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IEA HEAT PUMP CENTRE

NEWSLETTER
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Highlights from research

Heat Pumps - A key technology for the future

IEA **Heat Pump** CENTRE
NEWSLETTER

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In this issue

Heat Pump Centre Newsletter, 2/2014
The importance of research cannot be denied. This is true for virtually any field of technology, or indeed any field at all. For heat pumps, technological wonders relying on science, this is certainly the case, and heat pump research provides one of the cornerstones for heat pump markets.

The topic of this issue of the HPC Newsletter is Highlights from research. The Foreword, from the European Commission, provides a background. This is followed by an outline with examples from the US. As a non-topical article, the influence of GSHP system design on CO_2 emissions is presented.
This issue also contains a Strategic Outlook, embracing all world regions.

The 11th IEA Heat Pump Conference was held in Montreal on May 12-16. In this Newsletter issue, the Ritter von Rittinger awardees are presented. In upcoming issues, there will be more material from this conference.

Enjoy your reading!

Johan Berg, Editor

Heat pump news

Regulars

Topical articles

Non-Topical articles

COLOPHON

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IEA OECD heat pump centre

Foreword

Mark van Stiphout
Member of Cabinet of the Commissioner for Energy
European Commission

Europe's energy policy aims to achieve security of supply, sustainability and competitiveness by making full use of the opportunities provided by the internal energy market. This includes, inter alia efforts to reduce the overall energy demand, better links between the various energy networks, better management of the EU's energy system and promotion of new technologies including for storage.

Heating and cooling (H&C) systems are widespread energy commodities, accounting for a substantial share of final energy consumption in Europe - mostly in industry, households and services. The final energy consumption in Europe for H&C was estimated to be about 500 Mtoe in 2010 (about 47 % of the final energy consumption). Over 80 % of heating and cooling demand is met by fossil fuel sources, including imported natural gas.

To boost the security of our energy supplies as well as sustainability and competitiveness, the use of fossil fuels for heating and cooling could be reduced substantially by energy efficiency measures in buildings and by a fuel switch towards indigenous, low-carbon, energy sources, especially renewables. More efficient heating and cooling technologies also promise to reduce dependence on fossil fuels in the H&C sector. But this is not all.

Whilst the effects of such substitution on the whole energy system need to be fully analysed, heat pump systems offer a relevant opportunity to replace fossil fuel based H&C systems. Even when heat pumps are driven by electricity produced from conventional sources, the largest part of the final energy demand is covered by a renewable source. Furthermore heat pumps, coupled with thermal storage, improve the balance among generation and demand, allowing the integration of a larger share of variable renewable sources in the energy system. Storage plays also a central role in district heating, for developing more integrated electricity and thermal networks.

The "Highlights from research" in this newsletter provide a state-of-art overview of the heat pump technology sector, presenting experience in North America, reporting on past and recent trends and highlighting a few case studies.

The publication is an aptly-timed contribution to the ongoing debate and initiatives to improve the security of supply in the European energy system.

Column

IEA ETP 2014 Highlights Heat Pumps to Achieve Energy Savings Beyond the 2 Degree Scenario

Marc LaFrance
Energy Analyst - Building Sector
International Energy Agency (IEA)
Paris, FRANCE

The IEA recently released its Energy Technology Perspective (ETP) 2014 publication at the 5th Clean Energy Ministerial meeting in Seoul, Korea. The 2 Degree Scenario (2DS), the main focus of ETP 2014, describes an energy system that recent climate science research indicates would give at least a 50 % chance of limiting average global temperature increase to 2°C. It also identifies changes to ensure a secure and affordable energy system in the long run. It sets the target of cutting energy- and process-related CO_2 emissions by more than half by 2050, with continuing decrease thereafter.

ETP 2014 included a high electrification case in the EU and China for the buildings' sector, beyond 2DS, for larger energy and carbon emission reductions. These regions were analyzed to assess greater market penetration of heat pumps for space and water heating. In the EU, the focus is to reduce the consumption of natural gas for heating; in China, it is to reduce the expected increase in natural gas. A premise for the 2DS is that all countries will move towards cleaner electricity, with much higher rates of renewable energy. The results of the study were dramatic. EU reduced its natural gas consumption by around 30 % compared to business-as-usual (the 6°C scenario). China's growth for natural gas was around half compared to the case without a high penetration of heat pumps. The 2DS savings included building envelope measures, but the beyond-2DS scenario focused only on heat pumps and resulted in a further building sector energy reduction of 6 % for EU and 7 % for China in 2050.

To achieve high penetration rates of heat pumps globally, much more effort is needed from policymakers, researchers, and industry. Each country's domestic energy resources, environmental policy, energy prices, and climate are criteria affecting the market potential. A core market opportunity is to replace the millions of electric resistance water heaters being sold every year globally with heat pump water heaters (HPWHs). Japan's HPWH market is very mature, around half a million sold annually, yet sales in other regions are very low. The US has made progress in developing affordable HPWH models, but sales are limited. The EU, with its energy public policy leadership position, technical maturity, and natural gas concerns, should lead the world in this area. However, in the EU, HPWHs cost about 4 times more than in the US, and sales per capita are about 1/40th those of Japan.

Heat pumps are not limited to individual buildings, they are also being included in large-scale district heating and cooling networks, such as one of the world's largest applications using heat from waste water in Helsinki, or as part of a fully zero-carbon-emission district heating network in Denmark. Heat pumps can more than triple energy resources when coupled to ambient air. Also, heat pumps are not limited to electricity. R&D is needed to provide higher performance thermal gas heat pumps. This activity and many others, such as improving cold climate performance, are being addressed by the HPP, but much more effort is needed so that heat pumps can reach their full energy savings potential.

IEA Heat Pump Programme News

Five awardees recognized in the 2014 Rittinger Award

In a ceremony held at the conference banquet at the 11th IEA Heat Pump Conference in Montreal Dr. Michel Bernier, Mr. Frédy Burkhalter, Mr. Daniel Ellis, Dr. Andrew Pearson and Dr. Koichi Watanabe were given the prestigious Ritter von Rittinger Medal, the highest international award in the air conditioning, heating and refrigeration field.

The award highlights outstanding contributions to the advancement of international collaboration in research, policy and market development and applications for energy-efficient heat pumping technologies that result in environmental benefits. It is awarded every three years in conjunction with the International IEA Heat Pump Conference.

Dr. Sophie Hosatte, Chair of the IEA Heat Pump Programme Executive Committee, presented the awards: “It is my great pleasure to recognize these dignified gentlemen and honour them with the industry’s most prestigious prize”, said Dr. Sophie Hosatte during the ceremony. “Our award winners are undoubtedly five of the most influential individuals also in the history of the IEA Heat Pump Programme.”

Mr. Frédy Burkhalter, the CEO of the Swiss Friotherm company, Switzerland, was acknowledged for his contributions in market development and applications of large heat pumps. Mr. Burkhalter’s activities on the large capacity heat pump market, with various heat sources and high hot water production temperatures have made a big impact on the Sulzer Friotherm centrifugal compressor development. His work has led to many developments e.g. high temperature heat pump technology in district heating applications in Sweden, the first heat pump in Brazil, producing tap water at 80°C and the world’s largest sea water pump station in Stockholm.

Mr. Daniel Ellis, the President of ClimateMaster Inc., USA was recognized for his product innovation and market development activity for geothermal heat pumps. Mr. Ellis has been active with geothermal heat pumps since 1978 and is recognized as one of the industry pioneers and he led the industry efforts that resulted in U.S. federal tax incentives for GSHPs. Mr. Ellis has been a strong supporter of international technical collaboration and his technical contributions include residential energy analysis software, development of advanced technology heat pumps and design procedures for commercial systems.

Dr. Andrew Pearson from Star Refrigeration Ltd, Scotland was awarded for his contributions in research and industrial refrigeration systems engineering.

Dr. Pearson is well-known internationally through his IIR and ASHRAE activities and his work with more efficient refrigeration systems and troubleshooting of faulty, inefficient or unreliable equipment. He is very active in many associations and is Chairman of the Institute of Refrigeration’s Technical Committee and past-President of the Institute.

Dr. Koichi Watanabe, Professor Emeritus of Keio University, Japan was highlighted for his research and publications in the field of thermophysical properties.

Dr. Watanabe has during his career published more than 350 scientific and technical papers and books and is an internationally-recognized expert in the field of thermophysical properties of fluids. He has been Visiting Professor at the Polytechnical University of Marche at Ancona, Italy and at the Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, China.

Dr. Michel Bernier, Professor at Polytechnique Montréal, Canada, was given the award for his research and teaching contributions with particular reference to geothermal heat pump systems.

Dr. Bernier has made significant contributions to the advancement of heat pump technology through his research activities. With his graduate students, he has contributed to better understanding of dynamic processes in water to air heat pumps, and made numerous contributions to the improvement of modelling and design tools for ground-source heat pump systems.

He is also contributing to the education of the next generation of heat pump researchers and practitioners.

About the Peter Ritter von Rittinger International Heat Pump Award

The Rittinger award is named after Peter Ritter von Rittinger, the Austrian engineer who designed and installed the first known heat pump in 1855. The award celebrates the technical skills and entrepreneurial spirit of Rittinger that is shared by the award winners.

IEA HPP member of BUILD UP

The Heat Pump Programme was invited as a partner to the European BUILD UP initiative, which was first formed to support EU Member States in implementing the Energy Performance of Buildings Directive (EPBD).

Obviously heat pumps have a lot to contribute in this respect, just look at our annexes A32 and A40 for example, where the potential benefits of heat pumps in future low energy buildings have been at the center of our reseach.

We are proud to have been invited, and look forward to a new channel to disseminate our valuable heat pump information.The *BUILD UP web portal* is intended to reap the benefits of Europe's collective intelligence on energy reduction in buildings for all relevant audiences. It will bring together new practitioners and professional associations while motivating them to exchange best working practices and knowledge and to transfer tools and resources.

General

Fifth Clean Energy Ministerial meeting

Recognizing the growing urgency of the world's energy and climate challenges, energy leaders from the world's largest economies and others gathered in Seoul for the fifth Clean Energy Ministerial (CEM5) to strategize next steps in their efforts to accelerate the deployment of clean and efficient energy. Hosted by Korea on 12–13 May, CEM5 got underway with opening remarks from Yoon Sang-Jick, Korea's Minister of Trade, Industry and Energy, and U.S. Secretary of Energy Ernest J. Moniz.

