Conservation Association (CECA), among 40 key cities designated to create energy-saving public buildings by the Ministry of Housing and Urban–Rural Development (MOHURD) of China early this year, if each city renovates 4 million m2 of buildings to energy-saving designs, the 40 cities would create a market of RMB 400 billion (about US$ 63 billion) and expand business opportunities nationwide.
http://www.ejarn.com/news.asp?ID=17040

Hill Phoenix acquires Advansor A/S

Hill Phoenix Inc., a Dover Company, has announced the acquisition of Denmark-based Advansor A/S. The Danish company specializes in the design and manufacture of CO_2 transcritical refrigeration and heat pump systems for supermarkets and light industrial applications. According to Hill Phoenix, the two companies have more than 550 CO_2 systems operating in supermarkets in the United States, Canada, and Europe, making the combination the largest manufacturer of CO_2 refrigeration systems in the world.
http://www.achrnews.com/articles/118223-nov-11-2011-hill-phoenix-acquires-advansor-as

Electric heating appliance market in Japan

In the wake of the summer sales race, signs of the winter sales race are already turning up in the display corners of appliance retailers. As a result of the earthquake disaster in March and the subsequent setsuden (electricitysaving) mood, consumers are taking renewed interest in kerosene space heaters as a household heating appliance.
http://www.ejarn.com/news.asp?ID=17067

IEA Heat Pump Programme News

Canada to host the next IEA Heat Pump Conference

The Canadian GeoExchange Coalition (CGC) has been awarded the organization of the 11th International Energy Agency Heat Pump Conference (IEA-HPC). The prestigious world-industry conference, organized every three years under the auspices of the IEA Heat Pump Programme, will be held in Montreal in spring 2014. The IEA Heat Pump Programme Executive Committee, made up of one representative from each of fourteen member countries, decided the location in Atlanta (US) at its meeting in November.
http://www.geo-exchange.ca/en/UserAttachments/news518_PR%20 02-12-2011_E%20IEA%20HPC%20 2014.pdf

Change of alternate delegate for Japan

Japan has announced that the previous alternate delegate within the HPP Executive Committee, Makoto Tono, has left this position for new challenges. This ExCo alternate position will now be held by two individuals, see below.
We want to express our deep gratitude to Mr. Tono for the years of work for the HPP ExCo, and at the same time welcome the new ExCo alternate members.

The new alternate members are

Takeshi Hikawa
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Heat pump market and technology in China

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Summary

Living standards in China are rising in step with the rapid increase in urbanisation and the strong growth of GDP. Heat pumps are one way of improving indoor air quality. The increasing emphasis on energy efficiency in buildings and utilisation of renewable energy also assist the market penetration of heat pumps. This paper describes the general economic situation and heat pump market and technologies in China.

1. Background

1.1 High growth of GDP

Figure 1 shows the GDP growth rate from 1978 until 2010. China's average quarterly GDP growth was 9.3 %, reaching a historic high of 14.2 % in December 1992 and a record low of 3.8 % in December 1990. Over the last 30 years, China's economy has changed from a centrally planned system, that was largely closed to international trade, to a more market-orientated economy with a rapidly growing private sector. China continued its bullish growth rate by posting a 10.4 % GDP growth rate in 2010, reaching a total of USD 5159 billion that year (USD 1 = RMB 6.6). Over the same period, average GDP growth rate of the rest of the world economy was only about 3.3 %. The GDP growth gives people the space to improve their living standards, especially indoor temperatures.

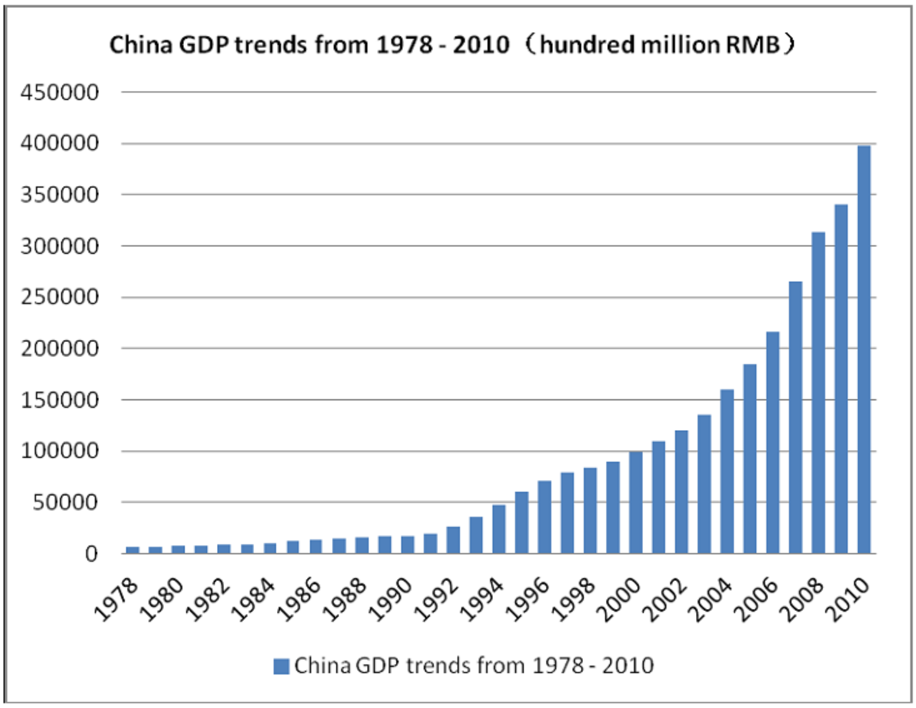

Figure 1 Chinese GDP trends, 1978-2010

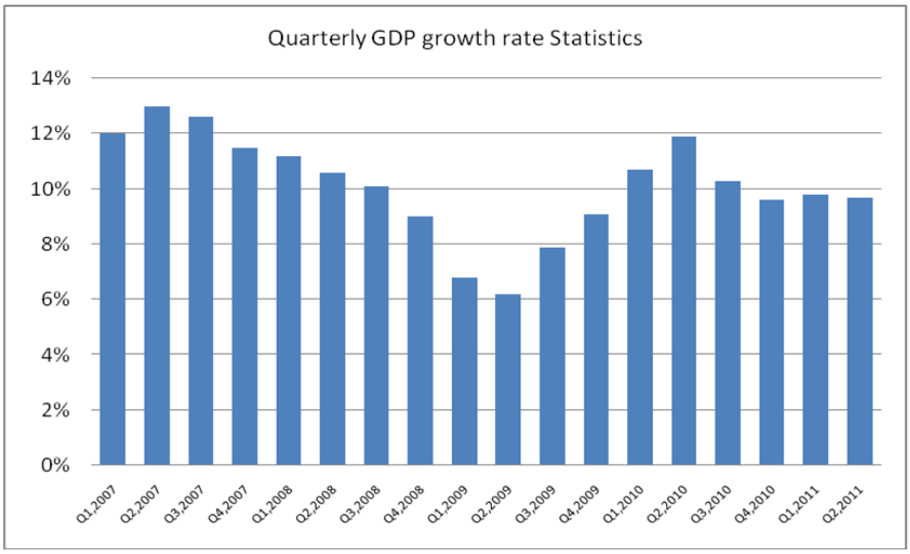

Figure 2 Quarterly GDP growth rate, 2007-2011

Even during the current world financial crisis, it continues to grow at more than 6 %. From Figure 2 we can see that the financial crisis hasn't had a particularly negative impact on China's economy.

1.2 Urbanisation rate

China is pushing forward urbanisation in an active and steady manner, focusing on gradually transferring rural residents qualified for urban household permits into cities. The urbanisation rate was just 10 % when the People's Republic of China was founded in 1949, with a slow increase to 17 % in 1978, after which the urbanisation rate started to increase more rapidly, as can be seen in Chart 3. It is expected that the urbanisation rate will rise from 47.5 % in 2010, based on the
Five-Year Plan, to 51.5 % by the end

of 2015. Before 2050, the urbanisation rate will reach 70 %.

1.3 Energy efficiency and renewable energy

Since 2004, in response to climate change, assurance of energy supplies and reduction of energy demand, the Chinese government has published a series of policies to promote energy efficiency and increase renewable energy supplies. The "State Council Decision on Strengthening Energy Conservation" sets a higher goal for energy efficiencies of buildings and related products, including heat pumps.

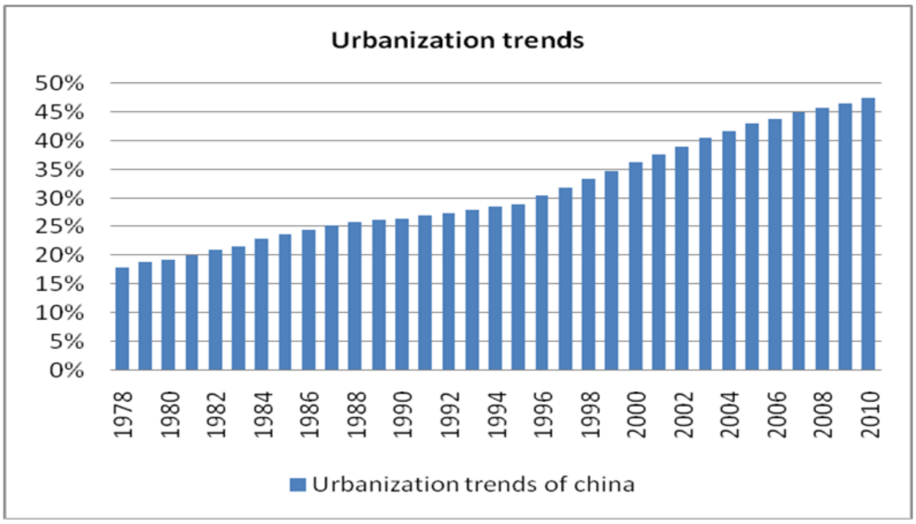

Figure 3 China urbanisation rate

2. The heat pump market

2.1 Domestic air conditioning units

In China, 85 % of domestic air conditioning is by means of air–to-air heat pumps. From about 40 units per 100 families in 2001, the number has tripled in the last ten years. Since China is going to set up the "Top Runner" scheme and continue to subsidise energy-efficient appliances, and intends to provide financial support for appliances sold to rural areas, coupled with replacement of old appliances, this number will be doubled in the next five years.

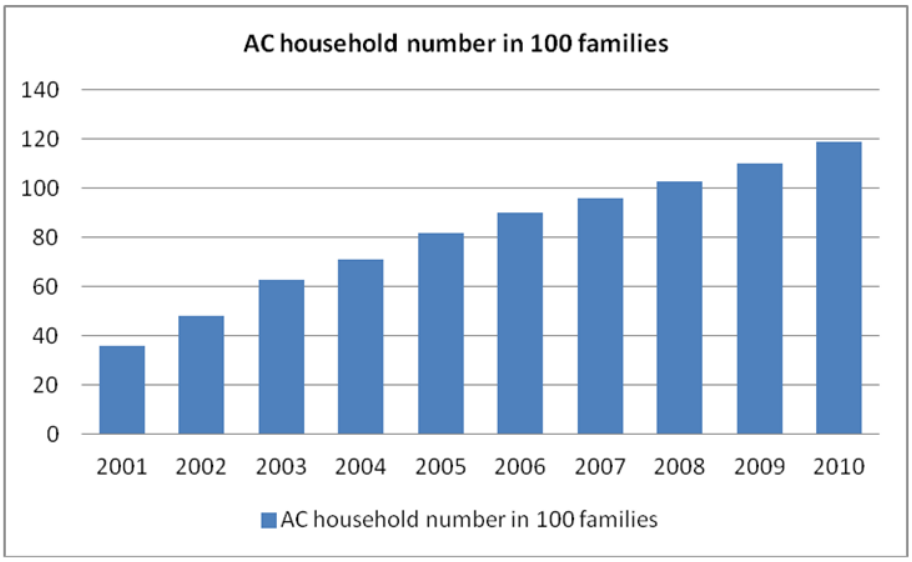

Figure 4 Domestic air conditioning growth rate

With low prices, exports have increased, with only a slight fall in 2008 and 2009. In 2010, exports amounted to 40 million units.

2.2 Ground-source heat pumps

Unlike the air-to-air heat pump, ground-source heat pump systems are considered as renewable energy systems, which can be utilised in buildings to provide heating, cooling and hot water together. The Ministry of Housing and Urban-Rural Development and Ministry of Finance therefore set up a special subsidy to promote and demonstrate the technology in special projects, cities and towns.

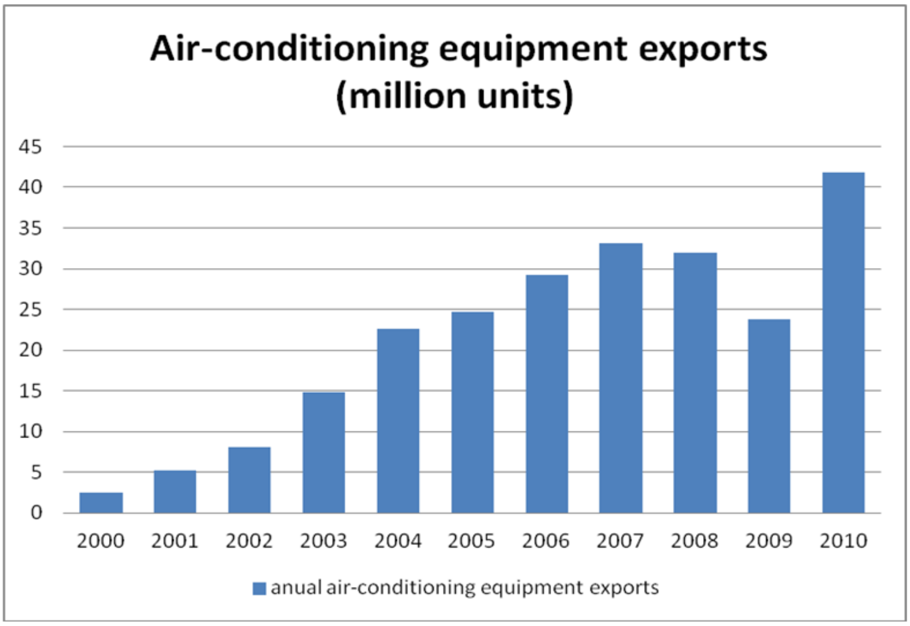

Figure 5 Domestic air conditioning export 2000-2010

With this strong promotion from government, the GSHP increased from nearly zero in 2000, to heat supply to 139 million m^2 in 2010. In the next five years, based on the objective from the MOHURD, the renewable energy utilised in buildings is expected to increase to 2.5 billion m^2, which include GSHPs and solar energy. As a comparison, two-bedroom dwellings (about 70-100 m^2) account for 45 %, and three-bedroom dwellings (about 90-150 m^2), account for 31 % of apartments.

2.3 Heat pump water heaters

In China, the domestic water heater was mainly dominated by electric water heaters, solar water heaters and gas water heaters. Statistics from 2008 show that heat pump water heaters accounted for only 3.2 % of the total market (with a total market worth RMB 1.8 billion), corresponding to 440 000 heat pump water heater units, out of a total of 150 million water heater units of all types. But total sales of heat pump water heaters amounted to only RMB 300 million in 2003, so the increase is actually very high. By 2010, total sales had already reached RMB 3 billion. The market is predicted to be worth RMB 10 billion in 2015.

3 Technology trends

3.1 Domestic air conditioning units

Recently, a group of related air conditioner standards has been updated. The standards are "Minimum allowable values of energy efficiency and energy efficiency grades for room air conditioners" (GB 12021•3-2010), "Minimum allowable values of energy efficiency and energy efficiency grades for variable-speed room air conditioners" (GB 21455-2008), and "Minimum allowable values of Integrated Part Load Value (IPLV) and energy efficiency grades for multi-connected air-conditioning (heat pump) units" (GB 21454-2008). Each of them increases the minimum required COP value from 2.6 to 3.21.

[1]*Test conditions: Indoor inlet air temperature: Dry bulb temperature is 27 ℃, wet bulb temperature is 19 ℃. Outdoor inlet air temperature: dry bulb temperature is 35 ℃, wet bulb temperature is 24 ℃.*

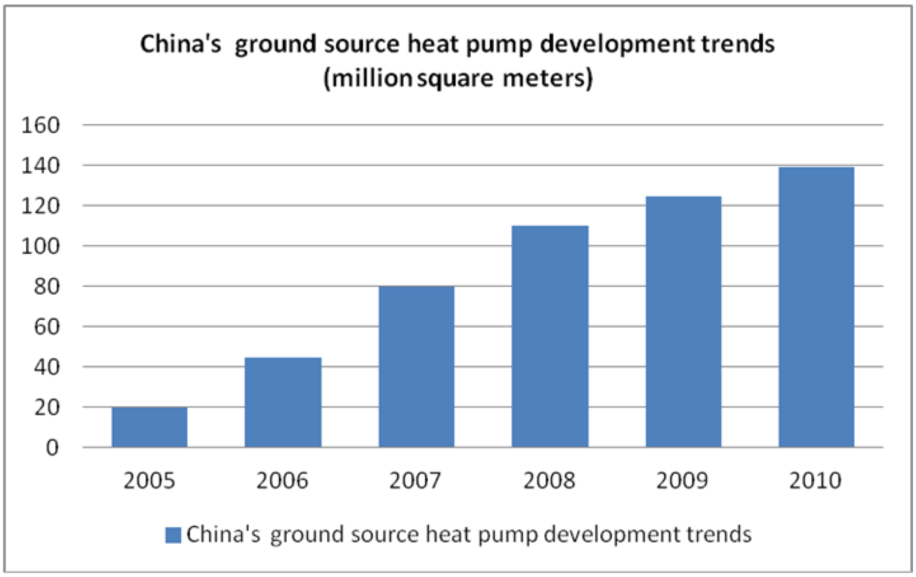

Figure 6 GSHP growth in China

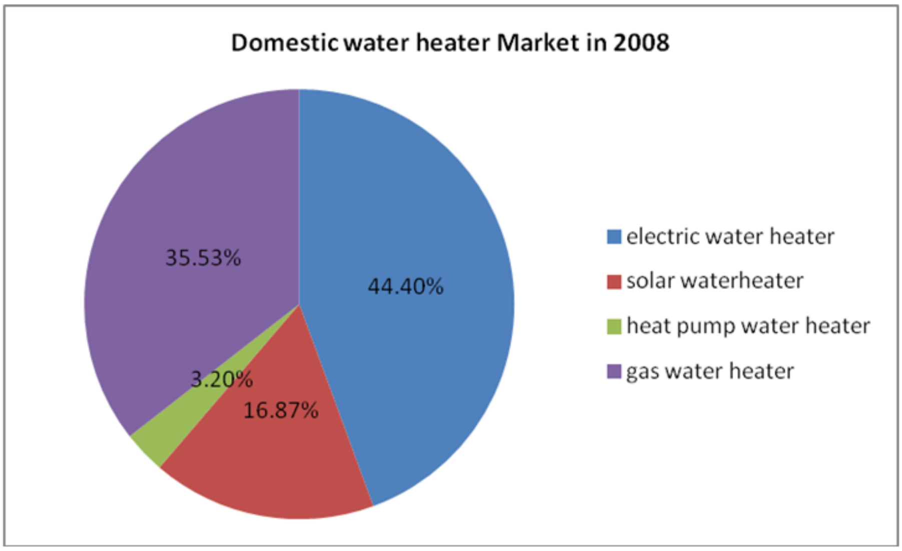

Figure 7 Domestic water heater market in China

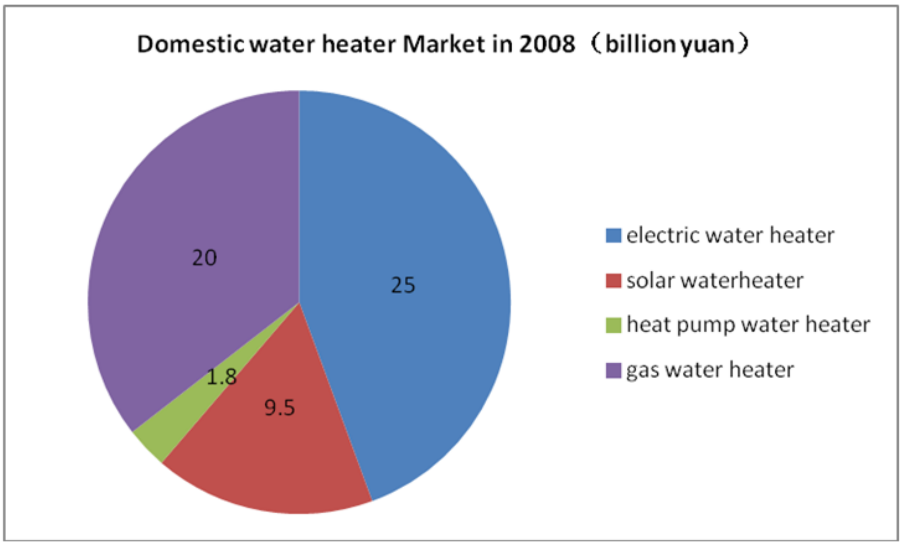

Figure 8 Domestic water heater market sales

In the future, the main area of competition between manufacturers will be in increased COPs. For domestic heat pumps, variable-frequency air conditioners will become more popular. For heat pumps intended for use in northern areas, problems of de-frosting and optimised operational control need to be studied. Research will be concentrated on the use of IPLV to evaluate air-to-air heat pumps, and on how to integrate heat pumps, solar heaters and floor heating systems.

3.2 Ground-source heat pumps

The "Technical code for ground-source heat pump systems" (GB 50366-2009), the national standard for GSHPs, was first published in 2005, and revised in 2009 in the light of R&D results from the 11th Five-Year programme ("Key Technology Research and Demonstration of Ground Source Heat Pump Systems").

- For GSHP systems, greater attention will be paid to next-generation design software, pre-design system evaluation, and integration with solar systems.
- For ground-coupled systems, greater emphasis will be given to standardisation of TRT and system integration.
- For underground water heat pump systems, there will be greater focus on collaboration between building engineers and geological engineers.
- For surface water systems, which include river water, sea water and sewage effluent, the main areas of work will be how to use the heat source without adverse effect on the environment.

For the WSHP units, the Variable Refrigerant Volume (VRV) water source (also known as VRF) system seems to be based on the rapid growth of GSHP systems and VAV systems. However, the higher initial cost, and lack of suitably trained installation engineers, are problems for this kind of system.

3.3 Heat pump water heaters

Some standards in this area came into effect recently:

- "Heat pump water heaters for commercial and industrial and similar applications" (GB/T21362-2008) came into effect on May 1st 2008;
- "Heat pump water heaters for household and similar applications" (GB/T23137-2008) on September 1st 2009, specifying a minimum required COP of 3.4 ;
- "Specifications of air source heat pump assisted domestic solar water heating systems" (GB/T 23889-2009) was published on January 1st, 2010.

The main obstacles for heat pump water heaters are high price, low awareness, and no government subsidy. How to solve these problems and compete with other domestic water heaters will be the main working area for the manufacturers. As far as the technology is concerned, trans-critical CO_2 heat pump water heaters will be promoted.

4 Final comments

During the 11th Five Year Plan (2006-2010), China made genuine progress in energy conservation, emissions reduction, ecological improvement and environmental protection. Energy consumption per unit of GDP fell by 19.1 %, chemical oxygen demand by 12.4 % and sulphur dioxide emissions by 14.3 %. These savings are equal to 630 million tonnes of carbon equivalents and 1.46 billion tonnes of CO_2. In the 12th Five Year Plan (2011-2015), the State has set the target of a 16 % decrease in energy consumption per unit of GDP, which means that all types of heat pump will be increasingly used in the future. Let's wait and see.

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Annexes, ongoing

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

While it is widely accepted that heat pumping processes play an important role in environ-mentally friendly heating and cooling of buildings, it is much less widely realised that the energy to drive this process need not necessarily be electricity. Fuels such as gas or oil can be used as the energy input, or even hot water. Such "thermally driven heat pumps" could be used to reduce the load on the electricity grid, or even show benefits in terms of primary energy savings in some cases. The goal of Annex 34 is therefore to widen acceptance and knowledge of these kinds of heat pumps.

Even though the technologies for thermally driven heat pumps have been available for several years, there has been no common standard for determination of their performance figures as, for example, for gas-driven heat pumps. Those involved in Annex 34 have therefore started with pre-normative work by defining a common understanding of boundary conditions and measurement procedures for these systems, to feed this material into standardisation bodies and the scientific community. The figure is a diagrammatic example of a heat pump system and its relationship to different energy sources, developed in conjunction with SHC Task 38 and 44, and providing a base for performance calculation.

The proposals from the Annex 34 group have been discussed within the German Guideline VDI 4650-2 "Gas driven heat pumps", published in October 2011, and in EN 12309 "Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances" which will be circulated for comments in January 2012.

In addition to the discussion concerning performance figures for heat pumps, Annex 34 has also developed a proposal for a standardised measurement procedure for sorption materials. This was presented at the International Sorption Heat Pump Conference ISHPC 2011, April 6-8 in Padua, Italy, at the HPC 2011 web conference, and at the OTTI Solar Air conditioning Conference in 2011.

In addition to this work on standardisation, several development projects - ranging from new sorption materials and new heat exchanger designs to system concepts - have been part of the work of the Annex and have been presented in recent HPC Newsletters.

After dissemination and discussion of the results of Annex 34, the work will continue in two different groups: SHC Task 48 for solar cooling, and a new HPP Annex for fuel-driven heat pumps.

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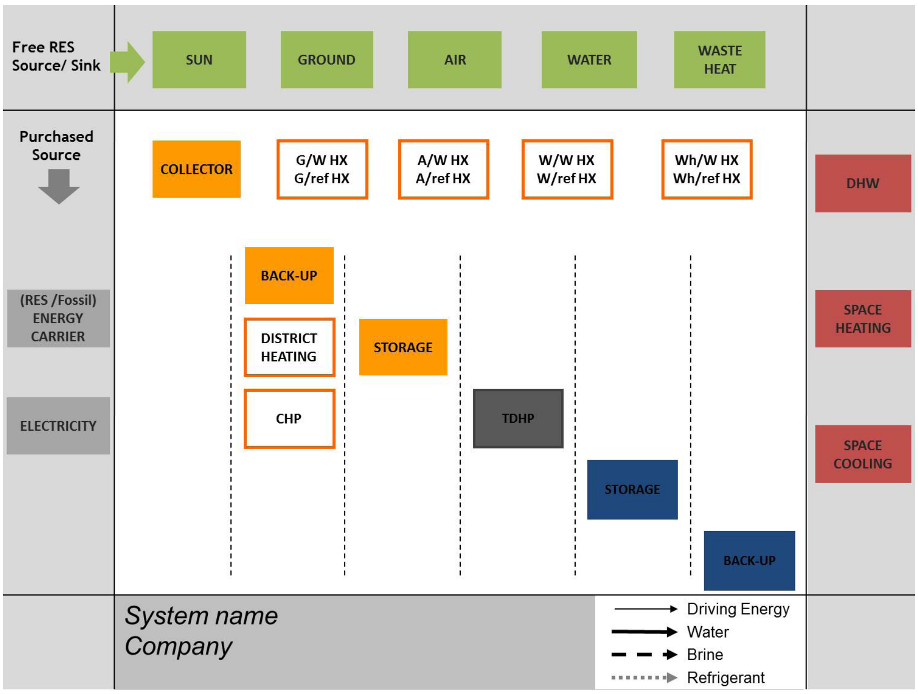

IEA HPP /IETS Annex 35 / 13 Application of Industrial Heat Pumps

On 27-28 September 2011, Annex 35 / 13 - a joint venture of the IEA Implementing Agreements "Industrial Energy-Related Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP) - organised its second Annex Meeting and a workshop on "Industrial Heat Pump applications" in connection with the European Heat Pump Summit at the Nuremberg/Germany Exhibition Centre.

The Annex Meeting was attended by 18 participants from nine member countries. On request of the Dutch participant, the definition of industrial heat pumps has again been discussed, resulting in the following definition:
"Heat pumps which are used for heat recovery and for heat upgrading or cooling/ refrigeration in industrial processes, or for heating and cooling in industrial buildings"

Discussions were again concentrated on Task 2, "Modelling calculation and economic models". An in-depth study (SWOT analysis) of available software and calculation procedure has been proposed by the Dutch and Swedish participants, and will be carried out by Delft University. Major discussion points have concerned user needs, use / update of the Annex 21 Screening program and recommendations for a draft survey for stakeholders (heat pump manufacturers, consultants, industrial requirements).

The first Annex Meeting of 2012 will be held in Denmark, hosted by the Danish Technological Institute. It was also agreed that an Annex 35/13 workshop will be arranged in connection with a major industrial conference, such as Achema 2012 in Frankfurt/M or Chisa 2012 in Prague.

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IEA Annex 36 Quality Installation / Quality Maintenance Sensitivity Analysis

Annex 36 is evaluating how installation and/or maintenance deficiencies cause heat pumps to perform inefficiently and waste energy. The focus and work to be undertaken by each participating country is given in the table below.

The Annex is scheduled to run through November 2013 with future working meetings planned for September 2012 (in the U.S.) and the fall 2013 (in France). In addition a web/ phone meeting is tentatively planned for early 2012 (in advance of the May 2012 ExCo meeting).

Progress since the June 2011 working meeting:
In the UK, based on analysis of data from the first year of the Energy Saving Trust's (EST) field trials, the Department of Energy and Climate Change (DECC), EST and the heat pump industry have collaborated to produce new guidelines for the installation of domestic heat pumps. DECC is currently funding road-

Annex 36 Participants	Focus Area	Work to be Undertaken
France	Space heating and water heating applications.	Field: Customer feedback survey on HP system installations, maintenance, and after-sales service. Lab: Water heating performance tests on sensitivity parameters and analysis.
Sweden	SP -Large heat pumps for multi-family and commercial buildings KTH/SVEP – Geothermal heat pumps	Field: SP – literature review of operation and maintenance for larger heat pumps. KTH/SVEP - investigations and statistical analysis of 22000 heat pump failures. Modeling/Lab: Determination of failure modes and analysis of found failures (SP) and failure statistics (KTH/SVEP).
United Kingdom	Home heating with ground-to-water, water-to-water, air-to-water, and air-to-air systems.	Field: Replace and monitor five geothermal heating systems Lab: Investigate the impact of thermostatic radiator valves on heat pump system performance.
United States (Operating Agent)	Air-to-air residential heat pumps installed in residential applications (cooling and heating).	Modeling: Examine previous work and laboratory tests to assess the impact of ranges of selected faults covered augmented by seasonal analyses modeling to include effects of different building types (slab vs. basement foundations, etc.) and climates in the assessment of various faults on heat pump performance. Lab: Cooling and heating tests with imposed faults to correlate performance to the modeling results.

shows to inform installers about the changes. The trade bodies and training associations are updating training programmes. The new guidance and the emitter guide can be found here *http://www.microgenerationcertification.org/installers/installers* (MIS 3005 Version 3.0 plus associated files). Principal differences between the old and new guidelines are:

1) Heat pumps to be sized to meet space heating demand for 99% of the hours in a year, with geographical variations in temperature throughout the UK taken into account.

2) Clearer guidance on sizing ground loops or boreholes.