Over the two-day meeting, energy ministers and other high-level delegates highlighted progress made through the Ministerial's collaborative initiatives and announced new and expanded actions that will enhance clean energy supply, improve energy efficiency and expand clean energy access around the world.

Source: www.cleanenergyministerial.org

HPTCJ publishes new best practise videos for HP applications

The Heat Pump and Thermal Storage Center of Japan has published a new set of videos on best practise applications for heat pumps. The examples presented include

1. Large heat pumps used in heating and cooling of sake production
2. Heating and cooling of a high rise building using renewable energy from a nearby river
3. Heating and cooling of the Kyoto Aquarium
4. "The energy efficient society": impact of heat pump use in residential buildings, a university and a swimming pool.

Sources: www.ehpa.org and www.hptcj.or.jp

EPA lists top 100 U.S. organizations using renewable energy

The U.S. Environmental Protection Agency (EPA)'s Green Power Partnership has released an updated list of the Top 100 organizations that are choosing to use electricity from clean, renewable sources like wind and solar power. Intel Corporation continues its seven-year run as the nation's largest voluntary user of green power, meeting 100 percent of its electricity load with renewable resources. Other technology companies in the top 10 include Microsoft Corporation, Google Inc., and Apple Inc.

Source: www.epa.gov

Americans more positive to energy efficiency

Energy efficiency is a priority for 79 percent of Americans, according to a poll released by the University of Texas. But nearly two-thirds believe political "squabbling" is the biggest barrier to increased energy efficiency. While most people are concerned about the environmental impact of high energy use, the biggest motivator for energy efficiency is savings, according to the UT Energy Poll, a scientific survey of more than 2000 U.S. residents, conducted in March 2014.

Source: powersource.post-gazette.com

Lessons learned to help close the building performance gap

The 12th annual CIBSE ASHRAE Technical Symposium, held at the Dublin Institute of Technology on 3 – 4 April, highlighted the problem of buildings failing to perform to their design intentions, and presented new processes, technologies and best practice to tackle this issue. Bringing together delegates from the UK, USA and beyond, the Symposium showed where international comparisons

could provide lessons in how to improve building performance.
Source: www.acr-news.com

ACREX India 2014

The ACREX India was held on February 27 – March 1 in New Delhi, India. Being the largest AC, ventilation, refrigeration, and building services show in South Asia, it was attended by 30,000 visitors and 400 exhibitors, from 25 countries. As Dipak Barma, National President, ISHRAE (Indian Society of Heating, Refrigerating, and Air Conditioning Engineers) pointed out, the Indian market is expected to grow by 30 % over the next two years, mainly due to activity in the infrastructure and real estate sectors. The ACREX also included Workshops (on energy storage, geothermal systems, energy security, seismic considerations, and BIM), interactive panel discussions (integrated approach to project delivery, and India's future cities), and an Awards of excellence ceremony. The next ACREX India will be held in Bangalore in February 2015.
Source: www.acrex.in

Policy

Buildings efficiency 'absolutely central' to EU 2030 climate package, but…

Unlocking the energy saving potential of the continent's ageing building stock will be "absolutely central" to a key review of EU policy this summer, the EU's top energy efficiency official has said.

But Paul Hodson, the head of the EU's energy efficiency unit, flagged "micro" public action as the way forward, dampening hopes of major policy advances in the review. It will identify and describe progress towards meeting 2020 energy-saving targets, as well as outline the issues for 2030 objectives. The paper will now be published in July, during the EU's summer vacation period.
Source: www.euractiv.com

A number of ACREX organisers and honourable guests… and five of the ACREX mascot, ACRO. The ACREX India was held on February 27 – March 1 in New Delhi, India.

Energy efficiency investment reaches "tipping point"

Europe has reached a crossroads at which energy saving investments can either be scaled up with market drivers that carry multiple benefits, or risk being sabotaged by a lack of funding, an official report says. "We are at a tipping point, with energy efficiency investing having the clear potential to emerge into the mainstream as a key driver of EU competitiveness, economic value, innovation and employment across Europe," says the new study by the Energy Efficiency Financial Institutions Group (EEFIG). But the paper also notes "insufficient public and private investment" in the sector at present, and warns that "if this trend continues, then EU Member States are at risk of missing their 2020 and longer-term energy efficiency targets."
Source: www.euractiv.com

UK Government launches domestic RHI scheme

The UK Government has launched its long awaited domestic Renewable Heat Incentive (RHI) scheme, which it says will offer homeowners payments to offset the cost of installing low carbon systems in their properties. The new scheme will effectively pay people for the green heat they generate for their homes. It is open to everyone from home owners and social and private landlords, to people who build their own homes and is available to households both on and off the gas grid.
Source: http://www.acr-news.com

New website section on EU publications

EHPA has created a new website section on EU publications, including all useful and recent reports on energy finance, strategies and related subject.
Source: www.ehpa.org

New F-gas regulation ready to enter into force

The Council of the European Union has adopted the new F-gas Regulation. As such, the Member States follow the European Parliament decision and clear the way for a fast completion of the file. The European heat pump industry favors such a quick finalization as it creates a clear framework for research and development as well as investment decisions.
Source: www.ejarn.com

Working **fluids**

Japanese groups launch new HFO-based air conditioning refrigerant

Japanese firm Asahi Glass Company (AGC), in collaboration with state technology researcher NEDO, has announced its own AC refrigerant, based on the new HFO molecule HFO 1123, with a GWP under 350, a sixth that of R410A and half that of R32. AGC has followed up its production venture with Honeywell on the automotive refrigerant R1234yf with the announcement of its own HFO-based refrigerant based on the hitherto unpublicised molecule HFO 1123. The refrigerant is trademarked as AMOLEA, and is aimed at room air conditioning applications.
Source: www.racplus.com

Daikin launches R32 units in India

Daikin Airconditioning India has launched air conditioners using the 'mildly flammable' refrigerant R32. This news from India follows a statement from Daikin's headquarters in Osaka last year that it planned to switch to R32 in Japan from the current R410A. According to The Hindu website, Daikin India is now poised to launch R32 units manufactured at its Neemrana plant in Rajasthan.
Source: www.acr-news.com

F-gas emissions in UK on the increase – slightly

The latest set of statistics from the Department of Energy & Climate Change show that the UK's greenhouse gas emissions have increased by 3.2 per cent. The report, which provides the latest estimates of UK greenhouse gas emissions from 1990-2012, highlights the rise from 563.2 million tonnes carbon dioxide equivalent ($MtCO_2e$) in 2011 to 581.1 million tonnes in 2012. This is primarily attributed to the residential sector which was up by 12.3 per cent (8.5 $MtCO_2e$) due to increase in residential gas use, and the energy supply sector, up by 5.9 per cent (11.2 $MtCO_2e$) due to greater use of coal in electricity generation.
Source: www.acr-news.com

Technology

Breakthrough in home refrigeration technology

Researchers from GE Appliances, USA, are developing the next advance in home refrigeration technology—magnetic refrigeration (magnetocaloric refrigeration). The company says that the technology uses no refrigerants or compressors and is 20 per cent more efficient than that currently used. In addition, the technology can be applied to other heat pump applications such as HVAC and has the potential for use in any heat pump application - up to 60 percent of total home energy consumption in the USA.
Source: www.acr-news.com

Use of all-aluminum coils are increasing

For years, copper tubes with aluminum fins have been the typical choice for condensing coils for HVAC&R equipment. Due to soaring copper prices, however, manufacturers have recently begun looking at adopting aluminum tubes as a way to reduce costs. Aluminum tube/aluminum fin condensing coils have actually been around for decades. However, the brazing of the aluminum tubes and interconnecting piping (between the indoor and outdoor units), which is done in the field, posed a particular challenge. In addition, maintenance and repairs when a leak occurred have proven difficult for field service mechanics. For these reasons, all-aluminum heat exchangers have not come into widespread use. However, now there has been brisk development in coatings for aluminum based HVAC applications similar to developments in alloys, which has led to new types of coatings that can further improve brazing quality and corrosion resistance.
Sources: www.ejarn.com (news 1) and www.ejarn.com (news 2)

Markets

UN panel: AC demand to increase 30-fold this century

Warming climates, and especially the rise of a global middle class, are going to send new populations in search of artificial cooling. That is one conclusion of a new report issued by the Intergovernmental Panel on Climate Change (IPCC). Throughout the developing world, rising incomes and warming temperatures will boost energy demand for residential air conditioning from nearly 300 TWh in 2000 to about 4,000 TWh in 2050,

to more than 10,000 TWh in 2100, according to the report.
Source: www.csmonitor.com

Heat Pump City of the Year 2014: Viborg

After an intense and successful public online vote, Viborg municipality (Bjerringbro) was elected as the new Heat Pump City of the Year. So, similar to the very first edition in 2011, the 2014 winner is a city in Denmark. The project represents a great example of heating and cooling heat pumps and a good model of cohesion in the local society as it ties together the company to the local community.
Source: www.ehpa.org

Heat pumps highlighted in Poland

The Polish Ministry of Economy has published a Decision on the method of calculating final gross energy consumption from renewable sources and the amount of electricity and heat from such sources. As such, this Decision is the first unambiguous document in Polish law, according to which a substantial part of the heat provided by heat pumps is derived from renewable sources.
Source: www.ehpa.org

Wine refrigerator market

According to GIFAM, a French association of household appliances manufacturers, the wine refrigerator market is expanding fast in France. Three types of wine refrigerators are available: wine cooling, wine storage, and combined cooling and storage multi-temperature models. The total number of wine refrigerators in France is currently 1.6 million units, and 6 % of households are equipped. 28 % of wine refrigerators are less than two years old, and 89 % were first acquisitions.
Source: www.ejarn.com

Ongoing Annexes

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

Annex 35, a joint venture of the IEA "Industrial Energy-related Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP) Implementing Agreements, expired at the 30th April 2014. Nine IEA countries have participated with 15 organizations. The framework of the programme has consisted of the following tasks:

1. Market overview and barriers for application
2. Modelling of calculation and economic models
3. Technology
4. Application and monitoring
5. External communication

At this stage the work is concentrated on preparation of the final reports of the different tasks, and should be finalized in June of this year. At the moment, more than 650 pages of information have been prepared.