3) An "Emitter Guide" has been produced to indicate to the installer and customer the effect on efficiency of using different types of heat emitter (standard radiators, oversized radiators, fan assisted radiators or underfloor heating).

In the US, the National Institute of Standards and Technology (NIST) completed heating mode laboratory tests of a heat pump in both fault-free (baseline) and single-fault heating status for the most common faults observed in US heat pump installations. Correlations were developed for performance degradation due to the selected installation faults. These correlations, along with the cooling mode correlations developed earlier, will be used in annual house/heat pump simulations. Laboratory testing with multiple faults will be performed later after annual simulation results are available indicating the most influential installation parameters.

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IEA HPP Annex 37

The aim of this project is to demonstrate and disseminate the economic, energy, and environmental potential with heat pumping technology. The focus will be on modern technology, and results from already performed field measurements will be used to calculate energy savings and CO_2 reductions. It should be possible to predict the most suitable heat source and heat pump system for a specific application in a specific geographic region. In order to draw the right conclusions, it is most important that the quality of the measurements is guaranteed. The criteria for good and assured quality will be defined in the project. An additional goal is to establish a database connected to the Heat Pump Centre website, where data from field measurements will be presented.

In order to achieve the objectives of the Annex, the activities have the following structure:

Task 1 (Task leader SP, Sweden)
Make a common template of what should be communicated. The focus is on the template content. Cosmetics are not considered in this task.

Task 2 (Task leader Plainair SA, Switzerland)
Define criteria for good quality of field measurements (e.g. boundaries of the measured systems, number and location of measuring points, measurement uncertainty, time increments etc.) and determine what parameters are important for assured quality.

Task 3 (Task leader AIT, Austria)
Collection and evaluation of ongoing and concluded field measurements on heat pump systems. The focus is on the best available technology.

Task 4 (Task leader not decided)
Agree how to recalculate the selected annual performance measures, such as seasonal performance factor, energy savings and carbon footprints. Calculation of SPF, electricity consumption, energy savings and CO_2 reductions from the collected measurements. These parameters will be compared with those for other heating systems. For thermally driven heat pumps, Annex 34's definition of SPF will be applied. Regarding systems with heat pumps combined with solar thermal, the results from the work of combining the solar fraction or solar savings fraction with an SPF, that is ongoing in Task 44 of the IEA Solar Heating and Cooling Programme/Annex 38 of the IEA Heat Pump Programme, will be considered.

Task 5 (Task leader SP, Sweden)
Establish a database connected to HPC website based on data from field measurements and the common template; the best examples will be documented.

Task 6 (Task leader DECC, United Kingdom)
Information dissemination

Information to installers and manufacturers should contain good examples, but it could also contain bad examples with mistakes that are often made and should be avoided. This information should support further development of training documentation (e.g. EU Certified Heat Pump Installer) and also installation manuals and regulations supplied by the manufacturers.

The work in Task 1 is completed (see HPC Newsletter no. 3, 2011)
The work in Task 2 is completed and there are three types of criteria for good quality of field measurements:

1. General selection (building, site, use, power….)

- Heat power output: no limit
- Heat sources: all possible
- Heat pump machine: only standards (no specials, no prototypes)
- Heat pump with label or certification (EHPA, CERT) is preferable
- Heat pump covers at least 80-90 % of yearly energy
- Situation: no extreme inside the region (regarding climate, height etc.)

- System new or retrofit
- Use for heating only or heating only and domestic hot water
- Hydronic: simple and standard, no exotics

2. Technical selection (method of measurement, accuracy…)

- SPF boundaries will be coordinated with Annex 39 and the SEPEMO project
- Climate correction of SPF according to FAWA
- Duration of measurement: at least one year
- Time step: maximum 1 week
- Collected data should be: Heat, Electricity, Running time, Starts/stops, Troubles, Running time electrical backup
- Placement of points of measurements according to the figure

3. Political selection by performance

- Availability (free from trouble) 99%
- Maximal cumulated time with faults of 20 h per year
- Maximum number of faults of 5 per year
- Consideration will be given to maximum energy consumption, since a building with high energy demand not is state of the art.
- Minimum SPF (not decided yet)

A working meeting was held on September 27th in Nürnberg in connection with the 2011 Heat Pump Summit. At the meeting participants from all four countries plus one observer from France contributed to finish Task 2.

A workshop was held together with Annex 39 on September 29th within the programme of 2011 Heat Pump Summit.
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IEA HPP Annex 38: Solar and Heat Pump Systems

The objective of Annex 38 of Solar Heating and Cooling, which is also Annex 38 of the Heat Pump Programme, is assessment of the performances and the relevance of combined systems using solar thermal and heat pumps. It also includes the creation of a common definition of figures of merit of such systems, the development of new simulation tools, and contribution to successful market penetration of these new systems.

The scope of the Annex comprises solar thermal systems in combination with heat pumps, for the supply of domestic hot water, space heating and (possibly) space cooling in residential buildings.

Participants are from research institutions, engineering firms and HVAC and the solar industry. There are about 50 participants at each meeting, from Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Portugal, Spain, Sweden and Switzerland.

Subtask A: Solutions and generic systems

Leader: Sebastian Herkel, Fraunhofer ISE, Germany
A review of market-available systems was started in Subtask A in 2010. The aim is to provide a more detailed description of each system, including specifications of the main components, hydraulic schemes and market availability. To date, 75 distinguishable products have been found. The greatest number come from German or Austrian manufacturers, followed by systems from Danish, French, Swiss and Swedish companies.

Classified by energy source of the heat pumps in these systems, the survey result indicates:

- 34 air;
- 34 ground;
- 2 water;
- 5 waste heat.

To visualize and to compare the most different concepts, a flow diagram has been developed, where all system components are shown either with an energy-storing function (blue) and/or with an energy transforming object (orange).

Along the top of the diagram are environmental energy sources (green): final energy or "energy to be purchased" is shown down the left-hand side. The right-hand side shows other useful energy applications. It is important to realise that the whole diagram is a qualitative representation, i.e. it does not show losses, component sizes or efficiencies. This means that any combination of components can be described, and all possible operational modes shown, in this conventional block-diagram format.

Subtask B: Performance assessment

Leader: Ivan Malenkovic, AIT, Austria
The objective of this subtask is to develop a common definition for performance figures of solar heat pump systems, and to define procedures for their assessment. This is an important goal, since the combined technology at present lacks standardised quality assurance methods – a fact that can have an adverse impact on future market development.

The results of the subtask should lead to a pre-normative definition of performance assessment methods for solar heat pump systems. The work is coordinated with a number of ongoing activities concerning other heat pump and solar thermal applications, and should provide a transparent basis for technology comparisons on both economic and ecological levels.

The output of the subtask should be of value to the industry for communicating the performance of the systems being promoted. The first achieved step in 2011 was to propose a systematic approach regarding the definition of performance figures.

This view is now shared among participants, enabling them to start working efficiently on the basis of a common language. All international activities need this step.

Subtask C: Modelling and simulation

Leader: Michel Haller, SPF, Switzerland

Subtask C of Annex 38 is about modelling and simulation, in the form of new models for components and systems for configuring a "solar and heat pump" systems.

Subtask D: Dissemination of results

Leader: Wolfram Sparber, Eurac, Italy

Subtask D covers dissemination of all the material and ideas produced by the Annex. The group is currently working on the production of teaching materials for S+HP courses.

These two subtasks' current production will be presented in a future Newsletter. 2011 was the second year of work for Annex 38, and more results on monitoring of systems and their simulation for sensitivity analyses will be available in 2012.

www.iea-shc.org/task44

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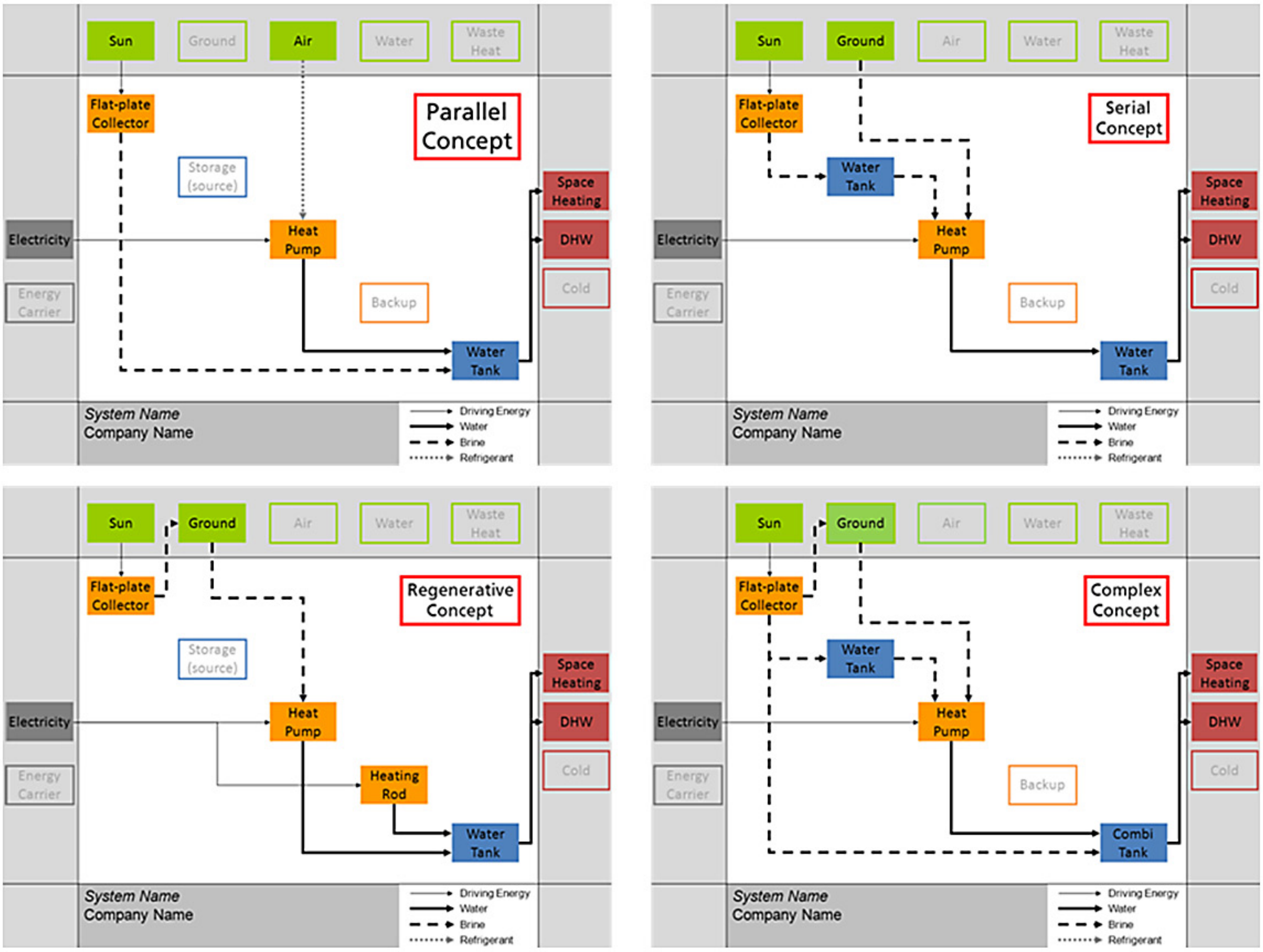
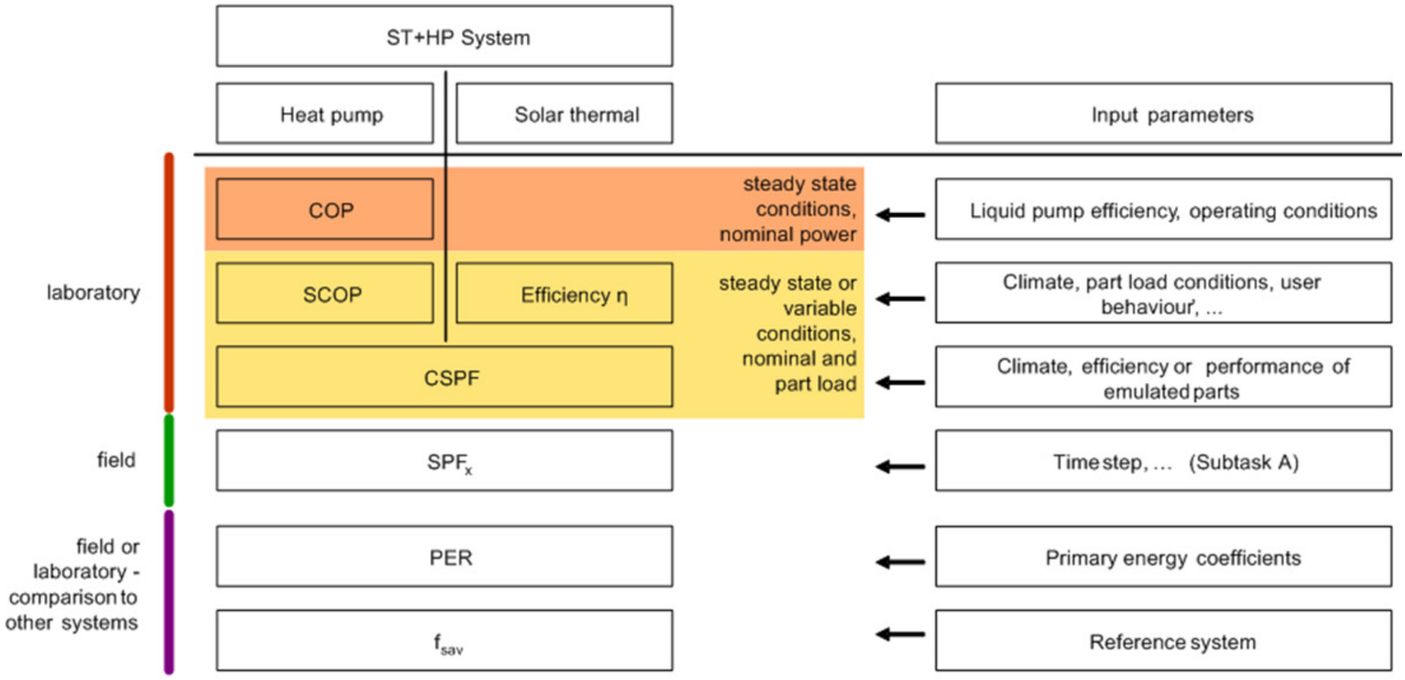


Visualisation schemes for four typical solar heat pump configurations (source: Fraunhofer ISE).



Understanding the multiple performance levels of a combined system, from components to the system, from steady state to dynamics, from laboratory to field monitoring (source: AIT)

Ongoing Annexes

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

Annex 34 Thermally Driven Heat Pumps for Heating and Cooling	34	AT, CA, CH, **DE**, FR, IT, NL, NO, US
Annex 35 Application of Industrial Heat Pumps (together with Task XIII of "Industrial Energy-Related Technologies and Systems" (IEA IETS))	35	AT, CA, DK**, FR, **DE**, JP, NL, KR, SE, CH*
Annex 36 Quality installation and maintenance	36	CA*, CH*, DE*, FR, JP*, KR*, SE, UK**, US**
Annex 37 Demonstration of field measurements of heat pump systems in buildings – Good examples with modern technology	37	AT, CH, **SE**, UK
Annex 38 Systems using solar thermal energy in combination with heat pumps	38	AT**, BE**, CA**, **CH**, DE, DK**, ES**, FI, FR**, IT**, UK
Annex 39 A common method for testing and rating of residential HP and AC annual/ seasonal performance	39	AT, CH, DE, FI, FR, JP, NL, KR, **SE**, US

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

Current status and trends in HCFC replacement in refrigeration and air conditioning equipment

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UNEP Refrigeration, Air Conditioning, and Heat Pumps Technical Options Committee

The current situation of refrigerant use and options is characterized by required global phase-out of HCFCs, the need to manage the lifetime operation of CFC-based and HCFC-based equipment, and concerns to reduce global warming. The technical choices are universal, but local laws, regulations, standards, economics, competitive situations and other factors influence regional and local choices. This article summarizes the 2010 Assessment Report of the UNEP Refrigeration, Air Conditioning, and Heat Pumps Technical Options Committee (http://ozone.unep.org/teap/Reports/RTOC/index.shtml). It describes the status and trends for future refrigerant alternatives, the primary current solutions being adopted in developed and developing countries for the several applications of refrigeration and air conditioning, and the estimated refrigerant bank.

Introduction

The Refrigeration, Air Conditioning, and Heat Pumps Technical Options Committee is one of six technical options committees (TOC) established under the UNEP Technological and Economical Assessment Panel, which is one of three Assessment Panels under the Montreal Protocol. The role of the TOCs and the TEAP is to provide the Parties to the Montreal Protocol with the latest information on technical options to phase out ODSs to assist in implementation of the Protocol. Currently, the emphasis is mainly on the phase-down of HCFC consumption and production in the developing countries.

The 2010 RTOC Assessment Report has been developed in the form of a number of chapters. There are chapters on refrigerants and their properties, on the different R/AC application areas, and one chapter on refrigerant conservation. 2-6 international experts in the specific sectors developed each of the chapters, and each chapter was chaired by a Chapter Lead Author - who did most of the drafting and co-ordination. The 2010 Committee (the Committee for the 2010 Assessment Report) included 29 representatives from Asian, European, Latin and North American companies, universities and governments, as well as independent experts. The RTOC report has been peer-reviewed by a number of experts, institutions and associations in a co-ordinated effort. This article summarizes the main aspects of the 2010 RTOC report, presenting the current status and main options for the various refrigeration and air conditioning applications

Refrigerants

Approximately 25 new refrigerants, many of them blends, have been introduced for use either in new equipment or as service fluids (to maintain or convert existing equipment) since the 2006 assessment report. Additional refrigerants are still being developed to enable completion of scheduled phase-outs of ozone-depleting substances (ODSs). There is a significant focus on alternatives, including blend components, offering lower global warming potentials (GWPs) to address climate change, concentrating more attention than in the past on flammable or low-flammability products. Considerable effort is concentrated on examination of unsaturated fluorochemicals – with the primary focus on unsaturated hydrofluorocarbons and unsaturated hydrochlorofluorocarbons – and on R-717 (ammonia), R-744 (carbon dioxide), and hydrocarbons. Research continues to increase and improve the physical, safety, and environmental data of refrigerants, to enable screening, and to optimise equipment performance.

The diversity of equipment types, of compressor types, and regional approaches also results in multiple fluid selections. More than 60 refrigerants, again including blends, are marketed at present, although that quantity is expected to fall as users converge on preferred options over time.

Domestic refrigeration

The conversion of new equipment production to the use of non-ODS refrigerants is essentially complete. More than one-third of newly produced units globally now use hydrocarbon refrigerant HC-600a; the balance uses HFC-134a. CFC emissions from the estimated 150 000 tonnes domestic refrigerant bank, being approximately 70 % in developing countries, are dominated by end-of-life disposal due to the high equipment reliability.

In domestic refrigeration, and to a lesser extent in commercial stand-alone equipment, an emerging trend is conversion from HFC-134a to HC-600a. Developed countries completed the conversion from ODS refrigerants in new domestic refrigeration approximately 15 years ago; older equipment now approaches the equipment's useful lifetime; this results in developed countries having a vanishing ODS refrigerant demand. The service demand for ODS refrigerants for domestic refrigeration in developing countries is expected to remain strong for more than ten years as a result of their later conversion to non-ODS refrigerants. In commercial stand-alone equipment in developing countries, the use of HCs is expected to increase.

Commercial refrigeration

Hydrocarbons and R-744 (CO_2) are gaining market shares for stand-alone equipment in Europe and in Japan, and are replacing HFC-134a, which is the dominant choice in most developed and developing countries. For condensing units and supermarket systems, the largest refrigerant bank consists of HCFC-22, which represents about 60 % of the global commercial refrigerant bank. In developed countries, the replacement of HCFC-22 in supermarkets is dominated by R-404A and R-507A, although a number of other options are used. In Europe, R-744 is used at the low-temperature level and HFC-134a, R-744 and HCs at the medium temperature level as alternatives to R-404A and R-507A because of the latters' high GWP. Several commercial chains have made good progress on the containment of refrigerant in supermarket systems. Indirect systems are the most effective option for emissions reductions and, in Europe, are gaining market share in new centralised systems for supermarkets. For dual-temperature centralised systems, R-744 is an option for the lower temperature level; in the near future, the choices for the medium-temperature level will be new low-GWP HFCs on the one hand and R-744 or HCs on the other.

Industrial refrigeration

R-717 (ammonia) and HCFC-22 are the most common refrigerants for new equipment; cost considerations have driven small new systems to HFC use. R-744 is being applied in low-temperature, cascaded systems, where it primarily replaces R-717, although the market volume is small for such systems. The refrigerant bank consists of 20 000 tonnes of CFCs and 125 000 tonnes of HCFCs and HFCs. Annual ODS emission rates are in the range of 10-25 % of the total banked refrigerant charge. R-717 remains the primary refrigerant in large industrial systems, especially those for food and beverage processing and storage. Technical development of alternatives in industrial refrigeration is expected to emphasise R-717 and R-744 in the near future. A significant amount of research, development and testing will be required before unsaturated HFCs can be deployed in large industrial systems, and even then their high refrigerant price will be an impediment to adoption. In industrial refrigeration, there are substantial banks of CFCs in developing countries, and HCFCs in both developed and developing countries, that need addressing.

Transport refrigeration

HCFC-22 has a low share in intermodal containers and road equipment, a high share in railcars (declining market) and a very high share in marine vessels. Virtually all new systems utilise HFC refrigerants (R-404A and HFC-134a). Non-fluorinated refrigerants have been commercialised to a small extent aboard marine vessels (R-717, R-744), and tested in marine containers, trailers (R-744) and trucks (HC-290). The refrigerant banks are estimated at 2700 tonnes of CFCs and 27 200 tonnes of HCFC-22. The annual leak rate is in the range of 20-40 %, depending on the specific application. In transport refrigeration, a rapid phase-out of remaining HCFCs due to the relatively short life span of intermodal containers, railcars and road vehicles (10-15 years) and marine vessels (< 25 years) is expected. HFCs will replace HCFCs and become a dominant refrigerant on passenger vessels and on small ships of all categories. The industry is working towards the use of non-fluorinated refrigerants in marine containers, trailers (R-744) and trucks (R-290): both are currently in the development and testing stage.

Air-to-air conditioners and heat pumps

HFC blends, primarily R-410A, but to a very limited degree also R-407C, are still the dominant near-term replacements for HCFC-22 in air-cooled systems. HC-290 is also being used to replace HCFC-22 in low-charge split system, window and portable air conditioners in some countries. Most developing countries are continuing to use HCFC-22 as the predominant refrigerant in air-conditioning applications. The refrigerant bank for unitary air conditioners is in excess of 1 million tonnes of HCFC-22. In air-to-air air conditioning and heat pumps, HFCs (HFC-32 or unsaturated HFCs such as HFC-1234yf), HFC blends and HC-290 are the most likely longer-term refrigerants to replace HCFC-22 in most air conditioning applications. Contrary to developed countries, the demand for service refrigerants in most developing countries will consist of HCFC-22 and HFC-based service blends: this tendency is driven by long equipment life and is also due to the costs of the field conversion to alternative refrigerants.

Water-heating heat pumps: Air-to-water heat pumps have experienced significant growth in Japan, Australia, China, and Europe during the last five years, especially helped by government incentives in Europe and Japan, and in the USA in earlier years. HCFC-22 is currently mainly used in developing countries. HFC blends R-410A and R407C are presently used in European and other countries. R-744 heat pump water heaters were introduced to the market in Japan in 2001 and have seen a steady growth since then, again assisted by significant subsidies. HC-290 is being applied, but its use in Europe has decreased due to the introduction of the Pressure Equipment Directive. R-717 is mainly used for high-capacity heat pump systems. Depending on the CO_2 emissions associated with the electricity production and the energy efficiency of the systems, there is a large potential to reduce CO_2 emissions generated by fossil fuel-operated heating systems by replacing them with heat pumps. In heat pumps for water heating, HFC-32 or unsaturated HFCs such as HFC-1234yf, or blends of this refrigerant, will be studied for future use by taking into account the performance, costs and the necessary safety regulations in relation to their mild flammability.

Chillers

HCFC-22 has been phased out in new equipment in the developed countries, but is still used in developing countries. Both HCFC-123 and HFC-134a are used in centrifugal chillers. HFC-134a and R-410A are the most common options in smaller systems with scroll and screw compressors: limited R-407C use is dropping. The application of HCs and R-717 in chillers is less common, and extremely rare as a fraction of the total in large chillers. Of particular note for both ozone depletion and global climate change, chillers as a group incur very low release rates for refrigerants. The environmental impact of chillers is dominated by the energy-related global warming associated with their energy consumption over their operating life (typically 20 years and sometimes longer than 40 years). Refrigerant emissions, with their direct global warming contributions, are a small fraction of the total global warming impact of chillers except for regions with very low carbon intensity for power generation.

Vehicle air conditioning

Today, all new AC-equipped passenger cars world-wide use HFC-134a: the transition from CFC-12 is complete for new systems, but not in old cars still in use, especially in developing countries. About one fifth of the total global refrigerant emissions are from mobile air conditioning systems (about 60 percent if only HFC refrigerant emissions are considered): this includes the emissions in production, use, servicing, and end-of-life. Up to now, car manufacturers and suppliers have evaluated several refrigerant options for new car (and truck) air conditioning systems including R-744, HFC-152a and HFC-1234yf. These three options have GWPs below the EU threshold of 150, and can achieve fuel efficiency comparable to the existing HFC-134a systems with appropriate hardware and control development. The use of hydrocarbons or blends of hydrocarbons has also been considered, but so far has not received support from vehicle manufacturers due to safety concerns. Most new bus or train air conditioning systems are currently equipped with HFC-134a or R-407C refrigerants: fleet tests of R-744 systems in buses are ongoing. The decision as to which refrigerant will be eventually selected for vehicle air conditioning will be made based on additional considerations, along with the GWP of the current alternative options (R-744, HFC-152a, and HFC-1234yf), including regulatory approval, costs, system reliability, safety, heat pump capability and servicing.

The front-running candidate among global car manufacturers for future vehicle air conditioning systems seems to be HFC-1234yf. One manufacturer has announced the intention to introduce this refrigerant in car serial production in 2013. OEMs indicate that they will design HFC-1234yf MAC systems in such a way that these systems can safely be used with HFC-134a refrigerant as well.

Conclusions

The technological options for air conditioning and refrigeration are expected to evolve over the next several years as designers continue to replace HCFC-22 with non-ODS alternatives and focus on developing lower GWP alternatives for R-410A and R-407C. There are several low- and medium-GWP alternatives being considered as replacements for HCFC-22. They include lower-GWP HFC refrigerants (HFC-32, HFC-152a, HFC-161, HFC-1234yf and other unsaturated fluorochemicals, as well as blends of them), HC-290, R-717, and R-744. HC-290 and some of the HFC refrigerants are flammable, which increases the need to advance charge reduction technologies, and will need to be applied in accordance with an appropriate safety standard such as IEC-60335-2-40 and ASHRAE 15, which establish maximum charge levels and ventilation requirements.

Worldwide, a significant amount of installed refrigeration equipment still uses CFCs and HCFCs. As a consequence, service demand for CFCs and HCFCs will continue. Refrigerant demand for service needs can be minimised by preventive service, containment, recovery, and recycling. Management of the CFC and HCFC banks is an important issue. A high degree of containment is needed in all future refrigerant applications, either for decreasing climate impact or for safety reasons.

The overarching climate change issue, as well as changing refrigerant options, will continue to advance innovations in refrigeration, air conditioning and heat pump equipment. The next RTOC assessment report, due on 31 December 2014, will give a further update of the trends that are occurring in this area.

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F-Gas Regulation: the way forward

By The European Partnership for Energy and the Environment (EPEE)

Although the name of the EU F-Gas Regulation is well known, few are aware of the details of this piece of legislation. With the F-Gas Regulation being due for review in 2012, this article aims to demystify the Regulation through a brief overview of its remit, its relation to the heat pump industry and a look at its future.

The F-Gas Regulation: what it regulates and why

Fluorinated gases, or F-gases, are industrial gases used in a number of applications: industrial and commercial refrigeration, air-conditioning systems, heat pumps, insulation foam, fire suppression systems, and other applications such as vending machines, coolers, etc. HFCs are the most common of the F-gases, but they are not the only ones: perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) are also part of the F-gas family.

F-gases have been developed following the global phasing out of HCFCs and CFCs under the Montreal Protocol. They replace CFCs and HCFCs, are non-ozone depleting, have low toxicity levels and most of them are non-flammable. However, they can have a high global warming potential (GWP), and are therefore considered as having a direct impact on greenhouse gas emissions. Currently, they make up for approx. 1.8 % of greenhouse gas emissions in the EU-27.

In 2003, to address their impact on global warming and to comply with the requirements as set out in the Kyoto Protocol, the European Commission proposed to regulate F-gases in order to reduce their emissions by 23 million tonnes of CO_2-equivalent by 2010.

After three years of negotiations, the F-Gas Regulation finally came into force in July 2006. It aims to reduce F-gas emissions by regulating their use, but not by restricting their production or market availability. To achieve this, the Regulation stipulates avoidance of the use of F-gases where environmentally superior alternatives exist, and improving the leak-tightness of equipment containing the gases. The main pillars of the Regulation are containment, recovery, training and certification of personnel, reporting of data on import, export and use of gases, labelling of equipment, control of use and placing of products containing F-gases on the market.

In its five years of existence, the Regulation has already started to deliver. In addition to reduced leakage rates, its main achievement is a major improvement in the quality of installations and of personnel. It has also led to:

- increased awareness of the need for tighter and better designed components and connections;
- the setting-up of training centres in 23 Member States;
- the setting-up of notified certification bodies in 21 Member States;
- massive improvement in the percentage of certified companies and personnel.

However, as stipulated by the Regulation's Article 10, the European Commission is due to assess its effectiveness, application and adequacy in 2011. The Commission has therefore in September 2011 published a report which starts to assess these points. In addition to the report, the Commission also launched a public consultation[1] in order to get stakeholders' input on possible options to strengthen the current EU measures in order further to reduce emissions to assist in achieving a low-carbon economy by 2050. The report and the public consultation will provide a basis for an impact assessment and, ultimately, the proposed legislative proposal for revision.

An outlook for 2012

With only five years of application and with several member states still not having fully implemented the Regulation, the European Commission acknowledges in its report that, although the F-Gas Regulation has already started to deliver, improvements are still needed in terms of training, certification, recovery and

[1] *http://ec.europa.eu/clima/news/articles/news_2011092602_en.htm*

reuse. In addition, the Commission is also already considering different policy options, which could affect emissions of F-gases, but will certainly also affect users, consumers and industry.

Although all stakeholders, regardless of their interest (industry, NGOs, public authorities etc.) see that the F-Gas Regulation can be strengthened and improved, the exact scope for improvement remains subject to substantial debate. The basic topic of discussion between stakeholders relates to the question whether the containment principle works and could be sufficient to ensure a significant reduction of F-gas emissions, or whether and to what extent it needs to be complemented by further measures.