At the 11th IEA Heat Pump Conference in Montreal, Canada, on May 12, 2014, a successful workshop with about 50 participants took place, with the following presentations:

- » Annex 35/13 Introduction & Status
- » French Industrial Heat Pump Developments applied to Heat Recovery
- » Pioneering Industrial Heat Pump Technology in Japan
- » Industrial Heat Pump R&D works and applications in the Canadian energetic context
- » Germany: How Heat Pumps can be used to improve Energy Efficiency of Industrial Processes
- » Korea: Thermal Energy Network based on Heat Pumps
- » Japan: Development of High Temperature Water Circulation Type Heat Pump for Industries (A-W HP with a maximum output of the water temperature of 90°C)
- » Summary of the Annex Workshop

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IEA HPP Annex 36 Quality Installation / Quality Maintenance Sensitivity Studies

Annex 36 is evaluating how installation and/or maintenance deficiencies cause heat pumps to perform inefficiently (i.e., decreased efficiency and/or capacity).

Also under investigation are the extent that operational deviations are significant, whether the deviations (when combined) have an additive effect on heat pump performance, and whether some deviations (among various country-specific equipment types and locations) have greater impact than others. The focus and work undertaken by each participating country is presented in the table below.

The intended audience for the Annex 36 output includes:

- HVAC practitioners responsible for designing, selecting, installing, and maintaining heat pump systems in varied applications.
- Building owners/operators interested in achieving improved comfort conditioning and efficiency performance from their HVAC equipment.
- Entities charged with minimizing energy utilization in varied heat pump applications and geographic conditions (i.e. utili-

Annex 36 Participants	Focus Area	Work Emphasis
France	EdF – 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	DECC – 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)	NIST – 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 model the performance of a heat pump operating under those faults.

ACCA → Air Conditioning Contractors of America
DECC → Department of Energy and Climate Change (UK)
EdF → Electricité de France
KTH → Royal Institute of Technology (Sweden)
NIST → National Institute of Standards and Technology (US)
ORNL → Oak Ridge National Laboratory (US)
SP → Technical Research Institute of Sweden
SVEP → Swedish Heat Pump Association

ties, utility commissions, energy agencies, legislative bodies, etc.)

- The three-year effort is essentially complete with results presented at the Annex 36 workshop held in conjunction with the 11th IEA Heat Pump Conference (Montreal, Quebec, Canada; 12 – 16 May 2014).

  The Annex 36 final report is being finalized with expected submission to the IEA HPC by July 2014.

Contact: Glenn C. Hourahan, Glenn.Hourahan@acca.org

IEA HPP Annex 37 Demonstration of field measurements on heat pump systems in buildings – good examples with modern technology

Annex 37 is close to finalisation

In the Annex 37 project, the focus has now been on finalizing the annex report. At the ExCo meeting in Tokyo (November 2013) it was decided to include results from studies made in Germany by the Fraunhofer institute, and in Denmark by the Technical Institute of Denmark (DTI). In addition to this, in the UK, a really nice piece of work as a follow-up on the EST field monitoring campaign has been released. We will update the study for UK with this material, before submitting the final report for the ExCo decision in June.

In September, the final report will hopefully be available for download from the Heat Pump Centre website. We will of course inform you when this happens.

Contact: Roger Nordman, roger.nordman@sp.se

IEA HPP Annex 38 Solar and heat pump systems

Annex 38 has completed its work

Annex 38 was concerned with solar and heat pump system for space heating and domestic hot water. A total of 55 experts from eleven countries attended some or all of its eight meetings over the period 2010 – 2013.

The **main results** are as follows:

- A survey of the market in 2010 was responded to by more than 80 companies.
- Four generic categories of SHP systems have been proposed and used throughout the Annex period, and taken over by several other teams in research projects.
- An energy flow chart solution was developed and used by all 32 Annex projects.
- Definitions of all performance indicators (from COP to SPF+) are now available and form a basis for a future EU standard.
- A simulation framework was developed from previous IEA work and proved to be a great tool for comparing SHP systems
- Laboratory testing procedures for any SHP system have been developed and used and described.
- 32 systems in the field were monitored by several teams, and 20 have been reported with a common reporting format.
- Not surprisingly, a high variance of SPFs was observed and the reasons why explained. The management of the store is one of the important ones, together with the overall control strategy and the temperatures of heat distribution systems.
- Validated models are now available for many SHP configurations.
- A comparison of different configurations with the same framework was produced and shows what solar heating can contribute (or not) to heat pump systems

ReportNo.	Report Title	Publication Date	Access (PUblic, REstricted)	Web or Print
A1	A Review of Market-Available solar heat pump systems	March 2013	PU / RE for details	Web
A2	Field test monitoring of SHP systems	March 2014	PU	Web
A3	Dissemination Activities of Subtask A of the IEA SHC Task 44 / HPP Annex 38	March 2014	PU	Web
B1	Definition of main system boundaries and performance figures for Reporting on SHP Systems	December 2013	PU	Web
B2	Testing solar and heat pump systems in laboratory	Dec 2013	PU	Web
B3	Definition of a standard test for SHP systems	March 2014	PU	Web
B4	Dissemination activities of Subtask B of the IEA SHC Task 44 / HPP Annex 38	March 2014	PU	Web
C1	The reference framework for system simulations of the IEA SHC Task 44 / HPP Annex 38 Part A: Summary Part B: Collector models Part C: Heat pump models Part D: Ground heat exchangers Part E: Storage models	March 2013	PU	Web
C2	Models of sub-components and validation for the IEA SHC Task 44 / HPP Annex 38	March 2014	PU	Web
C3	System Simulation Reports for the IEA SHC Task 44 / HPP Annex 38	March 2014	PU	Web
C4	Synthesis of system simulation results for the IEA SHC Task 44 / HPP Annex 38	March 2014	RE	Web
C5	Dissemination activities of Subtask C of the IEA SHC Task 44 / HPP Annex 38	March 2014	PU	Web
D1	Presentation of system performance calculation Educational material	Oct. 2013	PU	Web
D2	Newsletters issued by IEA Task 44 / Annex 38 from 2010 to 2013	Oct. 2013	PU	Web
D3	T44A38 presentations in conferences	March 2014	PU	Web
D4	Cancelled - information is included in C4			
D5	Solar and heat pump systems – A handbook	June 2014	PU	Print

- The final report from the project, in the form of a handbook, is of high scientific and technical quality and will soon be sent to the publisher. Publication date is planned for autumn 2014.
- An economic analysis model to enable systems to be compared has been developed, and will be included in the handbook as Chapter 8.
- S + HP systems are now considered as “standard technologies”, although there is still some work to be done to arrive at optimum high performing solutions.
- All categories of systems can deliver SPFs of 5.0 or more if solar energy is also used, provided that careful designs and control strategies are applied.

New ideas for future annexes have also been proposed as a result of experience from Annex 38:

- Optimisation of control strategies of a hybrid system
- PVT solution for ice storage heat pumps
- Bigger systems than 100 kW
- Thermally driven heat pumps
- Heating systems that can also provide cooling during the hot season.

All publicly available reports and articles can be downloaded from: http://task44.iea-shc.org
The final report will be available through the website soon.

List of reports of Annex 38: See table on previous page.

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

Annex 39 will investigate the experiences from using EN14825 Standard

Annex 39 is coming towards the end of the project, and a proposal for the final report contents was presented at the ExCo meeting in Montreal in mid-May.

At this meeting, it was proposed that the Annex could make a follow-up study about how manufacturers experienced the use of the standard EN14825, since it now has been in use for a couple of years. This was positively accepted, and a survey is therefore under preparation. This will be sent to manufacturers. The annex is scheduled to end in August, so the survey will be a short web-based questionnaire.

In conjunction with the 11th IEA HPP Conference in Montreal, Annex 39 also held a short open workshop, attended by some 30 people.
The Annex was introduced by Roger Nordman, then Kiyoshi Saito from the Japanese team gave an interesting presentation about "high accuracy simulation technologies needed for SPF calculations". Wayne Reedy from the US team presented the work that has been carried out to complete the new ASHRAE 206 standard "Method of Testing for Rating of Multipurpose Heat Pumps for Residential Space Conditioning and Water Heating". Roger Nordman ended the workshop by giving a presentation about "Overview of different standards for measuring and calculating SPF – How far apart are we really?"

The workshop presentations are available for download from the Heat Pump Centre website.

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

Annex 40 interim results presented at the IEA Heat Pump Conference in Montréal, Canada

IEA HPP Annex 40 is concerned with investigation and improvement of heat pump systems in Nearly or Net Zero Energy Buildings (nZEB). Six countries - CH, JP, NL, NO, SE and US - started work at the beginning of 2013: Canada and Finland joined at the end of 2013, so currently eight countries are collaborating in the annex. Finland is represented by VTT, Aalto University and SULPU, under the leadership of GreenNet Finland, while Canada is represented by CANMET Energy of Natural Resources Canada and Hydro-Quebec.

In addition, Germany has expressed interest in joining, but has not yet received final confirmation.

While the countries who joined the annex at the beginning of 2013 are working on Task 2 and Task 3 (design and simulation of heat pump concepts for nZEB, and development of adequate heat pump technology), as well as field monitoring to gather experience from existing nZEB, Canada and Finland will catch up with the status of the annex by working on Task 1, the state-of-the-art report.

Interim results from the annex were presented at the IEA Heat Pump Conference 2014 in Montréal in May in the frame of a joint workshop with the Canadian Smart Net Zero Energy Strategic Research Network (NSERC). The morning session was devoted to presentation of NSERC projects, while in the afternoon session discussed interim results from Annex 40. The member parties of the annex have already contributed to an HPP brochure on "Heat Pump Concepts for Nearly Zero Energy Buildings", which will be published in the frame of the IEA Heat Pump Conference.

An Annex 40 working meeting was held after the conference.

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IEA HPP Annex 41 Cold Climate Heat Pumps

Annex 41 began in July 2012 to revisit research and development work in different countries to examine technology improvements leading to successful heat pump experience in cold regions. The primary focus is on electrically driven air-source heat pumps (ASHP) with air (air-to-air HP) or hydronic (air-to-water HP) heating systems, since these products suffer severe loss of heating capacity and efficiency at lower outdoor temperatures. The main outcome of this Annex is expected to be information-sharing on viable means to improve ASHP performance under cold (≤ -7°C) ambient temperatures. The Annex web site is http://web.ornl.gov/sci/ees/etsd/btric/usnt/QiQmAnnex/indexAnnex41.shtml.