In order to improve clarity on this essential question, the French ERIE / ARMINES research bodies recently published a study commissioned by EPEE. It reveals that, thanks to Regulations on ozone-depleting substances and F-gases, CO_2-equivalent emissions from refrigeration, air-conditioning and heat pump equipment have already fallen by over 13 % since 1990, and can be expected to fall even further over the next 20 years. In addition to the introduction of lower-GWP refrigerants, emission reductions will be achieved by several factors, such as improvement of emissions rates, lower refrigerant charges and higher recovery volumes at the end of life of equipment containing refrigerant fluids.

In summary, the study's results demonstrate on the one hand that the F-Gas Regulation has already started to deliver, and that product or equipment bans are not necessary in the refrigeration, air conditioning or heat pumps sectors to significantly reduce CO_2-equivalent emissions. On the other hand, it shows that a realistic, balanced and gradual cap and phase-down scheme, under which HFC quantities placed on the market would be gradually reduced, could reduce CO_2-equivalent emissions by over 60 % compared to 2010 levels, without jeopardising energy efficiency, safety or affordability of products or equipment.

What to remember during the review

- Heat pump technology is key for the EU to achieve its 20-20-20 targets and to fulfil the roadmap to a low-carbon economy in 2050. To ensure that heat pumps –which rely to a large extent on F-gases-can continue to make their contribution to Europe's ambitions, the revision of the EU F-gas policy should take into account the rapidly growing heat pump market.
- The revision should not jeopardise the energy efficiency, safety or affordability of this important technology.
- Should regulators consider that further measures in addition to the F-Gas Regulation are necessary, only a cap and phase-down scenario will enable industry to adapt its technologies in a safe and economically sustainable way.
- Any political decisions should take into account the whole picture and should focus on overall CO_2 emissions. Such a holistic approach should take into account technological feasibility, safety, energy efficiency, environmental compliance and affordability (for consumers, governments and industry). Only an assessment of all these elements will point towards the most optimal refrigerant for each specific application.
- The choice of a refrigerant always depends on its application: whereas for some applications viable alternatives already exist, for other applications this is still not the case today. There is no perfect refrigerant, and therefore users of refrigerants should be able to choose the best one according to the intended application and taking into account the climatic conditions.
- Using lower-GWP refrigerants may require a re-assessment of their safety implications, as most of the alternatives are mildly or even extremely flammable, which excludes their use in certain applications.

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Presentation of "Guidelines for the safe use of hydrocarbon refrigerants - A handbook for engineers, technicians, trainers and policy-makers - For climate-friendly cooling"

Linda Ederberg, GIZ-Proklima, Germany

This article presents the publication "Guidelines for the safe use of hydrocarbon refrigerants - A handbook for engineers, technicians, trainers and policy-makers - For climate-friendly cooling", which was published in 2010 by GIZ Proklima and TÜV Süd and can be downloaded cost-free from http://www.gtz.de/en/themen/umwelt-infrastruktur/32681.htm.

Background: Replacements for HCFCs and HFCs under the Montreal Protocol

The rapidly growing refrigeration, air-conditioning and foam-blowing sectors have a huge and growing potential for greenhouse gas (GHG) emission reductions. Most applications and systems in these sectors currently use ozone-depleting hydrochlorofluorocarbons (HCFCs) as refrigerants or foam-blowing agents (typical applications include domestic and commercial installations, such as chillers, heat pumps, air conditioners and refrigeration equipment).

HCFCs will be phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer within the next few years. However, the most common replacement options for HCFCs are hydrofluorocarbons (HFCs), which do not deplete the ozone layer but have a very high global warming potential (GWP), typically between 700 and 4000 times that of CO_2 and are regulated under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Recent projections show a massive growth in HFC emissions in developing countries. If nothing is done to introduce climate-friendly alternatives already now, HFC emissions could increase up to 2.8 GT CO_2 equivalents by 2050. This corresponds to approximately 7 % of global GHG emissions as projected according to a recent study by the German Federal Environment Agency. [1]

Climate-friendly technologies using natural refrigerants (hydrocarbons, ammonia, water, CO_2) exist for almost all applications and can be introduced in all countries, including developing countries. Many of these technologies also have significantly improved energy efficiencies.

GIZ Proklima supports partner countries in overcoming barriers in technology transfer and facilitates the access of climate-friendly technologies to growing markets in developing and emerging countries. One means of achieving this is to provide sound know-how and guidance through publications.

[1] *German Federal Environment Agency 2009: "Projections of global emissions of fluorinated greenhouse gases in 2050 "(http://www.umweltbundesamt.de/produkte-e/index.htm.)*

Guidelines for the safe use of hydrocarbon refrigerants

The main issue of concern with the use of hydrocarbons is of course their

flammability characteristics. According to ISO 817 and EN 378, hydrocarbon refrigerants R290, R600a and R1270 are classified as A3 refrigerants, that is, low-toxicity ("A") but higher flammability ("3").[2, 3]

However, despite their flammability, HC refrigerants are currently widely applied throughout most parts of the world in a variety of systems. The main reasons for their widespread (yet evidently) safe use is centred on the broad use of good safety standards and extensive training of technicians and system designers.

Purpose of the handbook:

There are several standards, industry guidelines, technical papers, service handbooks etc. on the safe use of HCs that are available, but the information is widely dispersed or difficult to find. Also, in the case of standards, interpretation of rules is rarely easy. Most of these sources address discrete aspects of equipment lifetime, such as design or servicing, but much information is still missing. Therefore, the purpose of the GIZ Proklima handbook is to present a compilation of all relevant information, provide interpretation and comprehensive information in such a manner that all of the stages in system life are covered in an interlinked way.

The target group:

The handbook is targeted at an audience concerned with the introduction of HC refrigerants, at all levels from national policies to equipment design and manufacturing, installation, maintenance, servicing and end-of-life disposal. Advice is given to:

• Help policy-makers to encourage a nation-wide introduction of HC technology, emphasising safety and state-of-the-art technologies
• Enable manufacturers and installers of HCFC and HFC equipment to reliably assess the suitability of HC options and subsequently implement them
• Enable a transition from HCFC to natural refrigerants directly, bypassing the introduction of high-GWP transitional HFCs.

It is recognised that simply describing technical requirements is not always sufficient in itself to ensure that a high level of safety is achieved: introducing a robust infrastructure is equally important. Such aspects include how government or industry bodies could set up schemes for certification of technician training, or how manufacturers, distributors or contracting companies could organise their quality management systems to assist the ongoing improvement of safety levels, etc. All are important considerations.

The guidelines cover the following aspects:

Part 1: Safety Infrastructure
- General introduction: overview of the entire concept
- Basic safety with flammable refrigerants
- Development of safety management systems
- Identification of cooperation partners
- Framework of regulations and standards

Part 2: Quality systems for safety
- ¯ Introduction
- ¯ Feed-in elements (inputs)
- ¯ Testing
- ¯ Inspections
- ¯ Monitoring
- ¯ Feedback and preventative/ corrective action
- ¯ Accreditation and certification

Part 3: Training
- Introduction to training
- Training facilities
- Management systems
- Content of standard refrigeration training
- Training for design and development
- Training for production
- Supporting material provided within the appendices

Part 4: Production and manufacturing facilities
- Introduction
- Refrigerant supply
- Appliance production
- Factory safety
- Workshop/repair areas
- Transportation of systems
- Storage of systems

Part 5: Equipment design and development
- Safe design for HC refrigerants
- Avoidance of leakage
- Refrigerant charge size limits
- Charge size reduction
- Sources of ignition/avoiding ignition
- Design of system installation
- Marking and instructions
- Risk analysis

Part 6: working on systems and equipment
- Technician activities and refrigerant handling
- Installation of equipment
- Commissioning of installations
- On-site and workshop conversions
- Dismantling

Part 7: Case studies
A number of real examples are provided, showing how many of the concepts discussed within the handbook are applied:

- Benson air conditioning – split and larger air-conditioning products
- Carter Refrigeration Equipment (CRE) – retail refrigeration systems
- De'Longhi – small room air conditioners
- Hindustan Lever – HC ice-cream freezers
- Johnson Controls International (JCI) – large AC chillers
- Lidl – a supermarket chain
- Palfridge – a producer of domestic and commercial refrigeration appliances
- Victorian Transport Refrigeration – refrigerated transport systems
- Waitrose – a supermarket chain

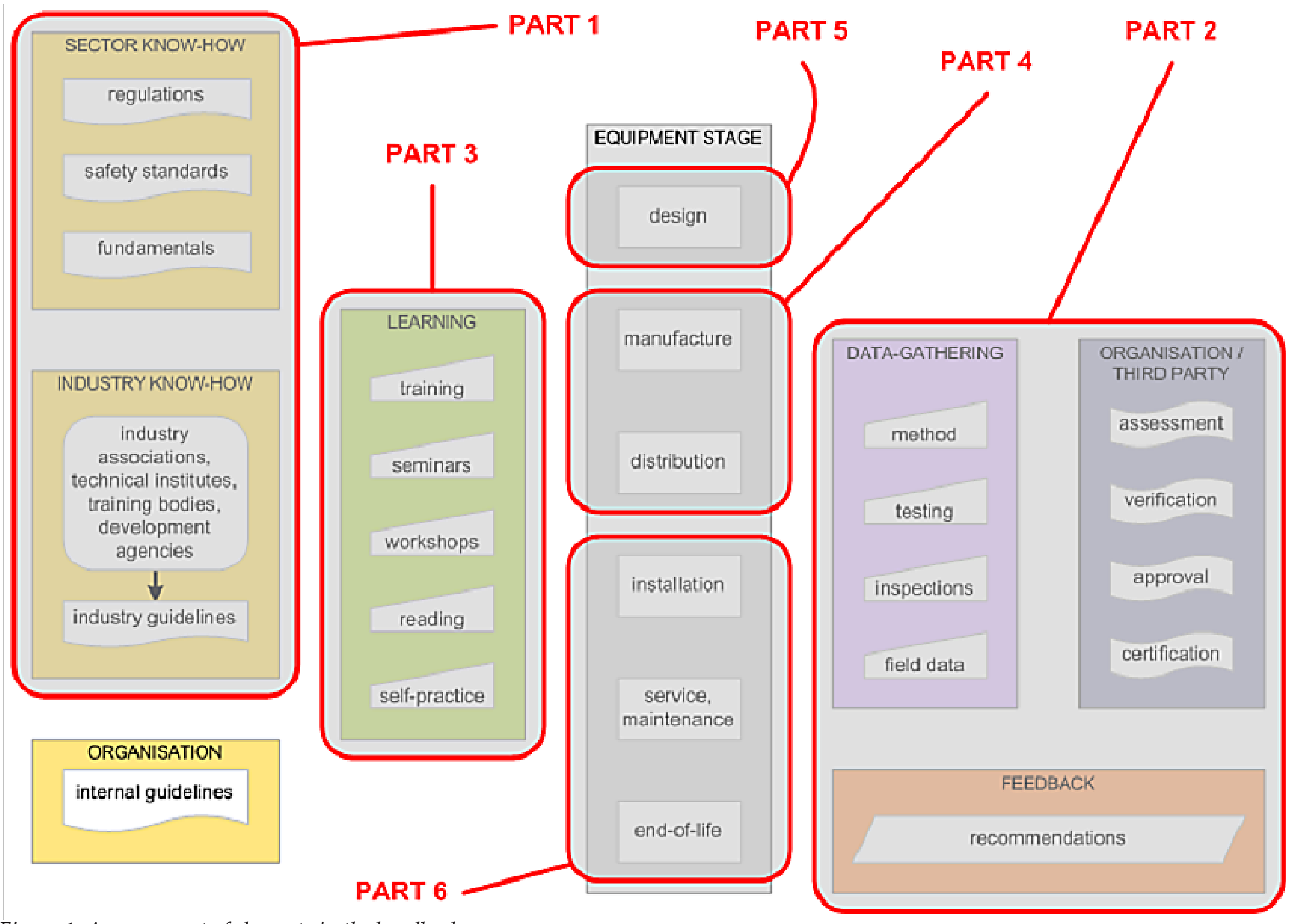

Figure 1: Arrangement of elements in the handbook

Appendices

- Non-safety-related technical aspects
- Examples of conversion procedures
- List of cooperation partners
- Flammable characteristics of HCs
- Calculation of concentrations from a release
- Equipment for technician training
- Content for refrigeration training standard
- Examples of assessment criteria for technicians
- Record sheet for refrigerant use
- Vapour pressure and liquid density tables

Outlook:

As a next step, individual booklets will be published to focus on particular aspects of introducing hydrocarbons. The first booklet to be published in 2011 will cover "Safe Conversion of HCFC/HFC Split Air-Conditioners for the Operation with Hydrocarbon Refrigerant", and deal with special considerations, which are required when converting a system from a non-flammable to a flammable refrigerant.

Showcase project for the application of hydrocarbons:

Climate-friendly room R290 air-conditioners with GREE Electric, Inc. in China

This demonstration project is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety within the framework of the International Climate Initiative, based on a decision of the German Federal Parliament. The project introduced HCs (R290) to the production of room air-conditioning systems at Gree Electric Appliances Inc. The conversion to HC reduced emissions from currently used ozone- and climate-damaging HCFCs and offered energy efficiency benefits. The project included training on safety measures and enabled the manufacturer to acquire experience of handling production and design of air conditioners using HCs.

On 14th July 2011, the production line was officially opened. Gree is the first original equipment manufacturer worldwide that is applying this sustainable technology in room air-conditioners.

The new R-290 air-conditioning systems provide an intrinsically safe system having GS, CE marking and VDE certifications. Specific features include:

[2] *Colbourne et al 2011: Cost analysis of producing split-type air conditioners using HC-290. Paper presented at the IIR/ICR 2011*

Figure 2: Demonstration unit of R290 air conditioner

- New optimised R-290 compressor
- Optimised heat exchanger
- Intelligent control system
- Other construction materials specifically intended for use with R-290

All R290 models conform to the international IEC 60335-2-40 safety standard (particular requirements for electrical heat pumps, air-conditioners and dehumidifiers).

In TEWI calculations, the R290 models currently installed at the Maldives Environment Ministry achieve better results than R410A or R22 models under similar conditions. The R290 models produce 7600 kg CO_2 equivalent emissions (around 7598 kg CO_2e indirect and 2 kg CO_2 eq. direct), compared to 10300 kg CO_2 equivalent (7700 kg CO2e indirect and 2600 kg direct) emissions for the R22, and 10600 kg CO_2 equivalent emissions for the R410A models. (around 8000 kg CO_2 eq. kg indirect emissions and 2600 kg direct emissions).

Conclusion

Hydrocarbons offer huge benefits when compared to fluorinated refrigerants, in terms of low GWP and energy efficiency performance, as well as of cost efficiency.

With application of the relevant safety standards – along with education and training of technicians involved in the installation and service of systems – the flammability risk of hydrocarbons can be dramatically reduced, such that the ignition risk becomes negligible.

The commercialisation of hydrocarbon-based products has started and will continue to expand in the future, as natural refrigerants are a climate-friendly and sustainable solution which offers long-term benefits.

About GIZ Proklima

Proklima is a programme of the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), commissioned by the German Federal Ministry of Economic Cooperation and Development (BMZ).

Proklima has been providing technical and financial support for developing countries since 1996 to introduce environment- and climate-friendly alternatives to ozone-depleting industrial gases (such as chlorofluorocarbon (CFCs). With more than 180 projects and a volume of contracts to date worth almost EUR 50 million, it is the largest bilateral partner under the Montreal Protocol.

Since 2008, Proklima has also been working successfully on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under its International Climate Initiative (ICI) to disseminate ozone-and climate-friendly technologies. Activities here range from solar-powered fridges for vaccines in health stations in rural areas of southern Africa, to the introduction of climate-friendly room air conditioners in China

Although launched to help protect the ozone layer, protection of the global climate has always been part of its overall strategy. One thing that is not clear to many people is that ozone-depleting gases such as CFCs, and the widely used hydrofluorocarbons (HFC), are also potent greenhouses gases (GHG) that contribute to global warming. Ever since it was launched, Proklima has been promoting the use of natural refrigerants and natural foam-blowing agents (such as hydrocarbons) having little or no greenhouse gas potential.

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Low GWP Working Fluids for Domestic, Commercial and Industrial Heat Pumps: DR-5 and DR-2

Kostas Kontomaris and Thomas J. Leck, USA

Two developmental refrigerants, DR-5 and DR-2, are evaluated as potential working fluids for residential, commercial and industrial heat pumps. Both fluids are based on Hydro-Fluoro-Olefin technology and have no ozone depletion potential. DR-5 is a promising R-410A substitute. DR-2 is a relatively low pressure fluid especially promising for high temperature heat pumps (HTHPs).

Introduction

A new class of compounds, known as Hydro-Fluoro-Olefins (HFOs), is currently under development in response to environmental concerns associated with the use of conventional heating and cooling working fluids. As has long been the case, no single refrigerant meets the requirements for every heat pump application efficiently and safely. The two refrigerants described in this article are based on different HFO compounds, to meet specific requirements for different heat pump applications.

I. Domestic and Light Commercial Applications: DR-5

DR-5 is a near-azeotropic refrigerant blend with physical and thermodynamic properties approximating those of R-410A. DR-5 can be used to replace R-410A in existing equipment designs. It is expected to meet the ASHRAE Class 2L low flammability criterion.

Background: DR-5

The refrigerant R-22 was used for many years as the preferred fluid for AC and heat pumps for residential and light commercial applications, until the recognition of the impact of chlorine on stratospheric ozone. After much evaluation, R-410A was selected, not as a direct substitute for R-22, but as an improvement that enabled use of smaller compressors, smaller heat exchangers, and high performance in AC and heat pump platforms with a compact footprint. While R-410A has become the globally predominant refrigerant for air source heat pumps, the transition to the new refrigerant proved to be slow and expensive. The qualification of new equipment, lubricants, and component designs has required several years of development and much expense for equipment manufacturers, and therefore end users as well.

Climate and environmental concerns are again precipitating calls for new regulations and new working fluids, and work is underway to determine how to best transition to more environmentally sustainable solutions for cooling and heating. Heat pumps, with superior COP performance relative to fossil fuel combustion or electric resistance heating, are seen as a critical part of the solution to the environmental concerns. Several working fluids are being considered, including CO_2, Propane, R-32, and the new HFO-1234yf. While each of these fluids offers some benefit, each has its own disadvantages. Further, because international regulations on GWP, efficiency, and safety are yet to be finalized, there is uncertainty among manufacturers as to which fluids to consider for development. Until climate protection regulations are finalized, and until requirements for safe use of class 2L flammable fluids are developed and implemented, R-410A use will likely continue to grow globally.

The identification of environmentally sustainable fluids that could replace R-410A in existing heat pump designs would be highly desirable. A "drop in" replacement refrigerant would avoid the extensive equipment re-design and qualification that was necessitated by the transition to R-410A and, thereby, it would conserve resources, minimize transition costs and accelerate the transition to more environmentally sustainable heating solutions.

DR-5 is a more environmentally sustainable near drop-in replacement for R-410A. It is a near-azeotropic blend that balances the properties of its key components, including HFO-1234yf and R-32, to overcome their disadvantages and optimize performance. DR-5 can be used in R-410A equipment to reduce direct GWP (by 75 %) as well as energy usage. It leads to low pressure drop, minimal temperature glide, and excellent miscibility in POE lubricants (widely used for R-410A systems). DR-5 can enable continued use of existing R-410A equipment with only a change of the refrigerant gas from R-410A to DR-5. It could allow the efficient transition from R-410A that equipment manufacturers have requested.

DR-5 key properties are summarized in Table 1.

Equipment Test Results: DR-5

DR-5 has been tested in several types of high performance AC and heat pump equipment, both as a direct "drop in" fluid, and with slight changes such as modifying compressor speed. For an OEM application, some light optimization, including optimizing TXV and superheat settings, would likely optimize the energy efficiency even more.

Results from dropping DR-5 into existing R-410A residential heat pumps by three equipment manufacturers are summarized in Table 2. The testing methods have been described in greater detail at various conferences and proceedings, c.f. Leck (2010)[1] and (2011)[2&3]. Very briefly, baseline conditions are determined with R-410A in an environmental chamber. The R-410A gas is replaced with DR-5, the charge is optimized, and the heating COP and Capacity are measured and reported relative to R-410A. In some cases a small reduction in capacity was observed upon simply "dropping-in" DR-5 for R-410A.

The tests shown in Table 2 as using inverter drive compressors were carried-out at JRAIA standard heating conditions of 7° C outdoor temperature. The single speed compressor test was conducted at an AHRI standard heating condition of 8.3° C outdoor temperature. In systems with variable speed (inverter drive) compressors, the speed during the DR-5 tests was increased to match the capacity of R-410A for a more relevant COP comparison. In every case, whether drop-in or capacity-matched, the measured COP with DR-5 was higher than with R-410A. Generally, as expected, increasing compressor speed to increase capacity led to a slight decline in COP. Testing is continuing to determine if additional low cost soft equipment optimization could yield even greater COP improvements.

Table 1 Key properties of DR-5 and DR-2

Property	DR-5	DR-2
Safety Class	A2L	A1 (expected) [(1)]
Atmospheric life time [days]	n.d.	24
ODP	None	None
GWP[(2)]	~500	<10
Critical Temperature [ºC]	> 80	171.3
Critical Pressure [MPa]	~5.7	2.9
Normal Boiling Point [ºC]	~ -51	33.4

Table 2 DR-5 Representative Heat Pump Test Results at Standard Rating Conditions

Refrigerant	Equipment Size, Type	Test Conditions	Capacity	COP
410A	all		1.00	1.00
DR-5	4 kW, Inverter	Capacity Match to 410A	1.00	1.01
DR-5	7.2 kW, Inverter	Drop In	0.92	1.05
DR-5	7.2 kW, Inverter	Capacity Match to 410A	1.01	1.04
DR-5	10 kW, Single Speed	Drop In	0.985	1.019

Discussion: DR-5

Tests in several types of residential type heat pumps have shown that DR-5, as the thermodynamic models predicted, is a viable, resource-efficient, substitute for R-410A in existing equipment designs. Testing is ongoing to determine what additional gains may be achieved by additional light optimization of some existing heat pump designs.

II. High Temperature Applications: DR-2

This section briefly evaluates a new developmental refrigerant, DR-2, as a potential working fluid for commercial and industrial high temperature heat pumps (HTHPs). DR-2 is a relatively low pressure fluid, based on hydro-fluoro-olefin technology, with no ozone depletion potential and a global warming potential (GWP) lower than 10. Key thermo-physical properties of the new refrigerant are summarized and its thermodynamic performance under cycle conditions representative of potential applications is evaluated through computational modeling. DR-2 is non-flammable and it has a favorable toxicity profile. It has a relatively high critical temperature and high thermal stability, attributes particularly attractive for upgrading low temperature heat to high temperatures. DR-2 could enable more environmentally sustainable heat pump platforms that could upgrade heat to higher temperatures and with higher energy efficiencies than incumbent working fluids.

Background: DR-2

Increasing energy prices and increasing awareness of the environmental impacts associated with energy use are motivating a renewed interest in HTHPs for a range of commercial and industrial applications. Many of the working fluids currently used in HTHPs are either ozone depleting substances under the Montreal Protocol or are coming under increasing scrutiny because of their high GWPs. Moreover, the maximum feasible condensing temperature with currently available working fluids is limited by the fluid critical temperature or the fluid thermal stability or the maximum permissible fluid condensing pressure in the equipment used.

Low GWP HFOs may enable the design and operation of energy efficient HTHPs with reduced environmental impact. DR-2 was recently evaluated as a replacement for HCFC-123 in centrifugal chillers by Kontomaris (2010)[4]. Table 1 summarizes key thermodynamic, safety, health and environmental characteristics of DR-2. Figure 1 shows the saturated vapor pressure of DR-2. DR-2 vapor pressure at temperatures up to 155 ^{o}C remains below the maximum working pressure (about 2.2 MPa) permissible with most widely used centrifugal heat pumps. The thermal stability of DR-2 in the presence of aluminum, steel and copper was scrutinized according to the familiar sealed glass tube methodology of ASHRAE-ANSI Standard 97. DR-2 remained remarkably stable up to the maximum temperature tested, 250 ^{o}C.

One objective of this brief article was to assess the potential of DR-2 as a working fluid for HTHPs. The thermodynamic performance of DR-2 was evaluated in idealized cycles, representative of potential applications.

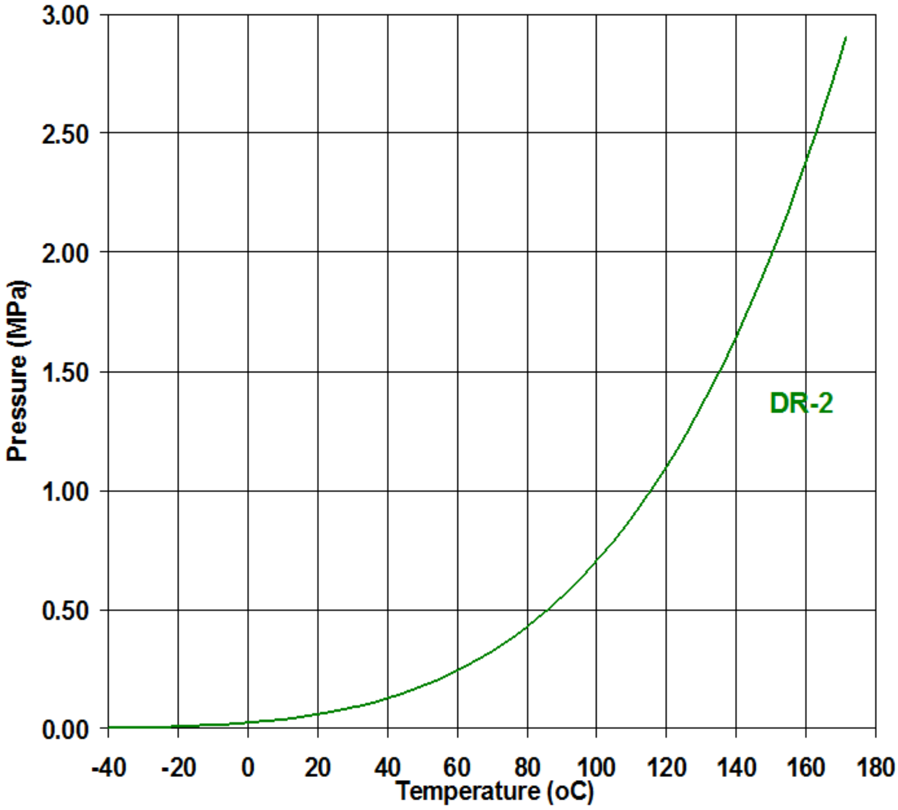

Figure 1. DR-2 vapor pressure.

Methods-Results

The thermodynamic performance of DR-2 was computed for two hypothetical HTHP applications prescribed to demonstrate the thermodynamic characteristics of the new fluid (Kontomaris 2011)[5]. The vapour superheat at the compressor inlet, the liquid sub-cooling at the condenser exit and the compressor isentropic efficiency were prescribed as ΔT_{suph}=15 ^{o}C, ΔT_{subc}=10 ^{o}C and η_{is}=0.80, respectively, for both cases.

The first application was prescribed to meet a heating duty at a condensing temperature of 125 ^{o}C uplifting heat supplied at an evaporator temperature of 75 ^{o}C. The predicted performance is summarized in Table 3, where: COPh is the coefficient of performance for heating, defined as the ratio of the amount of heat delivered at the condenser (including the compressed vapour superheat and the liquid sub-cooling) over the work of compression; and CAPh is the volumetric heating capacity, [kJ/m^3], defined as the amount of heat delivered at the condenser per unit volume of the working fluid entering the compressor.

The second application was prescribed to meet a heating duty at a condensing temperature of 155 ^{o}C uplifting heat supplied at evaporator temperatures in the range of 85 to 130 ^{o}C. The predicted performance is summarized in Table 4.

Discussion: DR-2

DR-2 seems promising as a working fluid in commercial and industrial heat pumps upgrading available low temperature heat to meet heating demands at higher temperatures. In addition to its attractive safety, health and environmental properties, DR-2 seems uniquely suitable to enable HTHP applications requiring condenser temperatures substantially higher than those achievable with currently available working fluids. The condenser pressures with DR-2 at temperatures up to about 155 ^{o}C could be accommodated with largely conventional centrifugal heat pump technology. The predicted energy efficiency for heating and volumetric heating capacity are quite attractive and improve as the temperature of the heat supplied to the evaporator approaches the duty temperature delivered at the condenser.

Overall Conclusions

Hydro-Fluoro-Olefins are emerging as a rich class of low GWP compounds each with its own idiosyncrasies. Low GWP HFO-based candidates have been designed for various applications. We have discussed here two developmental refrigerants, DR-5 and DR-2, that are based on different HFOs. Both DR-5 and DR-2 have attractive environmental properties. DR-5 is a high pressure blend, based on HFO-1234yf, that has proven in equipment tests to have a high potential as a R-410A replacement. DR-2 is based on a higher boiling point, lower pressure HFO. DR-2 has thermodynamic and chemical stability properties that make it particularly attractive for use in high temperature heat pumps.

Table 3 Predicted thermodynamic cycle performance of a HTHP operating with DR-2 at the following conditions: T_{cond}=125 °C; T_{evap}=75 °C; ΔT_{suph}=15 °C; ΔT_{subc}=10 °C; η_{is}=0.80.

$P_{condenser}$	MPa	1.22
$P_{evaporator}$	MPa	0.38
Pressure Ratio		3.26
COP_h		5.421
CAP_h	kJ/m³	2,869

Table 4 Predicted thermodynamic cycle performance of a HTHP operating with DR-2 at the following conditions: T_{cond}=155 °C; T_{evap}=85 - 130 °C; ΔT_{suph}=15 °C; ΔT_{subc}=10 °C; η_{is}=0.80.

$T_{evaporator}$	°C	85	100	115	130
$P_{condenser}$	MPa	2.18	2.18	2.18	2.18
$P_{evaporator}$	MPa	0.49	0.71	0.99	1.35
Pressure Ratio		4.46	3.09	2.20	1.61
COP_h		3.285	4.568	6.840	11.864
CAP_h	kJ/m³	2,700	4,122	6,154	9,022

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Latest Developments in Low Global Warming Refrigerants for Heat Pump Applications

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New refrigeration system working fluids with the positive attributes of both high thermal performance and low environmental impact are currently in development. These materials maintain the high level of system efficiency we are accustomed to with fluorocarbon refrigerants but with significantly lower global warming impact than current refrigerants. The evaluation of potential replacements for common heat pump refrigerants such as R-410A, R-407C, and R-22 will be discussed for several heat pumps applications. Chemical and physical properties for the new molecules, as well as experimental results for the heat pump applications using these developmental refrigerants are compared and contrasted.

Introduction

Two new low GWP refrigerant molecules (HFO-1234yf, HFO-1234ze) have been identified. These molecules are Hydro-Fluoro-Olefins (HFO) that have an extremely low global warming potential (GWP) of only 4 to 6 (as compared to 1430 for R-134a). We are in the process of developing and evaluating refrigerant blends that balance the attributes of higher capacity and low global warming potential while maintaining the efficiency of present systems without significant increases in system cost. This study will discuss properties and applications of potential refrigerant options to replace R-410A, R-407C, and R-22 in stationary heat pump systems.