In the past quarter the Japanese completed a draft of their interim report and work has begun to draft the overall Annex interim report (including Task 1 and 2 works to date). The photos below from the draft Japan report illustrate a field test installation of a heat pump water heating (HPWH) system with solar thermal & PV collectors. This system includes recovery of waste hot water and optimization of solar heat utilization through a smart control to improve system annual COP (up to 5.0). A workshop and brief business meeting were held at the 11th International Heat Pump Conference in Montreal with representatives from all participating countries (Austria, Canada, Japan, and the US) making presentations. The participants are discussing the possibility to extend the Annex period by 6-12 months to allow all Participants time to complete their planned contributions. The final Annex meeting and workshop are planned for August 2015 in Yokohama, Japan during the 2015 International Congress of Refrigeration.

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Annex 41: Field test installation of HPWH system combined with Solar thermal and PV collectors – Source: YAZAKI RESOURCES CO., LTD. Contribution to Japan Annex 41 draft interim report.

IEA HPP Annex 42 Heat Pumps in Smart Grids

We had a successful meeting in Nürnberg on 16th October 2013 and, as the operating agent, are making steady progress on the work.

A growing number of countries – confirmed participants being the United Kingdom, The Netherlands, South Korea, the USA, Switzerland and France, with Denmark, Sweden, Finland, Austria and Germany in the process of becoming full members – are interested in joining the annex.

During the last meeting, progress was made on gradually consolidating the annex into a more defined shape. Task leaders have been appointed, with task descriptions, expected outputs, planning and a table of contents of the task report being subject to further discussions.

This work was continued at the meeting on 13th and 14th February 2014 at EDF in France. During our meeting progress was made on task description and execution. In connection with this meeting, we also visited EDF's sophisticated smart-grid simulation facilities, which was of great interest for the participants.

A workshop meeting was held at EDF in January 2014 as preparation for the main meeting in February, and also to familiarise EDF personnel with the content of the project.

As Operating Agent, we participated in the tri-annual heat pump conference in Montreal, including a workshop on heat pumps in smart grids, accompanied by a regular Annex 42 project meeting.

We intend, in the not too distant future, to launch an Annex 42 website.

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IEA HPP Annex 43 Fuel-driven sorption heat pumps

During the work in Annex 34 "Thermally Driven Heat Pumps for Heating and Cooling" there was a rising interest in the area of fuel driven sorption heat pumps, and more and more products came closer to market. Therefore, a new Annex "Fuel driven sorption heat pumps" was proposed to the ExCo in March 2012.

After an Annex definition meeting a legal text was compiled and as draft accepted by the ExCo, so Annex 43 started officially in July 2013 with a planned duration of four years. A kick-off meeting was held on October 9-10 2013 in Freiburg, with participants from six countries. Main topics were the finalisation of the Legal Text and the work plan and the setting up of the organisational framework.

Objectives

The scope of the work under this Annex will be the usage of fuel driven sorption heat pumps in domestic and small commercial or industrial buildings or applications.

If applicable, the additional possibility of supplying cold will also be considered. The main goal is to widen the use of fuel driven heat pumps by accelerating technical development and market readiness of the technology, as well as to identify market barriers and supporting measures.

The Annex structure

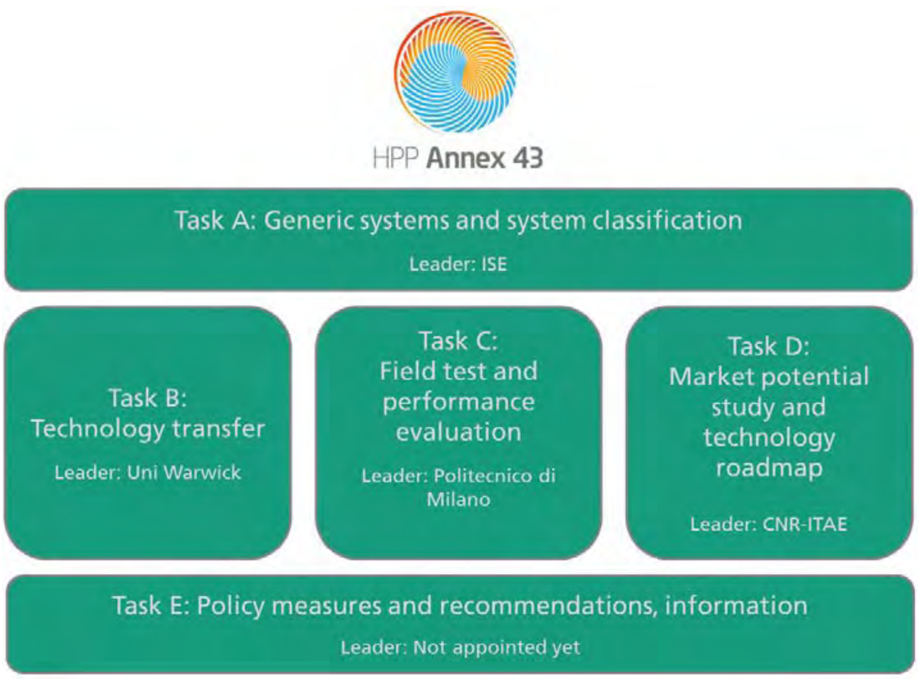
The tasks are further specified as follows.

Task A: Generic Systems and System Classification

- Available sources and heating systems
- Existing market and regulatory boundary conditions

Task B: Technology Transfer

- Link research to industrial development for faster market penetration of new technologies
- Novel materials (e.g. MOFs for adsorption heat pumps)
- Novel components (integrated evaporators/condensers, compact heat exchangers)
- System designs (e.g. façade collector as heat source)



Task C: Field test and performance evaluation

- Measurement/monitoring procedure standardisation (e.g. how to cope with different fuel quality, system boundaries, auxiliary energy, etc.)
- Extend standards to seasonal performance factors at the system level

Task D: Market potential study and technology roadmap

- Simulation study to evaluate different technologies in different climate zones, different building types and building standards
- Combine with market data and actual building stock for technology roadmap

Task E: Policy measures and recommendations, information

- Dissemination
- Workshops for planners, installers and decision makers
- Develop recommendations for policies, e.g. building codes and funding schemes

Within Task A, a template for the country report was prepared by ISE and send out to the participants.

A presentation about the Annex was given at the Heat Pump Summit 2013 in October 2013 in Nuremberg, Germany, and at several more local events.

So far, six countries confirmed joining the annex (AT, DE, FR, IT, UK, US); several more have expressed their interest (Korea, China), but of course more participants are welcome.
The second meeting will be held June 4-5 in Paris.

More information about the annex can be found at:
https://www.annex43.org/

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Annex 43: Group picture from the Kick-off meeting held in Freiburg, Germany, October 2013

IEA HPP Annex 44 Performance indicators for energy efficient supermarket buildings

Now that the preparations and outlines have been set, the work in Annex 44 has entered the phase of practical work on the Annex tasks, starting with task 1 "Mapping existing energy systems in supermarkets and collection of monitored data from selected supermarket chains and individual supermarkets."

In Sweden, a first successful meeting was held on February 20th with the reference group for the Annex in which trade associations, supermarket chains, supermarket owners, suppliers and consultants are represented. The group has been informed on the Annex objectives, and more importantly, the group has given input concerning the situation in the field and concerning the desires of the stakeholders concerning the outputs of the Annex. Currently, an inventory is being made of available measurement data and performance indicators in the Swedish supermarket sector.

In the Netherlands, a group of students at the Delft University of Technology has started to analyse supermarket measurement data on energy consumption and temperatures, to establish correlations between the data and performance indicators.

An Annex 44 meeting, open to all interested parties, has been planned alongside the International Conference on Sustainability & the Cold Chain on June 24th in London.

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Ongoing Annexes

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Annex 40 Heat Pump Concepts or Nearl ero- Energ u l ngs	40	CA CH I P N N E
Annex 41 Col Cl mate Heat Pumps Impro ng ow Am ent emperature Per ormance o A r- ource Heat Pumps	41	A CA P US
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IEA Heat Pump Programme part c pat ng countr es Austr a A Cana a CA enmar nlan I rance erman E Ital I apan P the Netherlan s N Norwa N outh orea we en E w t erlan CH the n te ng om an the n te tates .
All countr es are mem ers o the IEA Heat Pump Centre HPC . we en s the host countr or the Heat Pump Centre.

Strategic Outlook

Martin Forsén, Sweden

Governments all over the world are slowly realising the importance of energy efficiency and a shift towards the use of renewable energy sources. The shift is driven by the need to fight climate change and secure energy supply. However, the economic and political conditions vary considerably around the world and consequently result in the adoption of quite different energy policies. There are, nonetheless, a few common streams in the way new policies are adopted. One is the worldwide trend of implementation of minimum energy efficiency standards for appliances and buildings. Another is the need to reduce the dependency of energy imports. The US is putting a lot of hope to the exploration of shale gas, whereas Germany has launched the "Energiewende" in order to increase the use of renewable energy and to facilitate the phase out of nuclear power. The market constraints for heat pumps vary from country to country, and may shift dramatically due to incidents that are difficult to predict. Research and technological developments leave us with good hope for heat pumps in the future.

Introduction

In recent years, Beijing has turned up on my itinerary with some regularity. This gigantic city, where the traffic situation seems to get worse by every visit, always offers new insights and opportunities to reflect on the European energy scene from some distance. Most of the bicycles are long since gone from the streets of Beijing and replaced by an ever-increasing number of cars. The low-cost alternative, for those not yet in the fortunate position of being able to afford a car, is the moped. However, stinking two-stroke engines are surprisingly few: the great majority of the mopeds are electric. Similarly, bicycles with electric motor assistance are common.

These are examples where China is ahead of many countries, but the country is still lagging behind the western world in many energy aspects, and the challenges on how to build sustainable energy solutions are tremendous in the world's second largest economy.

Wuchang Garment District - charging batteries

The (r)evolution of smart cities and smart appliances is becoming big business

This vast country is developing rapidly, putting a lot of pressure on urban planning. McKinsey & Company [1] estimates that China will have 10 to 12 mega-cities with populations exceeding 15 million by 2025. The need for smart city development is a reality and companies offering smart city solutions are growing quickly. In October 2013, a smart city industry association was established in China, hosting more than 100 companies active in the field. The market for smart city solutions reached almost 140 billion yuan 2012, and is projected to reach 500 billion yuan by 2015.

Heat pumps definitely have a role in smart city development, but we must realise that our technology is only one of several technologies that make up the concept of smart cities: a concept that encompasses solutions for transportation, waste and waste water treatment as well as medical and social care, safety, education and communication along with generation of electricity, smart grids and smart appliances.