Table 1 - Working Fluid Properties

Refrigerant	GWP	PEL (ppm)	LFL / UFL (Vol%, 23°C)
R-134a	1430	1000	-
HFO-1234ze	6	1000	-
HFO-1234yf	4	500	6.2-12.3
R-32	675	1000	14.4-29.3
R-600a	~20	800	1.8-8.5
R-290	~20	1000	2.1-10.0

Table 2 – Honeywell's Refrigerant Options

Current Product	N-Series (Reduced GWP) (A1 Classification)	L-Series (Lowest GWP) (A2L Classification)
R-404A GWP=3922	HFO Blend – GWP ~1300 (retrofit) N-40 HFO Blend – GWP ~1000 (new equipment) N-20	HFO Blend – GWP ~200-300 L-40
R-407C/ HCFC-22 GWP= 1774/1810	HFO Blend – GWP ~1000 N-20	HFO Blend – GWP <150 L-20 HFO Blend – GWP <400 L-20+
HFC-134a GWP=1430	HFO Blend – GWP ~600 N-13	HFO-1234yf – GWP=4 L-YF HFO-1234ze– GWP =6 L-ZE
R-410A GWP=2088		HFO Blend – GWP <500 L-41

Working Fluids

Depicted in Table 1 are potential low global warming molecules as well as a reference higher global warming molecule, R-134a. Also shown in Table 1 are Permissible Exposure Limits (PEL) and flammability limits (LFL and UFL). It should be noted that fluids that do perform well in applications where R-134a is used doesn't imply that these same refrigerants will also perform well in other applications such as heat pumps where refrigerants with higher volumetric capacity, higher pressure, and other distinct properties are used. It is for this reason that refrigerant blends that are better suited for heat pump and other applications are currently in development.

Several low-GWP blends with operating characteristics close to R-404A, R-22, and R-410A are under investigation. Although blends can be formulated with a GWP below 150, trade-offs in performance are necessary to accomplish this. Blends with GWP greater than 150 can provide a better performance match with existing refrigerants, and still offer a GWP reduction of 75% to 95%

R410A Applications

A representative air-to-air reversible heat pump designed for R410A was tested. This ducted unit was tested in Honeywell's Buffalo, New York application laboratory.

The ducted unit is a 3-ton (10.5 kW cooling capacity) 13 SEER (3.8 cooling seasonal performance factor, SPF) with a heating capacity of 10.1 kW and an HSPF of 8.5 (rated heating SPF of ~2.5), equipped with a scroll compressor. This system has tube-and-fin heat exchangers, reversing valves and thermostatic expansion valves for each operating mode. Due to the different pressures and densities of the refrigerants tested, some of the tests required the use of Electronic Expansion Valves (EEV) to reproduce the same degrees of superheat observed with the original refrigerants.

Test Setup

Tests shown in table 3 were performed using standard [AHRI, 2008] operating conditions. All tests were performed inside environmental chambers equipped with instrumentation to measure both air-side and refrigerant-side parameters. Refrigerant flow was measured using a coriolis flow meter while air flow and capacity was measured using an air-enthalpy tunnel designed according to industry standards [ASHRAE, 1992]. All primary measurement sensors were calibrated to ±0.25ºC for temperatures and ±0.25 psi for pressure. Experimental uncertainties for capacity and efficiency were on average ±5%. Capacity values represent the air-side measurements, which were carefully calibrated using the reference fluid (R-410A). The developmental blend, L-41 was tested in this heat pump in both cooling and heating modes along with the baseline refrigerant R-410A.

Table 3 – Operating Conditions

Operating Conditions (Cooling Mode)				
Test Condition	Indoor Ambient		Outdoor Ambient	
	DB(°C)	WB(°C)	DB(°C)	WB(°C)
AHRI Std. A	26.7	19	35	24
AHRI Std. B	26.7	19	27.8	18
AHRI Std. C	26.7	14	27.8	-
AHRI Std. MOC	26.7	19	46.1	24

Operating Conditions (Heating Mode)				
Test Condition	Indoor Ambient		Outdoor Ambient	
	DB(°C)	WB(°C)	DB(°C)	WB(°C)
AHRI Std. H1	21.1	15.6	8.3	6.1
AHRI Std. H2	21.1	15.6	1.7	0.6
AHRI Std. H3	21.1	15.6	-8.3	-9.4

Note – MOC --> maximum operating condition

Cooling Mode Results

Table 4 shows performance results in cooling mode. L-41a shows efficiency comparable to R410A with capacities of 97% for a quasi drop-in

Table 4 – Cooling Mode Results – R-410A vs. L-41

R410A Options (L-41, A2L, GWP<500)								
Ref.		Cooling		Heating Std. Rating (AHRI H1)		Heating Low Temp. (AHRI H3)		
	Glide Ev (ºF)	Cap. @ 95ºF Amb (AHRI A)	Eff. @ 82ºF Amb (AHRI B)	Heating (47ºF/70ºF) Capacity	Heating (47ºF/70ºF) Eff	Heating (17ºF/70ºF) Capacity	Heating (17ºF/70ºF) Eff	
R410A	0.1	100%	100%	100%	100%	100%	100%	
L-41a	4.0	97%	102%	97%	104%	93%	101%	
L-41a*	4.0	107%	100%	104%	98%	102%	97%	
L-41b	2.4	98%	102%	99%	105%	96%	103%	

**Used larger compressor*

test and 107% when a larger compressor is used. The second alternative (L-41b) matches capacity and efficiency of R410A (differences lie within the experimental uncertainty). Due to the lower mass flow rates than R410A , there may be potential improvements of the heat exchangers. Discharge temperatures are just slightly higher than that of R-410A but remain at acceptable levels.

Heating Mode Results

Table 4 also shows performance results in heating mode. The trends seen in the cooling mode test results are also seen with heating results. When evaluated at the standard temperature test, L-41a shows efficiency and capacity comparable to R410A Mass flow rates are approximately 30% lower than R410A. Discharge temperatures remain at an acceptable level though marginally higher than that of R-410A.

Learnings

Overall, both L-41a and L-41b show potential to replace R-410A. Any slight performance differences between the two refrigerants can be reduced or eliminated with minor system changes. One of these options is using a slightly larger compressor, which was tested and provided satisfactory results. This performance can be achieved without concern of high discharge temperature and with a GWP of less than 500; it offers a considerable reduction from R-410A (more than 75%).

R407C Applications

A ducted reversible heat pump with a 3-ton (10.5 kW) cooling capacity, an efficiency rating of 13 SEER (3.8 seasonal COP), a heating capacity of 10.1 kW and an HSPF of 8.5 was used for this evaluation. This system was originally designed for R-22 but was converted to R-407C, which serves as the baseline refrigerant. R-407C was selected since R-22 has already been phased out for new equipment in many countries and R-407C is used in many types equipment that formerly utilized R-22.

In addition to R-407C, three alternative refrigerants were evaluated. L-20 and N-20 that were identified on Table 1 along with another option, L-20+. N-20 is a non-flammable refrigerant blend with a GWP under 1000 while L-20 has mild flammability with an expected flammability classification of "2L" but has a GWP under 150. L-20+ is another "2L" option that has a GWP under 400 (>80% reduction from R-407C) with performance characteristics nearly identical to that of R-407C.

Cooling Mode Results

Table 5 shows the results of this heat pump operating in cooling mode. All three alternatives operate with cooling efficiencies at or slightly above that of R-407C with acceptably low discharge temperatures. L-20+ also matches the cooling capacity of R-407C. L-20 would need a slightly larger compressor displacement to make up for the 10% lower capacity while N-20 comes closer to meeting the capacity of R-407C.

Table 5 – Cooling Mode Results – R-407C vs. L-20, L-20+, and N-20

Cooling Mode								
Refrigerant	AHRI-Std	Capacity	EER	Mass flow	Tcd	Tev	Tdisch	Pd/Ps
		% of R407C	% of R407C	% of R407C	% of R407C	% of R407C	°C	% of R407C
R-407C	A	100%	100%	100%	100%	100%	76	100%
	B	100%	100%	100%	100%	100%	66	100%
L-20	A	90%	105%	84%	100%	103%	70	99%
	B	88%	101%	84%	100%	103%	62	98%
L-20+	A	101%	101%	77%	101%	99%	82	101%
	B	100%	100%	77%	102%	99%	71	100%
N-20	A	93%	104%	106%	98%	104%	65	94%
	B	94%	104%	105%	98%	103%	57	94%

Table 6 – Heating Mode Results – R-407C vs. L-20, L-20+, and N-20

Heating Mode								
Refrigerant	AHRI-Std	Capacity	EER	Mass flow	Tcd	Tev	Tdisch	Pd/Ps
		% of R407C	% of R407C	% of R407C	% of R407C	% of R407C	°C	% of R407C
R-407C	H1	100%	100%	100%	100%	100%	75	100%
L-20	H1	87%	104%	84%	104%	97%	66	93%
L-20+	H1	102%	101%	77%	100%	103%	85	102%
N-20	H1	97%	99%	106%	95%	102%	68	105%

Heating Mode Results

Heating mode results are depicted in Table 6 with basically very similar results as those seen in cooling mode. L-20+ again shows nearly identical heating capacity and efficiency performance to R-407C with the other candidates matching efficiency but with somewhat lower capacity.

Discussion

Three low global warming refrigerant candidates were evaluated with promising results. L-20 with a GWP less than 150 (>90% reduction from R-407C) achieved comparable efficiency and with minor system changes would likely achieve the same capacity as the baseline refrigerant. Another refrigerant option, L-20+ matches both the capacity and efficiency of R-407C with a greater than 80% reduction in GWP. N-20, a non-flammable option with a GWP reduction of more than 45%, achieves comparable efficiency and only sees a slight reduction in capacity.

It should be noted that the heat pump used for the R-407C evaluations is noticeably larger in size (primarily the outdoor heat exchanger) than the previous unit used for the R-410A so it is difficult to compare the two series of tests. R-407C and its alternatives discussed here are likely to perform worse in the smaller R-410A unit even if measures were taken to make it function with R-407C using the correct compressor and other minor components.

GWP Impact on Life Cycle Climate Performance (LCCP)

An evaluation was conducted on the contribution of the direct impact of refrigerant GWP on overall system contribution to global warming. LGWP refrigerants with GWPs of 500 and 150 were compared to R-410A.

Calculations were performed using a conservative 5% annual leak rate estimate, 15 year life and 15% end-of-life charge loss. A Southern EU climate was used with the CO_2 equivalent of electrical energy consumption being 0.59 kg CO_2/kWh. This value was calculated using a population weighted average of four countries (Spain, Italy, Portugal and Greece). The units are reversible (heat/cool) with no efficiency loss relative to R-410A for LGWP-500. There is an assumption of an 8% lower COP for LGWP-150 and it would be an R-407C-like refrigerant. In addition, the heat exchanger size was the same as it is for R-410A and its alternative. This last assumption was made since the analysis should assume that the equipment costs are comparable.

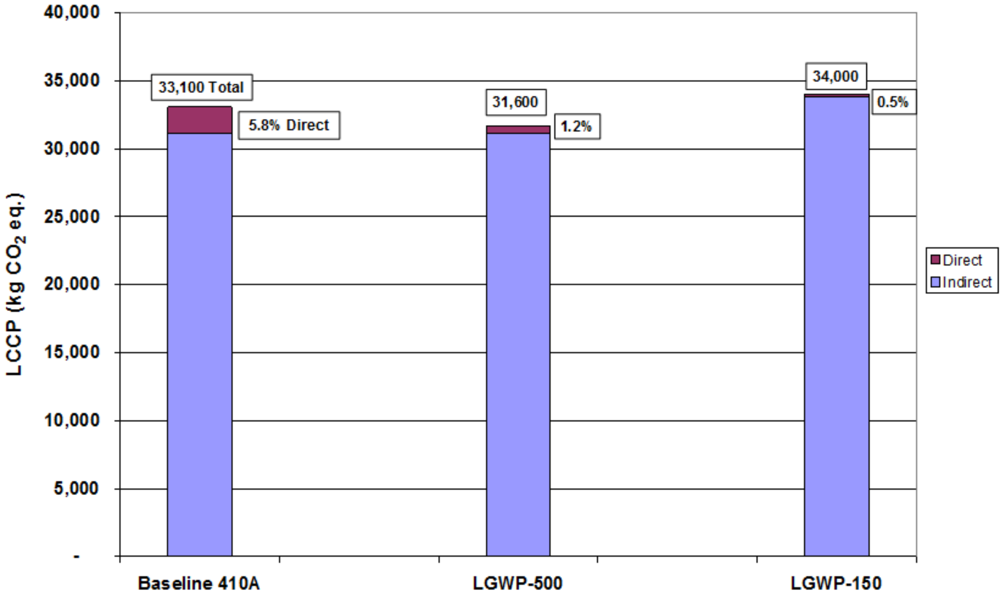

Figure 1 – LCCP Analysis

Results show minimal gain in direct impact when reducing GWP below 500 (figure 1). Any decrease in efficiency would more than offset any reduction in direct impact

This analysis is based on paper presented at Earth Technology Forum [Spatz, 2004] and heat pump results obtained in the present study.

Conclusions

Recently developed low global warming molecules may have potential applications in systems that currently employ medium pressure refrigerants such as commercial refrigeration and AC systems. Unlike CO_2, comparable performance to existing refrigerants can be achieved in applications investigated to date without significant hardware modification.

Preliminary evaluations of higher pressure blends show promise; however there are trade-offs in performance, flammability, and GWP that need to be made.

This initial work is encouraging but further work is needed to more fully explore these applications. This would include additional performance evaluations as well as conducting flammability risk assessments where appropriate

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Sorption Cooling – a technology review

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In general, sorption cooling driven by waste heat from CHP units or industrial processes, or from solar energy and district heat and biomass, could lead to a considerable reduction of energy consumption. Therefore, various new sorption chillers (thermally driven heat pumps) for small and medium-scale cooling capacities up to 500 kW, have been developed during the last few years and are now available on the market. This report describes and discusses the latest sorption chiller developments, with particular concentration on heat source temperatures and COPs.

Introduction

Worldwide, energy consumption for cooling and air conditioning is rising rapidly. In particular, sales of electrically driven compressor chillers (split units), with a cooling capacity range up to 5 kW, have risen rapidly in recent years. The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) has estimated worldwide sales of 94.5 million units in 2011 [1]. Conventional split units have a high-energy consumption and use non-environmentally friendly refrigerants. The refrigerants that are currently used in compressor chillers no longer have ozone depletion potential (ODP), but they have a considerable global warming potential (GWP) through refrigerant leakage of the order of 5-15 % per year. Against this, sorption chillers use refrigerants with low environmental impact (water or ammonia), and have only very low electricity demand. The operating costs of these chillers are therefore very low, with considerably less CO_2 emissions than from compressor chillers. In case of waste heat from CHP units, the benefit is the longer operating time of the CHP unit itself and therefore also of increased electricity production. However, for solar cooling, the main advantage is the coincidence of solar irradiation and cooling demand.

Technologies

Single-effect absorption chillers, using the working pair of water/lithium bromide or ammonia/water, generate cold using a closed, continuous cycle. Ammonia/water absorption chillers generate evaporator temperatures down to –60 °C, which are useful for industrial cold processes. Water/lithium bromide chillers use water as the refrigerant, and so the evaporator temperature is limited to temperatures around +5 °C. In absorption chillers, the refrigerant (water or ammonia) is absorbed by a liquid sorbent (lithium bromide or water). The liquid passes to a directly or indirectly heated generator, in which the temperature is in the range 65-120 °C, and where the refrigerant is desorbed from the solution. This generates a high refrigerant vapour pressure, with the vapour being condensed in the condenser. After passing an expansion valve and evaporating in the evaporator, the refrigerant vapour is absorbed in the solution in the absorber. The solution is pumped to the generator by a solution pump where it is regenerated and pumped back to the absorber via an expansion valve.