The smart appliances are required to serve as load-matching for the increasing share of intermittent and uncontrollable generation of renewable electricity from sources such as solar photovoltaic and wind power. The initiative within the German heat pump association, BWP, to design a smart grid ready (SG Ready) logo [2] was a first move in a direction to position our technology as part of the future energy-smart society. Smart control of heat pumps designed for smart grids will optimise their operation in response to the current and projected availability of electricity.

This will undoubtedly push the technology in a somewhat new direction where cost-optimised operation does not necessarily always mean the highest energy efficiency. The development offers several opportunities, but not without challenges. Systems need to be designed to store heat either by means of storage or by use of systems with high thermal inertia. The industry needs to come up with new standards on how to communicate with the grid and new ways to communicate performance with the customers. The future will inevitable require more IT and electronics in all our products.

Shanzhai

Fierce competition is pushing the technology further. Chinese companies formerly prospering from manufacturing cheap copies of well-known brand names find it ever more difficult to compete in times when the market is overflowing with competitors. Low quality at low cost is no longer a viable business model. In order to survive, companies need to provide functionality at high quality. Chinese companies are gradually moving up the value chain from being copycat providers to companies offering products of genuine design through micro-innovations.

Some of the most successful companies are those that add functionality to the products they are imitating and deliver high quality look-alikes that surpass the original. The Chinese word ***shanzhai*** that was formerly used to describe the widespread existence of counterfeit products has acquired a new meaning. Shanzhai is today more often associated with re-engineering and successful companies that deliver products with better performance and functionality than the original they are copying. Sina Weibo, the Chinese version of Twitter, and Taobao, similar to eBay, are sometimes used to describe the phenomenon.

However, shanzhai is not confined to IT business. It is becoming increasingly common in appliance and component manufacturing. The company BYD started off with 20 employees in 1995 as true followers, copying state-of-the-art products. Today, BYD employs more than 10 000 in R&D and is seen as one of the market leaders in the field of batteries and cars. Gree [3], founded in 1991, is today the world's largest manufacturer of residential air conditioners, with a production capacity of 60 million units in nine factories worldwide. The company is a good example of Chinese industry moving up the value chain to become a market leader. Gree has since long left the group of "followers" and is well positioned in the group of technology leaders. Even though R22 is still used in many markets, Gree has production facilities for air conditioners using R290 and R32.

China has since long been established as the world's largest producer of air conditioners, with an annual production exceeding 100 million units. The focus is still on air conditioners, but the government's ambition to improve energy efficiency has attracted attention to water heaters. Minimum energy performance standards (MEPS) [4] have been adopted, and can be seen as a worldwide trend. The implementing measures for the Eco-design and Energy Labelling Directive were adopted for water heaters earlier this year in the EU. The US MEPS [5] on water heaters that will come into force in 2015 will require heat pump technology for all storage water heaters with a volume exceeding 50 gallons. Similarly, MEPS for laundry dryers in Switzerland can at present be met only by heat pump technology.

The introduction and sharpening of MEPS is a general trend, and applied all over the world for an increasing number of product groups. The legislation is constantly pushing the technology forward. The development will lead to the introduction of heat pumps in several new applications and appliances. It is, for example, foreseen that heat pumps will be a necessity in electric vehicles and introduced in washing machines and in dishwashers. Electric heat pumps will play an important role in our struggle for sustainability, but it will require considerable efforts and investments to improve generation and distribution of electricity.

Consequences of the Fukushima accident and the shale gas revolution

It goes without saying that the competitiveness of electric heat pumps is highly dependent on the price of energy and the availability of electricity. When analysing the market opportunities for electric heat pumps in a specific country, one of the first things to look at are the existing energy price ratios, i.e. the ratio between the price of electricity and the price of 1 kWh of heat produced by the competing technologies. The energy price ratio corresponds to the seasonal performance factor that has to be beaten in order to result in lower heating costs for the heat pump system. The low energy price ratio between electricity and heating oil is the main explanation for the tremendous success for heat pumps in Sweden. A relatively low price of fossil fuels (predominantly natural gas, heating oil and coal) compared to the price of electricity is still the most important explanation for the slow uptake of heat pumps in many countries around the world. Even though electricity is often seen as the way forward to decarbonise the energy sector, development might from time to time slow down due to unpredictable incidents, unforeseeable discoveries and political crises.

The Fukushima accident has intensified the discussions on the risks and opportunities of nuclear power, and nations have chosen different pathways at the crossroads. In the aftermath of the disaster in Japan 2011, Germany and Switzerland have decided to phase out nuclear power. In order to facilitate the phase-out, Germany has initiated a large-scale energy turnaround (*Energiewende*), which intensifies investments in renewable electricity such as wind power and solar PV: investments that come at the cost of higher electricity prices, and thus put additional barriers on many promising technologies, including heat pumps. The consequences for Switzerland are potentially more severe than for Germany, as nuclear accounts for nearly 40 % of the electricity mix. At the same time, other countries have come to the conclusion that nuclear power is feasible and can be operated safely at justifiable costs. Finland and the United Kingdom have decided to expand the use of nuclear power, and there are no signs of downsizing in nuclear-dominated France.

Just as important as the price and availability of electricity is the price of conventional fossil fuel. Countries that for decades have been spoiled by access to cheap natural gas in abundance have spent an increasing amount of resources on prospecting as the gas fields are in decline. The introduction of "fracking", which enables access to previously inaccessible reservoirs, has attracted a lot of attention in recent years. The tremendous growth of shale gas production in the US has sent natural gas prices into a fall. The low price of gas has effectively eliminated the economic incentives to switch from the conventional gas-driven hot air furnaces. The shale gas revolution in the US has raised hopes for a way out of its strong dependence on energy imports. Some even go so far as to say that the US might become self-sufficient. Others claim that the resources are vastly exaggerated, and that the environmental impact and extraction costs will set a relatively short time frame for a risky capital-intensive industry. It remains to be seen whether the US shale gas [6,7] will only serve as a short-term solution, delaying inevitable investments in renewables, or if it will put the US back on track for a longer period. The economic potential for European shale gas is largely unknown. Large reservoirs have been identified in the UK and in Poland, but costs for drilling, lack of infrastructure and legal issues often result in a negative economic equation.

Concluding remarks

Given the worldwide trend of a greater focus on energy efficiency, heat pump technology stands out as one of the most promising technologies to replace fossil fuels as the predominant solution for providing space heating and domestic hot water. Despite this conviction among enlightened policy-makers, progress is still slow. We cannot deny that renewable energy gets implemented at the speed of profit. As long as the economic constraints are not in favour of our technology, we will not see any substantial growth other than with the support of subsidies, which may only temporarily change the economic parameters in the equation. Minimum energy performance standards on appliances and buildings, as well as limitations on carbon footprints, are being introduced worldwide but too often watered down and delayed due to economic constraints. It is sadly still often less costly to destroy the environment than to preserve it. Changes are, however, on their way, and most of the changes that we see play in favour of energy-efficient technologies using renewable energy with a low carbon footprint. Heat pumps will play an important role in the future energy system.

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Highlights of North America's Heat Pump Research

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This article provides an overview of recently completed and ongoing research activities related to heat pumps in the United States. Projects undertaken by the U.S. DOE, its national laboratories, academia and industry on heat pump technologies for cold climates, integrated application, and gas-fired absorption applications are summarized. In addition, next generation low GWP working fluids as applied to heat pumps are briefly discussed.

Overview

Heat pumps are air conditioning devices that provide cooling in summer and heating in winter in residential and commercial buildings. The devices transfer heat from low temperature sources to high temperature sources via work input. The common cycle applied to the heat pumps is the vapor compression cycle. Depending on the heat sources, one could see air-source, water-source and ground-source heat pumps in the market. Another type of heat pump for residential applications is the absorption heat pump, also called a gas-fired heat pump [1].

Heat pumps are becoming more and more popular in the U.S. Figure 1 shows the last twenty years of shipments of the air-source heat pumps in the U.S. [2]. The annual shipment of heat pumps was more than doubled from mid-90s until the U.S. economy had its downturn around 2008. As the economy recovers gradually after the recession, the annual shipments gradually increase as well.

In the past, research on heat pumps was primarily focused on improving performance. In the past 35 years, U.S. heat pump efficiency increased significantly as illustrated in Figure 2. The data is based on AHRI averages the Seasonal Energy Efficiency Ratio (SEER) of unitary heat pumps (single-package and split systems) sold in the U.S., and shows that the shipment weighted SEER more than doubled between 1976 and 2013. Current research efforts are not only focusing on improving performance and extending operating envelope, but also on new applications and

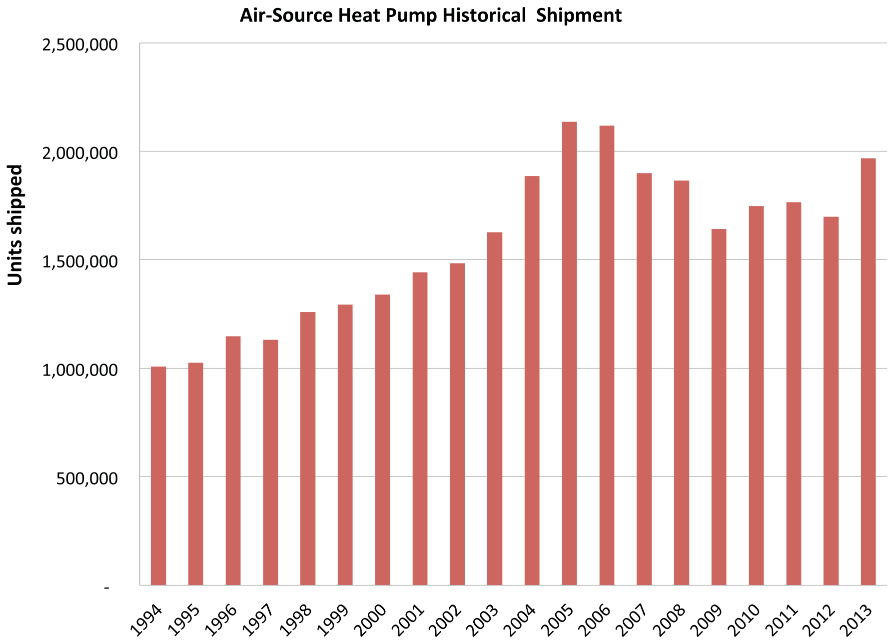

Figure 1: Historical shipments data for U.S. air-source heat pumps. Source: Air-Conditioning, Heating, and Refrigeration (AHRI) website [2]

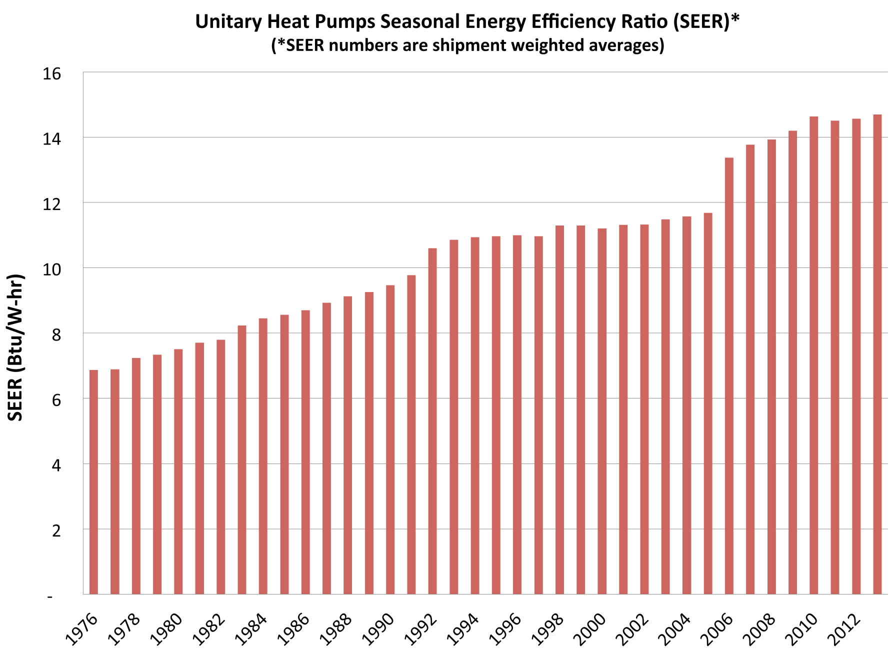

Figure 2: Historical SEER for unitary heat pumps sold in U.S. Source: AHRI website [2]

new working fluids. This article is a high level highlight of some recent U.S. research activities on heat pump technologies in terms of heat pump applications and working fluids.

Heat pump systems

The U.S. Department of Energy (DOE) Building Technology Office (BTO) sponsors many heat pump technology related research projects in DOE's laboratories, universities, and private companies. These research efforts are to support and facilitate achievement of a DOE BTO goal of 50 % reduction in building energy use by 2030 (using 2010 Annual Energy Outlook baseline [3]).

Advanced Variable-Speed Air Source Integrated Heat Pump

Oak Ridge National Laboratory (ORNL) and a U.S. heat pump manufacturer are conducting a project to develop a fully variable speed version of an air-source integrated heat pump (IHP) product intended to fit the U.S. market. The IHP includes all HVAC & water heating services in one highly efficient system [4]. Figure 3 is a schematic of the IHP system. Using its cooling mode with water heating function as an example, the compressed refrigerant dissipates heat to the water in the water heater tank and the outdoor heat exchanger. Depending on the space cooling load and water heating load, the IHP acts as a water-source heat pump, or an air-source heat pump water heater, or a combination of the two. This process will be realized using the proper control mechanism and variable speed compressor, pump, and fans to meet the load requirement [5].

The ORNL's goal is to develop an IHP system with ≥50 % energy savings compared to minimum efficiency systems. An initial laboratory prototype was built and tested. The test result demonstrated an approximately 30 % HVAC savings and 70 % water heating savings. The combined annual energy savings estimates based on the initial design showed an overall 54 % savings for Atlanta climate [4].

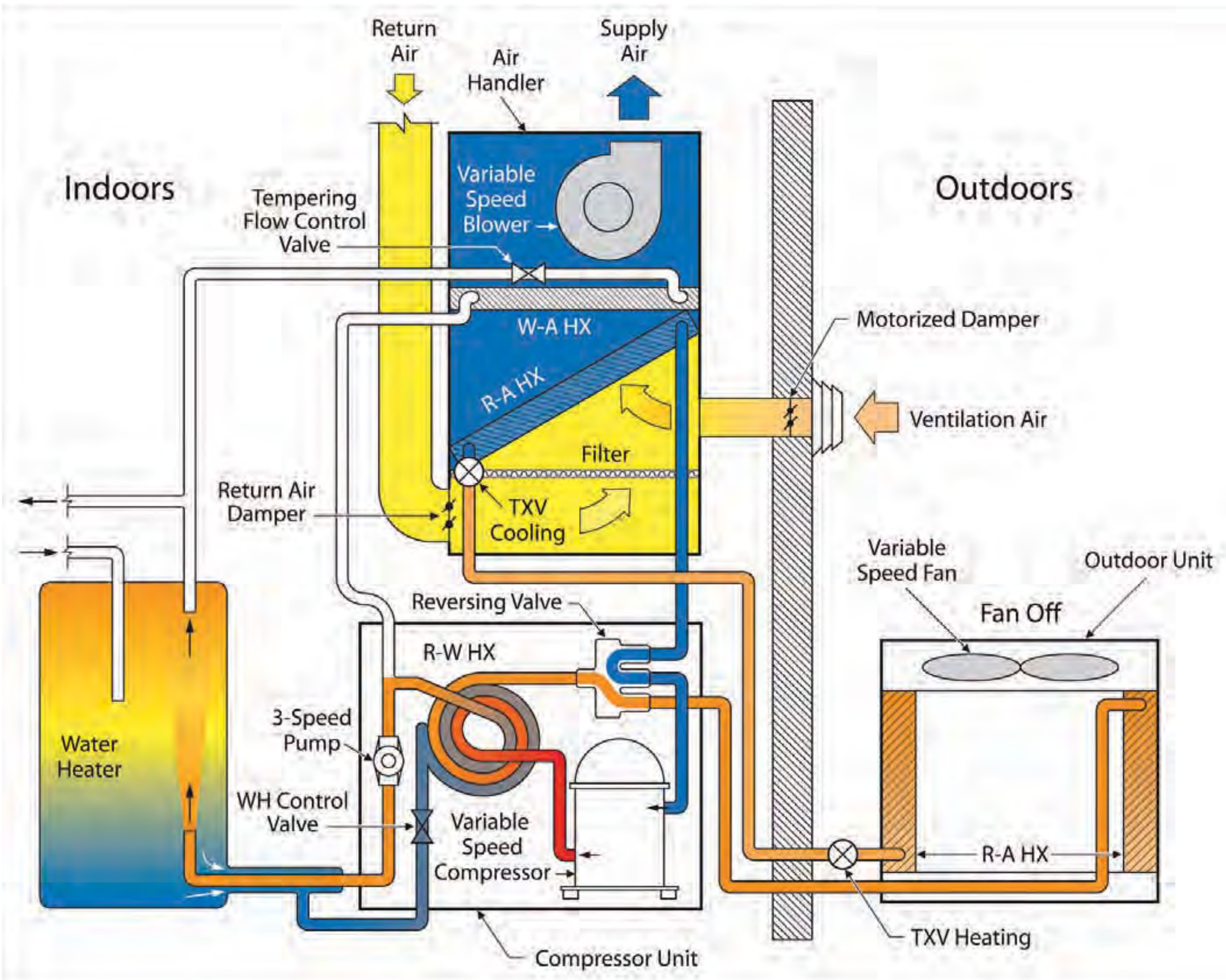

Figure 3: Air-source integrated heat pump (IHP) Concept: Space cooling plus "on demand" water heating mode - diagram source: [4]

Heat Pump for Cold Climates

The low ambient temperature in winters leads to a low refrigerant density at the compressor suction line. This significantly decreases the refrigerant mass flow rate through the indoor heat exchanger, and leads to a decrease of the capacity of a given heat pump. In such a case, the system will need backup heat in cold climates. BTO has an ongoing project to design and build a prototype supercharger. The supercharger will be installed in heat pumps serving as pre-compressors that will enable efficient operation of the heat pumps in the coldest U.S. climates without the need of backup heat [6].

Multi-Function Fuel-Fired Heat Pump

ORNL together with another manufacturer and a gas utility company are conducting a project to develop a residential multi-function fuel-fired heat pump. The multi-function heat pump is equipped with a natural gas engine-driven compressor, a 1.5 kW power generation module, waste heat recovery for space heating/water heating, and smart controller to achieve optimal efficiency. The power generation module would supply all the power for ancillary loads and emergency power back-up, thus reducing peak electric demand.

Achieving the proposed cooling source coefficient of performance (COP) of 1.3, and heating source COP of 1.5, while maintaining the hot water capacity of 40 gallons would deliver an annual primary energy savings for space conditioning and water heating of 30 % and 80 % respectively compared to separate HVAC and water heating equipment [7].

The BTO also has efforts on gas-fired absorption air-source heat pumps, advanced ground source heat pump technology, variable speed heat pump technologies for cold climates, and natural gas heat pumps and air conditioners. The status of these projects will be updated in the BTO's peer review meeting in April 2014 (http://energy.gov/eere/buildings/events/buildings-technologies-office-peer-review-2014).

Working Fluids

Refrigerant R-410A is commonly used in vapor compression heat pumps. However, it has come under closer scrutiny due to climate change concerns. In response, the industry and government laboratories are conducting new working fluids related research.

Performance

AHRI is currently leading an industry-wide cooperative research program, the Low Global Warming Potential Alternative Refrigerants Evaluation Program (Low-GWP AREP). The program aims at identifying and evaluating promising low-GWP alternative refrigerants for major air conditioning and refrigeration products. Eleven air-conditioners and heat pumps (air-source and water-source) were tested with different low-GWP refrigerants. Figure 4 demonstrates the relative seasonal performance of these low GWP refrigerants to the baseline R-410A.

These refrigerants had different performance than R-410A on a drop-in basis. Most of them showed improvements in the Heating Seasonal Performance Factor (HSPF) and a comparable or slightly decreased Seasonal Energy Efficiency Ratio (SEER) or cooling seasonal performance.

The National Institute of Standards and Technology (NIST) conducted an extensive thermodynamic evaluation of low GWP refrigerants. Researchers explored the thermodynamic performance limits for four different vapor compression cycles and identified optimal refrigerant thermodynamic parameters that lead to the best performance [8]. Furthermore, they applied screening criteria to narrow the list of fluids that might be suitable low-GWP refrigerants from more than 56,000 down to 62 candidates [9].