In adsorption chillers, the refrigerant is water and, as vapour, is adsorbed on a solid sorbent such as silica gel while releasing its latent heat of adsorption to the material. The amount of heat being transferred as latent heat of adsorption decreases as more water molecules arrive at the surface, so that it is only latent heat of condensation that is being given up.

The adsorbed water is desorbed by the incoming hot water source (in the temperature range of 45-70 °C) that dries out the silica gel, turning the adsorbed water back into vapour and creating pressure to drive the vapour to the condenser, so that this technology is especially appropriate for the application of solar energy. Closed adsorption chillers can provide cold water down to about 5-6 °C from their periodical, non-continuous cycle.

Market-ready thermally driven sorption chillers

Medium and large-scale sorption chillers with cooling capacities above 35 kW have been available for several years. Today, they are mainly manufactured in China, India, Japan and South Korea. In contrast, new small and medium-scale sorption chillers have been developed over the last 5 to 10 years. These absorption chillers have cooling capacities from 10 kW to 500 kW, and the adsorption chillers have capacities from 8 kW to 370 kW.

The German company, EAW, has been offering water/lithium bromide

Figure 1: Integrated absorption system with 23 kW water/lithium bromide absorption chiller, wet cooling tower and pumps. (Source: Jiangsu Huineng)

(LiBr) absorption chillers with 15 kW to 200 kW cooling power since 1998. At an evaporation temperature of 11 °C, a heat rejection temperature of 30 °C and a 90 °C hot water temperature, these absorption chillers deliver a COP of 0.75. Low generator temperatures, in the range 70-90 °C, can be used, with correspondingly reduced cooling capacity.

The Japanese company Yazaki has offered water/lithium bromide absorption chillers with a capacity range of 17.5 kW to 105 kW since 1977. The smallest absorption chiller, with 17.5 kW cooling capacity, delivers a cold water temperature of 12.5/7 °C and a COP of 0.70 from driving temperatures of 88/83 °C and heat rejection temperatures of 31/35 °C.

Another supplier of water/LiBr absorption chillers is the Indian Thermax company, producing chillers in the range of 17.5 kW to 282 kW. The COP of these chillers is about 0.70 from driving temperatures of 91/85 °C, heat rejection temperatures of 29/36.5 °C and cold water temperatures of 12.5/7 °C.

The Chinese Jiangsu Huineng company also produces water/LiBr absorption chillers from 11 to 350 kW. The heating temperature is 90/85 °C, with heat rejection at 30 °C, for cold water temperature of 15/10 °C. The company also produces an integrated absorption system, which is a combination of absorption chiller, wet cooling tower and pumps in one enclosure (Figure 1).

Crystallization in conventional absorption chillers can damage the machine if it occurs internally. Swedish Climatewell, however, specifically uses the principle of crystallization of highly concentrated lithium chloride solution (LiCl) to increase the internal thermal storage capacity. Additional thermal heating is needed to expel the refrigerant water from the salt solution and to crystallize the salt. Extended operation of the chiller, with about four hours of full load, is then possible. This is particularly interesting for applications with cooling demand after sunset. The first chillers, with a cooling capacity range of 7 to 10 kW, have been in field tests in Spain since 2005. A new machine, with 20 kW cooling capacity, was introduced to the market in the summer of 2009 (Figure 2).

Small-scale ammonia/water (NH_3/H_2O) absorption chillers have been available since the end of 2006, with driving temperatures in the range of 65-95 °C. The Austrian company, Pink, offers chillers with cooling capacities of 14 and 19 kW. The 19 kW chiller has a COP of 0.63 at driving temperatures of 85/75 °C, heat rejection temperatures of 24/31 °C and cold water temperatures of 12/6 °C. If water/glycol temperatures of 0/-3 °C

Figure 2: Water/lithium chloride absorption chiller with 20 kW cooling capacity. (Source: ClimateWell)

are required, then cooling capacity is reduced to 10 kW, with a COP of 0.5.

Other ammonia/water chillers have been available since 2008 from AGO in Germany with 50 kW to 500 kW, and from Tranter Solarice, also in Germany, with 40 kW capacity (Figure 3).

One problem of closed adsorption chillers is the poor heat transfer between the solid adsorbent material around a heat exchanger and the heat transfer medium. Operation of adsorption chillers with very short cycle times (a few minutes) is beneficial in terms of the COP, but currently only possible using heat exchangers coated with adsorption material, rather than packed adsorbent beds. The German company of InvenSor has developed such direct-coated water/zeolite adsorption chillers; three chillers with a cooling capacity of 9, 10 and 11 kW have been produced. The 11 kW chiller is intended for high ambient temperatures above 40 °C and a COP about 0.5 (Figure 4). The 9 and 10 kW chillers have been developed for very low heating temperatures, starting at 45 °C for waste heat applications and delivering a nominal COP of 0.6. The 10 kW chiller also includes an integrated chilling station, which means that installation essentially comes down to the external pipework systems, as the necessary pumps, mixers and valves are already included in the machine (Figure 4).

The Japanese company of Mayekawa also offers water/zeolite chillers with 92 to 370 kW cooling capacity. The cold water temperatures are 16/9 °C, with heating and heat rejection temperatures of 75/67 °C and 29/34 °C respectively.

German SorTech also offers water/silica gel adsorption chillers, with 8 and 15 kW cooling capacity. They deliver cold water at temperatures of 18/15 °C, with a COP of 0.60 at driving temperatures of 72/65 °C and heat rejection temperatures of 27/33 °C (wet cooling tower). Using a dry cooler (33/38 °C) requires driving temperatures of 85/75 °C.

Figure 3: 40 kW ammonia/water absorption chiller. (Source: Tranter Solarice)

Figure 4: Latest 10 kW water/zeolite adsorption chiller with integrated chilling station. (Source: InvenSor)

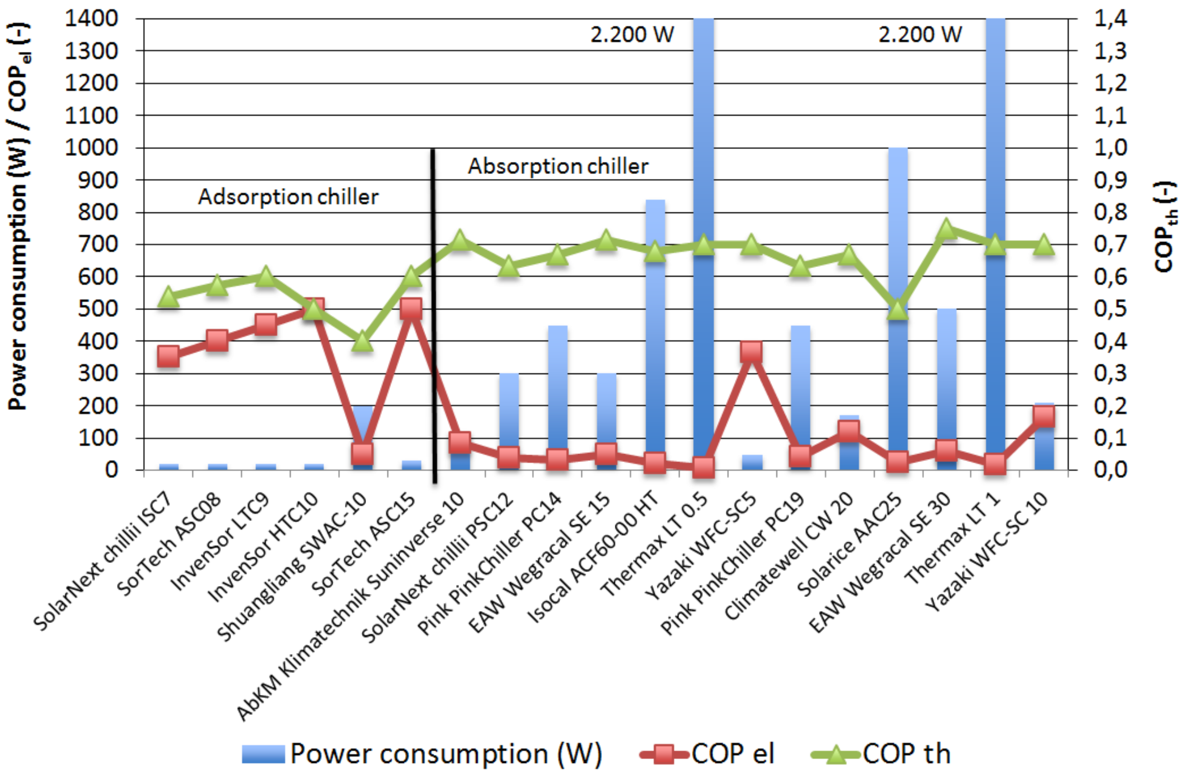

Figure 5: Power consumption, electrical and thermal COP of small-scale adsorption and absorption chillers. (Source: Dr. Jakob energy research)

From China, Shuangliang also offers a 10 kW water/silica gel adsorption chiller, with a COP of 0.4 from 85 °C heating temperature.

Performance review

Reference [2] provides a detailed overview and performance analysis of the different small-scale absorption and adsorption chillers (up to 35 kW) that are available, with information on the working pairs, cooling capacity, COP and dimensions. From the performance analysis it could be seen that, in general, the adsorption chillers have a higher electrical COP_{el}, because of their very low power consumption of 20 to 30 W, but that their thermal COP_{th} is 20 % lower than that of the absorption chillers (Figure 5). On the other hand, the absorption chillers have a higher power consumption, which ranges between 120 W and 2.2 kW. The Yazaki 17.5 kW absorption chiller, however, needs only 48 W.

The specific cooling power (SCP, ratio between cooling capacity and chiller weight) for both sorption chiller technologies ranges between 20 W/kg and 35 W/kg. The lowest value is that for the Shuangliang adsorption chiller, with 6.3 W/kg. Against it, the highest value is that for the Yazaki 35 kW absorption chiller, with 58.3 W/kg. In addition, the average power density of the investigated absorption chillers is about 70 % higher than that of the small-scale adsorption chillers (7.4 kW/m^3). The highest power density reached by an absorption chiller is 23.4 kW/m^3.

Conclusion

In the small and medium-scale cooling capacity range, up to 500 kW, several novel single-effect water/lithium bromide, water/lithium chloride and ammonia/water absorption chillers, as well as water/zeolite and water/silica gel adsorption chillers, are available on the market. The Green Chiller Association of Sorption Cooling from Berlin, Germany, which represents about 60 % of the European sorption chiller manufacturers, has published statistics on their produced and commissioned chillers from 2005 to 2009, indicating 225 absorption and adsorption chillers with an accumulated cooling capacity of 5.8 MW [3]. The market potential for sorption cooling is very large, so that companies have also developed complete cooling kits (sorption chiller, heat rejection, etc.) for the target business, with specific costs between 1,000 and 3,000 EUR/kW cooling capacity (without installation costs).

Maximum operating time and low cost of driving heat for sorption chillers are the keys for economic efficiency of sorption cooling systems.

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[2] Jakob, U., Performance analysis of small-scale sorption chillers, Proceedings of the IMPRES 2010 conference, Singapore, paper no. 63, 2010.

[3] Jakob, U., Solar cooling – Green Chiller industry association, Proceedings of the EUROSUN 2010 conference, Graz, Austria, 2010.

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World Energy Outlook 2011

The 2011 edition of the World Energy Outlook was released on 9 November and brings together the latest data, policy developments, and the experience of another year to provide robust analysis and insight into global energy markets, today and for the next 25 years. This edition of the IEA's flagship WEO publication gives the latest energy demand and supply projections for different future scenarios, broken down by country, fuel and sector.

It also gives special focus to such topical energy sector issues as Russia's energy prospects and their implications for global markets; the role of coal in driving economic growth in an emissions-constrained world; how high-carbon infrastructure "lock-in" is making the 2°C climate change goal more challenging and expensive to meet; the scale of fossil fuel subsidies and support for renewable energy and their impact on energy, economic and environmental trends; or the scale and type of investment needed to provide modern energy to the billions of the world's poor that do not have it.

http://www.worldenergyoutlook.org/

Guidance on the "How-Tos" of Energy Audits

Seeking to promote best practices and offer a "how-to" approach, ASHRAE has released updated guidance on building energy audits. While energy audits are a commonly used component of the industry, there is great diversity in the services delivered to customers, and little industry standardization. The second edition of Procedures for Commercial Building Energy Audits promotes best practices, provides "how-to's" and fills a void in available information for engineers, building owners, managers and government entities. The new publication includes time-saving tips for energy auditors, how to hire an auditor, what to ask for in a comprehensive audit report and how to build a successful energy efficiency retrofit team.

http://www.ashrae.org/pressroom/detail/ashrae-provides-guidance-on-the-how-tos-of-energy-audits--------------------

2012

21-25 January
ASHRAE Winter Meeting
Chicago
http://www.ashrae.org/events/page/Chicago2012

7-9 February
Chillventa Rossija 2012
Moscow, Russia
http://www.chillventa-rossija.com/en/

23-25 February
ACREX India 2012 "For a greener tomorrow"
Biec, Bangalore, India
http://www.acrex.org.in/pdf/brochure.pdf

12-13 March
High Performance Buildings Conference
San Diego, California
http://www.ashrae.org/events/page/hpbconf/

27-30 March
Mostra Convegno Expocomfort
Milan, Italy
http://www.mcexpocomfort.it/en/aspx/showFolder.aspx?Folder=1750

17-20 April
2nd European Energy Conference
Maastricht, the Netherlands
http://energy-conference.eu/

26-27 April
3rd Annual conference of the RHC-Platform
Copenhagen, Denmark
http://conference2012.eu/

13-17 May
2012 World Renewable Energy Forum
Denver, Colorado
http://ases.org/index.php?option=com_content&view=article&id=18&Itemid=147

23-27 June
ASHRAE Annual Conference
San Antonio, Texas
http://ashraem.confex.com/ashraem/s12/cfp.cgi

25-27 June
10th IIF/IIR Gustav Lorentzen Conference on Natural Refrigerants
Delft, the Netherlands
http://www.gl2012.nl/

8-12 July
Healthy buildings 2012
Brisbane, Australia
http://hb2012.org/

16-19 July
21st International Compressor Engineering Conference at Purdue
14th International Refrigeration and Air Conditioning Conference at Purdue
2nd International High Performance Buildings Conference at Purdue
West Lafayette, Indiana, USA
https://engineering.purdue.edu/Herrick/Events/2012Conf/index.html
http://www.conf.purdue.edu/

29 July - 1 August
10th IIR Conference on Phase Change Materials and Slurries for Refrigeration and Air-Conditioning
Kobe, Japan
http://www2.kobe-u.ac.jp/~komoda/pcms/

9-11 October
Chillventa
Nuremberg, Germany
http://www.chillventa.de/en/

25-26 October
3rd IIR Workshop on Refrigerant Charge Reduction in Refrigerating Systems
Valencia, Spain
http://www.imst.upv.es/iir-rcr2012

12-14 November
Cold Climate HVAC 2012
Calgary, Alberta, Canada
http://www.ashrae.org/events/page/coldclimate2012

2013

26-30 January
ASHRAE Winter Conference
Atlanta, Georgia, USA
http://www.ashrae.org

2-4 April
2nd IIR International Conference on Sustainability and the Cold Chain
Paris, France

9-11 May
5th International Conference Ammonia Refrigeration Technology
Ohrid, Republic of Macedonia

7-8 June
15th European Conference - Italy
United Nations Environment Programme
Milan, Italy

16-19 June
CLIMA 2013
Prague, Czech Republic
http://www.clima2013.org/

In the next Issue

Industrial heat pumps

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International Energy Agency

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

IEA Heat Pump Programme

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

Vision

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

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

Mission

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

IEA Heat Pump Centre

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

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