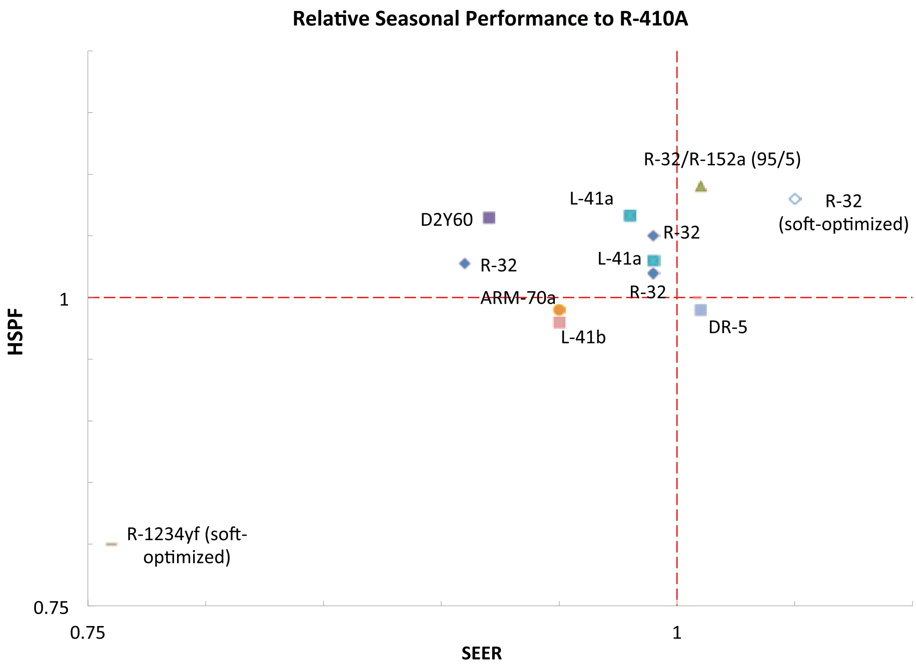

Figure 4: Low GWP refrigerants relative seasonal performance to R-410A in air-source air-conditioners and heat pumps

Safety

Most of the low GWP working fluid candidates aimed at replacing R-410A in heat pump applications are classified or intended to be classified as A2L, according to ASHRAE Standard 34-2013 [10]. These refrigerants have low burning velocity and are mildly flammable. ASHRAE conducted a study to develop scientifically valid input data to be used in risk assessments for the use of class 2L flammable refrigerants in residential central air conditioners and heat pumps, as well as small commercial refrigeration applications [11]. The study identified potential ignition sources, potential leak scenarios that could create flammable concentrations of refrigerant, and tested some of these potential leak scenarios. Almost concurrently, AHRI completed a research project employing fault tree analysis (FTA) to assess the ignition risks of using A2L refrigerants in residential heat pump systems [12]. The study consisted of CFD modeling of the refrigerant dispersion patterns for different leak scenarios, actual testing to validate the CFD results, and a fault tree analysis to evaluate the likelihood of refrigerant ignition. The study concluded that the risks due to refrigerant release and ignition are far below risks of other hazards that are commonly accepted by the public, e.g. slip/fall injury requiring medical treatment.

Environmental Impact

Several efforts were undertaken to evaluate the Life Cycle Climate Performance (LCCP) of residential heat pumps. AHRI developed a standardized methodology and an excel-based tool to evaluate residential heat pumps' direct and indirect emissions over their lifetime when using different refrigerants in different regions [13]. The University of Maryland in partnership with ORNL and DOE [14] extended the AHRI effort to an open source tool to design heat pumps for an optimal LCCP. Currently, an International Institute of Refrigeration (IIR) Working Party is leading an effort to assess the merits of different methods aimed at evaluating the LCCP of refrigerating systems [15].

Summary

This article highlights some recent completed or ongoing research activities related to heat pumps in the United States. The U.S. DOE and its national laboratories, academia and industry are undertaking significant effort on heat pump technologies for cold climates, integrated application, and gas-fired absorption applications to improve heat pump system efficiency and extend their application. In addition to these efforts, seeking next generation low GWP working fluids and understanding the impact of these fluids in terms of safety and environment are of great interest as well.

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Effect of Residential GSHP System Design on CO_2 Emissions in Sweden

Jeffrey D. Spitler (USA), Mei Yung Wong (USA), Signhild Gehlin (Sweden)

In Sweden residential ground source heat pump systems incorporate auxiliary electric resistance heating. Ground heat exchanger size and heat pump capacity both strongly affect electric resistance heating and electricity consumption. As the highest heating requirements occur in winter time when a larger fraction of electricity is produced with fossil fuels, the system design can strongly affect the emissions. This is investigated with a parametric study of 121 system designs serving a house in Stockholm. The emissions are estimated using a temperature-dependent emissions factor model.

Introduction

Ground source heat pump (GSHP) systems in Sweden are commonly designed so that the heat pump only provides 60-70 % of the peak heating load, with the remainder being provided by an auxiliary electric resistance immersion heater. This strategy, which has been in use since the 1970s, allows for smaller and less costly heat pumps and ground heat exchangers. It is generally justified by the idea that, over the year, the amount of heating that will be provided by electric resistance is relatively small.

Yet, since the electric resistance heating will often be utilized at the coldest time of year, coincident with when the otherwise low-CO_2-emissions Swedish electricity generation will be augmented by coal-fired electricity production from Denmark, Germany, Finland, and Poland, the resulting emissions may be disproportionate to the electricity consumption[1]. Furthermore, with about a fifth of all single-family houses in Sweden using GSHP systems for space heating and domestic hot water (DHW) production, these emissions are of some interest.

This article presents an investigation of the effects of GSHP system design on CO_2 emissions due to manufacturing, installation, and operation. Because the electricity generation mix changes over the year, monthly distribution of electricity consumption, power generation, and resulting emissions have been considered for a range of GSHP system designs.

Methodology

This paper extends the results of recent research performed by the authors [1, 2] which investigated electricity consumption and emissions for a renovated 1940s era house in middle Sweden. Domestic hot water (DHW) loads are taken from the Swedish Energy Agency [3]. Modeling of the heat pump and ground heat exchanger are briefly described below. A total of 121 combinations of borehole depth and heat pump sizes were simulated to determine hourly electricity consumption and emissions.

Heat Pump Model

The residential GSHPs used in Scandinavia have several key features; one is the integrated DHW generation and storage, where there is, most commonly, a double walled DHW tank within the heat pump unit storing 160—200 liters of hot water. Typically, no desuperheater is used and the water is heated with hot water coming from the heat pump. Other features include non-reversible heating only, fluid to water distribution, back up electric resistance immersion water heater and a user controlled setpoint for internal controls with priority given to DHW heating, as described in detail by Gehlin and Spitler [1].

The heat pump model used here implements these features where DHW heating loads are met first and any excess capacity of the pump goes into building heating. If the heat pump does not cover the full capacity required, the electric resistance immersion water heater will be used and it is specified such that all the loads are met. This model is a quasi-steady state model and thus assumes that the DHW heating loads that occur in any hour are met during that hour.

GHE Model

Ground heat exchangers (GHE) in Scandinavia are commonly ungrouted, groundwater-filled closed loops, using a single U-tube. The borehole is typically drilled in hard crystalline rock with a high groundwater level, and the U-tube is suspended in the borehole. The groundwater is protected from surface pollution by a steel casing on the upper borehole (about 6 m or 20 ft). The ground heat exchanger model used was described by Yavuzturk and Spitler [4] and several validations have been previously described, e.g. Gentry et. al. [5]

Test Cases

To examine the effect of system design on electricity consumption, 121 combinations of heat pump size and borehole depth are simulated. The heat pump capacity varied from 5—15 kW in increments of 1 kW, and the borehole depths varied from 100—300 m in 20 m increments. For

1 To be sure, the actual distribution of electrical power generation and resulting CO_2 emissions depend on many factors - plant shutdowns for maintenance, droughts affecting available hydropower, etc. Resulting year-to-year changes in emissions can be observed in data we present later in the paper.

each case, the simulation was done for a five year period and results from the fifth year were used to determine the electricity consumption and emissions.

Weather Data

Building heating loads were generated with Energy Plus using a typical Stockholm weather year from the International Weather for Energy Calculations (IWEC) data set. [6]

Emissions

For annual emissions, previous studies, e.g. Saner et al. [7] have taken a relatively simple approach, using an annual distribution of electricity production sources in a given country. If CO_2 emissions per kWh are assigned to each electricity production source, an overall emissions factor in kg of CO_2 per kWh of electricity can be calculated as a weighted average. This is then multiplied by the annual electricity consumption to estimate the annual emissions. We refer to this approach as the annual emissions factor approach.

A possible problem with the annual emissions factor approach is that it neglects the time-varying distribution of electricity production sources. It seems likely that Swedish GSHP systems tend to switch to electrical resistance heating under peak heating load conditions at the same time as national electricity consumption peaks, requiring import of power with higher CO_2 emissions (see footnote 1). To analyze this problem more fully, data on how the electricity production sources change with time are needed. Here, we have used typical power source emission factors, the PSEF-B set as described in [2], combined with monthly distributions of electricity production sources obtained from the ENTSO-E database [8]. This gives the monthly emission factors shown in Figure 1 for January 2010 through August 2013. These monthly emission factors were fitted to:

$$EF = 0.1115 - 0.022 Ln(\overline{T} + 9)$$

where:

- EF is the monthly emission factor (kg CO_2/kWh)
- $\overline{T}$ is the monthly mean air temperature (°C) for Stockholm.

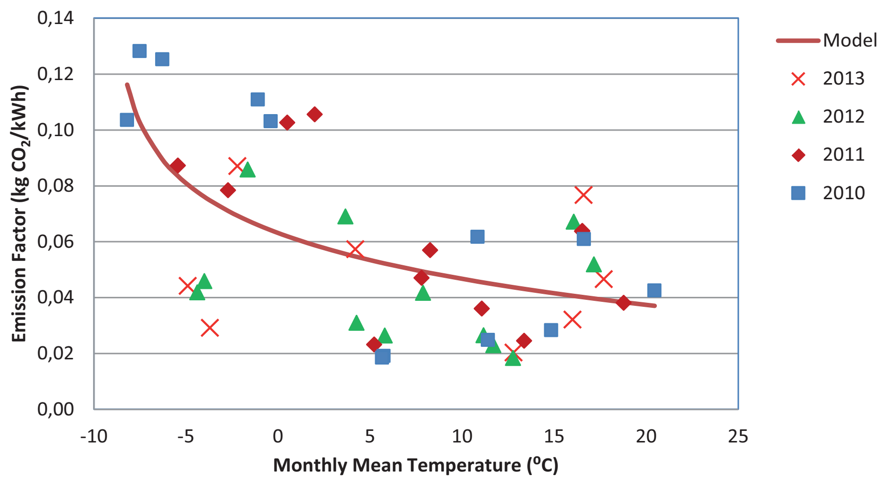

Figure 1: Monthly emission factors for each month in Sweden in 2010-2013

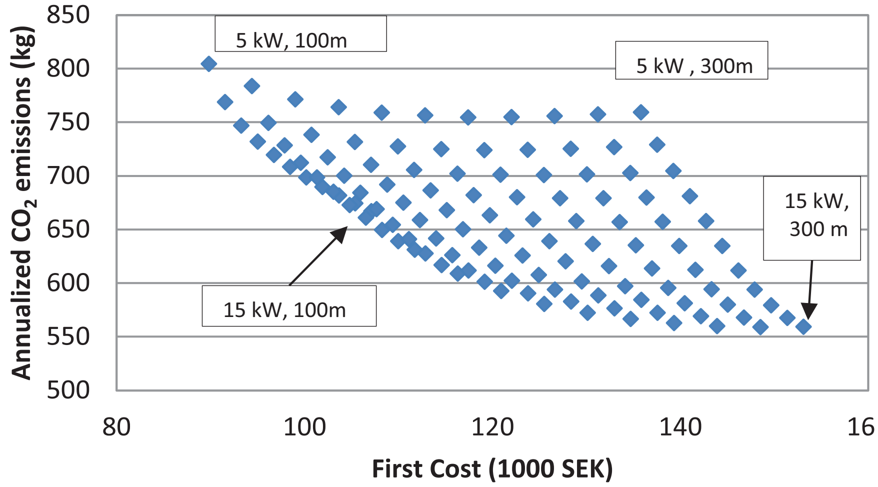

Figure 2: Annualized CO_2 Emissions vs. First Cost

Fitting a model to such widely disparate data is admittedly difficult as the power generation situation varies from year-to-year with plant maintenance, rainfall, and other factors. This is reflected in the RMSE value of 0.025 kg CO_2/kWh. However, for comparison purposes, one might consider that one of the most comprehensive studies to date of emissions from GSHP systems by Saner, et al. [7] simply used a value of 0.105 kg CO_2 /kWh of electricity produced as an annual average for Sweden. Using this value gives an RMSE of 0.052 kg CO_2/kWh of electricity produced.

Initial Emissions

The emissions due to manufacturing of the heat pump and drilling of the borehole were modelled according to the heat pump capacity and borehole size. Heat pump weights given by the manufacturer were fitted as a function of heat pump capacity. The percentage weight for each component [9] was determined based on data provided by the manufacturer. The corresponding emission factors were estimated from the literature, as described in [2] and normalized to a per annum basis by dividing them by the estimated service life of 20 years. [10]. Similarly, emission factors were estimated for drilling the borehole and for manufacturing the various components, on a per borehole and per meter basis, as described in [2] and divided by an estimated life of 50 years. [10].

Results

Comparisons of all 121 combinations of heat pump sizes (5—15 kW) and borehole depths (100—300 m) were made using the emission factor model described above. (Spitler, et al. [2] also look at the sensitivity of the predictions to the emissions factors; significant variations in the estimate can be obtained.) Annualized emissions due to manufacturing the heat pump, drilling the borehole, and installing the U-tube are included in the annualized totals. Figure 2 shows the annualized emissions plotted against the first cost. As found by Gehlin and Spitler [1] when comparing the life cycle cost per kWh of heating provided to the first cost, the results form a Pareto front – a family of optimal solutions that give the best combinations of the borehole lengths and heat pump sizes. Figure 3 shows the distribution of emissions more clearly. The total emissions are calculated to include the initial annualized emissions from the heat pump and borehole components and the annual emissions from operation of the heat pump. Total annualized emissions are plotted against first cost (Fig 2) and nominal borehole load (Fig 3), and a comparison of emissions of the three base cases in the study (Fig 4) is made.

Figure 4 shows the contributions of the annual emissions and the initial emissions to the annualized emissions. As expected, as the initial emissions increase due to a larger heat pump and deeper borehole, the annual operation emissions decrease due to more efficient operation. The initial emissions are significant enough to be accounted for in the analysis.

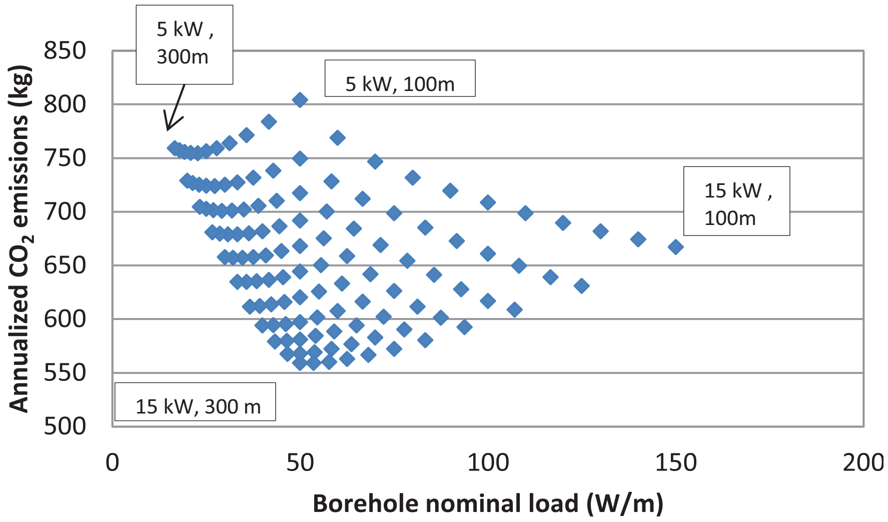

Figure 3: Annualized CO_2 Emissions vs Borehole Nominal Load

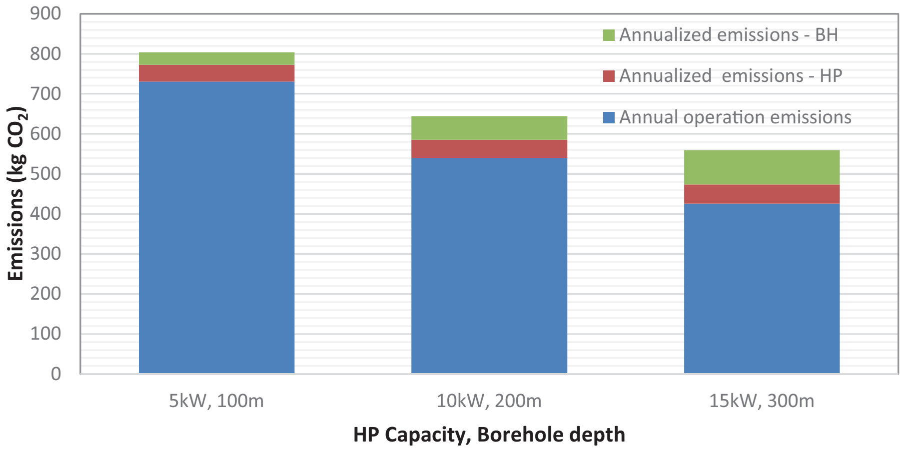

Figure 4: Comparison of annualized initial CO_2 emissions and annual CO_2 emissions from operation

Conclusions

From the standpoint of CO_2 emissions in Sweden, the larger heat pump and deeper borehole give significantly improved performance, with the best design having about 30 % lower emissions than the worst design. As shown by Gehlin and Spitler [1] this same combination also gives the lowest life cycle cost, but has a significantly higher investment cost. In addition, this study has illustrated some of the limitations in available emissions data – better time resolution and more accurate source emissions data would be highly desirable, as would further development of models that could be used to predict time-varying emissions for typical weather yearstypical weather years.

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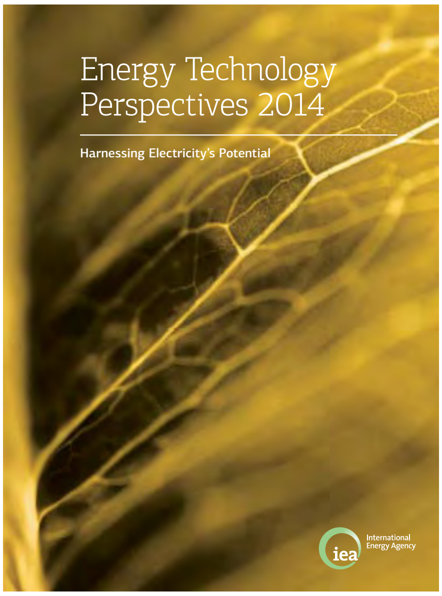
Energy Technology Perspectives 2014 - Harnessing Electricity's Potential



Energy Technology Perspectives sits at the heart of the International Energy Agency's work on energy technology and policy. It offers a comprehensive, long-term analysis of trends in the energy sector - and of the technologies that are essential to achieving an affordable, secure and low-carbon system.

Starting from the premise that electricity will be an increasingly important vector in energy systems of the future, Energy Technology Perspectives 2014 (ETP 2014) takes a deep dive into actions needed to support deployment of sustainable options for generation, distribution and end-use consumption.

In addition to modelling the global outlook to 2050 under different scenarios, ETP 2014 incorporates the IEA's annual progress report on global efforts to engineer a clean-energy transformation.

Moreover, ETP 2014 provides insight on many key questions about the future energy system, including:

- How much will the transformation to a clean-energy system cost?
- Is solar the answer to decarbonising the electricity supply?
- How can technologies help continue to exploit the advantages of natural gas in a decarbonised energy system?
- Can electrification have a meaningful impact on transportation, and if so, how?
- Is energy storage the game changer that many want to believe?
- What will it take to reach high-efficiency power generation in India?

Since it was first published in 2006, Energy Technology Perspectives has evolved into a series that sets out pathways to a sustainable energy future in which optimal technology choices are driven by cost, energy security and environmental factors.

For a Heat Pump view of the ETP 2014, see the Column of this Newsletter issue.

Source: www.iea.org/etp/

Events

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10 – 12 June
The 5th International Conference on Heating, Ventilating and Air Conditioning
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31 August – 2 September
11th IIR-Gustav Lorentzen Conference on Natural Refrigerants
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